Münir Öztürk
Volkan Altay
Recep Efe *Editors*

Biodiversity, Conservation and Sustainability in Asia

Volume 1: Prospects and Challenges in West Asia and Caucasus

Springer

Biodiversity, Conservation and Sustainability in Asia

Münir Öztürk • Volkan Altay • Recep Efe
Editors

Biodiversity, Conservation and Sustainability in Asia

Volume 1: Prospects and Challenges in West Asia and Caucasus

Springer

Editors
Münir Öztürk
Department of Botany & Centre for Environmental Studies
Ege University
Izmir, Turkey

Volkan Altay
Biology Department
Faculty of Science & Arts
Hatay Mustafa Kemal University
Hatay, Turkey

Recep Efe
Department of Geography
Balikesir University
Istanbul, Balikesir, Turkey

ISBN 978-3-030-59927-0 ISBN 978-3-030-59928-7 (eBook)
https://doi.org/10.1007/978-3-030-59928-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

1922–1985

This volume is dedicated to late Prof. Dr. Ali Rıza Çetik.
A pioneer in the field of vegetation ecology. Graduated from the Agricultural Engineering Faculty of Ankara; got his Ph.D. in 1953; D. Sc. in 1958; full professorship in 1968; dean in the Faculty of Science, Ankara University, 1969–1970; member of Turkish UNESCO Commission on Turkish Nature Conservation Society, 1973–1976; first vice chancellor of Selçuk University, Konya, Turkey (1976–1979); 25 published books and large number of papers on vegetation ecology.

Preface

Real concerns exist over the impacts of biodiversity loss. This loss is increasing following population pollution, which is producing strong impacts. There is a strong determination to succeed in halting biodiversity loss and achieving sustainable development. We have enough knowledge base from science and great experience, both good and bad, to build our future. The rate of biodiversity loss needs to be addressed by implementing more transformative solutions. The benefits provided by our global biodiversity is the fundamental way for achieving the sustainable development goals. The efforts to understand the importance of biodiversity as well as ecosystem services are increasing; however, we need more effective action towards the main drivers of biodiversity loss. The biodiversity vision adopted in 2010 discusses living in harmony with nature, where, by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for living beings. We keep on talking about living in harmony with nature but we certainly are not doing so currently. The loss is affecting human welfare, including health, nutrition and food security.

Biodiversity is a collective term that describes the totality and variety of life on Earth. Biodiversity includes genetic diversity within species, the variety among species and the range of ecosystems within which life exists and interacts. Estimates of the number of species on Earth vary from 3 million to 100 million. As per some reports, there are nearly 13 million species, and out of these, only 1.7 million have been described. According to IUCN, 1.8 million species have been described out of an estimated 5 million to 30 million in existence; these include bacteria (4.000), algae + protozoa (80.000), vertebrates (52.000), invertebrates (1.272.000), fungi (72.000) and plants (270.000), and possible number is given as 14 million. Generally, species density is greatest in the southern hemisphere; countries such as Australia, Brazil, China, Colombia, Costa Rica, the Democratic Republic of Congo, Ecuador, India, Indonesia, Madagascar, Mexico and Peru include 70% of the global species diversity. The biodiversity hotspot concept was developed by environmental scientist Norman Myers of the UK in an attempt to identify priority areas for biodiversity conservation. A map of hotspots on the basis of their plant diversity and the impacts upon them has been produced. In addition to harbouring at least 1.500 endemic plant species, hotspots must also have lost more than 70% of their original natural vegetation. There are 25 biodiversity hotspots which contain 44% of all plant species, and 35% of all terrestrial vertebrates live in only 1.4% of the planet's land area. The Living Planet Report, published by the WWF, provides useful information on the state of global ecosystems, tracking population trends for more than 1.600 freshwater, marine and terrestrial taxa. This datum reveals that some ecosystems are more threatened than others. Currently, only 1/5 of the global original forest cover remains in large tracts of relatively undisturbed forest named as frontier forest.

Agriculture is a major contributor to biodiversity loss. The rate at which agricultural land is expanding varies greatly. Much work has been done on the economic value of biodiversity. Individual species play a critical role in human food, medicine, biological pest control, materials (such as timber) and recreation. The plant species used as food by humans include total described species (250.000), edible (30.000), cultivated (7.000), nationally important (120) and making up 90% of world's calories (30). Out of 25 top-selling drugs, 10 have been derived from natural sources. The global market value of pharmaceuticals is estimated to vary between 75 and 150 billion US $ annually. In addition to the importance of individual species, researchers are discovering that ecosystems, too, play an important role in providing "services" to humans and that these services can be given a monetary value. Robert Costanza and group have calculated that the Earth provides "services" worth a minimum of 16–54 trillion US $ to humans a year. UN List of Protected Areas includes 102,102 sites covering 18.8 million km^2. Of the total area protected, nearly 17.1 million km^2 are terrestrial protected areas, or 11.5% of the global land surface; approximately 1.64 million km^2 is in marine protected areas – an estimated 0.5% of the world's oceans, and less than 1/10 of the overall extent of globally protected areas. The UN had declared 2010 the International Year of Biodiversity, and member states of the UN Convention on Biodiversity have set out a vision for 2050. They are identifying new targets and devising a new strategy to prevent biodiversity loss.

Of the world's seven continents, Asia is the largest, with its physical landscapes, political units and ethnic groups, both wide-ranging and many. Southwest, South and Middle Asia is a highly populated region with nearly 3 billion people. Out of these, the "Southwest" is often called the Middle East, which includes 18 countries. Central Asia has five republics lying between the Middle East, Russia and China. The region on the whole shows varied geography, including high passes and mountains. The current volume has tried to fill the gap by focusing on the diverse and dynamic biodiversity of Southwest Asia and the Caucasus. It covers wealth of information on plant, animal and agro diversity together with biogeography. Much of the land in the region is too dry or too rugged, with many geographical extremes. Overgrazing, oil and mineral extraction, and poaching are the major threats in the area. Livestock raising is also a dominant activity. A number of rare plant species are of a high value as food or medicinal plants. This volume will be of great interest among research workers and the teaching community. It will serve as a strong reference material for professional researchers working in the fields of plant diversity and vegetation, animal diversity and animal populations, and agro-diversity and their sustainable use. Southwest Asia and the Caucasus are unique areas in terms of plant diversity and large vegetation zones with different communities and biomes. They are rich in endemics, with rich specific and intraspecific diversity of plants. Only few sources in the form of books are available; therefore, this gap in the latest data on their biodiversity is much needed. This volume will focus on the diversity and dynamics of plants, animals and agro-diversity in the region. As pre-emptive measures to enhance the conservation of species for future ecological studies, data have been included for the species facing a threat of extinction.

The estimates for Asia by 2100 are that nearly 30% of the species will vanish due to habitat degradation and nearly 50% may represent global extinctions. Habitat degradation is proportional to its negative impact on biodiversity, with irreparable losses.

The biodiversity of Palestine reviews and discusses some of the data known on biodiversity in Palestine in Chap. 1. It mentions the threats – focusing on climate change, water and liquid waste, occupation/colonization, and efforts at environmental conservation. The chapter highlights opportunities for moving forward towards a strategy that ensures sustainability of both nature and human population. Environmental education rooted in justice and sustainability is stressed as a key factor in forging future strategies.

The significant role that lichens play in desert ecosystems has been evaluated from the "Negev Desert" in Israel. The study in Chap. 2 highlights water availability as the main factor influencing growth and activity in different habitats.

In Chap. 3, attempt has been made to provide information on the basic structural and metabolic characteristics of lichens, their uses from the past to the present and their importance together with the effects of lichen metabolites. The chapter also summarizes taxonomical revision studies on various genera and biological effects of lichen products with examples from Turkey.

Chapter 4 explains observations on six swamp forests in Turkey known as "Important Plant Areas". As an important ecological heritage, these forests have been separated as protected areas, and impact of current and potential changes in the near future has been evaluated together with the scope of sustainability, their floristics, ecological and syntaxonomic analysis vis-a-vis the prospects, and challenges regarding these ecologically unique forests.

Fire is an important dominating factor in the Mediterranean ecosystems, leading to several changes. Authors emphasize that reactions of the ecosystem in total have become more vulnerable, more susceptible, within the shortened adaptation time, and all these aspects are summarized in Chap. 5.

In Chap. 6, a detailed study on the wild orchids of Turkey has been presented. Wild orchids are generally defined as "salep" or "salep grass" by the locals, mostly used in the production of a beverage called "salep" and Maras ice cream – a traditional product in Turkey. 10–20 million wild orchids are removed from nature every year, and for 1 kg of salep, approximately 1.000–4.000 tubers, ranging from 0.25 g to 1 g, are required. The wild orchids in Turkey are facing a threat of extinction, but they can be saved by focusing on studies related to the determination of other wild species more suitable for salep production as well as Maras ice cream.

Chapter 7 presents a detailed overview of agrodiversity in Turkey, emphasizing on rice. Aerobic rice has been introduced in the recent past in place of conventionally irrigated rice owing to its lower water needs and labour requirements. It is mentioned as a candidate which can ease mechanical harvesting operations owing to lower moisture in the soil than conventional rice. The yields are similar to the conventional method, and it can be harvested better if managed properly.

In the agro-diversity in West Asia, an emphasis has been laid on Pepper which is widely grown in most of the West Asian countries and the Caucasus. Authors have evaluated the contribution of different pepper cultivars in the food production, agriculture, and regional economy, and an updated summary has been presented in Chap. 8 together with the efforts made by these countries to protect and increase biodiversity in agriculture.

Information on the data related to the promising small molecules from *Ganoderma* genus against cancer has been reviewed in Chap. 9. The compounds isolated from different species during the last 20 years have been evaluated along with their anticancer and related biological activities. The terpenoids, steroids, phenolics and alkaloids, with biological activity related to cancer from 17 *Ganoderma* species, are reported herein.

The vertebrate biodiversity of Turkey has been reviewed in Chap. 10. It shows that Turkish vertebrate fauna consists of 1728 species. Endemism rate is given around 13.14%, and 5 species are noted as extinct and 212 species are under threat globally.

Within the Caucasus part, first-hand information on the "Medicinal Plants of Northeast Anatolia" has been discussed in Chap. 11 along with data on a total of 510 medicinal vascular plants, including 10 endemics reported to show distribution in this region which abounds in a variety of ecosystems and habitats in the Caucasus. This is followed by Chaps. 12, 13, 14, 15 and 16 from the Caucasus region, mainly Georgia, with a detailed description on the main problems of sustainable development in South Caucasus and processes of landscapes (ecosystems) biodiversity transformation, forest cover for the safety of biosphere and environment in Georgia, agrodiversity and sustainable development in Georgia, the plant diversity and general vegetation of Georgia, and a general perspective of the faunal diversity in Georgia.

The follow up on the Caucasus region covers Chaps. 17, 18, 19 and 20 from Azerbaijan entitled: "An Overview of the Plant Diversity of Azerbaijan", "Agrodiversity of Azerbaijan", "Faunal diversity of Azerbaijan" and "Genus *Crataegus* in the flora of Nakhchivan".

In Chap. 21, the herbals used in Western Iran as food and for health treatments present information on 331 herbs belonging to 65 families used in the treatment of ailments. The list includes some edible plants. Most interesting is the information on *Allium tripedale* and *A. ampeloprasum* used here by some ethnic groups for making a delicious and appetizing bread called "Kalaneh".

Chapter 22 explains the knowledge collected during 2001–2018 on the fish fauna in the Amur Water system of the Jewish Autonomous Region in Russia with number of specific ecocenotic and biological characteristics. The composition is noted to vary considerably depending on how far the entrance to the Amur River is and the river flow characteristics. There are 92 species from 66 genera in 25 families found here, which is 74.2% of the species diversity of fish in the basin, and 6 species of rare fishes are found in the Amur basin.

Paleogeography of the Caspian Sea, water level fluctuations and consequences on the environment and civilization are discussed in Chap. 23. The chapter covers information on the Caspian as area of the first civilization; big Caspian floods including Noah flood and its consequences; the water fluctuations; name of the sea as Hazar, which is said to be related with the fluctuation of sea level; its connections to the Black Sea by the Manych Spillway; other water connections; climate change issues; appearance as epicentre of the flood; and the most sensitive indicator of other events, Oasis theory.

With the climate change and the increasing frequency of other destructive forces, reduction in biodiversity as well as agrodiversity can lead to catastrophic consequences for humans. Maintaining biodiversity poses a great challenge for humanity. The porosity of international borders and demands for wildlife will continue to threaten marketable species. Fragmentation, together with huge demand for wildlife as food, medicine and pets, will lead to increased trafficking, and many species with high commercial value are and will face the threat of extinction. This volume covers these issues together with other facets related to this theme in West Asia and the Caucasus region. Attempts have been made to highlight the research gaps in the countries covered.

Izmir, Turkey Münir Öztürk
Hatay, Turkey Volkan Altay
Istanbul, Balikesir, Turkey Recep Efe

Acknowledgment

The editorial team is highly indebted to the actively working colleagues from different parts of the world, who were kind enough to collaborate with us. We owe a deepest sense of gratitude for their full cooperation and support as they had to wait patiently for our lengthy submission procedure.

The motivation from IPBES mail messages inspired us greatly to work on this book. The editors would like to express their special thanks to them.

The success in the preparation of this volume depended largely on the encouragement from the Springer team who collaborated with us; therefore, our greatest appreciation goes to them.

Contents

About the Editors

Prof. Dr. Münir Öztürk holds a Ph.D. and D.Sc. from Ege University, Turkey, and has served at the same university for 50 years in different positions. He is currently vice president of the Islamic World Academy of Sciences. Prof. Ozturk received fellowships from the Alexander von Humboldt Foundation, the Japanese Society for Promotion of Science, and the National Science Foundation of the USA. He has served as chairman of the Botany Department and founding director of the Centre for Environmental Studies, Ege University; as consultant fellow, Faculty of Forestry, Universiti Putra Malaysia, Malaysia; and as distinguished visiting scientist, ICCBS, Karachi University, Pakistan. His fields of scientific interest are plant ecophysiology, medicinal and aromatic plants, conservation of plant diversity, biosaline agriculture and crops, pollution, and biomonitoring. He has published more than 40 books, 80 book chapters, and 190 papers in journals and has served as guest editor for more than 10 journals.

Prof. Dr. Volkan Altay is professor of ecology and environmental sciences at the Hatay Mustafa Kemal University, Turkey. His fields of scientific interest are plant ecology, vegetation ecology, taxonomy, biodiversity, biomonitoring, pollution ecology, and sustainable use of medicinal plant resources. He has a proven track record of nearly 50 research publications in highly reputed journals. Prof. Altay has also published one book with Springer, written several reviews, and has contributed in numerous international conferences and seminars.

Prof. Dr. Recep Efe completed his Ph.D. and D.Sc. degrees along with postdoctoral studies in the U.K. He has over 200 publications, has published more than 120 papers in national and international journals, and authored and co-authored/edited 600 books and 18 book chapters in Turkish and English. He has organized and chaired 18 national and international conferences. Dr. Efe is member of International Geographical Union (IGU), Association of American Geographers (AAG), International Associations of Geomorphologists (IAG), International Association of Hydrological Sciences (IAHS-6648), Balkan Geographical Association, and Turkish Geographical Association. He is on the editorial board of several national and international journals. Dr. Efe works in the fields of ecology, ecosystem analysis, geomorphology, vegetation, biogeography, land degradation, land use, and ecotourism.

Chapter 1
Biodiversity and Environmental Conservation in Palestine

Mazin B. Qumsiyeh and Mohammed A. Abusarhan

1.1 Introduction

In the late twentieth century, the conservation of biological diversity became a main goal of global actions for a sustainable planet. This followed significant decline in biodiversity accompanying the industrialization that spread widely in the nineteenth and twentieth centuries resulting in climate change and habitat destruction (Nurlu et al. 2008). Two key organizing documents emerged to set the stage for global actions: the Global Biodiversity Strategy and the Convention on Biological Diversity (CBD) (both in 1992).

Palestine connects Africa with Eurasia, and it is where the first humans migrated out of Africa and also where the first human agriculture developed. The geologic history especially the formation of the Great Rift Valley formed varied topography and evolutionary changes with a rich fauna and flora. There are diverse habitats covering five ecological zones (Central Highlands, Semi-coastal Region, Eastern Slopes, Jordan Rift Valley, and Coastal Regions) and five phytogeographical areas (Coastal, Mediterranean, Irano-Turanian, Saharo-Arabian, and Sudanese/Ethiopian) (Qumsiyeh 1985; Soto-Berelov et al. 2015). Mild weather, rich soils, rich wildlife, and presence of wild edible fauna and flora allowed humans to go from being hunter-gatherers to developing an agricultural and nomadic shepherd life (McCorriston and Hole 1991; Eshed et al. 2004). The transition to agriculture from hunter-gatherer communities also allowed increase in population and more time for people to develop civilizations.

Our region has undergone significant human-induced environmental changes including those caused by migrations, industrialization, climate change, and colonization, among others. This had a huge impact on biodiversity, but few studies have

M. B. Qumsiyeh (✉) · M. A. Abusarhan
Palestine Institute for Biodiversity and Sustainability, Bethlehem University, Bethlehem, Palestine
e-mail: mazin@qumsiyeh.org

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_1

addressed this. Just this year (2019), we noted numerous ecologically destructive incidents: trees were uprooted and agricultural lands ravaged by the Israeli army in Battir and Nahalin in Bethlehem governorate; wastewater dumped by colonists from "Betar Illit"; seedlings sabotaged by settlers in Burqa, Nablus governorate; continued environmental siege on Gaza that is devastating the environment; and much more.[1] Israel's tendency to put polluting industries in Palestinian areas has unsurprisingly produced negative health consequences for the people living there as well as for the local ecosystem. For example, significant genotoxicity is caused by Israeli industrial settlements on the Palestinian villagers near Salfit (Hammad and Qumsiyeh 2013), and recycling of e-waste that mostly originates in Israel in Idhna in the Hebron District impacted local health and environment (Khlaif and Qumsiyeh 2017). Also the local people engaged in many practices that impact the environment. Thus, in this chapter, we review data on what is known about threats to biodiversity in Palestine (a small but critical part of the Fertile Crescent) and discuss opportunities for conservation and sustainable living for both people and fauna and flora.

1.2 Status of Key Taxa Related to Conservation

The area has been sporadically studied before by visitors to the "Holy land" from Tristram (1866, 1884) to Morton (1924) to David Harrison in the 1960s (e.g., Harrison and Bates 1991). In the 1950s and 1960s, there were some studies of fauna and flora by the Israelis. The most notable of these was a series called "Fauna Palaestina" issues by the Israel Academy of Sciences, and good published work continued to flow into the 1980s (Levy and Amitai 1980; Yom-Tov and Tchernov 1988; Zohary 1973; Werner 1988).

Due to the colonization and occupation, research here still lags behind in Palestine (Qumsiyeh and Isaac 2012). Among native Palestinian zoologists, Dr. Sana Atallah (d. 1970) focused on mammals (Atallah 1977, 1978). Key taxa/groups that are useful for measuring environmental threats and thus important for conservation status were studied in Palestine. These include mollusks (Amr et al. 2018; Bdir and Adwan 2011, 2012; Handal et al. 2015, 2016; Heller and Arad 2009), amphibians (Salman et al. 2014), birds (Khalilieh 2016; Awad et al. 2016), and mammals (Atallah 1977, 1978; Qumsiyeh 1985, 1996; Werner 1988; Harrison and Bates 1991; Whitaker et al. 1994; Qumsiyeh et al. 1996; Qumsiyeh et al. 1998; Mendelssohn and Yom-Tov 1999; Benda et al. 2010). For example, earlier studies on the freshwater snails of historical Palestine include those of Tristram (1884) and Germain and de Kerville (1922) and were supplemented by work of Abdel-Azim

[1] See, for example, http://www.lrcj.org/publication-3-1169.html, http://www.lrcj.org/publication-3-1170.html, http://www.lrcj.org/publication-3-1171.html.

and Gismann (1956), Heller et al. (2005), and Handal et al. (2015). Those clearly show the utility of these taxa in assessing water quality.

So far, 373 bird species belonging to 23 orders, 69 families, 21 subfamilies, and 172 genera have been recorded from the occupied Palestinian areas (Awad et al. 2016). Birds of prey can be of good utility in assessing environmental changes (because of their position in the food web) (Brett 1988). Amr et al. (2016) showed a decline in biodiversity in the Bethlehem district evidenced by the study of old and newer food pellets of the Eagle owl. Saeed and Qumsiyeh (2020) compared records of birds reported by the first studies done in the nineteenth century with what is found today and showed significant negative trends (related to human effects) such as the disappearance of the brown fishing owl. It is then clear that a study of the threats to biodiversity is critical.

1.3 Environmental Threats in Palestine

Environmental threats are global in nature but are exacerbated in developing countries especially in regions of conflict. In Palestine, even in ancient times, there is evidence of Canaanitic villages stripping their populations of gazelles. In the more modern era, forests in the Eastern Mediterranean region were cut down for household, industrial, and commercial uses. Under British occupation (1917–1948), and Israeli and Jordanian rule (>1948), destruction continued, but also interventions that were supposed to be beneficial like forestation were done mostly with European pine trees (monoculture of *Pinus halepensis*) (Qumsiyeh 1996).

Under Israeli occupation and colonization, Palestinians were prevented not only from doing much of their usual agriculture but also from managing lands. Many forested hills were converted to residential Jewish-only colonial settlements (e.g., Jabal Abu-Ghneim became Har Homa colony near Bethlehem) and generated far more pollution than similar settlements inside Israel.

The modern threats were not unanticipated. For example, Ives (1950) discussed the land's capacity and the fact that trends which started in the 1930s if continued would devastate the area. Not only was he right, but more threats evolved since the 1950s (Qumsiyeh 1996; Tal 2002; Qumsiyeh 2004). Alon Tal acknowledged even before he wrote his book (2002) that: "We came here to redeem a land and we end up contaminating it" (Beyer 1998).

The main threats to doing better conservation efforts can be simply categorized as issues that are peculiarly Palestinian (like occupation/colonization) or global issues. Anecdotal notes and opinions on the Palestinian environment are not reviewed in this work (for an example of the genre of this kind of work, see Alleson and Schoenfeld 2007; Abu Safieh 2012). The ranking of threats to the Palestinian Environment according to the fifth national CBD report is available and seems reasonable though could be adjusted when and if additional data become available (EQA 2015; Table 1.1). Another report used the Delphi approach to ask some "experts" what the main threats are and came up with a somewhat different answer

Table 1.1 Selected threats to the Palestinian environment (After EQA 2015)

Threats	Threat ranking	
	West Bank	Gaza
Habitats fragmentation (due to urbanization, destruction of forests, climate change, desertification, colonial activities)	Very High	Very High
Desertification and soil erosion (due to overgrazing, climate change, infrastructure construction etc)	High	Very High
Urbanization and population growth	Very High	Medium
Removal of rocks for construction (stone querries etc)	Very low	Very High
Uprooting trees	Low	High
Overgrazing	Low	Very low
Land degradation (poor planning, soil erosion etc.)	High	Very High
Invasive alien species	No data	No data
Climate change	Low	Medium
Overexploitation (including poaching, overfishing etc).	High	Very High
Pollution (waste water, solid waste, use of chemical pesticides/insecticides/fertilizers)	Medium	Very High
Colonial residential and industrial settlements and associated infrastructure (like the Segregation wall)	Very high	Very low

(Abdallah and Swaileh 2011; AlHirsh et al. 2016). But the key threats need not even be prioritized to be analyzed. AlHirsh et al. (2016) used interviews with selected individuals involved in environmental issues in Palestine to see what threats are most prominent to the majority of those individuals.

Here we highlight three of the main threats to the Palestinian environment (climate change, water and waste water, and occupation/colonization) taken as key examples that set the stage to discuss interventions. But even here we will have to be limited because of space.

1.3.1 *Climate Change*

Climate change has a significant effect on biodiversity, human health, and sustainability (Harvell et al. 2002; Portnov and Paz 2008; Rinawati et al. 2013; Altay and Ozturk 2018; Imanberdieva et al. 2018; Ozturk 2018; Ozturk and Altay 2018; Ozturk et al. 2020), and this requires us to integrate educational, evolutionary, and ecological responses into models and potential remedies (Settele et al. 2017; Lavergne et al. 2010; Sternberg et al. 2015). The joint statement by world science academies warns that "Developing nations that lack the infrastructure or resources to respond to the impacts of climate change will be particularly affected..".[2] We in

[2] http://nationalacademies.org/onpi/06072005.pdf.

countries in the southern Mediterranean areas, the MENA region, will be particularly vulnerable (Sala et al. 2000).

Human-induced climate change will drastically effect the Arab world (Verner 2012). A World Bank study shows impacts including water resource decline will be drastic by 2040. In the West Bank and Gaza, while demand will double, supply will shrink dramatically! When coupled with population growth and habitat destruction (see Table 1.1), both the World Bank (Verner 2012) and the UN predict situation to become unlivable (UN 2012).

Newer models attempt to integrate species' own responses (ecologically, genetically, etc.) in predicting changes in species distribution following climate change and its impact on the habitat (Ozturk et al. 2004, 2012a; Lavergne et al. 2010). But preliminary data in Palestine in at least one study shows decline in vertebrate biodiversity as desertification spread into the Bethlehem district (Qumsiyeh et al. 2014).

1.3.2 Water and Liquid Waste

The situation of water is becoming very critical in the MENA region. While it is clear how it impacts human health and well-being, it is also critical for the ecosystem. Open water sources if closed off to use only for humans will impact a diversity of organisms. The government of the state of Israel which controls Palestinian (native) water claims there is water shortage, but the reality is that there is simply unequal distribution. For example, Israel diverts and uses most of the water resources of the Jordan River basin for irrigation farming through the so-called Israel national water carrier/canal (Elmusa 1998). From 1250 million cubic meters (mcm) per year, the river's flow declined to <20 mcm (Soffer 1994). Palestinians used 140 pumping units along the Jordan River before 1967, and all were destroyed or confiscated by the occupation authorities. Now Palestinians use <0.5% of the river basin waters. After a thorough review of the hydrological data, Elmusa (1998) concluded that: "Israel takes 80–90% of the freshwater resources of geographic Palestine. … The disparity in extraction between the two sides has translated into a conspicuous water gap in all sectors. … The gap is even more conspicuous between the Palestinians and the Israeli settlers who consume five to six times as much per capita as do the Palestinians and are profligate irrigation water users" (Elmusa 1998).

The UN Commission on Human Rights reported in 2000 that:

> The Palestinian use of the Jordan River before 1967 was through 140 pumping units. Israel either confiscated or destroyed all of those pumping units. In addition, Israel closed the large, irrigated areas of the Jordan Valley used by Palestinians, calling them military zones that later were transferred to Israeli settlers. At present Israel extracts more than 85 per cent of the Palestinian water from the West Bank aquifers.

Through military orders, all water in the occupied territories is designated "state owned by Israel" even though this violates the Fourth Geneva Convention (UNEP 2003). Palestine (a state not recognized by Israel as the occupying authority) did attempt to draft water and other natural resources' laws. The Palestinian authority even failed to get Israel to agree to many waste water and solid waste projects.

As Israel takes 91% of the West Bank Water resources, it provides much of it to illegal settlers (UN Commission of Human Rights 2000). It is obvious that all these measures contravene International law and conventions such as the Fourth Geneva Convention and the International Covenant on Economic, Social and Cultural Rights (Elmusa 1998). Israel also declared places like the Jordan valley closed military zones. Vast tracks of Palestinian agricultural lands were thus essentially confiscated and many of them turned to Jewish settlements.

The Oslo agreements were supposed to lead to ending the occupation but simply entrenched it with all attendant strengthening of Israeli control over the natural resources including water. International treaties and laws pertaining to water were ignored in deference to "might makes right." Regardless of political outcomes, there is simply a very small geographic territory (historic Palestine) with one hydrological system (Elmusa 1998). One democratic state ensuring distribution of water to its citizens based on international guidelines is actually most logical. The situation in Gaza is now catastrophic and cannot continue (Baalousha 2006; UN 2012). Water desalination projects as solution in Gaza have their own environmental issues.

The Israeli actions toward water sources have been catastrophic for nature biodiversity since the creation of "State of Israel," starting from drying out al Hula wetlands which eradicated life there and not ending with the Red Sea-Dead Sea Canal project. The latter is a prime environmental problem and should not have been implemented (the project already started). Its impact in the OPT will be most acutely felt in the unnatural "replenishment" of the Dead Sea while leaving the Jordan valley essentially dry and with continued environmental deterioration. We did some work on this, but much more research needs to be done, and the summary of these things are beyond the scope of this report.

But there is also mismanagement of the shrinking and limited water resources on the Palestinian side. A decaying water infrastructure is not upgraded because state funding has other priorities (like security, education, and healthcare). So there is some loss of water through the existing pipeline structures. In some areas, there is poor protection to freshwater supplies. For example, in the biodiversity important area of Al-Bathan near Nablus, the sewage water course merges with the freshwater spring course just below the picnic and park areas (ARIJ 2015). Further, there is no organized program to alert tourists to conserve water even as the ministry of tourism pushes hard to increase number of pilgrims to the Holy Land. Clearly some things can and should be done regardless of the status of the occupation.

The situation for sewage management in the occupied Palestinian areas is critical. In Gaza, a significant portion of the sewage flows untreated to the Mediterranean Sea. According UNEP (2003), 70% of solid waste in the occupied Palestinian territories is organic waste. This is a very high number and one that gives us an opportunity for significant reduction via composting to generate fertilizers. Sewage can also be treated, and other solid waste like metals and plastics and glass can be recycled. Waste water is dumped on some significant supposedly protected areas like Wadi Qana, Wadi Nar, and Wadi Far'a (Bathan), around Salfit (EQA 2015), and into the Mediterranean Sea where it is highly damaging to the environment (Akram and Cheslow 2016).

There is a real crisis in logistics and financing for proper solid waste disposal in Palestine (Abu Thaher 2005; Al-Khatib et al. 2007). The majority of solid waste disposed of in Palestinian areas like Nablus is organic which indicates a great potential for resource utilization such as for composting/fertilizer generation (Al-Khatib et al. 2010). But as in many developing countries, management of such solid waste lags behind significantly (Ahmed and Ali 2004).

1.3.3 Occupation/Colonization

Palestine had an indigenous Canaanitic population going back thousands of years and living in small village communities with few urbanized areas (like Jerusalem, Hebron, and Nablus). At the dawn of the industrial revolution, the population was a few hundred thousand (3% Jewish, 13% Christian, 80% Muslim, 4% other). The industrial age and improvement in health resulted in population expansion, but the Zionist project resulted in ethnic cleansing of most of the natives to be replaced by an immigrant, mostly European-Jewish population (Pappe 2006). Over 500 villages and towns were destroyed (most in 1948–1950, some in 1967). While Israel was created on 78% of Palestine, the remaining 22% was occupied in 1967 (Masalha 1992; Qumsiyeh 2004). In 1967, Imwas village was depopulated, and in its place, Canada Park was built. In all other areas of the occupied territories, forests and vegetation cover was removed to build the Israeli settlements which now house hundreds of thousands of Israelis. Simultaneously, rules were introduced that prevented Palestinians not only from doing much of their usual agriculture but also from managing forested lands or building in open spaces.

Currently nearly one million Israelis live in the occupied West Bank (WB). The WB is also divided into several categories: Jerusalem annexed to Israel, area C under Israeli civil and military control, area B under Israeli military control only (18.3%), and Area A under Palestinian civil and partial security control (17.7%) (ARIJ 2015). 30% of the territory is designated as closed military zones and "nature reserves" (these are occasionally reclassified to allow colonization). Israeli colonies were built on hilltops to fit into a pattern as to control the natural resources and control the native Palestinians (Benvenisti 2002). Environmental and human sustainability were not taken into considerations in these political decisions (ARIJ 2015). Untreated sewage water is discharged by settlers on Palestinian areas (ARIJ 2005; Newman 2009).

Israeli polluting industries were built near Palestinian communities in the occupied territories (due to tax incentives and lax laws). Gishuri Industries as an example manufactures pesticides and fertilizers next to Tulkarm. Significant pollution from this and other companies in this area has damaged citrus and vineyards (ARIJ 2015). We also showed significant genotoxic effect of the Barqan Industrial settlement on Burqeen village (Hammad and Qumsiyeh 2013).

Israel built "bypass" roads and other infrastructures in the occupied areas to serve the Jewish colonies. Lands were confiscated to build these, including extra "security zones and buffers" around roads, walls, etc. The landscape was severely damaged; 51.2 km^2 were destroyed just in 2000 for roads that do not served the local population. Land that was used by Palestinians or by wildlife thus was urbanized. Palestinians in the West Bank make 2.5 million people living in a built-up area of 367.7 km^2, a density of 6800 Palestinians per square kilometer which is 10 times more dense than for Israelis (ARIJ 2015). The disparity between settlers and natives in land control, economy, and access is also compounded by disparity in use of natural resources discussed earlier (Gordon 2008).

There are many other issues where the occupation negatively impacts sustainable development and the environment (MOPAD 2014). For example, tourism industry was mostly taken over, and it is supporting Israeli economy while negatively impacting the Palestinian economy and the Palestinian environment (Shay 2016; Isaac et al. 2016). Another example is the destruction of Bedouins life in the Negev (creating "concentration areas" for them) (Weizman and Sheikh 2015).

Politics trumping facts can be devastating to understanding of issues like environment and water. For example, deliberately misstating facts, hiding them, selectively using (mis)information, and much more were done by Israeli officials to serve their political interests in the Jordan River basin (Messerschmid and Selby 2015). Israel's unilateral actions of colonial settlement expansion and destruction of native lives have had devastating impacts on the Palestinian environment and raise significant questions about the possibility of planning let alone sustainability under occupation (Isaac et al. 2004). There may be a good reason to engage in legal proceedings that would be backed by good research and enlisting the services of good legal scholars and lawyers to pursue clams of environmental injustice and damages at local, national, and international fora.

The term "Green-washing the occupation" comes to mind when we realize that in many cases Israel takes land on the pretext of protecting it only to build colonies on it (Etkes and Ofran 2007). Ras Imweis and adjacent areas are a good example of this (became the settlement Nahal Shiloh). "Nature Reserves" and closed areas became pretexts for land confiscation. Such exploitation was obvious in the Bethlehem Governorate, when Har Homa settlement was established in 1997 on Abu Ghneim Mountain (Fig. 1.1).

1.4 Biodiversity Conservation Strategies in Palestine

The key vision that drives or should drive environmental conservation in Palestine as elsewhere should be a vision of a sustainable human population in a sustainable diverse natural environment. The latter must protect all elements of the ecosystem including plant-animal interactions. Since the industrial revolution, sustainability of ecosystems around the world has eroded due to human activity that causes habitat loss and environmental degradation. In the last few decades and especially with the growing realization of global human-induced climate change, there has been increased awareness and efforts focused on environmental conservation and at least

Fig. 1.1 The Israeli colony of Har Homa which was built and is still being expanded on a forested Palestinian Hill (called Jabal Abu Ghneim)

trying to halt destruction and mitigate effects with even some efforts going toward reversal of human-induced habitat changes. Most efforts are focused on in situ conservation of natural resources (Adams et al. 2004; AlHirsh et al. 2016).

The Governing Council/Global Ministerial Environment Forum in Cartagena, Colombia, asked the United Nations Environment Program (UNEP) to look at the state of the environment in Palestine. The results of a detailed study (UNEP 2003) led to more work and finally summarized in the Fifth National Report to the Convention on Biological Diversity (EQA 2015).

In 2015, EQA, through funds from the Belgian Cooperation Program, conducted a study of rich biodiversity areas. A total of 50 proposed protected areas were listed in the occupied Palestinian territories (Table 1.2); several of them are already listed as protected or important plant areas. Results of this study excluded some of these sites, since they are located within towns or cities or used as quarry pits. A detailed report is still under revision at the EQA. Boundaries of 29 areas were modified; three were not modified, while 18 were excluded from the proposed list. Two additional sites were suggested: Dura al Qare'a and Um al Safa 2. We also have a new study in the Wadi Makhrour area near Bethlehem that proposes it as a protected area (PIBS unpublished data).

Biodiversity conservation and protected areas in particular are covered by the National Biodiversity Strategy and Action Plan (NBSAP). The Plan focuses on protected areas and participation by the local and encourages capacity building in areas of biodiversity conservation. The Plan also addressed gaps that are very essential to develop concepts in biodiversity and protected areas conservation. These gaps include

Table 1.2 Key biodiversity areas that were listed in the Palestinian territories

Governorate	No.	Area
Bethlehem	7	Al Jaba'h, Jabal Abu Ghunaim, Mar Saba, Suleiman pools, Wadi Herodian, Wadi Makhrur, Wadi Fouqin
Hebron	11	Adderat-Yatta, Al Fawwar, Beit Fajjar, Beit Kahil, Beit Umar, Beit Ummar, Deir Razeh, Ithnah-Souba, Kanar, Tarqoumia, West Karma
Jenin	5	Aqqaba, Kufer El Rai, Qufien, Um Al Rihan, Um Al Tut
Jericho	3	Ain Esultan, Deir Hajalih, Wadi Auja
Jerusalem	8	Abu Deis, Anata, east of Aza'ym, Hizma, Mar Elias, Nabi Musa, north Tuur, beginning of Wadi Ennar
Nablus	6	Aqrabaniya, El Mizrab, Ein Sabastia, Salman Faresi, Talouza, Wadi Faraa
Qalqilya	2	Azzoun, Jayous
Ramallah	6	Al Jalazon, Ain Qinia, Beir Zeit, Jabal El Nijma, Turmus Ayya, Um Safa
Salfit	2	Al Matwi, Wadi Esha'ir

lack of primary scientific data, information, and documentation on biodiversity in Palestine and lack of and/or limited human resources. There are very few biologists especially marine and wildlife biologists and taxonomists, oceanographers, conservation managers, etc. and adequate legal frameworks and environmental policy and legal framework on which to base all activities for the conservation and sustainable use of biodiversity in Palestine, lack of coordination among national and local stakeholder agencies in biodiversity, and inadequate awareness and commitment to biodiversity. The objectives of the NBSAP for Palestine are in line with other countries in environmental conservation and sustainability. Now the EQA is engaged with us to build an updated and new NBSAP and produce the Sixth National CBD Report.

The earlier report from the state of Palestine in compliance with CBD listed many priorities ranging from basic research in biodiversity, threat assessments, better private-public relationships, using cultural heritage, better protected area management, stemming desertification, mitigation and adaptation to climate change, and habitat restoration (EQA 2015). The report lists in its executive summary 14 recommendations. Here they are paraphrased:

- Collaborative Management of Biodiversity
- Updating NBSAP
- Meet Aichi targets
- Mainstream biodiversity
- Better research to fill the gaps in knowledge
- Emphasize ecosystem services
- Work on areas like poaching (see, e.g., Helal and Khalilieh 2005), wildlife trade (e.g., Yom-Tov 2003), genetic diversity, biosafety, genetic modified organisms (GMOs), invasive species, and mitigation and adaptation
- Better investigations and rankings of threats as well as modeling and structuring responses scientifically and with community involvement

The five NBSAP objectives were identified with very limited progress achieved since the Fourth National Report. The only thing mentioned elsewhere in the same report but not clearly mentioned in these five objectives is the value of doing research; see above also from (EQA 2015). Vulnerable areas are of particular interest for further study because environmental degradation in Palestine has been accelerated with industrialization and large-scale deforestation.

In terms of conservation, there are even fewer scientific research studies published in the last 25 years. However, there were important larger reports that we considered that contributed to our understanding of environmental issues in the OPT, including biodiversity conservation. There were of course hundreds of other documents and research reports consulted during the course of this study (list of references cited at the end of the chapter). Two key factors that enter into success of environmental conservation in any country are economic and social factors. As noted above, the level of GDP is directly correlated with environmental concern (Mills and Waite 2009). The 13 million Palestinians in the world are now dispersed in many countries with 7.5 million being refugees or displaced people. In historic Palestine, over 6.2 million Palestinians still live, but nearly 30% of them are internally displaced or recognized as refugees. The GDP per capita of Palestinians is 1/8th that of Israelis who share with them the space of historic Palestine, but this gets more distorted during the cyclical uprisings against the occupation (Hever 2010). This has impact on environment and R&D (Qumsiyeh and Isaac 2012). For example, according to UNEP (2003), the GDP of the OPT which grew at 6% in 1999 shrunk by 6.5% in 2000 due to Israeli measures in response to the 2000 uprising. Further, there was a decline in GDP growth in the past few years as population grew while the economy did not expand (MOPAD 2014). There was some evidence that poorer communities and countries do worse in protecting their own environments, but this has been challenged, and richer countries may be fueling their own prosperity via exploitation of natural resources in poor countries (Mills and Waite 2009).

There has to be benefit sharing from conservation and biodiversity. Gorlach et al. (2011) summarized potential economic benefits from environmental conservation efforts (if successful) in the OPT. Though this benefit assessment was mostly based on little data collected on the ground, it does highlight the significant potential impact of saving our environment financially. Here are examples:

- Air: If air pollution is cut by 50%, modeling suggests premature mortality could decline by 220 and morbidity by 440 per year. Monetary benefit could be of 68 million euros per year.
- Water: Improved access to water services could significantly improve the quality of life for 1.2 million Palestinians. Improved wastewater treatment (perhaps concomitant with reduction of waste water in general) could have significant impacts on biodiversity, groundwater quality, and human health.
- Waste: Reducing solid waste would have significant impact on air quality, on environmental health, on human economy, and on biodiversity.

The use of plants and animals for humans is a field that needs much examination as it related to environmental conservation directly especially in terms of sustainable use of resources (Nurlu et al. 2008; Gucel et al. 2006, 2012; Khan et al. 2014; Altay et al. 2015; Ozturk et al. 2012b, 2014, 2017a, b). In Palestine as elsewhere, there is an interest in ethnobotany and ethnozoology (Ali-Shtayeh and Jamous 2006; Ali-Shtayeh et al. 2014; Palevits and Yaniv 2000; Said et al. 2002).

Poverty reduction and environmental conservation are directly linked, and we are not able to do proper conservation without tackling poverty in developing countries (Adams et al. 2004; Ozturk and Kebapci 2005; Ozturk et al. 2010; Ozturk 2013). Further it is possible to use socioeconomic incentives at periphery of protected areas or even allow managed use of natural resources as a form of poverty reduction which also incentivizes the local people to protect their environment (Ozturk and Kebapci 2005; Sunderlin et al. 2005; Ozturk et al. 2010).

Modern conservation philosophy argues that the local buy-in is critical for success of conservation efforts. We in Palestine certainly need to think strategically about how people around protected areas are to benefit from protection. There are models in nearby areas, for example, the way the Royal Society for Conservation of Nature worked with local communities to ensure active buy-in via direct benefit from things like ecotourism and environmentally sensitive agriculture.

Religious attitudes can be of potential use to promote environmental awareness and conservation. Religious clerks (Muslim and Christian) can introduce many concepts of conservation and environmental practices in the Friday and Sunday sermons. Several authors dealt with the ethical and divine relation of Islam to environment conservation (Amr and Quatrameez 2002). Islamic teachings are full of orders and events that encourage conservation as the concept of “Al Himma,” to save water, clean environment, and many others. Similarly, in Christianity, basic teachings include many environmentally friendly practices. In Palestine, The Holy Land, with so many religious connections and about a million devout pilgrims per year, it is incumbent upon policy makers and stakeholders to research ways to reach out to those who are religious with the message of environmental conservation.

The Palestinian Environmental Law needs to be updated. Violations of the law should include higher penalties. Obstacles to implementation include the fact that most (81%) of the protected areas are in Area C under Israeli rule. For example, the nascent state of Palestine cannot plan or protect its natural resources including areas like the unique corridor of Ein Fash’kha to Ein Jedi along the Dead Sea if it cannot access them (Garstecki et al. 2010; EQA 2015; http://www.nsp.pna.ps/en/). It is also worth noting that 36.2% of the designated protected areas overlap with Israeli settlements and 39.5% overlap with closed military areas and bases. Such utilization of a protected area confirms that their declaration does not respond to the international definition of a protected area, which calls mainly for biodiversity conservation (Ghattas 2008).

Despite all these obstacles, we think some things can still be done. The Palestine Institute for Biodiversity and Sustainability (PIBS), the Palestine Museum of Natural History (PMNH), and the Palestine Conservation Botanical Gardens (PCBG) were started at Bethlehem University with a vision of sustainable human and natural communities and ecosystems. The mission focuses on research, education, and conservation. The motto is RESPECT—for ourselves, for others, and for the environment. Via working with mainly school children, we do education tailored to different ages (Figs. 1.2, 1.3 and 1.4). We also built educational material via intensive research to assess need and local cultural peculiarities. For example, we developed six educational modules in the areas of agriculture, biodiversity, geogra-

Fig. 1.2 Children learning via playing, for example, imagining being a scorpion

Fig. 1.3 Museum staff member (Elias Handal) with students in show and tell

Fig. 1.4 Girls at the museum showing their gifts and decorations made from recycled solid waste

Fig. 1.5 One of many locally sensitive educational modules (in this case a poster on biodiversity) done related to climate change and conservation

phy, energy and transportation, waste and chemicals, and climate change (see the example in Fig. 1.5). PIBS/PMNH annual report is found here: https://www.palestinenature.org/about-us/final-annual-report.pdf.

For short videos about other activities/accomplishments, please see https://youtu.be/BPhFLOsEIM0 and https://youtu.be/AZOoOzXU7tQ.

1.5 Discussion

Palestine (renamed Israel in 1948) now has over 12 million people. Half the population is Israeli-Jewish, and they control 91.7% of the land, and the other half are native Christians and Muslims who control less than 8.3% of the land. Additionally, close to 6 million Palestinians live outside the country (mostly refugees). Israel is trying a three-pronged program: (a) preventing refugees from returning, (b) incentives and other tools to lure in as many Jewish (or even non-Jewish but not native) immigrants who identify with Zionism, and (c) making life so hard for the remaining Palestinians that they leave (or even outright removing them) (Qumsiyeh 2004). Environmental destruction is related to instability, inequality of resource distribution, and habitat destruction in Palestine (Kelly and Homer-Dixon 1996; Qumsiyeh 2013). Solving this requires addressing these issues.

Alatout (2006) showed that differences in perception of power relationships impact perceptions of issues of environmental justice between Palestinians and Israelis. Basically those in power view environmental issues in terms of improvements in their quality of life, while Palestinians view them as issues of sovereignty, property rights, and mere survival.

In the past 25 years, there has been a revival of interest in studies of biodiversity among native Palestinians. Of course we have in no way even approached the level of publications or interest in nearby countries like Jordan or Israel, but we must guard against a decline of that interest in biodiversity research seen, for example, in Israel in association with industrialization (Dayan et al. 2011). We will discuss below examples of this revival of interest, including the establishment of a number of programs at universities (e.g., master programs in Environmental Studies at Al-Quds and Birzeit and the Institute of Biodiversity and Sustainability at Bethlehem University). But we must also separate scientific work from anecdotal notes and opinions on the Palestinian environment.

A big challenge to the EQA and relevant agencies working on Palestinian diversity is that there are so few baseline studies on where are the rich biodiversity areas and what they contain in the OPT (a gap of knowledge). Recent work in the past 5 years on protected areas and their buffer zones in Palestinian areas can provide a model for biodiversity conservation while promoting ecosystem services. Two prominent examples from our work is Wadi Al-Quff (Qumsiyeh 2016a, b; Qumsiyeh et al. 2016; Khalilieh 2016) and Wadi Makhrour. Al-Makhrour is the last remaining biodiversity-rich area in the Bethlehem district, 2.6 km^2 of natural areas interspersed with agriculture and rich flora and fauna and an equivalent buffer zone of more than 5 km^2. It is also one of 13 important bird areas in Palestine rich in cultural heritage, including old Roman tombs, ancient wells, old Palestinian watchtowers, and a part which is considered a World Heritage Site by UNESCO. However, no management plans or conservation programs have been implemented by any organization in the area. The valley suffers from habitat loss and land fragmentation, causing biodiversity loss, and from challenging livelihood conditions as a result of (among others) the lack of economic motivations, no subsidies for farming practices, and inadequate markets for extra production. A project initiated by our institute there showed that we can use education, permaculture, agricultural, and ecotourism to actually make a difference even under these difficult circumstances of occupation and colonization.

1.6 Recommendations

1.6.1 Research

Palestine needs scientific data covering all areas relevant to protected areas and potential protected areas by using the best available data collection methods. We recommend this effort to collect baseline data be led by qualified academic centers covering areas like geography, geology, hydrology, fauna, and flora. The only protected area where such data was collected is Wadi Al-Quff (Qumsiyeh 2016a, b; Qumsiyeh et al. 2016; Khalilieh 2016). With upward of 48–51 areas in need of protection, the work ahead of us is daunting and will take a few years. We suggest prioritizing the work in the next 5 years to study Al-Qarn, Wadi Haramya, Wadi Al-Qelt, Um Al-Tut, and Wadi Qana. The studies must use experts after proper announcements of funding availability.

1.6.2 Management Plans to Deal with Threats

Management plans must use ecosystem approaches and deal with social, cultural, and economic issues. Designing Management Plans for protected areas are done by trained experts (we have so few of those in the Middle East). Thankfully, groups like the RSCN (Jordan) are willing to help. The conflict between EQA and the MOA in terms of authority over parks should be resolved one way or another. That the EQA with help of some experts came up with a draft management plan for Wadi Al-Quff is a first step. That project costs over $100,000 and 2 years of work for just one locality. The next should be sitting down at high-level government officials to decide how to and who should implement the plan. There is unfortunately a failure to do that, and instead there is now a plan afoot to transfer the responsibility of Wadi Al-Quff PA to the municipality of Hebron to manage it. Local municipalities are subject to various pressures which cannot result in sustainable conservation efforts. This would be a very bad omen for this rich area with key endangered species like raptors. It could also set a very bad precedent.

1.6.3 Economy and Ecotourism

Strategies for conservation that also enhance local economic development (e.g. through use of permaculture) must be developed. Much can be done in promoting tourism even under occupation if partnerships are built such as what happened with Masar Ibrahim between academia and NGOs. Other possible partnerships are the ones involving the private sector and civil society groups and the government ministries with civil society groups in more official capacities. The most important is to revive and invest in the capacity of a restructured EQA to oversee these partnerships and ensure outcome-driven projects are implemented without duplication of efforts and with maximum efficiency. Tourism must be developed only if it is sustainable. We believe in developing areas like agricultural tourism, ecotourism, cultural tourism, and other forms of alternative/sustainable tourism. Similarly, much can be done to make sure that conservation is beneficial to the local community rather than harmful to their economy.

1.6.4 Conservation Mainstreaming

Knowledge base of conservation issues in Palestine linked to global conservation efforts (mostly developed by researchers with some support from NGOs and EQA and MOA) must be expanded. Conservation awareness must be structured in a unified way to (a) explain what conservation is, (b) why we need it, and (c) how each of us can affect the change in behavior. Existing officials in NGOs, academic institutions, and governmental bodies must prioritize conservation. In 2005, 170 Palestinian civil society organizations called for using the strategy of boycotts, divestments, and sanctions as a peaceful non-violent strategy to end the occupation and achieve other internationally recognized rights of the Palestinian people. Since then, thousands of NGOs and all major academic institutions in Palestine have adopted this call (see bdsmovement.net). Credible environmental groups did join this campaign. Environmentally sensible choices of consumers can also be encouraged that are protective of the environment/ethical consumerism (see Dajani and Isma'il 2014). The EU and other funders must stop any and all efforts to promote normalization because they do not lead to peace. Peacemaking in situations of occupation and colonialism has a very well-developed theoretical and practical body of knowledge that can be evaluated but is beyond the scope of this work. Further such efforts only make the environmental situation worse by delaying freedom and sovereignty for the native people.

Acknowledgments We would like to thank Prof. Zuhair Amr, Elias Handal, Mohammad Najajrah, and our PIBS team for their support. Thanks are also due to the Environmental Quality Authority (esp. Dr. Issa Baradiya and Mohammad Mahasne) for their help. Funding for part of the work came from the City of Geneva, the Darwin Initiative, and the EU Peace Initiative (project Unity and Diversity in Nature and Society).

References

Abdallah T, Swaileh K (2011) Effects of the Israeli Segregation Wall on biodiversity and environmental sustainable development in the West Bank, Palestine. Int J Environ Stud 68:543–555

Abdel-Azim M, Gismann A (1956) Bilharziasis survey in South-Western Asia; covering Iraq, Israel, Jordan, Lebanon, Sa'udi Arabia, and Syria: 1950–51. Bull World Health Organization

Abu Safieh Y (2012) The radical transformation of Palestine's environment: Israel's occupation is largely responsible for the pollution and radical transformation of the Palestinian environment. In: Al Jazeera. http://www.aljazeera.com/indepth/opinion/2012/04/201242811593745665.html

Abu Thaher A (2005) Solid wastes collection, disposal, and financial aspects in the West Bank. Environmental Quality Authority, Ramallah

Adams WM, Aveling R, Brockington D et al (2004) Biodiversity conservation and the eradication of poverty. Science 306:1146–1149

Ahmed SA, Ali M (2004) Partnerships for solid waste management in developing countries: linking theories to realities. J Habitat Int 28:467–479

Akram F, Cheslow D (2016) Gaza sewage poisons coastline, threatens Israel. In: phys.org. https://phys.org/news/2016-05-gaza-sewage-poisons-coastline-threatens.html. Accessed 20 Feb 2019

Alatout S (2006) Towards a bio-territorial conception of power: territory, population, and environmental narratives in Palestine and Israel. Polit Geogr 25:601–621

AlHirsh I, Battisti C, Schirone B (2016) Threat analysis for a network of sites in West Bank (Palestine): an expert-based evaluation supported by grey literature and local knowledge. J Nat Conserv 31:61–70

Ali-Shtayeh MS, Jamous RM (2006) Ethnobotany of Palestinian herbal medicine in the northern West Bank and Gaza strip: review and comprehensive field study. Biodivers Environ Sci Stud Ser 4:1–122

Ali-Shtayeh MS, Jamous RM, Abu-Zeitoun SY (2014) National list of medicinal plants in Palestine-west bank and Gaza strip. Palestine Biodiversity & Environmental Research Center, Til, Nablus

Al-Khatib IA, Arafat HA, Basheer T et al (2007) Trends and problems of solid waste management in developing countries: a case study in seven Palestinian districts. Waste Manag 27:1910–1919

Al-Khatib IA, Monou M, Zahra ASFA et al (2010) Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus District. Palest J Environ Manag 91:1131–1138

Alleson I, Schoenfeld S (2007) Environmental justice and peacebuilding in the Middle East. Peace Rev 19:371–379

Altay V, Ozturk M (2018) Potential impact of climate change on relict plant species. In: 2nd international science conference on "natural sciences, climate & biodiversity", September 15–17, 2018, Muzaffarabad, Pakistan, 68–69

Altay V, Keskin M, Karahan F (2015) An assessment of the plant biodiversity of Mustafa Kemal university Tayfur Sokmen campus (Hatay-Turkey) for the view of human health. Int J Sci Technol Res 1(2):83–103

Amr ZS, Quatrameez M (2002) Wildlife conservation in Jordan: a cultural and Islamic perspective. Heaven and earth and I: ethics of nature conservation in Asia. Penguin Enterprsie, Delhi, pp 172–184

Amr ZS, Handal EN, Bibi F et al (2016) Change in diet of the Eurasian eagle owl (*Bubo bubo*) suggests decline in biodiversity in Wadi Al Makhrour, Bethlehem governorate, Palestinian territories. Slovak Raptor J 10:75–79

Amr ZS, Najajreh MH, Zawahrah M et al (2018) Diversity and ecology of the land snails of the Palestinian territories of the West Bank. Zool Ecol 28:25–35

ARIJ (2005) The nature reserves in light of the Israeli assaults. Applied Research Institute, Jerusalem

ARIJ (2015) Status of environment in OPT. Applied Research Institute, Jerusalem

Atallah SI (1977) Mammals of the eastern Mediterranean region; their ecology, systematics and zoogeographical relationships. Säugetierkundliche Mitteilungen 241–319

Atallah SI (1978) Mammals of the eastern Mediterranean region; their ecology, systematics and zoogeographical relationships. Säugetierkundliche Mitteilungen 1–50

Awad S, Abu Saada RK, Farhoud MH, Khair MI (2016) Checklist of the birds of Palestine. Beit Jala

Baalousha H (2006) Vulnerability assessment for the Gaza strip, Palestine using DRASTIC. Environ Geol 50(3):405–414

Bdir S, Adwan G (2011) Larval stages of digenetic trematodes in Melanopsis praemorsa snails from freshwater bodies in Palestine. Asian Pac J Trop Biomed 1:200–204

Bdir S, Adwan G (2012) Three new species of cercariae from *Melanopsis praemorsa* (L. 1758, Buccinum) snails in Al-Bathan fresh water body, Palestine. Asian Pac J Trop Biomed 2:1064–1069

Benda P, Lucan RK, Obuch J et al (2010) Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 8. Bats of Jordan: fauna, ecology, echolocation, ectoparasites. Acta Soc Zool Bohemicae 74:185–353

Benvenisti M (2002) Sacred landscape: the buried history of the Holy Land since 1948. University of California Press

Beyer L (1998) Trashing the Holy Land. Times Int Mag 62

Brett J (1988) Birds of prey in Palestine. In: 1st Palestinian ecology conference. Department of Life Sciences, Bethlehem University, 109–112

Dajani M, Isma'il L (2014) Conscious choices: a guide to ethical consumerism in Palestine. Heinrich-Böll-Stiftung

Dayan T, Ben-Avraham Z, Nathan R et al (2011) Biodiversity research and higher education at the Research Universities of Israel. Jerusalem

Elmusa SS (1998) Water conflict: economics, politics, law and Palestinian-Israeli water resources

EQA (2015) Fifth National report to the convention on biological diversity

Eshed V, Gopher A, Gage TB, Hershkovitz I (2004) Has the transition to agriculture reshaped the demographic structure of prehistoric populations? New evidence from the Levant. Am J Phys Anthropol 124:315–329

Etkes D, Ofran H (2007) Construction of settlements and outposts on nature reserves in West Bank

Garstecki T, Al-Rabi T, Mahassneh M, Mezyed B (2010) Assessment of some Palestinian nature reserves. IUCN

Germain L, de Kerville HG (1922) Mollusques terrestres et fluviatiles de Syrie. J.-B. Baillière et fils

Ghattas R (2008) Beyond the natural scenes of Palestinian nature reserves. 34–39

Gordon N (2008) From colonization to separation: exploring the structure of Israel's occupation. Third World Q 29:25–44

Gorlach B, Möller-Gulland J, Bar-On H, Atrash I (2011) Analysis for European neighbourhood policy (ENP) Countries and the Russian Federation of Social and Economic Benefits of Enhanced Environmental Protection

Gucel S, Gokcekus H, Ozturk M (2006) Biodiversity of Northern Cyprus and its conservation strategies. Int. Meeting, October, 2006, Foca, Turkey

Gucel S, Kadis C, Ozden O et al (2012) Assessment of biodiversity differences between natural and artificial wetlands in Cyprus. Pak J Bot 44:213–224

Hammad KM, Qumsiyeh MB (2013) Genotoxic effects of Israeli industrial pollutants on residents of Bruqeen village (Salfit district, Palestine). Int J Environ Stud 70:655–662

Handal EN, Amr Z, Qumsiyeh MB (2015) Some records of freshwater snail from the occupied Palestinian territories. Jordan J Nat Hist 2:23–29

Handal EN, Amr ZS, Qumsiyeh MB (2016) Some records of reptiles from the Palestinian territories. Russ J Herpetol 23:261–270

Harrison DL, Bates PJJ (1991) The mammals of Arabia, 2nd edn. Harrison Zool Museum Publ Sevenoaks, Kent

Harvell CD, Mitchell CE, Ward JR et al (2002) Climate warming and disease risks for terrestrial and marine biota. Science 296:2158–2162

Helal H, Khalilieh A (2005) National report on hunting. Unpublished report to the EU

Heller J, Arad Z (2009) Land snails of the land of Israel: natural history and a field guide. Pensoft Publ 144:229–260

Heller J, Mordan P, Ben-Ami F, Sivan N (2005) Conchometrics, systematics and distribution of *Melanopsis* (Mollusca: Gastropoda) in the Levant. Zool J Linnean Soc 144(2):229–260

Hever S (2010) The political economy of Israel's occupation. Pluto Press, London

Imanberdieva N, Imankul B, Severoğlu Z et al (2018) Potential impacts of climate change on plant diversity of Sary-Chelek biosphere Reserve in Kyrgyzstan. In: Egamberdieva D, Ozturk M (eds) Vegetation of Central Asia and environs. Springer Nature, Cham, pp 349–364

Isaac J, Rishmawi K, Safar A (2004) The impact of Israel's unilateral actions on the Palestinian environment. Appl Res Institute- Jerusalem

Isaac R, Hall CM, Higgins-Desbiolles F (eds) (2016) The politics and power of tourism in Palestine, New York

Ives RL (1950) The Palestinian environment. Am Sci 38:85–104

Kelly K, Homer-Dixon T (1996) Environmental scarcity and violent conflict: the case of Gaza

Khalilieh A (2016) Avifaunal baseline assessment of Wadi Al-Quff protected area and its vicinity, Hebron, Palestine. Jordan J Nat Hist 3:58–69

Khan MA, Boer B, Ozturk M et al (eds) (2014) Cash crop halophytes and biodiversity conservation, Sabkha ecosystems IV: (Tasks for vegetation science 47). Springer, New York. 339 p

Khlaif N, Qumsiyeh MB (2017) Genotoxicity of recycled electronic waste in Idhna, Hebron District, occupied Palestinian territory: a case-controlled study. Intern J Environ Stud 74:66–74

Lavergne S, Mouquet N, Thuiller W, Ronce O (2010) Biodiversity and climate change: integrating evolutionary and ecological responses of species and communities. Annu Rev Ecol Evol Syst 41:321–350

Levy G, Amitai P (1980) Fauna Palaestina, Arachnida I: Scorpiones. Israel Academy of Sciences and Humanities

Masalha N (1992) Expulsion of the Palestinians: the concept of "transfer" in Zionist political thought, 1882–1948. Institute for Palestine Studies

McCorriston J, Hole F (1991) The ecology of seasonal stress and the origins of agriculture in the near east. Am Anthropol 93:46–69

Mendelssohn H, Yom-Tov Y (1999) Mammalia of Israel. Israel Academy of Sciences and Humanities

Messerschmid C, Selby J (2015) Misrepresenting the Jordan River basin. Water Altern 8:258–279

Mills JH, Waite TA (2009) Economic prosperity, biodiversity conservation, and the environmental Kuznets curve. Ecol Econ 68:2087–2095

MOPAD (2014) State of Palestine National Development Plan 2014–2016. Ministry of Planning and Administrative Development

Morton KJ (1924) The Dragon-flies (Odonata) of Palestine, based primarily on collections made by Dr. P. A. Buxton, with Notes on the Species of the Adjacent Regions. Trans R Entomol Soc London 72:25–44

Newman D (2009) In the name of security: in the name of peace - environmental schizophrenia and the security discourse in Israel/Palestine. In: Brauch HG et al (eds) Facing global environmental change. Hexagon series on human and environmental security and peace. Springer, Berlin/Heidelberg

Nurlu E, Erdem U, Ozturk M et al (2008) Landscape, demographic developments, biodiversity and sustainable land use strategy: a case study on Karaburun Peninsula, Izmir, Turkey. In: Petrosillo I et al (eds) Use of landscape sciences for the assessment of environmental security. Springer, Dordrecht, pp 357–368

Ozturk M (2013) Biodiversity and conservation strategies. Application of frontier technologies in documentation and conservation of biodiversity and climate change, 29–30 November, Shaheed Benazir Bhutto University, Pakistan

Ozturk M (2018) Biodiversity and climate change: our home is on fire. In: 2nd international science conference on "natural sciences, climate & biodiversity", p 68, September 15–17, Muzaffarabad

Ozturk M, Altay V (2018) Impact of climate change on sea level, bioresources, biodiversity, marine invasive species, ecology and food web: Past, present, and future. Understandıng the Problems of Inland Waters: Case Study for the Caspian Basin (UPCB), p 30–34, 12–14 May, Baku, Azerbaijan

Ozturk M, Kebapci U (2005) Biodiversity & Conservation: past, present and future. Xth EURECO European ecological congress, 8-13 November, Kusadasi, p 9

Ozturk M, Parks CR, Coskun F et al (2004) Vanishing tertiary genetic heritage in the East Mediterranean, *Liquidamber orientalis* Mill. Environ Forensic 10(4):6–8

Ozturk M, Aksoy A, Gucel S, Altundag E (2010) Biodiversity & conservation-a case study from Europe & Turkey. In: Bhatti R, Soomro SA (eds) Proceedings of 2nd international conference “Biodiversity is our life” (IC Biour-life). Center for Biodiversity & Conservation, Shah Abdul Latif University, Khairpur, pp 1–12

Ozturk M, Gucel S, Altay V, Altundag E (2012a) *Alliums*, an underutilized genetic resource in the East Mediterranean. Acta Hort (969):303–309

Ozturk M, Kebapci U, Gucel S et al (2012b) Biodiversity & land degradation in the lower Euphrates subregion of Turkey. J Environ Biol 33(Suppl):311–323

Ozturk M, Altay V, Gucel S, Guvensen A (2014) Halophytes in the East Mediterranean-their medicinal and other economical values. Sabkha ecosystems. Vol. IV: Cash crop halophyte and biodiversity conservation tasks for vegetation science, Vol. 47, Springer, Dordrecht, p 247–272

Ozturk M, Altay V, Gonenç TM (2017a) Herbal from high mountains in the East Mediterranean. In: Bhojraj S et al (eds) Drug discovery from herbs – approaches and applications. DAYA Publishing House, New Delhi, pp 327–367

Ozturk M, Altay V, Gucel S, Altundag E (2017b) Plant diversity of the drylands in Southeast Anatolia-Turkey: role in human health and food security. In: Ansari AA, Gill SS (eds) Plant biodiversity: monitoring, assessment and conservation. CABI, Wallingford, pp 83–124

Ozturk M, Egamberdieva D, Milica P (2020) Biodiversity and biomedicine-our future. Academic Press is an imprint of Elsevier, London. 600 p

Palevits D, Yaniv Z (2000) Medicinal plants of the Holy Land. Modan Publishing House

Pappe I (2006) The ethnic cleansing of Palestine. Oneworld Publication, Oxford

Portnov BA, Paz S (2008) Climate change and urbanization in arid regions. Ann Arid Zone 47:457

Qumsiyeh MB (1985) The bats of Egypt. Texas Tech Press

Qumsiyeh MB (1996) Mammals of the holy land. Texas Tech University Press

Qumsiyeh MB (2004) Sharing the land of Canaan: human rights and the Israeli-Palestinian struggle. Pluto Press, London

Qumsiyeh MB (2013) The coming environmental Nakba. In: The third Palestinian environmental awareness and education, conference. EEC, Bethlehem, pp 57–59

Qumsiyeh MB (2016a) Fauna of Wadi Al-Quff protected area: amphibians, reptiles and mammals. Jordan J Nat Hist 3:70–79

Qumsiyeh MB (2016b) Invertebrate Fauna of Wadi Al-Quff protected area, Palestine. Jordan J Nat Hist 3:80–92

Qumsiyeh MB, Isaac J (2012) Research and development in the occupied Palestinian territories: challenges and opportunities. Arab Stud Q 34:158–172

Qumsiyeh MB, Amr ZS, Budari AM (1996) Status and conservation of Artiodactyla (Mammalia) in Jordan. Mammalia:417–430

Qumsiyeh MB, Amr ZS, Al-Oran RM (1998) Further records of bats from Jordan and a synopsis. Turkish J Zool 22:277–284

Qumsiyeh MB, Zavala SS, Amr ZS (2014) Decline in vertebrate biodiversity in Bethlehem, Palestine. Jordan J Biol Sci 7:01–107

Qumsiyeh MB, Khalilieh A, Albaradeiya IM, Al-Shaikh B (2016) Biodiversity conservation of Wadi Al-Quff Protected area (Central Palestine): challenges and opportunities. Jordan J Nat Hist 3:6–24

Rinawati F, Stein K, Lindner A (2013) Climate change impacts on biodiversity-the setting of a lingering global crisis. Diversity 5:114–123

Saeed R, Qumsiyeh MB (2020) Are 19th century studies relevant to understanding changes in raptor bird fauna in the Fertile Crescent? An example from Tristram’s work. Sandgrouse (J Ornithol Soc Middle East) 42:69–77

Said O, Khalil K, Fulder S, Azaizeh H (2002) Ethnopharmacological survey of medicinal herbs in Israel, the Golan Heights and the West Bank region. J Ethnopharmacol 83:251–265

Sala OE, Chapin FS, Armesto JJ et al (2000) Global biodiversity scenarios for the year 2100. Science 287:1770–1774

Salman I, Salsaa M, Qumsiyeh M (2014) Distribution and cytogenetics of amphibians from the occupied Palestinian territories (West Bank of Jordan). Jordan J Nat Hist 1:116–130
Settele J, Hammen V, Hulme P et al (2017) Alarm: assessing large-scale environmental risks for biodiversity with tested methods. GAIA Ecol Perspect Sci Soc 14:69–72
Shay T (2016) The Ethnocracy of the Palestinian urban space and the indigenous approach: praxis and theory. Archaeologies 12:73–90
Soffer A (1994) The relevance of Johnston plan to the reality of 1993 and beyond. In: Isaac J, Shuval H (eds) Water and peace in the Middle East. Elsevier, Amsterdam
Soto-Berelov M, Fall L, Falconer E, Ridder E (2015) Modeling vegetation dynamics in the southern Levant through the bronze age. J Archaeol Sci 53:94–109
Sternberg M, Gabay O, Angel D et al (2015) Impacts of climate change on biodiversity in Israel: an expert assessment approach. Reg Environ Chang 15:895–906
Sunderlin WD, Angelsen A, Belcher B et al (2005) Livelihoods, forests, and conservation in developing countries: an overview. World Dev 33:1383–1402
Tal A (2002) Pollution in a promised land: an environmental history of Israel. Univ of California Press
Tristram HB (1866) Report on the mammals of Palestine. Proc Zool Soc London 36:84–93
Tristram HB (1884) The survey of Western Palestine: the fauna and flora of Palestine. Committee of the Palestine Exploration Fund
UN (United Nations) (2012) Gaza in 2020. A liveable place?
UN Commission on Human Rights (2000) Report on the situation of human rights in the Palestinian territories occupied since 1967/submitted by Giorgio Giacomelli, Special Rapporteur, pursuant to Commission on Human Rights resolution 1993/2 A, 15 March
UNEP (2003) Desk study on the environment in the occupied Palestinian territories
Verner D (2012) Adaptation to a changing climate in the Arab countries: a case for adaptation governance and leadership in building climate resilience. The World Bank, Washington, DC
Weizman E, Sheikh F (2015) The conflict shoreline: colonialism as climate change in the Negev Desert
Werner YL (1988) Herpetofaunal survey of Israel (1950-85), with comments on Sinai and Jordan and on zoogeographical heterogeneity. Monogr Biol 62:355–388
Whitaker JO, Shalmon B, Kunz TH (1994) Food and feeding habits of insectivorous bats from Israel. Zeitschrift fur Saugetierkd 59:74–81
Yom-Tov Y (2003) Poaching of Israeli wildlife by guest workers. Biol Conserv 110:11–20
Yom-Tov Y, Tchernov E (eds) (1988) The zoogeography of Israel: the distribution and abundance at a zoogeographical crossroad. Monographiae Biologicae
Zohary M (1973) Geobotanical foundations of the Middle East

Chapter 2
Lichens of the Negev Desert (Israel): Diversity, Distribution, and Relationship with Microclimate

Marina Temina

2.1 Introduction

Lichens play a significant role in all ecosystems where they live. They are important sources of carbon, nitrogen, and other mineral and organic matters (Evans and Lange 2001). They participate in rock weathering and soil forming (Fry 1927; Syers and Iskandar 1973; Danin and Garty 1983; Schwartzman and Volk 1989) as well as play a significant role in different food chains (Shachak et al. 1987). Lichens are of great importance in desert areas where scarcity of rain drastically limits the ecosystem production. The Negev desert represents a very stressful environment where severe climate and limited resources considerably impact on the biota development. It occupies about 60% of territory in the southern part of Israel. The climate of the Negev is arid with annual rainfall ranging from 250 mm in the northwest to about 25 mm in the south (Fig. 2.1). Most of the Negev territory consists of limestone rocks and stones. In some Negev areas, rocks, stones, and soil are densely covered by lichens (Fig. 2.2).

The first data on lichens of the Negev desert were reported by Müller Argo at the end of the nineteenth century (Müller 1884). Afterward, lichenological studies of this region were continued by Professor Israel Reichert in the first half of the twentieth century (Reichert 1937a, b, 1940). Later, Reichert and his student Margalith Galun presented data on 37 lichens from the Negev desert, 7 of which were new species for this area (Galun and Reichert 1960). Six new species were added to the list of the Negev lichens in 1966 (Galun 1966). The monograph *The Lichens of Israel* (Galun 1970) included data on 168 taxa among which 53 species were distributed in the Negev desert. From 1970 to 1996, the list of Negev lichens increased by 13 species, mainly as a result of the taxonomic studies of some lichen genera (Alon and Galun 1971; Marton and Galun 1981; Egea 1989; Lumbsch 1989;

M. Temina (✉)
Institute of Evolution, University of Haifa, Haifa, Israel
e-mail: marina@evo.haifa.ac.il

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_2

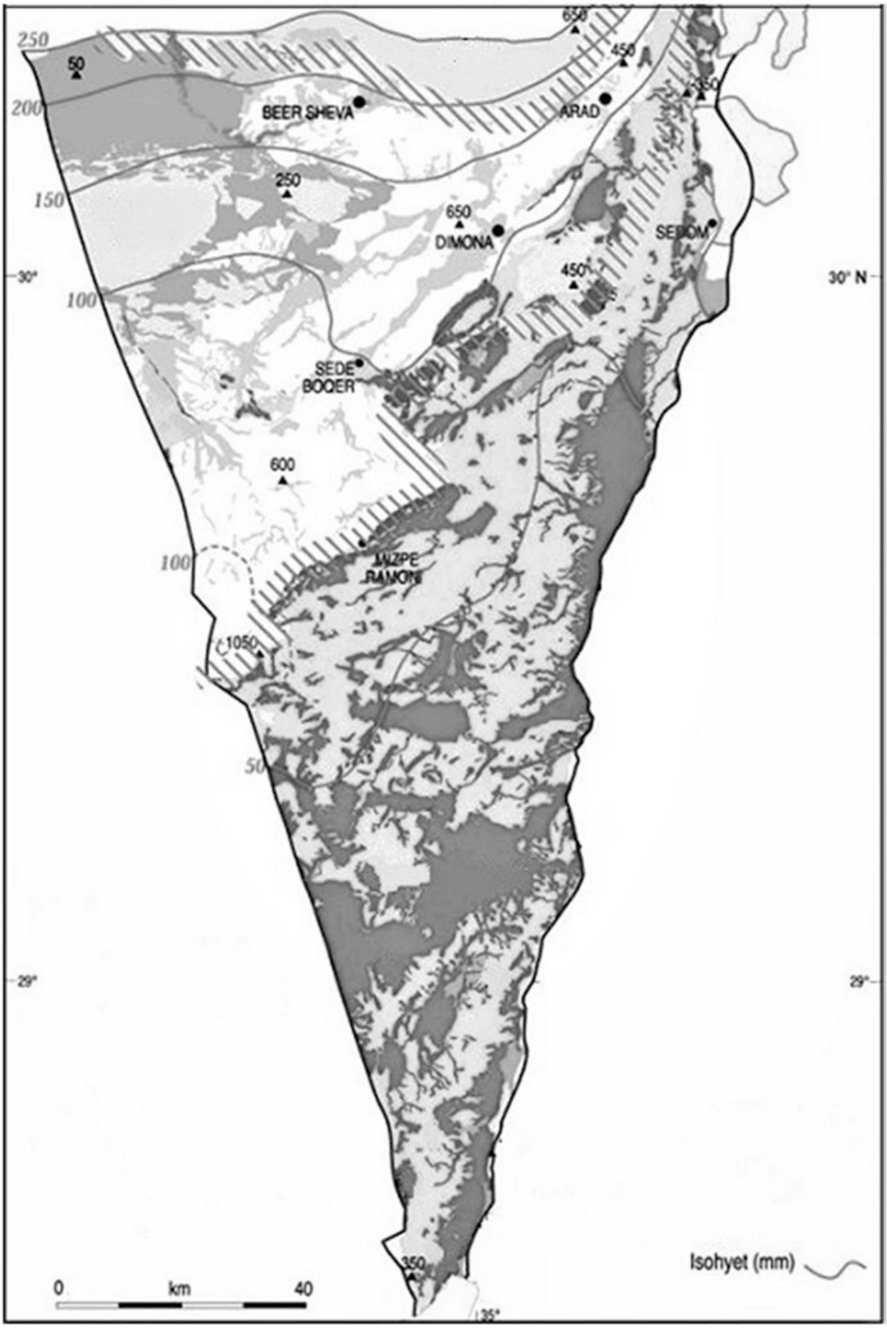


Fig. 2.1 Map of the Negev Desert with annual rainfall distribution

Fig. 2.2 Lichens on rock and soil in the Negev Desert

Moreno and Egea 1992; Giralt et al. 1993). Moreover, numerous studies focusing on lichen ecology, distribution, and physiology were carried out in the Negev desert (Galun 1963; Friedmann and Galun 1974; Lange 1969; Lange et al. 1970a, b, 1977; Kappen et al. 1979, 1980; Danin and Garty 1983; Garty 1985; Garty et al. 1995; Insarov and Insarova 1995, 1996; Insarov et al. 1999). In 2005, the book *Lichen-forming, Lichenicolous, and Allied Fungi of Israel* was published (Temina et al. 2005). The book contained the information on 335 taxa found in Israel up to 2005, including 79 species found in the Negev desert. The studies on the effect of dew on lichens of the Negev, conducted in recent years (Kidron 2000, 2002; Kidron and Temina 2008, 2010, 2013, 2017; Kidron et al. 2011; Temina and Kidron 2011, 2015), have significantly widened the knowledge on the biology and ecology of desert lichens, as well as enriched the lichen list of the Negev desert. A short review of the lichen diversity of the Negev desert and information on lichen distribution and ecology are presented below.

2.2 Diversity and Distribution of Lichens in the Negev Desert

2.2.1 Species Diversity

The lichen biota of the Negev desert includes 81 species from 14 orders, 21 families, and 35 genera (Table 2.1). Most of the Negev lichens belong to the orders *Teloschistales* (31% of total species number) and *Lecanorales* (21% of total species number). The highest species diversity was found in the family *Teloschistaceae* (22 species) and in the genus *Caloplaca* (16 species). Most lichens recorded in the Negev desert are rather common species in dry-warm habitats of many regions in the world. However, about one-third of the Negev lichenobiota are represented by rare species occurring in some arid areas of the Mediterranean region and in the Near East. Among them, more than half are endemics of the Levant. Amoung lichens found in the Negev desert, seven species (*Acarospora areolata*, *Buellia servediosa*, *B. zoharyi*, *Caloplaca negevensis*, *Candelariella minuta*, *Dermatocarpon convexum*, and *Lecanora negevensis*) as well as one lichenicolous fungus (*Sclerococcum*

Table 2.1 Taxonomic diversity of lichens in the Negev desert

	Number of taxa		
Order	Family	Genera	Species
Acarosporales	1	2	5
Arthoniales	1	1	3
Caliciales	1	3	7
Candelariales	1	1	3
Collemopsidiales	1	1	1
Lecanorales	5	8	17
Lecideales	1	1	1
Lichinales	3	5	5
Ostropales	1	1	2
Peltigerales	1	1	3
Pertusariales	1	1	4
Sclerococcales	1	1	1
Teloschistales	2	5	25
Verrucariales	1	4	4
Total	**21**	**35**	**81**

acarosporae) were described as new for science (Galun and Reichert 1960; Poelt and Sulzer 1974; Kondratyuk and Zelenko 2002).

2.2.2 *Inhabited Substrates, Growth Forms, and Photobiont Types*

The highest number of lichens in the Negev desert belong to saxicolous species inhabiting limestone substrates (Fig. 2.3). Terricolous species constitute near third of the lichen biota (27%), while the corticolous and parasitic species are rarely occurring.

The long process of adaptation of lichens to the natural conditions led to the selection of species that, by morphological and biological features, mostly corresponded to these conditions. The main adverse environmental factors for lichens in deserts are lack of moisture and sharp temperature fluctuations; thus the evolution of lichens here went mainly in the direction of selection and creation of xeromorphic growth forms which can provide the balance between sufficiently fast water uptake and its loss. Three types of growth forms were identified on the soil in the Negev desert, fruticose, foliose, and squamulose, and five types of growth forms were identified on rocks, fruticose, foliose, squamulose, epilithic crustose (species having the cracked-areolated thalli and growing on the rock surfaces), and endolithic (species dwelling within the rock) (Fig. 2.4). The species with thick squamulose thalli dominate on soil and rocks in the Negev desert (40%), while 28% of species belong to saxicolous crustose lichens, 23% to saxicolous endolithic species, 7% to foliose, and 2% to fruticose lichens.

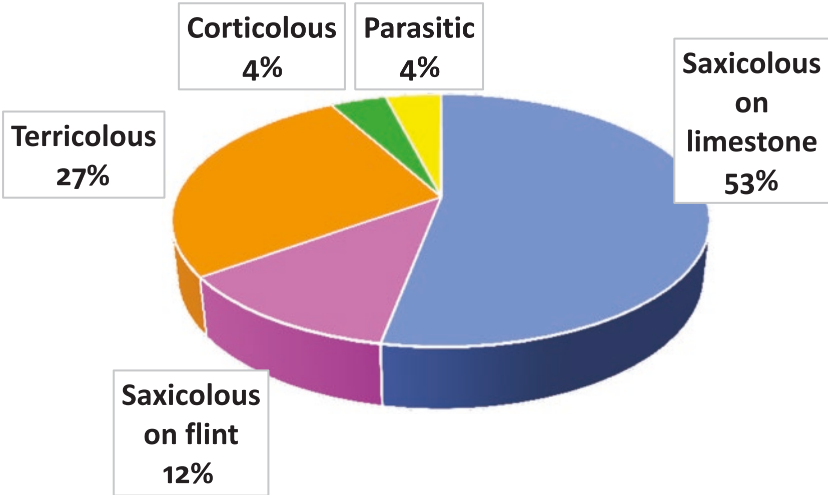


Fig. 2.3 Relative abundance of lichens on different substrates

Fig. 2.4 Endolithic lichens on rock in the Negev Desert

The great majority of lichens of the Negev (90%) have green algae as their photobionts (they are called chlorolichens), and only 10% of lichens contain cyanobacterial photobionts (they are called cyanolichens) (Fig. 2.5).

2.2.3 Distribution

The Negev desert is subdivided into three climatic zones according to spatial distributions of mean annual rainfalls: semiarid (250–120 mm), arid (100–80 mm), and extreme arid (<50 mm) (Dan et al. 1976). The mean annual temperature is 19 °C in the semiarid zone, 18 °C in the arid zone, and 23 °C in the extreme arid zone.

Fig. 2.5 Cyanolichen *Collema tenax* on soil in the Negev Desert

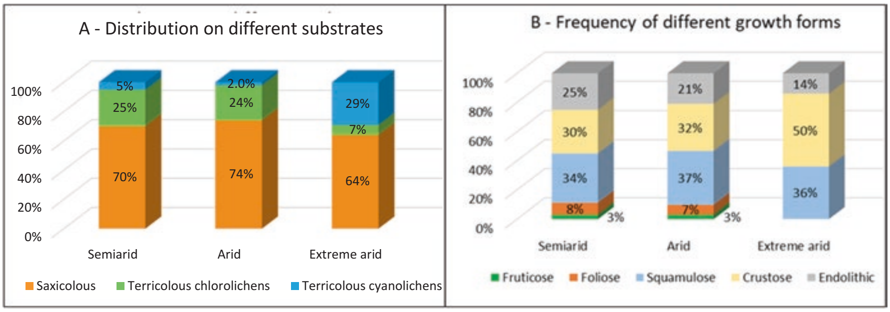


Fig. 2.6 Distribution of lichen species on different substrates (**a**) and lichen growth forms (**b**) in three climatic zones of the Negev Desert

A total of 60, 62, and 14 lichen species were found in the semiarid, arid, and extreme arid zones, respectively. The saxicolous species dominate in all zones of Negev (Fig. 2.6A). While the proportion of terricolous species is similar in all zones (30% in semiarid zone, 26% in arid zone, 36% in extreme arid zone), the composition of terricolous species (their phycobiont type) in the extreme arid zone is substantially different as compared to the semiarid and arid zones. The great majority of soil lichens in the semiarid and arid zones consists of chlorolichens, while in the extreme arid zone, cyanolichens dominate among soil species (Fig. 2.6a).

Both in the semiarid and arid zones, the species with squamulose thalli prevail. But in the extreme arid zone, the crustose species dominate (Fig. 2.6b). This is not surprising, because many investigations reported on an increase in the frequency of occurrence of crustose species with the increase of environment aridity (e.g., Kappen 1973; Friedmann and Galun 1974). Fruticose and foliose species were recorded on soil and rocks only in the semiarid and arid zones in Negev. Among foliose species, three cyanolichens from the genus *Collema* were found on the soil and two chlorolichens from the genus *Xanthoria* on limestone rocks. Fruticose lichens are represented by *Teloschistes lacunosus* living on soil (Fig. 2.7a) and

Fig. 2.7 *Teloschistes lacunosus* on soil (**a**), *Ramalina maciformis* on flint (**b**)

Ramalina maciformis inhabiting the rocks and stones (Fig. 2.7b). It is interesting to note that *Ramalina maciformis* was found only on the flint in the semiarid zone, while in the arid zone, this lichen was recorded both on flint and limestone.

The occurrence of 37 basic lichen species in different climatic zones is presented in Table 2.2. Only seven species, *Buellia subalbula* var. *fuscocapitellata*, *Caloplaca circumalbata* var. *bicolor*, *C. circumalbata* var. *circumalbata*, *Diplotomma epipolium*, *D. venustum*, *Placidium squamulosum*, and *Rinodina bischoffii* var. *aegyptiaca*, were recorded in all zones. These species are the most common lichens in the Negev desert.

2.3 Effect of Microclimate on Lichen Diversity and Distribution

2.3.1 Water Sources

Lichens are poikilohydric organisms, in which water content equilibrates with the surrounding humidity conditions. They become physiological inactive when their thalli dry out. However, they quickly restore normal photosynthetic and metabolic activity after saturation with water. Thus, water availability is of prime importance for their survival and can explain the pattern of their distribution.

Three water sources are available for lichens in the Negev: rain and dew (liquid water) and fog (water vapor). However, only chlorolichens can use all these sources. Cyanolichens cannot photosynthesize under conditions of high relative humidity. They need liquid water for photosynthesis and may solely rely on rainwater for their growth. On the other hand, cyanolichens are less sensitive to extreme fluctuations in temperature and moisture than chlorolichens. Thus, in arid areas where rainfall is rare and dew and fog events are insignificant, cyanolichens prevail, while in arid areas where fall of dew and fog are common events, chlorolichens dominate. Lichen activity also depends upon wetness duration of the substrate surface on which they live. From this point of view, the soil is more xeric substrate for lichens than rocks, since water evaporates faster from the soil surface than from the rock surface.

Table 2.2 Occurrence of basic lichen species in different climatic zones of the Negev desert [Table is based on the data of lichenological collections of Haifa and Tel-Aviv Universities and also on the information from literature sources]

	Semiarid zone	Arid zone	Extreme arid zone
Species	Commonness-rarity status		
*Acarospora areolata**	–	Rare	Very rare
Acarospora nodulosa var. *reagens***	Very rare	Rare	–
*Aspicilia desertorum**	Rare	Very rare	–
*Aspicilia farinosa**	Rather common	Common	–
*Buellia sorediosa**	Rare	Rare	–
Buellia subalbula var. *fuscocapitellata**	Rare	Rather common	Very rare
*Buellia zoharyi***	Very rare	Rare	–
*Caloplaca alociza**	Common	Common	–
*Caloplaca aurantia**	Very common	Very common	–
Caloplaca circumalbata var. *bicolor**	Common	Common	Rare
Caloplaca circumalbata var. *circumalbata**	Very common	Very common	Rare
*Caloplaca citrina**	Rather common	Rare	–
*Caloplaca ehrenbergii**	Rare	Rather common	–
Caloplaca erythrina var. *pulvinata**	–	Rare	Very rare
*Candelariella minuta**	Rather common	Common	–
*Collema tenax***	Common	Rather common	–
*Diploicia canescens**	Common	Common	–
*Diploschistes candidissimus**	Very rare	Rare	–
*Diploschistes diacapsis***	Rather common	Rather common	–
*Diplotomma epipolium**	Common	Common	Very rare
*Diplotomma venustum**	Very rare	Rather common	Rare
*Fulgensia fulgens***	Rare	Rare	–
*Gloeoheppia turgida***	–	–	Very rare
*Lecania subcaesia**	Rather common	Common	–
*Lecanora crenulata**	Rather common	Rather common	–
*Lichinella sinaica***	-	–	Rare
*Peltula psammophila***	–	–	Very rare
*Placidium squamulosum***	Rather common	Rather common	Very rare

(continued)

Table 2.2 (continued)

	Semiarid zone	Arid zone	Extreme arid zone
Species	Commonness-rarity status		
*Psora decipiens***	Common	Common	–
*Ramalina maciformis**	Very common	Very common	–
Rinodina bischoffii var. *aegyptiaca**	Common	Common	Rare
*Rinodina dubyana**	Very rare	Rather common	–
Squamarina cartilaginea var. *cartilaginea***	Rare	Rare	–
*Squamarina lentigera***	Common	Common	-
*Teloschistes lacunosus***	Common	Common	–
*Toninia sedifolia***	Common	Rather common	-
*Xanthoria mediterranea**	Common	Common	–

*saxicolous species, **terricolous species

The above factors can explain the distribution of lichen species in the Negev. In the extreme arid zone, where the average annual rainfall is less than 50 mm, and dew events are very rare, the species composition of lichenobiota is very poor and differs from the other two zones of Negev in more high number of soil cyanolichens (Fig. 2.6a, Table 2.2). In this zone, lichens occur rare. They are usually common in places where water can accumulate in quantities sufficient for the life of these organisms. The semiarid and arid zones of the Negev receive much more amount of precipitation than the extreme arid zone, so the lichen species richness in the first two zones is much higher than in the extreme arid zone. However, lichenobiota of semiarid zone differs from lichenobiota of arid zone by a higher content of soil lichens, which is the result of a higher amount of rainfall in this zone compared to the arid zone. At the same time, saxicolous species dominate both in the semiarid and arid zones (Fig. 2.6a), and almost no difference in species composition and frequency of occurrence of rock-inhabiting lichens is found in these zones (Table 2.2). That fact demonstrates the ability of lichens to utilize dew and fog as a water source, in addition to rain.

The effect of dew on lichens was particularly studied in the arid zone of Negev.

In the central Negev, dew amount reached 33 mm per year (Evenari et al. 1982), being mainly abundant during the fall season (Zangvil 1996). During severe droughts, dew may even exceed rain precipitation (Evenari et al. 1982), thus providing the primary and stable water source for lichens in this harsh environment. Numerous studies of dew regime in the Negev desert demonstrated effect of dew on the lichen photosynthetic activity (Lange 1969; Lange et al. 1970a, b, 1977; Kappen et al. 1979, 1980), their growth rate (Lange 1990; Kidron and Temina 2010), and distribution of endolithic and epilithic growth forms in different habitats (Friedmann and Galun 1974; Danin and Garty 1983; Kidron 2000, 2002; Kidron and Temina 2008; Kidron et al. 2011).

The relations between the dew regime and the structure of lichen communities inhabiting stones as well as the distribution of lichen species were studied in different sites in the central Negev. We studied the effect of dew on lichen communities: (1) on limestone cobbles located on flat hilltops along a high-altitude gradient on three sites, Nizzana, Sede Boqer, and Har Harif, which were 250, 530, and 990 meters above sea level, respectively (Kidron and Temina 2013); (2) on the limestone and flint cobbles located at the foot of the north-facing slopes of two sites, Sede Boqer and Nizzana (Temina and Kidron 2015); and (3) on limestone cobbles at 18 stations located within 4 aspects of a drainage basin near Sede Boqer (Temina and Kidron 2011). These sites had similar rain precipitation (90–100 mm) but different dew amount.

Our studies showed that dew is the main factor controlling lichen species richness and cover, as well as lichen distribution pattern and chlorophyll content in lichens. The studies also revealed that dew duration was a more significant factor for lichen living activity than the dew amount. Dew duration rather than dew amount was found to influence lichen biomass, the predominant growth form, and structure of lichen communities. It was demonstrated that an increase in dew duration caused the replacement of endolithic lichens with epilithic species. According to our studies, endolithic species dominate on rock substrates with average daily dew duration of 1.3–4.4 h (Fig. 2.8). Replacement of the dominant endolithic species by epilithic species occurs when the average duration of daily dew is ≈ 4.5 h (Temina and Kidron 2011, 2015; Kidron and Temina 2013) (Fig. 2.9). The study of the effect of dew on lichen communities inhabiting slightly acidic flint and slightly alkaline limestone cobbles detected that, namely, dew duration determines the distribution of

Fig. 2.8 Endolithic lichens are distributed on south-facing slope in the drainage basin near Sede Boqer where average daily dew is 3.1 h

Fig. 2.9 Epilithic lichens are distributed on north-facing slope in the drainage basin near Sede Boqer where average daily dew is 4.5 h

some species for which it is a more important factor than alkalinity of the substrate (Temina and Kidron 2015). In addition, studying the relationship between the composition and distribution of lichen species and the dew regime on cobbles at four aspects of the drainage basin at Sede Boqer, we found some species which can serve as biomarkers for dew amount and especially for dew duration (Temina and Kidron 2011).

2.3.2 Temperature

Temperature does not play such a remarkable role in the life of lichens as water plays, and usually is not a limiting factor for lichen development. Lichens show amazing sustainability to the effects of both very high and low temperatures. However, Lange (1953) found that while lichens were rather tolerant to high-temperature stress in dry state, their heat resistance declined when they were moistened.

In the Negev desert, influence of temperature on species composition and structure of lichen communities dwelling on soil and cobbles was studied at several sites in the arid and extreme arid zones (Temina 2016). These sites were located in the areas with different mean annual amount of rain precipitation and air temperatures. Four sites were situated at the erosional cirque in Makhtesh Ramon (central Negev), two of which were located in the northern part of the cirque, where rainfall was 85 mm per year and mean annual air temperature was 19 °C (Fig. 2.10), and two sites were located in the southern part of the cirque, where rainfall was 56 mm per year and mean annual air temperature was 23 °C (Fig. 2.11). The fifth and sixth sites

Fig. 2.10 Lichen communities in the northern part of Makhtesh Ramon

Fig. 2.11 Lichen communities in the southern part of Makhtesh Ramon

were situated on two opposite slopes of the canyon in Nahal Shaharut (southern Negev), where rainfall was 40 mm per year and mean annual air temperature was 24 °C. At each site, lichen communities on soil and cobbles were studied, and soil moisture and temperatures of air, soil, and cobbles were measured. The study showed that the lichen communities on each type of the substrates significantly differed from each other. A comparative analysis of structure and distribution of lichen communities on soil and cobbles in the studied sites revealed that while the distribution of saxicolous lichens was related to soil moisture and temperatures of substrates, these factors had no effect on the distribution of terricolous lichens. It was also revealed that the increase in air temperature increased the temperature of soil and cobbles at the sites studied. The temperature of substrates above 32 °C was critical for lichen communities. At this temperature, the communities of both substrates underwent significant changes. This was expressed in a decrease of species diversity and total lichen cover on both substrates, as well as in an increasing abundance of endolithic lichens on the cobbles and the complete replacement of chlorolichens by cyanolichens on the soil.

Thus, the lichens of the Negev desert demonstrated remarkable adaptive abilities to extreme stressful environmental conditions.

Acknowledgments I would like to thank Dr. I. Grishkan for editing the manuscript and Mr. A. Temin for his help with the original illustrations.

References

Alon G, Galun M (1971) The genus *Caloplaca* in Israel. Israel J Bot 20:273–292

Dan J, Yaalon DH, Koyumdjisky H, Raz Z (1976) The soils of Israel. Division of Scientific Publication, The Volcani Center, Bet Dagan

Danin A, Garty J (1983) Distribution of cyanobacteria and lichens on hillsides of the Negev highlands and their impact on biogenic weathering. Z Geomorph 27:423–444

Egea JM (1989) Los generos *Heppia* y *Peltula* (Liquenes) en Europa Occidental y Norte de Africa. Bibliotheca Lichenologica 31:1–122

Evans RD, Lange OL (2001) Biological soil crusts and ecosystem nitrogen and carbon dynamics. In: Belnap J, Lange OL (eds) Biological soil crusts: structure, function, and management. Springer, Berlin, pp 263–279

Evenari M, Shanan L, Tadmor N (1982) The Negev, the challenge of a desert, 2nd edn. Harvard University Press, Cambridge

Friedmann EI, Galun M (1974) Desert algae, lichens and fungi. In: Brown GW (ed) Desert biology II. Academic Press, New York, pp 165–212

Fry EJ (1927) The mechanical action of crustaceous lichens on substrata of shale, schist, gneiss, limestone and obsidian. Ann Bot 40:437–460

Galun M (1963) Autecological and synecological observations on lichens of the Negev, Israel. Israel J Bot 12:179–187

Galun M (1966) Additions to the lichen flora of the Negev, Israel. Israel J Bot 15:144–149

Galun M (1970) The lichens of Israel. Israel Academy Science Human, Jerusalem

Galun M, Reichert I (1960) A study of lichens of the Negev. Bull Res Counc Isr 9:127–148

Garty J (1985) The amounts of heavy metals in some lichens of the Negev Desert. Environ Pollut 10:287–300

Garty J, Harel Y, Steinberger Y (1995) The role of lichens in the cycling of metals in the Negev Desert. Arch Environ Contam Toxicol 29:247–253

Giralt M, Nimis PL, Poelt J (1993) Studien über einige Arten der Flectengattung *Xanthoria* mit isidiaformen vegetativen Diasporen. J Hattori Bot Lab 74:271–285

Insarov G, Insarova I (1995) The lichens of calcareous rocks in the Central Negev, Israel. Israel J Plant Sci 43:53–62

Insarov G, Insarova I (1996) Assessment of lichen sensitivity to climate change. Israel J Plant Sci 44:309–334

Insarov GE, Semenov SM, Insarova ID (1999) A system to monitor climate change with epilithic lichens. Environ Monit Assess 55:279–298

Kappen L (1973) Response to extreme environments. In: Ahmadjian V, Hale ME (eds) The lichens. Academic Press, New York/London, pp 311–380

Kappen L, Lange OL, Schulze E-D et al (1979) Ecophysiological investigations on lichens of the Negev Desert IV: annual course of the photosynthetic production of *Ramalina maciformis* (Del.) Bory. Flora 168:85–105

Kappen L, Lange OL, Schulze E-D et al (1980) Ecophysiological investigations on lichens in the Negev Desert VII: the influence of the habitat exposure on dew imbibition and photosynthetic productivity. Flora 169:216–229

Kidron GJ (2000) Dew moisture regime of endolithic and epilithic lichens in habiting calcareous cobbles and rock outcrops, Negev Desert, Israel. Flora 195:146–153

Kidron GJ (2002) Causes of two patterns of lichen zonation on cobbles in the Negev Desert, Israel. Lichenologist 34:71–80

Kidron GJ, Temina M (2008) The mycobiont role in crustose lichen expansion on cobbles in the Negev Desert. Geomicrobiol J 25:95–100

Kidron GJ, Temina M (2010) Lichen colonization on cobbles in the Negev Desert following 15 years in the field. Geomicrobiol J 27:455–463

Kidron GJ, Temina M (2013) The effect of dew and fog on lithic lichens along an altitudinal gradient in the Negev Desert. Geomicrobiol J 30:281–290

Kidron GJ, Temina M (2017) Non-rainfall water input determines lichen and cyanobacteria zonation on limestone bedrock in the Negev highlands. Flora 229:71–79

Kidron GJ, Temina M, Starinsky A (2011) An investigation of the role of water (rain and dew) in controlling the growth form of lichens on cobbles in the Negev Desert. Geomicrobiol J 28:335–346

Kondratyuk SY, Zelenko SD (2002) New lichens and lichenicolous fungi from Israel and the near east. Ukrainian Bot J 59(5):598–607

Lange OL (1953) Hitze- und Trockenresistenz der Flechten in Beziehung zu ihrer Verbreitung. Flora (Jena) 140:39–97

Lange OL (1969) Experimentell-okologische Untersuchungen an Flechten derNegev-Wuste I. CO_2-Gaswechsel von *Ramalina maciformis* (Del.) Bory unterkontrollierten Bedingungen im Laboratorium. Flora 158:324–359

Lange OL (1990) Twenty-three years of growth measurements on the crustose lichen *Caloplaca aurantia* in the Central Negev Desert. Isr J Bot 39:383–394

Lange OL, Schulze E-D, Koch W (1970a) Ecophysiological investigations on lichens of the Negev Desert II: CO_2 gas exchange and water conservation of *Ramalina maciformis* (Del.) Bory in its natural habitat during the summer dry period. Flora 159:38–62

Lange OL, Schulze ED, Koch W (1970b) Ecophysiological investigations on lichens of the Negev Desert III: CO_2 gas exchange and water metabolism of crustose and foliose lichens in their natural habitat during the summer dry period. Flora 159:525–538

Lange OL, Geiger IL, Schulze ED (1977) Ecophysiological investigation on lichens of the Negev Desert V.a model to simulate net photosynthesis and respiration of *Ramalina maciformis*. Oecologia 28:247–259

Lumbsch HT (1989) Die holarktischen Vertreter der Flechtengattung *Diploschistes* (*Thelotremataceae*). J Hattori Bot Lab 66:133–196

Marton K, Galun M (1981) The cyanophilous lichen population of the Arava Valley and the Judean Desert (Israel). Israel J Bot 30:125–155

Moreno PP, Egea JM (1992) El genero *Lichinella* Nyl. en el sureste de España y norte de Africa. Cryptogamie, Bryologie-Lichénologie 13(3):237–259

Müller J (1884) Lichens de Palestine. Lichenes Palaestinenses s. Enumeratio lichenum a cl. Et amic. W. Barbey-bossier anno 1880 in Palaestina lectorum. Revue Mycologique 6:12–15

Poelt J, Sulzer M (1974) Die Erdflechte *Buellia epigaea*, eine Sammelart. Nova Hedwigia 25(1–2):173–194

Reichert I (1937a) Steppe and desert in the light of lichen vegetation. Proc Linnean Soc London 149:19–23

Reichert I (1937b) Eine lichenologische Skizze Palästinas. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien 86-87:288–296
Reichert I (1940) A new species of *Diploschistes* from oriental steppes and its phytogeographical significance. Palestine J Bot Rehovot Ser 3:162–182
Schwartzman DW, Volk T (1989) Biotic enhancement of weathering and the habitability of earth. Nature 340:457–460
Shachak M, Jones CG, Granot Y (1987) Herbivory in rocks and the weathering of a desert. Science 236:1098–1099
Syers JK, Iskandar IK (1973) Pedogenetic significance of lichens. In: Ahmadjian V, Hale ME (eds) The lichens. Academic Press, New York/London, pp 225–248
Temina M (2016) Lichen communities in extreme desert conditions. In: Abstract book. The XV OPTIMA meeting, 6–11 June, 2016, Montpellier, France, p 164
Temina M, Kidron GJ (2011) Lichens as biomarkers for dew precipitation in the Negev Desert. Flora 206:646–652
Temina M, Kidron GJ (2015) The effect of dew on flint and limestone lichen communities in the Negev Desert. Flora 213:77–84
Temina M, Kondratyuk SY, Zelenko SD et al (2005) In: Wasser SP, Nevo E (eds) Lichen-forming, lichenicolous and allied fungi of Israel. A.R.G. Ganter Verlag, Ruggell
Zangvil A (1996) Six years of dew observation in the Negev Desert, Israel. J Arid Environs 32:361–372

Chapter 3
Lichens: Characteristics, Importance, Uses, and Distribution in Turkey

Şule Öztürk

3.1 Introduction

The partners that make up the lichen thallus come together in a variety of ways, creating an extraordinary relationship. The shape of thallus is basically provided by the fungus, its substrate binding on which it develops, and procurement of water; whereas the photosynthetic partner alga undertakes the function of feeding vis-a-vis organic matter production. The biological feature essentially reflects the fungal characteristics, and accordingly we find "lichen-forming fungi" or "lichenized Fungi" (Zheng et al. 2007). The members of this group are peeled on the substrates developing and forming fragmented surface appearances, and this is why in Greek its meaning implies fragmented (Yavuz and Özyiğitoğlu 2015). The work done on this group includes a large number of publications; notable among these are Brodo et al. (2001), Nash III et al. (2002), Nash III (2008), Smith et al. (2009), and Wirth et al. (2013).

The placement of fungus and photosynthetic partner in lichen thallus is generally under two different types. The texture of thallus is surrounded by the upper and/or lower cortex, formed by tightly packing the outer fungal hypha. The cortex protects thallus against external impacts. Algal partner lies just under the cortex layer with tightly packed photosynthetic joint and fungal hyphae. The medulla layer at the bottom consists of relatively loosely knitted fungal hyphae. This structure is called heteromeric thallus. The second model is known as homomeric thallus, where cyanobacteria as a photosynthetic partner join and fungal hyphae are homogeneously distributed throughout the thallus. The upper and lower cortex are either absent, as in the genus *Collema*, or as in genus *Leptogium*, the upper cortex and/or both the upper and lower cortex are present. The fungus in general forms tissues; although

Ş. Öztürk (✉)
Biology Department, Faculty of Sciences and Arts, Bursa Uludag University, Gorukle-Bursa, Turkey
e-mail: ozturks@uludag.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_3

not resembling those of plants, these are mainly responsible for thallus formation. Plectenchyma, with its adherent growth of fungal filament in the cortex layer, forms the tissue, providing protective and strengthening features of thallus, with two different types in the cortex layer depending on how the fungal filaments come together. The paraplectenchyma consists of thin-walled and short-celled fungal filament appearing as a tissue under microscope with large round lumen cells. The prosoplectenchyma is as long cells with thick walls, arranged paralled to each other. The paraplectenchyma and prosoplectenchyma differ much in very closely related species and even between the upper and lower cortex of the same species. The shell is made up of tightly packed hyphae which hamper the gas exchange between outside and inside. Pseudocyphellae are located on the thallus of many lichens, as a broken or cracked structure in the form of a point or line. Cyphella has a similar function, as special opening, bit larger, and anatomically more complex. Cyphella and pseudocyphella provide ventilation of thallus. In very large and leafy species like *Peltigera,* gas exchange is fully fulfilled by lower surface when there is no lower cortex layer. Rhizine, rhizomorph, and hamper created by the fungal filaments are responsible for the binding of thallus to the substrate. Rhizines are generally composed of hyphae of prosoplectenchymatic structure, clustered in certain areas on the lower face or scattered to cover the entire lower surface. Simple or differently branched forms are important taxonomic characters. On the edge of the thallus is prothallus, varying from white or dark brown to black, consisting only of fungal filaments. This structure, which is frequently seen on the edge of the crustose lichens, is the fastest-growing region of the thallus.

Lichens are classified on the basis of morphological structure of thallus. In earlier systems these were classified under three groups, namely, crustose-squamule, foliose, and fruticose. This distinction proved inadequate as it did not consider different forms of development. The terms expressing the growth forms of lichens provide an easy way for their identification and determination keys. The basic growth forms are outlined below. The crustose lichen thallus consists of the medulla, which consists of the upper cortex, algal layer, and fungal hyphae penetrating the substrate on which it is present. The lower cortex is lacking here as such these cannot be separated from their firmly attached substrates, without breaking their thallus. If these developed on rocks and are completely buried in the substrate, these are called endolithic; if thallus is more or less pronounced on the substrate, then it is epilithic. Those found on the bark of trees are called epiphytic and when growing in the bark endoxylic, and if they have a distinguishable thallus on the crust of tree, then they are epixylic. Thallus buried in the substrate can usually be noticed due to the reproductive organs on the surface. Crustose lichens are named as granular (leprose), areolate, long lobed (effigurate), and fluffy lobe (placoid) without any substrate separation. Most primitive type of thallus, in which fungus and algae simply come together without any stratification, is called granular. The polygonal crustal thallus pieces of different sizes and shapes, which are usually separated by cracks and fractures, are called areoles. If whole thallus consists of such particles, it is called areolate. Among the areoles, sometimes gray or black prothallus is distinguished. Thallus type, with its central part areoles, and the lobes that are elongated at the edge and develop in radial order, is called effigurate. The crustose lichens with very prominent thallus lobes are called fluffy lobes. Some species belonging to the genera *Acarospora*, *Calogaya*, *Dimelaena*, and *Pleopsidium* include species with such thallus structures. Areoles that are partially embedded in the substrate in areolate lichens begin to become relatively free in squamulose lichens. Later can be accepted as a transition form lying just between crustose and foliose lichens. This group is divided into subgroups depending on the features of scales forming thallus, such as shape, structure, and thickness. In some squamulose lichens, the upper parts of areoles are bulging, but the lower part is partially fresh. This thallus type occurs in *Catapyrenium*, *Peltula*, *Psora*, and *Toninia* genera. In soma the scales are flattened forming a circle and connected to the substrate with the connection point in the center of the lower surface, like a shield. These lichens are called peltate, generally including species developing on soil or rock surfaces in hot and dry regions of the world.

The leafy lichens possess a flat thallus with upper and lower faces showing anatomical differentiation as homeomerous or heteromerous. Its dimensions can start from a few millimeters, which are hardly noticeable to the naked eye, and can reach quite large thalli. These lichens usually attach to their substrates by rhizine, hamper, or special attachments. Thallus lobes can be arranged in different shapes, from radial (*Parmelia*) to cremite (*Hypocoenomyce*, *Peltigera*). In some genera, the thallus lobes are placed in such a way that there is a gap in the center when the section is taken (*Hypogymnia*, *Menegazzia*).

Umbilicate lichens generally possess circular thallus with a single lobe or divided into several lobes. The organ of attachment connecting thallus to the substrate is called umbilicus, formed by the fusion of fungal filament which generally runs parallel to each other. It may also contain rhizomorphs on the lower surface. Umbilicus has the most beautiful structure particularly in the species of genus *Umbilicaria* and *Dermatocarpon.*

Fruticose lichens have thallus in the shape of a shrub or small shrub rising or hanging upright on the substrate. Their cross sections are circular or double faced. In the latter thalli, the algal layer can be located on both sides, and connection to the substrate is provided by the attachment point with sparse or intense branching.

Stripy lichens, also known as half-branch lichens, are intermediates between branch and leafy lichens. The thallus shows lower and upper surface differentiation, and lobe widths can vary from a few millimeters to several centimeters. These are mostly attached to the substrate with the attachment point formed by the main axis; branching can occur either by regular, double, triple, or quadruple forks of the lobe ends but may also be irregular. *Evernia prunastri* and *Pseudevernia furfuracea* are characteristic species of this group.

The filamentous lichens have thin long thallus with cylindrical cross sections and can be observed under the light microscope with two different anatomical features. In the first as in the genus *Bryoria*, the central part of threads is filled loose or tightly packed with fungal filaments and second type as in *Usnea* has a central thread in the middle of thallus, with very tight fungal filaments. The central thread is also an important taxonomic character. Filamentous lichens are usually attached to the substrate by the attachment point at the base of the main thread. In the lichens where branching varies according to the species, there are soredium, isidium, wart, or fibril-like structures on the filaments giving a fishbone appearance.

Dimorphic lichens include the group containing the squamule or foliose forms besides the branchy thallus. The first part developing in this group is the primary thallus consisting of horizontal basal scales and leaflets. The secondary thallus or podetium is more or less striking with branched or unbranched shape. In some species, the basal scales disappear, while the secondary thallus develops. Reproductive organs like apothecium or pycnidium are formed on the podetium. In some *Cladonia* species, the ends of podetium become bowl shaped with apothecium on the edges.

Asexual reproduction is achieved vegetatively with the rupture of a part of thallus followed by the development of a new thallus from this piece. The pieces of species belonging to the genus *Bryoria* and *Ramalina* fall down from the trees due to wind, insect damage, or heavy rain, and these immediately form a new thallus. In case of soi forms like *Cetraria* and *Cladonia* species, breeding type differs. The thalli are very fragile under dry condition and are carried by wind or trampled by animals. Another way of asexual reproduction takes place with specialized structures located on thallus, soredium, isidium, and schizidium. These units contain both the fungus and the photosynthetic partner, serving as a shortcut for the rapid thallus formation under harsh conditions. These special structures can be regarded as a type of vegetative reproduction, as the partners leave from main thallus together. The isidia are the structures that develop on the upper surface or edge of thallus as a result of wrapping of several algal cells and fungal hyphae with the cortex. These structures which are finger, cylindrical, spherical, ovoid, simple, or branched type play a role in increasing the thallus surface as well as reproduction. The color and shape of isidia are used as an important character in the classification. Soredia are small units formed by several algal cells by combining with fungal hyphae on thallus surface. These are very similar to isidia in terms of content and function, but lack cortex layer. In terms of size, soredia of very small particles are called pruinose and those of larger particles granular. Those found in bulk in areas bordered by the upper cortex on the surface of the thallus form the soralia, which according to their location and shape in the thallus are known as marginal, laminal, or labriform, head, and helmet soralia.

The sexual reproduction in lichens is carried out only by fungus. The *Ascomycota* members of lichen are of apothecium and perithecium types, which contain ascus, whereas in the *Basidiomycota* members, reproductive organs are called basidium. Apothecia are located in various shapes on the surface of thallus, in cup, disc or other form, varying in anatomical and morphological features. If the apothecium has a margin as a continuation of thallus, it is named as lecanorine; if the edge of apothecium is formed only by the fungal tissue, it is called lecideine; if it doesn't contain the edge of apothecium, it is called biatorine. In some species, young apothecia are of lecideine type, and as they age, their edges may disappear and turn into biatorine type. Apothecium, which is characteristic for a smaller number of genera, in the form of a stick or line and its hymenium is separated by a cleft; it is called lirellate apothecium and is seen in *Graphis* and *Opegrapha* genera. In the members of the *Caliciales*, stalked apothecium develops on a thin stalk.

The longitudinal section taken from an apothecium shows hymenium (thecium) layer formed by the ascus and paraphysis. The section with the ends of paraphysis is longer than the ascus is the epitecium (epihymenium) layer. Secondary metabolites, crystals, and oil drops in these two layers are taxonomically important. The structure of ascus plays an important role in the classification of *Ascomycota* members. The number, shape, size, number of chambers, and color feature of the spores varies much with species. The hypothecium layer located under the hymenium is important in the lichen classification with its features such as algal cell and/or whether it is with crystal or not. If there is a two-layer differentiation at the edge formed by the fungal tissue in the apothecium, the inner layer is called parathecium and the outer layer is called amphithecium. Whether or not some lichen species have crystals in the amphithecium layer and their size are important criteria used in determining the size of these crystals. Perithecium is a sexual reproductive organ formed by fungi in *Ascomycota* members forming lichens and more or less buried in the thallus. At the base of perithecium, there is a layer of hymenium consisting of ascus and paraphysis. The opening in which matured spores come out of perithecium is called ostiole. In the interior of perithecium, paraphysis near the ostiole opening is called periphysis. Except for the real edge surrounding the perithecium, there is an outer tissue called involucre, which is usually black in color and varies with species.

There are very few *Basidiomycota* members in the fungi which form basidium as the reproductive organ and participate in the formation of lichen. Karyogamy and meiosis occur within the structure called basidium, and the spores formed here are called basidiospores. Typical reproductive structures of *Basidiomycota* members are seen in *Aphyllophorales* and *Agaricales*, which form the lichens. This reproductive structure is shell-shaped as in the *Dictyonema* genus, cylindrical or cube-shaped as in the members of genus *Multiclavula*, or cap mushroom as in the genus *Omphalina*.

3.2 Metabolic Features

Algae and fungus combination in these symbiotic life members continue under conditions not suitable for their independent growth. This is facilitated by the formation of common life and adaptation to inappropriate environments. Lichens, as the smallest ecosystem model on earth, form a mutualistic life model, based on mutual aid of at least one fungus and at least one photosynthetic partner, which need each other in order to live together and sustain their lives more easily. The green algae or blue-green bacteria species that have adapted to the land from the water environment are protected by the tissue formed by the fungal hyphae, as well as providing water via fungal hyphae. The fungi that live saprophytic life use photosynthesis products produced by the photosynthetic partner when they are located in the lichen thallus, that is, the nutrition of fungus changes. The requirements and lifestyle of algae in lichen structure are similar to green algae and blue-green bacteria. The question of xenobiont (foreign organism) in the structure of lichens has been discussed much.

Azotobacter is a suitable xenobiont. It is believed that bacterium settlement in the lichen thallus has occurred following an evolutionary process. Qualitative and quantitative data of microorganisms in thallus have been evaluated within the scope of three different biont hypotheses in lichens. The antibiotics formed by microorganisms play a role as protective chemicals, especially in lichens unable to produce secondary metabolites. In this small ecosystem model created by the participation of spider, mite and birds the lichen structure is used. The variety of organisms and the subsrate on which lichen grows differs and lichens are used as habitat or food. Algae and fungi that participate in the lichen thallus adapt to the new life model by changing their many features in their independent lives.

3.3 Water and Photosynthesis

In addition to being a reaction medium where metabolic reactions take place, water has important functions, such as preserving the shape of cells and tissues due to the turgor pressure created by the water taken especially for vegetative organisms, the transport medium of the synthesized organic substances, and protection from overheating. Creation and preservation of thallus tissue in lichens is provided with fungal hyphae. As in higher plants, the water content of thallus constantly changes in parallel with the change in the ambient atmosphere due to the fact that they lack the cuticle layer on the epidermis layer and do not have hairlike formations to help in water economy. Since there are no stomata, loss of water in dry atmosphere occurs from the entire lichen thallus by evaporation. There is extracellular water storage in lichens. Due to these properties, lichens are poikilohydric. All lichen species are capable of absorbing moisture from the atmosphere, but in lichens containing rhizine, water intake is provided from the atmosphere with the entire thallus surface. The rhizines of foliose lichens do not absorb water; they only work on holding the substrate. Many metals collected from the atmosphere or from ionic solutions are deposited in the lichen thallus. These metal ions, which have a toxic effect and are not metabolically beneficial in living organisms, are extracellularly bound. Metabolic poisons and inhibitors are completely eliminated or strongly reduce cation uptake. The active uptake mechanism is complex and less important than passive uptake. Widespread extracellular ion exchange in lichen occurs only by physicochemical reactions. In the use of lichens as bioindicators for air pollutants, epiphytic lichens are used, in order to eliminate the effect of mineral contamination from substrate originating from the rock and soil.

The natural habitats of lichens are mostly dry, but they take carbon dioxide and water vapor from air for photosynthesis via diffusion; it depends on the density difference between lichen thallus and the atmosphere as well as physical structure of the tissues through which the diffusion process occurs, namely, thallus structure and shape. Lichens have low resistance to water loss and can be compared to a moist filter paper. Important resistances faced in CO_2 uptake occur in the medulla tissue and in the pore system in the structure of cyphella or pseudocyphella. Lichens have an ability to regulate metabolic events. When photosynthesis is suppressed, thallus has a high water content, the internal CO_2 concentration increases, the diffusion paths of liquid water on the surface are partially or completely blocked, and CO_2 diffusion is considered to be 10,000 times slower in the water than in the air. Full saturation of lichen thallus by water negatively affects photosynthetic efficiency. Lichens can stay alive even in low water content and is an indication that they use water very economically. Their photosynthetic activity is controlled by water and light, and respiration is controlled by water and temperature life (Palmqvist 2000).

Algae, as a partner of lichen structure, are generally single-celled or blue-green bacteria that have different structures than the cells of higher plants. It is possible that they have a different metabolic process than the basic photosynthesis mechanisms of higher plants. Some of these differences are the photobionts in the lichen thallus do not contain vacuoles; although chloroplasts of plant cells have about 30–50, a single large chloroplast is generally found in algae. There is no clear information on the type of photosynthesis mechanism in lichens, if it is C3 or C4 model. However, the presence of high-speed light respiration in macro-lichens growing in the southern hemisphere strengthens the possibility of C3 photosynthesis mechanism in lichens. In these lichens, photosynthesis rates increase by approximately 50% at oxygen concentrations as low as 1%. In some lichens, no light respiration has been observed at very slow speed. The level of CO_2 compensation is high, and true photosynthesis has not been stimulated with 1% oxygen. Therefore, photosynthesis in lichens is thought to be similar to C4 type. According to similar free-living relatives, the fact that many blue-green bacteria possess photosynthetic CO_2 concentrate mechanism (CCM), unlike some higher plants, C4 and CAM metabolism is another difference and a matter of debate (Palmqvist 2000).

Blue-green bacteria developed as oxygenic photosynthetic bacteria on earth about 2.7 billion years ago. During this period, a more efficient photosynthesis model developed in the evolutionary process with decrease in CO_2 in the changing environment and increase of O_2. The CO_2 concentrate mechanism (CCM) seems more effective which improves CO_2 fixation of rubisco enzyme (Price and Long 1989). This mechanism is a process that ensures survival and lasting photosynthetic properties under limited CO_2 concentrations. CCM is a process that actively controls inorganic carbon (Ci: HCO_3 and CO_2) accumulation and transport. Ci acts as a pool to increase the CO_2 concentration around the enzyme (CO_2 fixing enzyme ribulose biphosphate carboxylase oxygenase (rubisco)). Rubisco is found in blue-green bacteria surrounded by original microsections in two types, known as α-carboxysome and β-carboxysome. Rubisco is in the form of parallel crystal sequences within these organelles. In addition, blue-green bacteria have five different transport systems for bicarbonate uptake (Price et al. 2008).

3.4 Nutrition

The photosynthetic partner in a lichen transfers 90% of the carbon it fixes via photosynthesis to the fungus. However, when removed from symbiosis, the release stops or 1–2% of total fixed carbon is released. Following photosynthesis, the mobile carbohydrates are formed which are transferred to fungi; some are converted to secondary metabolites, while others are converted to fungal carbohydrates. When the symbiont is isolated, the amount of cell products increases, and the amount of mobile carbohydrates decreases. Most of the blue-green bacteria in lichen thallus belong to *Calothrix*, *Gloeocapsa*, *Nostoc*, and *Scytonema* genera and green algae to *Coccomyxa*, *Dictyochloropsis*, *Trebouxia*, *and Trentepohlia* genera. The basic growth requirements and behavior of photosynthetic partner participating in the lichen structure are similar to free-living algae that do not form lichen. While the carbohydrate that is transferred from the blue-green bacteria to the fungus in lichen thallus is glucose, three different polyols are transmitted from the green algae to the fungus. Erythritol from *Trentepohlia*, sorbitol from *Hyaloccus* and *Stichococcus*, and ribitol from *Coccomyxa*, *Myrmecia*, *Trebouxia*, and *Trentepohlia* are transferred.

Mycobionts and photobionts store different polyols; the former stores mannitol and arabitol; these substances are not found in the photosynthetic partners; the latter stores polyols such as ribitol not found in fungus or are very rare. The slow movement of carbohydrates from algae to fungus is an indication that these substances are also slow to be converted by fungi. Laboratory studies don't reflect the natural movement in lichen thallus; we need to explain as to how carbohydrate transfer is the same throughout the year. Some questions about the transport of carbohydrates and other compounds in thallus needs a full explanation: Is there a lateral transport like vertical transport of the compounds? What is the movement intensity of compounds from a photobiont cell to the fungus partner? Is there a control mechanism that regulates the carbohydrate transport between partners? And finally what is the ecological role of carbohydrate pools in partners?

3.5 Nitrogen Fixation

The presence of nitrogen in the protein structure constitutes an essential building block of living beings on earth with the availability of nitrogen element. Its recovery is of great importance. In terrestrial plants, major nitrogen source is nitrate and ammonium in the soil; higher plants do not have the ability to bind it in the form of gas or molecular nitrogen from the air. The non-photosynthetic fungus in the lichen not only needs nitrogen in the formation of protein and nucleic acids but also for chitin in the fungal cell walls (Palmqvist et al. 2002). Blue-green bacteria are photosynthetic prokaryotes which produce oxygen, and many species fix N_2. A few species live as symbiotic with various eukaryotes, but majority live free in nature. The blue-green bacteria are primary symbiont in some and as secondary symbiont in some lichens. These structures are cephalodia if blue-green bacteria are present as secondary symbionts. Cephalodia can be compared to nodules formed by blue-green bacteria in the roots of *Fabaceae* family plants. *Lobaria* and *Sticta* genera are rich lichen species with cephalodium. Blue-green bacteria are present in approximately 50 genera and 1000 species as primary partner and in approximately 20 genera and 500 species as secondary partner, meaning it takes place in a lesser number as secondary partner in lichen thallus.

Approximately 8% of the identified lichens contain blue-green bacteria as symbiotic partners. These are known as nitrogen-fixing lichens and are an important part in different ecosystems. Nitrogen fixation is important in humid areas, where plants with nodules are rare, and ecosystems containing lichen with blue-green bacteria prove helpful. The nitrogen fixation by lichens is far from anthropogenic effects, nitrogen input due to precipitation is more than nitrogen fixed by lichens, and it is also important in the water boundary line in ecosystems. Nitrogen fixation by lichens is especially important in humid environments with abundant cyanophilic species. The lichen cover in these areas increases nitrogen, which is useful for organisms of the area. Cyanobacteria found in many lichens form heterocysts, structures necessary for nitrogen fixation under oxygen-free conditions. They form association with fungus which follow aerobic respiration and fix nitrogen. Although heterocysts contain photosynthetic lamellas, the photosystem II pathway doesn't occur. Therefore, there is no oxygen production in photosynthesis caused by the breakdown of water. The carbon compounds introduced into the fungus are provided with photosynthetic vegetative cells that are functional under oxygen-free conditions. These vegetative cells can fix nitrogen. However, studies using labeled metabolites in cyanobacteria have found that nitrogenase activity is only in heterocysts. If cyanobacteria are found as secondary partner in lichen thallus, they contain more heterocysts than the primary partner. It is difficult to explain this major difference in the number of heterocysts.

In lichens with green and cyanobacterium symbionts, the primary green symbiont is thought to assist in the development of heterocyst by providing nutrients in the blue-green symbiont in the cephalodium. In *Peltigera aphthosa* thallus, there is an *Ascomycota* species and a species belonging to the genus *Coccomyxa*, which is green alga as a phycobiont. The secondary photosynthetic member is located in the superficial (ectotrophic) cephalodium on the upper surface of the thallus. Cephalodium constitutes 2.6% of the mass of thallus by dry mass of thallus and accounts for the bulk of cyanobacterium cephalodial protein, about 82%. Cephalodia are numerous and small at the growth points of thallus, and heterocyst frequency of cyanobiont in these cephalodia is lower. This type of cyanobiont is a nitrogen-fixing partner, as compared to the free-living *Nostoc* species; the number of heterocyst is much, as such there is high nitrogenase activity, which is higher in the center of thallus compared to the bottom and end parts of thallus. In *Peltigera* and *Lichina* genera, nitrogenase activity increases with increase in light intensity and activity in the dark decreases, which reflects the decrease in depot carbon volume in thallus.

3.6 Metabolic Products

The metabolic products synthesized in lichens are called lichen substances, lichen products, or lichen acids. Although the ingredients known in lichens are acidic, there is insufficient evidence that these substances contain an acidic functional group. Approximately 200 lichen compounds have been reported up to the early 1900s. In the following years, methods used in determining lichen compounds advanced, following classical point tests, microcrystallography, paper chromatography, thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), chemical methods, gas chromatography, and mass spectrophotometry (Rankovič 2015). Most of the organic compounds in these are characteristic phenolic compounds like depsit, depsidone, benzoquinone, naphthaquinone, antroquinone, xanttone, biphenyl and dibenzofuran. All these are synthesized by the fungal component. Although this is not a very important feature in many plant groups, they are extremely useful and practical in identifying lichens species. The color reactions they give with various reagents in the tissues of lichen thallus are an important criterion in determining lichens. They live in environments so extreme and with specific climatic condition that it is possible that they produce many metabolic products. These metabolites provide good protection against various negative physical and biological effects and are divided into two groups according to their occurrence in thallus, as primary and secondary. Primary ones are intracellular, whereas the secondary ones are extracellular (Nash III 2008). Former in lichens are proteins, amino acids, polyols, carotenoids, polysaccharides, and vitamins. These are mostly water soluble and can be extracted with boiling water, but some are synthesized by algae and some by fungal compenent (Goga et al. 2018). Due to the complex nature of the lichen thallus, it is often not possible to decide on the synthesis location of a particular compound. Most of the primary metabolite (intracellular) products that are isolated from lichens are not specific and are also produced in free-living fungi, algae, and higher plants. The free amino acids found are similar to those found in plants (Rankovič 2015). Majority of organic compounds in lichens are usually found as 0.1% to 10% of dry weight and are secondary metabolites (extracellular); sometimes this rate reaches 30%.

More than 800 secondary metabolites have been identified in lichens, majority peculiar to them, and only a small part is also produced in fungi and higher plants. All secondary metabolites in lichens are of fungal origin, generally isolated from lichens with organic solvents (Bačkorová et al. 2012). Although studies have shown that algae play a role in the last stage of characteristic lichen substances in recent years, a large part of the synthesis of these substances is associated with fungal metabolism. Apart from lichens, many natural products that are similar to complex lichen products are synthesized only in free-living fungi that don't form lichens. The secondary metabolites of lichen origin have been found to be extremely stable. There is no significant decrease in the density of lichen substances even in very old lichen herbarium specimens (Rundel 1978). It is also stated that secondary compounds are mainly genetically controlled, and in some cases morphology and geography in individuals of the genus and species level may play a role (Culberson and Culberson 2001; Zhou et al. 2006). Lichen secondary metabolites get accumulated either in the cortex or more commonly in the medulla; most common cortical compounds are usnic acid, atranorine, anthraquinone, pulvinic acid derivatives, and xanthones. The cortical accumulated compounds are easily differentiated from those in the medulla; this is also related to their biological roles. The cortical compounds are considered as a kind of light filter; those in the medulla under the algae layer lack such a function (Marques 2013).

Lichens synthesize enough quantity of substances in nature, but under sterile cultures in the laboratory, the amounts produced are largely different from nature. Mycobionts which develop without photobionts synthesize special secondary compounds under certain conditions, but they can also produce substances that are different from symbiotic metabolites. *Lecanora dispersa* contains 2,7-dichlorolixantone as a secondary metabolite, but when isolated, spores are cultivated and develop without algae; it produces pannarin, a depsidon; as such the natural source of pannarin is not considered to be lichen; the biosynthetic potential of this depression has not been proven in the herbarium specimen of the species. Similarly the production of atranorin in *Usnea hirta* is possible when cultured in a laboratory setting, because it is not found in all *Usnea* species. Lichenized fungi produce compounds similar or nearly similar to those produced by non-lichenized fungi. According to Goga et al. (2018) secondary metabolites of lichens are produced in different ways. These are; acetyl-malonate pathway secondary aliphatic acids, esters and their related derivatives, mononuclear phenolic compounds, depsites, tridepsides and benzyl esters-depsidones and diphenyl esters, depsons, dibenzofurans, usnic acid and its derivates, anthroquinones and biogenetically related xanthones, chromones, naphtoxins are produced in this way. In mevalonate pathway Di-, ester and triterpenes-steroids are produced but in the shikimate pathway the terphenylquinones-pulvinic acid derivates are produced. There are also some very uncommon compounds formed by different mechanisms such as arthogalin, an annular depsipeptide, and other amino acid derivatives like cytotoxic scabrosin esters are isolated from *Xanthoparmelia scabrosa*. The substance responsible for the acetyl-polimalonyl pathway is acetyl CO-A and malonyl-CoA, the derivatives of coenzyme A; especially the aromatic products of lichen secondary metabolites are formed in this way. Most important features of this group of substances are that two or three orcinol or β-orcinol-type phenolic units are connected with ester, ether, and carbon. Depsidon, dibenzofuran, usnic acid, and depson are all produced by a similar mechanism and all are specific to lichens. Other aromatic compounds like xanthones and anthraquinones are likely formed by the internal ringing of single-folded polymer chain. They are same or similar to non-lichenized fungi or products of higher plants. In addition to these, most of the compounds with unknown structure are given general names and included here as these compounds are frequently encountered and easily identified by microchemical tests (Rankovič 2015). The most surprising feature of lichen compounds is the acetate-polymalonate formed by aromatic phenols, most formed by esterification or oxidative bonding of two or three phenolic units or by bonding together. In the cultures only a few lichenized fungus-specific substances like pulvinic acid derivatives, phenolic acid units, chromones, and anthraquinones are identified (Zheng et al. 2007). All of the acetate-derived aliphatic products and unbranched products are defined in this group.

Terphenylquinones and pulvinic acid pigment are well-investigated secondary lichen products. The lichen genus well-known to produce pulvinic acid belongs to the *Stictaceae* family. In this family photosynthetic partner is cyanobacterium. Many lichen families contain only green alga and typically form acetate-polymalonate derivative aromatic esters and bound products. Green algae containing lichens have very low nitrogen content unless they develop in high-nitrogen-containing substrates. The nitrogen metabolism in lichens is little known; few secondary metabolites and alkaloids in lichens have been shown to be severely limited in the supply of beneficial nitrogen to the fungus. Some lichens prefer habitats such as farmyards and poultry where organic nitrogen is high. Unlike green algae, many cyanobacteria have been found to contain a lot of nitrogen compared to the substrates on which they develop. Many, but not all, lichen-containing cyanobacteria contain pulvinic acid derivatives (Goga et al. 2018). In general most of the lichens with pulvinic acid pigment or terphenylquinone don't contain nitrogen-fixing algae. The phenylalanine was found to be the precursor for pulvinic acid derivatives here. The compounds other than rhizocarpic acid and epanorin do not contain nitrogen in their molecules and can be formed from nitrogen-free prephenic acid derivatives or by some mechanisms with continuous return allowing small nitrogen concentration. Pulvinic acid derivatives (calicin, epanorin, leprapinic acid, leprapinic acid methyl ether, pinastric acid, pulvinic acid, pulvinic dilactone, rhizocarpic acid, stictaurin, vulpinic acid) are known, but only two terphenylquinones (polyporic acid and thelephoric acid) are known (Rankovič 2015).

It has been observed that in the past, uses of lichens were in the form of utilizing metabolic products. Today, the effects of lichen secondary metabolites on cancer are evaluated largely. Secondary metabolites produced by lichens primarily are self-protective possessing defense molecules. These substances have different colors and crystal structures and protect the lichen thallus against changing light stress (Al-Amoody et al. 2020). The extract of *Cetraria aculeata* has been reported to show antigenotoxic activity in bacterial systems and cytotoxic activity in some mammalian cancer cells (Zeytinoglu et al. 2008). The antioxidant, antigenotoxic, and antimutagenic potencies of methanol extracts of *Usnea articulata* and *U. filipendula* have been reported (Ceker et al. 2015). Extracts of *Evernia prunastri, Parmelia sulcata*, and *Pseudevernia furfuracea* var. *furfuracea* have been reported to inhibit micelle and spore growth of various plant pests (Karabulut and Ozturk 2015). It has also been reported that methanol extract of *Parmelia sulcata* has a strong anticancer activity against breast cancer cell lines by inducing apoptosis, depending on the type of tumor cell (Ari et al. 2015).

3.7 Economic Uses

The lichens have been used as food, medicine, and poison; in tanning and beer making; in paints; in perfumery; as bioindicators; and for age determination (lichenometry) (Brodo et al. 2001; Nash III et al. 2002; Smith et al. 2009). The lichens have formed the food of various groups in nature from many small animals to humans. Insects such as moths, spiders, and snails are the examples benefiting from these. However, some acids, for example, rhizocarpic acid and pinastrinic acid found in lichens can prove toxic to these organisms. Vulpinic acid is toxic only to vertebrates. Therefore some of these animals have developed a protective mechanism against these acids. The bitter acids from lichens can be removed by holding them in a 1% soda solution for 24 h and then washed. *Cladonia rangiferina* has served as food for reindeer and cattle and is thus known as "reindeer moss." If *C. rangiferina* is missing in the area, brownish-black foliose and epiphytic lichen *Alectoria jubata* are used instead. *Stereocaulon paschale* is also consumed by reindeer and other animals. It forms large dense pillows on soil in mountainous areas. Similarly, *Cetraria islandica* is stored by Icelanders and used as animal feed. Lichens contain neither real starch nor cellulose. However, some are used as a nutrient especially *C. islandica*. The Egyptians have used *Evernia prunastri* flour in bread making and rarely *Pseudevernia furfuracea* flour. *Parmelia perlata*, known as "rathapu" or "rock flower" in Telugu language, has been used in making a kind of tomato paste; *Lecanora esculenta*, a desert lichen, is considered to be the manna of the Jews and named as bread from the sky.

The medicinal uses of lichens date back for centuries and with a few exceptions; these are nontoxic. They have been used in the treatments according to their morphological features. *Usnea barbata* with a long threadlike structure has been used in some treatments; similarly, *Lobaria pulmonaria* with a reticulate thallus has been used in lung disease. *Xanthoria parietina*, a yellow lichen, has been proposed for the treatment of jaundice, and *Peltigera aphthosa* with small wart-like tubercules has been used in the treatment of children suffering from thrush. *Parmelia saxatilis* and some other species known as skull lichens have been as valuable as gold for the treatment of epilepsy. *Peltigera canina* has also been used in rabies treatment. Due to their bitter taste, some lichens have been used instead of quinine in high fever. *Pertusaria amara* and few other species have been proposed for fever attacks. *Usnea* species and *Pseudevernia furfuracea* have been used as in the treatment of hemorrhoids. Many of the acidic substances present in some lichens like *Letharia vulpina* and *Cetraria pinastri* are toxic; they are irritating if consumed. The former contains vulpinic acid, found in the cortex cells in the form of lemon yellow crystals and has been used in northern countries to poison wolves. The latter forms pinastrinic acid as orange or golden yellow crystals in medulla hyphae. Lichens have also been used to make alcohol. It was discovered at the beginning of the nineteenth century. Lichens used for this purpose are *Physcia ciliaris, Ramalina fraxinea, Ramalina fastigiata, Ramalina farinacea, Usnea florida, Cladonia rangiferina, Cetraria islandica,* and *Alectoria jubata.* When weak H_2SO_4 and HNO_3 are applied to the lichen substance in thallus, it turns into glucose, and alcohol is formed by glucose fermentation.

The fixing feature in *Cetraria islandica* and *Lobaria pulmonaria* has been used in tanning. Injury from lichen coloring properties is an old story. The oldest genus which has attracted the attention with its paint feature is *Roccella*; its paint is known as orseille (orchill or archil). Orseille or orchill is not just composed of erythrin and lecanoric and orsellinic acids. It can also be obtained from any lichen containing erythrinic, gyrophoric, evernic, and ramalic acids. Under the influence of acids, orcin and carbonic acid break down, and over time, orcin with the O_2 and N_2 of the air turns into orcein; it gives the main color of the orchill, and the conversion event takes nearly 30 days to complete. This dye is used to dye silk and wool but is ineffective in dyeing cotton, as vegetable fiber. *Roccella* species are very important as paint lichens and these were the first used to obtain blue and violet paints. Lichens with less coloring ability are *Umbilicaria pustulata, Gyrophora, Parmelia, Pertusaria, and Lecanora tartarea.* The use of lichens in producing paints is an old industry dating back to Linnaeus. The paints obtained were reddish, rust red, and brown from *Haematomma ventosa,* brown tones from *Parmelia perlata, Hypogymnia physodes, Lobaria pulmonaria,* and *Cetraria islandica*, and yellow-brown from *Parmelia caperata. Xanthoria parietina* from the yellow lichens usually gives yellow dye. A similar dye is obtained from *Letharia vulpina.*

Lichens have also been used in the perfumery industry. *Evernia prunastri* or "oak moss" produces an extremely good perfume fixator; similarly, *Ramalina calicaris* and *R. fraxinea* are used for the same purpose. A better fixator is obtained from *Lobaria pulmonaria*; this lichen is called "moss at the base of the oak," as it develops where the tree trunk converges into the soil. In the seventeenth century, a hair powder called Pulvis Cyprius or Cyprus Powder was obtained from lichens for cleaning and beautifying the hair. The examples are *Evernia prunastri, Physcia ciliaris*, and *Usnea* spp. Many *Cyanobacteria* members in lichens contain mucilage. For this reason, it has been shown that it is possible to obtain gum and mucilage from lichens. These substances are obtained by sufficiently boiling the lichens. Lichen mucilage is used in the manufacture of paint instead of gum arabic in lion.

Lichens are highly sensitive organisms to pollution. They cannot live in areas with high air pollution. The air quality of places where lichens are abundant is always regarded as good. Regions where lichens are not observed are regarded as lichen deserts. Only a few species resistant to air pollution can be seen in such areas. Few lichens found in the nearby zone are the ones which can resist moderate air pollution. Lichens therefore serve as a guide for city planners in the planning of new settlements. Lichens are also used as bioindicators of atmospheric heavy metal pollution and in the assessment of climate change. Many studies have been conducted on how lichen diversity changes depending on the air quality. The lichens respond to all changes on a habitat they live in and the substrate on which they develop. For example, with increased air pollution, the lichens start disappearing. Growth rate of lichens and lichen colonization is affected by elevation, dominating plant cover, moisture, wind, light intensity, temperature, and the mineral composition of the habitat. Lichenometry is a method based on determining historical background based on lichen growth rate. This technique is useful in determining the historical past in geomorphological, geo-chronological, tectonic, and archeological studies. For example, *Rhizocarpon geographicum* (map lichen) is an important crustose lichen used in this technique (Armstrong 2004). Lichenometry is now an accepted method of determining the date of a substrate and interpreting the features of the past. The growth curve in lichens is determined by two ways, directly or indirectly (Joshi et al. 2012). The growth rate of lichen thallus is recorded for a certain time in the direct method. In the indirect method, lichens on the substrates with known date are measured. It has been reported that colonization occurs on granite in 78 years and in gneiss between 50 and 78 years (Gupta et al. 2014).

3.8 Lichen Diversity of Turkey

The studies on lichens in Turkey started nearly a century back; these are in the form of travel notes by non-Turkish travelers. Therefore very few species are mentioned in these records. From 1980 onward, local workers started investigating lichens with a revision of certain species as well as determining the lichen diversity and abundance on regional basis together with studying various biological activities of metabolic products. These studies were pooled up in the form of a list in 2017 (John and Türk 2017). In all 1898 taxa of lichens and lichenicolous fungi have been recorded together with the distribution areas (Figs. 3.1, 3.2 and 3.3). The figure plates include well-known and widely distributed species of lichens in Turkey. The photographs have been taken using a light microscope, and magnifications are given in the brackets.

Lichens are mostly known as moss in Turkish community. This was followed by the work where each taxon identified has a Turkish name. Lately it has been seen that the revision studies which contain some taxa with taxonomic confusions has helped to solve the systematic errors and incomplete sampling made in the past. With the systematic revision studies to be carried out in the future, it is estimated that the number of 1898 mentioned in the work will increase in different regions and even re-evaluations will be required. Turkey is very suitable for lichen development due to its ecological and geographical features.

IUCN red list is an important measure in the monitoring of biodiversity, providing critical information. This information covers rules not to be ignored as these explain the determination and protection of natural resources together with the extent to which necessary protection measures should be taken. In Estonia, Switzerland, and Italy, much work has been done on lichen taxa under threat (Randlane et al. 2008; Scheidegger and Werth 2009; Nascimbene et al. 2013). The results published from these studies ensure habitat and substrate protection of lichens. In Turkey not many studies have been carried out in this direction, in particular preparing a list according to IUCN criteria. Currently we have found that some of species in Turkey (John and Türk 2017) are found only in very few localities, as compared to their earlier records (Randlane et al. 2008). These may be in one of the threat categories (CR, critically endangered; EN, endangered; VU, vulnerable). Our studies reveal that the species in the CR category are *Hypogymnia*

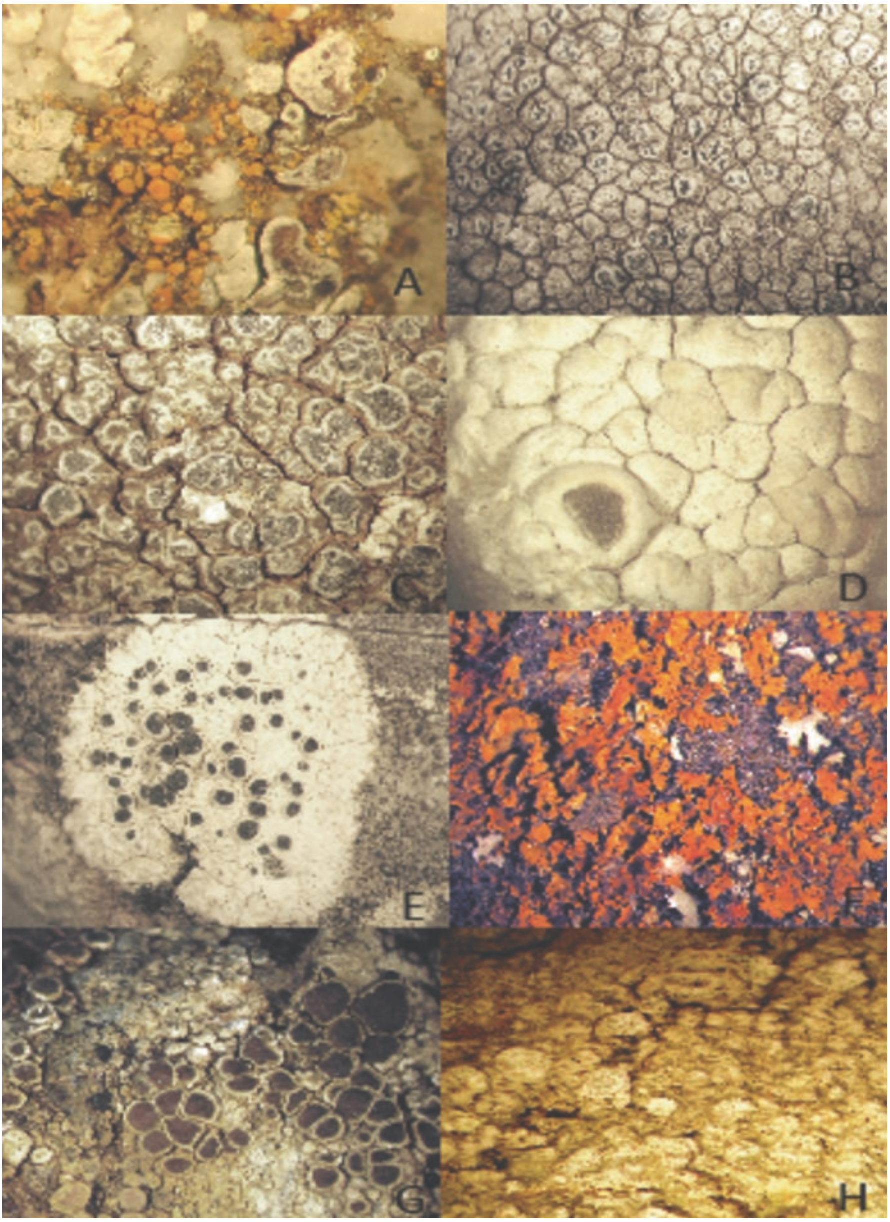


Fig. 3.1 Some examples of lichens distributed in Turkey. (**a**) *Caloplaca inconnexa* (Nyl.) Zahlbr. (X8.8); (**b**) *Circinaria calcarea* (L.) A. Nordin, Savic, & Tibell (X5.5); (**c**) *Circinaria contorta* (Hoffm.) A. Nordin, Savic, & Tibell (X4.3); (**d**) *Diploschistes ocellatus* (Vill.) Norman (X6.8); (**e**) *Diplotomma epibolium* (Ach.) Arnold (X4.3); (**f**) *Gallowayella fulva* (Hoffm.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, Hur, & A. Thell (X5.5); (**g**) *Lecanora chlarotera* Nyl. (X5.5); (**h**) *Marfloraea albescens* (Huds.) S.Y.Kondr., L.Lökös, & J.-S. Hur (X5.4)

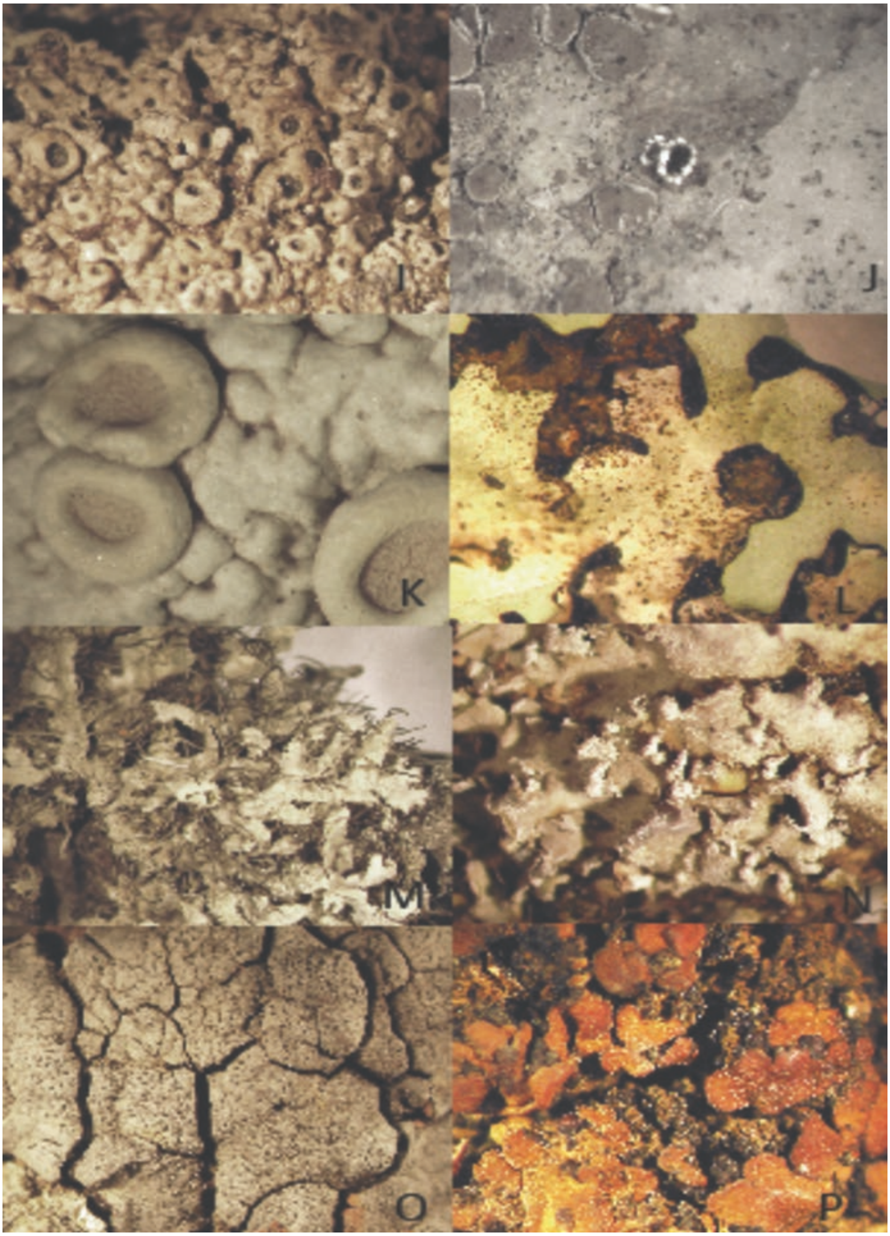


Fig. 3.2 Some examples of lichens reported from Turkey. (**i**) *Megaspora verrucosa* (Ach.) Hafellner & V. Wirth (X5.4); (**j**) *Myriolecis crenulata* (Hook.) Sliva, Zhao Xin, & Lumbsch (X13.7); (**k**) *Ochrolechia pallescens* L.) A. Massal. (X15); (**l**) *Parmelina tiliacea* (Hoffm.) Hale (Hoffm.) Hale (X6.9); (**m**) *Physcia adscendens* (Fr.) H. Olivier (X6.9); *N*, *Physconia perisidiosa* Erichsen) Moberg (X8.6); (**o**) *Placocarpus schaereri* (Fr.) Breuss (X4.3); (**p**) *Psora decipiens* (Hedw.) Hoffm. (X5.4)

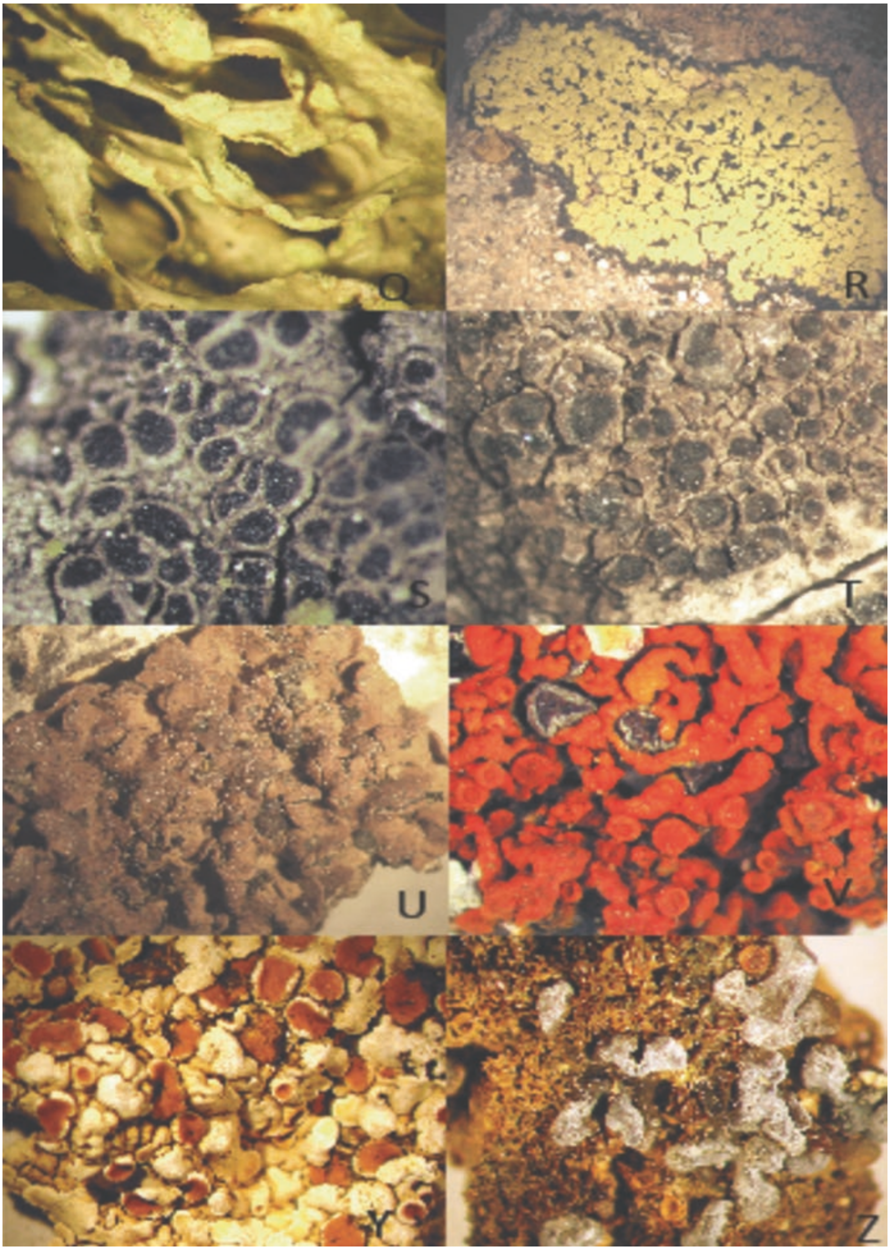


Fig. 3.3 Some examples of lichens found in Turkey. (**q**) *Ramalina farinacea* (L.) Ach. (X6.9); (**r**) *Rhizocarpon geographicum* (L.) DC. (X3.4); (**s**) *Rinodina exigua* (Ach.) S. Gray (X27); (**t**) *Rinodina lecanorina* (A. Massal) A. Massal (X11); (**u**) *Romjularia lurida* (Ach.) Timdal (X4.3); (**v**) *Rusavskia elegans* (Link) S.Y. Kondr. & Kärnefelt (X11); (**y**) *Squamarina lentigera* (Weber) Poelt (X3.4); (**z**) *Toninia sedifolia* (Scop.) Timdal (X6.9)

vittata, Lobaria scrobiculata, Peltigera collina, and *Umbilicaria polyrrhiza*; species in the EN category are *Bacidia biatorina, Catapyrenium cinereum, Cladonia coccifera, Eupyrenula leucoplaca,* and *Peltigera venosa*; and species in the VU category are *Cetrelia olivetorum, Collema nigrescens, Evernia divaricata, Physcia leptalea,* and *Toninia sedifolia.*

3.9 Conclusions

Lichens as members of our ecosystems share the habitats of plants, although they are not included in the plant kingdom, but have a very important basic role in the formation of soil. Even the smallest herbaceous plant on a bare rock cannot survive without soil. Lichens play an important role in the formation of soil in the form of a thin layer at the start. Crustose lichens developing on a bare rock undergo physical and chemical actions; in this way lichens help in soil formation. This group of organisms releases CO_2 during the respiration, and a part of it dissolves in water, and the rocks affected by the acid formed lead to primary formation of soil. Lichens also penetrate the rocks, causing physical disintegration. Their fungal partner is affected by the changes in temperature and humidity, and thus rocks break down forming soil. Secondary products synthesized by lichens help transform the metals in rocks into organic complexes ending up in the mineralization of soil. The different morphological form of lichens prevent soil erosion and also enrich the soil.

The studies on the samples of epiphytic lichens has revealed that these organisms are an accurate method in determining air quality. These have been used in measuring pollution types and as indicators of especially sulfur dioxide pollution. Slow growth ensures absorbance of pollutants in lichens. Pollutants disrupt the balance between fungus, alga, and cyanobacterium and disrupt lichen thallus. Even if there are suitable substrates in the city center, there are no lichens in the center due to the pollutants released from the automobiles and industries. Lichens appear in natural park areas and areas where industrial contamination is less, suggesting that lichens are highly sensitive to air pollution, therefore good indicators of air quality. Lichens make up an average of 8% of vegetation covering the earth's surface. In certain regions, such as tundras, the lichens cover the entire region. Since significant amounts of CO_2 is fixed during photosynthesis in lichens, they help in preventing global warming, play a role in the recovery of minerals such as nitrogen and phosphorus in poor soils in terms of basic nutrients, and increase photosynthetic capacity in Arctic tundra regions, where they serve as important food source of reindeers. In addition to these features, molecular nitrogen in the atmosphere is fixed by the cyanobacteria that settle in the roots of species of the *Fabaceae* family. Lichens containing blue-green bacteria as primary photobionts in thallus or secondary photobiont in cephalodia are also capable of fixing nitrogen. So, they have an important ecological role in providing nitrogen to other life forms. Out of 79% nitrogen in the atmosphere, only a few organisms are able to directly use it from the atmosphere. Nitrates stored in lichens also provide nitrogen enrichment of the soil around them.

References

Al-Amoody AA, Yayman D, Kaan T et al (2020) Role of lichen secondary metabolites and pigments in uv-screening phenomenon in lichens. Acta Biologica Turcica 33(1):35–48

Ari F, Ulukaya E, Oran S et al (2015) Promising anticancer activity of a lichen, *Parmelia sulcata* Taylor, against breast cancer cell lines and genotoxic effect on human lymphocytes. Cytotechonology 67:531–543

Armstrong R (2004) Lichens, Lichenometry and global warming Microbiologist (September) 32–35

Bačkorová M, Jendželovsky R, Kello M et al (2012) Lichen secondary metabolites are responsible for induction of apoptosis in HT-29 and A2780 human cancer cell lines. Toxicol In Vitro 26:462–468

Brodo IM, Duran-Sharnoff S, Sharnoff S (2001) Lichens of North America. Yale University Press, New Haven/London

Ceker S, Orhan F, Kizil HE et al (2015) Genotoxic and antigenotoxic potentials of two *Usnea* species. Toxicol Ind Health 31(11):990–999

Culberson CF, Culberson WL (2001) Future directions in lichen chemistry. Bryologist 104(2):230–234

Goga M, Elecko J, Marcincinova M et al (2018) Lichen metabolites: An overview of some secondary metabolites and their biological potential. In: Merillon JM, Ramawat KG (eds) Co-evolution of secondary metabolites. Springer Nature, Cham

Gupta V, Vaidesvaran SC, Dobhal DP (2014) Colonization delay of *Rhizocarpon geographicum*: study from the Gangotri Glacier, Northwestern Himalaya. J Geol Soc India 84:335–340

John V, Türk A (2017) List of Turkish lichens. Ali Nihat Gökyiğit Foundation, Nezahat Gökyiğit Botanical Garden Publication, NAMAŞ- İstanbul, Turkey

Joshi S, Upreti DK, Das P, Nayaka S (2012) Lichenometry: a technique to date natural hazards. Earth Sci India II:1–6

Karabulut G, Ozturk S (2015) Antifungal activity of *Evernia prunastri*, *Parmelia sulcata, Pseudevernia furfuracea* var *furfuracea*. Pakistan J Bot 47(4):1575–1579

Marques J (2013) A frame for assessing the vulnerability of schist surface to lichen-induced weathering in the upper Douro region (NE Portugal). Faculty of Science, Biology Department, University of Porto

Nascimbene J, Nimis PL, Ravera S (2013) Evaluating the conservation status of epiphytic lichens of Italy: a red list. Plant Biosystems 147(4):898–904

Nash H III (2008) Lichen Biology, 2nd edn. Cambridge University Press, London

Nash H III, Ryan D, Diederich P, Gries C, Bungartz F (2002) Lichen Flora of the greater Sonoran Desert region, vol 1. Lichens Unlimited, Tempe

Palmqvist K (2000) Carbon economy in lichens. New Phytol 148:11–36

Palmqvist K, Dahlman L, Valladares F et al (2002) CO_2 exchange and thallus nitrogen across 75 contrasting lichen associations from different climate zones. Oecologia 133:295–306

Price S, Long SP (1989) An in vivo analysis of the effect of SO_2 fumigation on photosynthesis in *Zea mays*. Physiol Plant 76:193–200

Price GD, Badger MR, Woodger FJ, Long BM (2008) Advances in understanding the cyanobacterial CO_2 - concentrating - mechanism (CCM): functional components, Ci transporters, diversity, genetic regulation and prospects for engineering into plants. J Exp Bot 59(7):1441–1461

Randlane T, Jüriado I, Suija A et al (2008) Lichens in the new red list of Estonia. Folia Cryptog Ectonica, Fasc 44:113–120

Rankovič B (2015) Lichen secondary metabolites. Springer, Cham

Rundel PW (1978) The ecological role of secondary lichen substances. Biochem Syst Ecol 6:157–170

Scheidegger C, Werth S (2009) Conservation strategies for lichens: insights from population biology. Fungal Biol Rev 23:55–66

Smith CW, Aptroot A, Coppins BJ et al (2009) The lichens of Great Britain and Ireland. British Lichens Society, London

Wirth V, Hauck H, Schultz M (2013) Die Flechten Deutschland. Vol. 1 and 2, Ulmer Verlag
Yavuz M, Özyiğitoğlu G (2015) Tıp tarihinde likenlerle ilgili terimler. Avrasya Terim Dergisi 3(1):1–9
Zeytinoglu H, Incesu Z, Tuylu BA et al (2008) Determination of genotoxic, antigenotoxic and cytotoxic potential of the extract from lichen *Cetraria aculeata* (Schreb.) Fr. In vitro. Phytother Res 22:118–123
Zheng X-L, Sheng H-M, An L-Z (2007) Phylogenetic analysis of lichen - forming fungi *Rhizoplaca* Zopf from China based on ITS data and morphology. Z Naturforsch 62:757–764
Zhou Q-M, Guo S-Y, Huang M-R, Wei J-C (2006) A study of the genetic variability of *Rhizoplaca chrysoleuca* using DNA sequences and secondary metabolic substances. Mycologia 98(1):57–67

Chapter 4
Endangered Swamp Forests in Turkey—An Ecological Inventory, Prospects, and Challenges

Münir Öztürk, Volkan Altay, Celal Yarcı, Ersin Yücel, and Hamdi G. Kutbay

4.1 Introduction

The four billion ha of world forest coverage has decreased by nearly 40% since the advent of agriculture, either through land clearance, afforestation, reforestation, revegetation, and wood cutting (FAO 2006). The net loss during that last decade has been more than 35 million ha, which includes a third of temperate and tropical forests leading to an increase in the species extinction (IUCN 2006; Altay 2015). Out of 30 percent of the current forested global land area more than 1/3 are primary, but nearly 60.000 km^2 of this is annually lost. The annual forest loss in the world has been recorded as 130.000 km^2 per year during 2000–2005. The current deforestation rates threaten the forest biodiversity all over the world. This jeopardizes the ecosystem services provided by the forests such as protection of fisheries, watersheds and soils as well as important carbon pools (MEA 2005). According to Schmitt et al. (2009) they constitute a vital source of raw materials, both for industry and meet basic livelihood needs of rural communities. The analyses of several

M. Öztürk (✉)
Botany Department & Centre for Environmental Studies, Ege University, İzmir, Turkey

V. Altay
Biology Department, Faculty of Science & Arts, Hatay Mustafa Kemal University, Hatay, Turkey

C. Yarcı
Biology Department, Faculty of Science and Arts, Marmara University, Istanbul, Turkey
e-mail: celalyarci@marmara.edu.tr

E. Yücel
Biology Department, Faculty of Science, Eskisehir Teknik University, Eskisehir, Turkey
e-mail: eyucel@eskisehir.edu.tr

H. G. Kutbay
Biology Department, Faculty of Science and Arts, Ondokuzmayıs University, Samsun, Turkey
e-mail: hguray@omu.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_4

studies covering forest cover, forest type, and biogeographical pattern with targets for forest protection reveals that large numbers of forest areas still have very low levels of protection.

Swamp forests are distinctive habitats supporting a rich ecological as well as biodiversity (Yarcı 1994; Calhoun 1999; Schnitzler et al. 2005), being highly diverse ecological communities (Fickert and Gruninger 2010). Swamp forests have a great biological diversity and usually consist of later successional, shade-tolerant species. Swamp forest species developed several number of structural and physiological traits and these traits contribute to persistence in the deep shade of the forest understory in such forests. These structural attributes include some leaf traits such as low specific leaf mass and these traits not only promote survival by conferring resistance to herbivory and pathogens but also increase survival of shade-tolerant species (Kutbay 2001). These forest habitats provide significant ecosystem services, such as carbon sequestration, and sustain productive fisheries. However, wetland forests are vulnerable not only to excessive direct use, but also to an unsustainable water use. The estimates of the extent of coverage for this forest type under existing protected area systems are not possible due to lack of dependable data (MEA 2005). These forests represent habitats where the water table is usually at or near the surface and the land is covered periodically with shallow water (Paal et al. 2007). These conditions are favorable for occurrence of numerous moisture-demanding species including the marshland plants, spring specialists, and common species of wet habitats (Hrivnák et al. 2013). These unique habitats form an important part of biological richness if protected, but their sustainability is related to the natural flooding regime (Schuck et al. 1994; Kopeć et al. 2014). They are important in terms of ecosystem conservation, ecologically sensitive, and easily affected by biotic and abiotic factors (Kavgacı et al. 2016). All these features (Tockner and Stanford 2002). A strong dominance of a few tree species is a common feature in global swamp forests (Yarcı 1994). The reasons for this are the harsh edaphic conditions due to saturated waterlogged soils, as only plants developing metabolic and morphological adaptations to flooding grow in such environments (Imbert et al. 2000). The activities like urbanization, agriculture, construction of dams and hydroelectric power stations, agriculture, drainage channels, grazing, and road networks that dominate on their landward edge prevent swamp forests from shifting toward inlands (Moffatt and McLachlan 2004; Kavgacı et al. 2016). To assess the possible impact of current and future changes on these forests, we need to understand the key determinants of their structure and dynamics (Koponen et al. 2004; Rivera-Ocasio et al. 2007; Migeot and Imbert 2011).

According to the Habitat Directive, these forests belong to the habitats of the greatest importance for nature protection on the European scale (Košir et al. 2013). They are particular types of wetlands, classified by the Ramsar Convention as "freshwater, tree-dominated wetlands" in category (Xf) (Ramsar Convention Secretariat 2006), helping to slow erosion processes, control floods (Hauenstein et al. 2005) and with their high biological and environmental value as providers of ecosystem services (Peña-Cortés et al. 2011). They are also recognized as threatened ecosystems under the Bern Convention (Kavgacı et al. 2016) and have been thoroughly studied in Europe (Paal et al. 2007; Klimo 2008; Baričević et al. 2009; Poldini et al. 2011).

This chapter has been prepared with the aim to summarize the biological and ecological conditions of Turkish swamp forests in order to understand and conserve this threatened ecosystem for their restoration and rehabilitation. This will pave the way for future conservation activities of these forests.

4.2 Data Analyses

The results on the floristic richness, priority site conservation, phytosociology, edaphic relations, and ecology covering of the swamp forests in Turkey have been published by several workers notable among these being: Quézel et al. (1980), Aydoğdu (1988), Akman et al. (1993), Yarcı (1994), Vural et al. (1995), Kutbay et al. (1997, 1998), Kutbay (2001), Çiçek (2004), Yalçın et al. (2004), Tecimen and Kavgacı (2010), Korkmaz et al. (2012), Hüseyinova et al. (2013), Sürmen et al. (2014), and Kavgacı et al. (2007, 2011, 2016). The endemic and rare plant taxa whose status or name has changed, or have become synonyms, or have been included under new combinations have been corrected following the "List of Turkish Plants-Vascular" (Güner et al. 2012).

4.3 Forest Diversity

There are 14 swamp forests existing in Turkey, namely: Hendek-Süleymaniye, Dokuma-Döşeme, Meşeligöl, Karasu Turnalı-Acarlar (Adapazarı Province); İzmit Büyükderbent (Kocaeli Province); Bektaşağa-Aksaz (Sinop Province); Dalaman plateau, *Liquidambar orientalis* Mill. (Muğla Province); Kızılırmak Delta Galeric Forest, Hacıosman Longos, Terme-Gölardı Wild Life Protection Area (Samsun Province); Kocaçay Delta: Ovakurusu-Karacabey-Batakgöl (Bursa Province); Demirköy-İğneada: Sakapınargölü, Kocagöl and Erikligöl longos forests (Kırklareli Province). In all 4 are situated in Adapazarı; 3 each in Kırklareli and Samsun; 1 each in Kocaeli, Sinop, Muğla and Bursa. The most important are: Kırklareli-İğneada longos forest, the forest in Samsun Bafra on Kızılırmak delta, Acarlar around the Sakarya Karasu and Hacıosman swamp forest near Çarşamba-Çınarlık.

4.3.1 Floristic Diversity

Slezák et al. (2014) emphasized that the floristic spectrum of swamp forests seems to be more homogeneous at supra-regional scale, when a species growing across different areas independently of factors of the vegetation zonation are accompanied by plants reflecting phytogeographical and environmental gradients. İğneada swamp forests generally get flooded during different periods of the year (Fig. 4.1). The

Fig. 4.1 Different photographic views of Iğneada longos forests in Turkey

plant diversity of this area is represented by the tree species like *Fraxinus angustifolia* subsp. *oxycarpa*, *Alnus glutinosa, Carpinus orientalis, Quercus robur, Ulmus laevis, U. minor, Acer campestre, A. heldrechii* subsp. *trautvetteri*, and *Juglans regia*. But, the terrestrial part surrounding these forests abounds in the oak species like; *Quercus frainetto, Q. petraea,* and *Q. cerris*. A mixture of *Fraxinus ornus* species also joins the oaks at places (Kavgacı et al. 2007). The climbers usually found in the area are: *Clematis vitalba, Dioscorea communis*, *Hedera helix, Smilax excelsa*, and *Vitis sylvestris*. The dominating herbaceous taxa are: *Geum urbanum, Rumex conglomeratus, Lamium maculatum, Viola sieheana, Dactylis glomerata,* and *Mercurialis annua* (Yarcı 1994; Kavgacı et al. 2011).

The Acarlar Lake area is the second largest swamp forest in Turkey, with a very rich forest cover and undercover. It is completely under water during winter and spring seasons, but dries up in summer when we can see the forest soil. The most important tree species are *Fraxinus ornus, Alnus glutinosa,* and *Ulmus glabra*. *Fraxinus ornus* covers nearly 80% of the area it is accompanied by the climbers like *Calystegia sepium, Clematis vitalba, Hedera helix,* and *Smilax excelsa*. The most common herbaceous taxa are: *Hypericum androsaemum, H. perforatum, Geum urbanum, Leucojum aestivum, Euphorbia stricta, E. amygdaloides, Carex remota, Sparganium erectum, Galega officinalis, Plantago lanceolata, Daphne pontica, Galium verum, Lysimachia vulgaris, Iris pseudacorus, Epilobium hirsutum, Lythrum salicaria, Lycopus europaeus,* and *Butomus umbellatus* (Ketenoğlu et al. 2014).

Hacı Osman Swamp Forest is spread over an area of approximately 86 ha and is classified as a unique and endangered world-class alluvial ecosystem. The area has a rich floristic composition including different growth forms (Kutbay et al. 1998). The tree layer is mainly characterized by *Fraxinus angustifolia* ssp. *oxycarpa* forests. *Fraxinus excelsior*, *Pterocarya pterocarpa*, *Quercus hartwisiana*, and *Alnus glutinosa* ssp. *glutinosa* are the co-dominant tree species; cover values of the tree species range from 70% to 80% (Kutbay 2001; Hüseyinova et al. 2013). Most common climbers met within the area are: *Clematis vitalba*, *Vitis sylvestris, Smilax excelsa, Hedera helix*, and *Perioplaca graeca*. This forest includes an important relict species *Pterocarya pterocarpa*. Water table rises during spring and autumn, reaching a level of 50 cm (Anşin et al. 1997). This area includes later successional, shade-tolerant species like *Acer campestre* ssp. *campestre*, *Alnus glutinosa* ssp. *glutinosa*, *Frangula alnus*, and *Staphylea pinnata* (Kutbay 2001).

Liquidambar orientalis forests are the relict endemic swamp forests existing in Turkey since Tertiary period. The forest is spread over wide alluvial plans on the shallow swamps toward the northeastern fringes of Köyçeğiz lake (Ozturk et al. 2004). The most important tree species found here are: *Liquidambar orientalis*, *Alnus orientalis* var. *pubescens*, *Populus nigra* ssp. *caudina*, *Platanus orientalis*, and *Fraxinus angustifolia*. The common climbers are: *Dioscorea communis*, *Vitis sylvestris, Smilax aspera, S. excelsa, Hedera helix*, and *Perioplaca graeca*. The herbaceous taxa found here are: *Brachypodium sylvaticum, Carex muricata, C. otrubae, C. pendula, C. remota, Equisetum telmateia, Iris pseudacorus, Oenanthe pimpinelloides, Adianthum capillus-veneris,* and *Rumex tuberosus* (Akman et al. 1993; Vural et al. 1995).

4.3.2 Phytosociological Situation of the Turkish Swamp Forests

A detailed geographical differentiation analysis of zonal forest communities published by Kavgacı et al. has been updated in 2016. It shows that such a differentiation is valid for the azonal communities as well. These forests are grouped as Western (İğneada region), Middle (Sakarya and Bursa provinces), and Eastern (Samsun Province) Euxine swamp forests followed by the swamp forests in the Mediterranean region (SW of Turkey-Muğla Province) on the basis of floristic similarity (Vural et al. 1995; Kavgacı et al. 2016). Following the data published by different workers, the syntaxonomical scheme of swamp forests in the Euxine and Mediterranean regions of Turkey is as follows (Akman et al. 1993; Vural et al. 1995; Kavgacı et al. 2016):

In all, 18 plant communities have been described (Table 4.1). In the Euxine region, 10 plant communities have been recorded but only one plant community is found in the class *Querco-Fagetea* (Kavgacı et al. 2016). In Mediterranean region, 2 plant communities are from the class *Alno-Populetea* and 5 plant communities from the class *Molinio-Juncetea* (Table 4.1) (Akman et al. 1993; Vural et al. 1995).

4.3.3 Conservation Priorities

There are 122 **Important Plant Areas (IPA)** in Turkey. Out of these, 6 are the swamp forest areas and their environs (Ozhatay et al. 2003, 2013):

1. **(IPA 5):** Kırklareli: Demirköy-İğneada Longos (swamp) forests (includes three separate areas: Sakapınargölü, Kocagöl and Erikligöl Swamps)
2. **(IPA 13):** Sakarya: Kefken-Karasu Coastal area
3. **(IPA 17):** Bursa: Kocaçay Delta
4. **(IPA 28):** Samsun: Kızılırmak Delta
5. **(IPA 29):** Samsun: Hacıosman Longos
6. **(IPA 49):** Muğla: Dalaman Plateau

On the basis of information taken from these criteria data pooled up is given in Table 4.2.

4.3.4 Endemic and Rare Plant Taxa in Turkish Swamp Forests

In Table 4.3, we find the list of species according to the endemic taxa, rare species, and Bern species. In all, 44 plant taxa have been recorded here. Out of these, 12 are endemics (2 among the Bern species) and 32 are rare (4 among the Bern species) (Table 4.3). *Liquidambar orientalis* and *Pterocarya pterocarpa* are the relict endemics (Kutbay 2001; Ozturk et al. 2004, 2008).

Table 4.1 Syntaxonomical scheme of Turkish swamp forests

No	Swamp forest communities	Alliance	Order	Class
1	*Fraxino angustifoliae-Ulmetum laevis subass. allerietosum petiolatae*	Alno-Quercion	Populetalia alba	Salici-Populetea
2	*Fraxino angustifoliae-Ulmetum laevis subass. junglandetosum regiae*	Alno-Quercion	Populetalia alba	Salici-Populetea
3	*Leucojo aestivi-Fraxinetum angustifoliae subass. alnetosum glutinosae*	Alno-Quercion	Populetalia alba	Salici-Populetea
4	*Smilaco excelsae-Fraxinetum angustifoliae subass. prunellotosum vulgaris*	Alno-Quercion	Populetalia alba	Salici-Populetea
5	*Apocyno veneti-Fraxinetum angustifoliae*	Alno-Quercion	Populetalia alba	Salici-Populetea
6	*Euphorbio strictae-Fraxinetum angustifoliae*	Alno-Quercion	Populetalia alba	Salici-Populetea
7	*Aro hygrophyli-Fraxinetum angustifoliae*	Periploco-Fraxinion	Populetalia alba	Salici-Populetea
8	*Pterocaryo pterocarpae-Alnetum barbatae*	Periploco-Fraxinion	Populetalia alba	Salici-Populetea
9	*Platanthero chloranthae-Fraxinetum oxycarpae*	Periploco-Fraxinion	Populetalia alba	Salici-Populetea
10	*Sambuco ebuli-Alnetum barbatae*	Periploco-Fraxinion	Populetalia alba	Salici-Populetea
11	*Geranio robertiani-Carpinetum betuli*	Carpino-Fagion	Rhododendro-Fagetalia	Querco-Fagetea
12	*Periploco-Liquidambaretum orientalis*	Platanion orientalis	Planetalia orientalis	Alno-Populetea
13	*Alno pubescentis-Liquidambaretum orientalis*	Platanion orientalis	Planetalia orientalis	Alno-Populetea
14	*Irido xanthospuriae-Liquidambaretum orientalis subass. juncetosum sparganii-folii*			Molinio-Juncetea
15	*Irido xanthospuriae-Liquidambaretum orientalis subass. fraxinetosum angustifoliae*			Molinio-Juncetea
16	*Irido xanthospuriae-Liquidambaretum orientalis subass. lauretosum nobilis*			Molinio-Juncetea
17	*Irido xanthospuriae-Liquidambaretum orientalis subass. apietosum nodiflori*			Molinio-Juncetea
18	*Irido xanthospuriae-Liquidambaretum orientalis subass. juncetosum bulbosi*			Molinio-Juncetea

Table 4.2 Data covering information on the Turkish swamp forests provided by different criteria

Important Plant Area (IPA)	IPA 5	IPA 13	IPA 17	IPA 28	IPA 29	IPA 49
Coordinates	41°51′ N-27°57′ E	41°07′ N-30°30′ E	40°23′ N-28°29′ E	41°43′ N-35°22′ E	40°30′ N-37°14′ E	36°45′ N-28°47′ E
Size (ha)	5757	26.451	4068	17.043	238	25.060
Globally threatened (endemic taxa)	4	4	–	–	–	6
Threatened taxa European Concern (Bern species)	5	3	1	–	1	4
Rare species for Turkey	12	12	7	6	4	–
[a]**Endangered rare habitats**	16.2113, 16.2124, 16.22B11, 22.412, 22.415, 41.47, 41.7371, 41.76A1, 41.76A12, 41.76A4, 44.4322	16.2124, 16.227, 16.22B11, 16.31, 22.3232, 44.4322	16.2122, 16.224, 16.227, 16.28, 22.415, 44.432	15.A24, 16.22B3, 44.43	44.43	15.51, 15.8, 16.2122, 42.85B1
Protection status	National Park, Permanent Wildlife Reserve Area, Strict Reserve Area, Natural Heritage Area, Important Bird Area, Important Plant Area	Wildlife Protection Area, Strict Reserve Area, Important Plant Area	Not under Protection, Strict Reserve Area, Important Bird Area, Important Plant Area	Wildlife Protection Area, Ramsar Area, Important Bird Area, Important Plant Area	Nature Protection Area, Strict Reserve Area, Important Plant Area	Special Environmental Protection Area, Plant Diversity Centre, Important Plant Area

[a]**According to the Working Group Declaration No. 4 (1996) of the European Wildlife and Living Habitats Conservation Treaty (Bern Treaty), the endangered habitats in Turkey are listed** as; **15.A24**: Euxin Saline Swamps; **15.51**: Tall *Juncus* saline swamps in the Mediterranean; **15.8**: Saline steppes of the Mediterranean; **16.2113**: Embrionic Sand Dunes of the Black Sea;

(continued)

Table 4.2 (continued)

16.2122: White dunes of the Mediterranean; **16.2124**: White dunes of the Black Sea; **16.22B3**: Stable dunes of the South Black Sea; **16.22B11**: Stable dunes of the Southwest Black Sea; **16.224**: Stable dunes of the east Mediterranean; **16.227**: Annual rare Gramineae sandy communities; **16.28**: Hard leaved sandy shrub communities; **16.31**: Slack sandy ditches ponds; **22.3232**: Small *Cyperus* communities; **22.412**: *Hydrocharis morsus-ranae* communities; **22.415**: *Salvinia* groups; **41.47**: Euxine floodplain forests; **41.7371**: Thrace White *Quercus-Carpinus orientalis* forest communities; **41.76A1**: Euxin-Thrace *Quercus frainetto-Quercus cerris* forests; **41.76A12**: Lower Euxine areas of *Quercus frainetto-Quercus cerris* forests; **41.76A4**: Istranca mountains *Quercus petraea* ssp. *iberica* forests; **42.85B1**: South Anatolia Red Pine Forests; **44.43**: Southeast Europe *Fraxinus-Quercus-Alnus* Forests; **44.432**: Balkans *Fraxinus-Quercus-Alnus* Forests; and **44.4322**: West Black Sea Swamp Forests

Table 4.3 Important plant taxa distributed in and around the swamp forests in Turkey

		Important Plant Areas in Turkey					
No	Plant taxa - Family	IPA5	IPA13	IPA17	IPA28	IPA29	IPA49
1	[a]*Alnus orientalis* Decne var. *pubescens* Dippel (**Betulaceae**)						**x**
2	[a]*Anchusa leptophylla* Roem. & Schult. ssp. *incana* (Ledep.) D.F. Chamb (**Boraginaceae**)	**x**					
3	[b], [c]*Aurinia uectritziana* (Bornm.) Culen & T.R. Dudley (**Brassicaceae**)	**x**					
4	[b]*Centaurea arenaria* M. Bieb. ex Willd. (**Asteraceae**)	**x**					
5	[a]*Centaurea kilaea* Boiss. (**Asteraceae**)	**x**	**x**				
6	[b]*Cladanthus mixtus* (L.) Oberpr. & Vogt (**Asteraceae**)						**x**
7	[b]*Convolvulus lanatus* Vahl (**Convolvulaceae**)						**x**
8	[b]*Corispermum filifolium* C.A.Mey (**Amaranthaceae**)				**x**		
9	[b], [c]*Cyclamen coum* Mill. ssp. coum (**Primulaceae**)	**x**	**x**			**x**	
10	[b]*Euphorbia lucida* Waldst. & Kit. (**Euphorbiaceae**)				**x**	**x**	
11	[b]*Filago minima* (Sm.) Pers. (**Asteraceae**)	**x**					
12	[a]*Galanthus plicatus* M.Bieb. ssp. *byzantinus* (Baker) D.A. Webb (**Amaryllidaceae**)		**x**				
13	[b]*Hottonia palustris* L. (**Primulaceae**)		**x**				
14	[b]*Hydrocotyle vulgaris* L. (**Araliaceae**)		**x**				
15	[a]*Iris xanthospuria* B. Mathew & T.Baytop (**Iridaceae**)						**x**
16	[b]*Jurinea kilaea* Azn. (**Asteraceae**)	**x**	**x**		**x**		
17	[b]*Lathyrus palustris* L. ssp. *palustris* (**Fabaceae**)			**x**			
18	[b]*Leucojum aestivum* L. ssp. *aestivum* (**Amaryllidaceae**)		**x**	**x**		**x**	

(continued)

Table 4.3 (continued)

No	Plant taxa - Family	Important Plant Areas in Turkey					
		IPA5	IPA13	IPA17	IPA28	IPA29	IPA49
19	[a]*Liquidambar orientalis* Mill. (**Altingiaceae**)						x
20	[b]*Lotus suaveolens* Pers. (**Fabaceae**)			x			
21	[b]*Matthiola fruticulosa* (L.) Maire ssp. *fruticulosa* (**Brassicaceae**)		x				
22	[a]*Minuartia mesogitana* (Boiss.) Hand.-Mazz. ssp. *mesogitana* (**Caryophyllaceae**)						x
23	[b]*Nymphoides peltata* (S.G. Gmel.) Kuntze (**Menyanthaceae**)		x				
24	[b]*Ononis serrata* Forssk. (**Fabaceae**)						x
25	[b]*Ophrys argolica* H.Fleischm. (**Orchidaceae**)						x
26	[b]*Pancratium maritimum* L. (**Amaryllidaceae**)		x				
27	[b]*Peucedanum obtusifolium* Sibth. & Sm. (**Apiaceae**)	x	x				
28	[b]*Polygonum mesembricum* Chrtek (**Polygonaceae**)			x			
29	[b]*Pterocarya pterocarpa* (Michx.) Kunth ex I.Iljinsk. (**Juglandaceae**)					x	
30	[b]*Radiola linoides* Roth (**Linaceae**)			x			
31	[a]*Rumex tmoleus* Boiss. (**Polygonaceae**)						x
32	[b,c]*Salvinia natans* (L.) All. (**Salviniaceae**)	x		x			
33	[b]*Secale sylvestre* Host (**Poaceae**)	x					
34	[a]*Silene lycaonica* Chowdhuri (**Caryophyllaceae**)						x
35	[b]*Silene thymifolia* Sibth. & Sm. (**Caryophyllaceae**)	x	x				
36	[b]*Symphytum tuberosum* L. ssp. *nodosum* (Schur) Soo (**Boraginaceae**)	x					
37	[b]*Thelypteris palustris* (A. Gray) Schott (**Thelypteridaceae**)		x		x		
38	[b]*Tournefortia sibirica* L. var. *sibirica* (**Boraginaceae**)				x		
39	[b,c]*Trapa natans* L. (**Lythraceae**)	x					
40	[b]*Trifolium bocconei* Savi (**Fabaceae**)	x		x			
41	[a,c]*Trifolium pachycalyx* Zohary (**Fabaceae**)		x				
42	[a]*Trifolium elongatum* Willd. (**Fabaceae**)	x					
43	[b]*Trifolium suffocatum* L. (**Fabaceae**)		x				
44	[a,c]*Verbascum degenii* Halacsy (**Scrophulariaceae**)	x	x				

Ozhatay et al. (2003)
[a]Endemic
[b]Rare
[c]Bern

4.3.5 Edaphic Relations of Some Plant Communities in the Turkish Swamp Forests

Hydromorphic alluvial soils dominate in these habitats. pH values range from slightly acidic to slightly alkaline, and soil fertility is quite high (Ozturk et al. 2004). A comparison of the general features of the soils of Turkish swamp forests is presented in Table 4.4.

Yalçın et al.'s (2004) results supported the results of Hseu and Chen (2000) who found that P, Mg, Ca, and clay content of soil affect the species composition of swamp forest. However, Yalçın et al.'s (2004) results failed to support the results of Økland and Eilersten (1993) who found that pH is a single environmental parameter that explains the variation along a poor-rich coenocline. Goldberg (1982) stated that calcium, in particular, plays an important role in "maintaining the integrity of the absorption and selectivity mechanisms involved in uptake of cations general" and calcium is a good indicator of forest soil fertility. Thus, low availability of calcium may further decrease availability of other nutrients (Yalçın et al. 2004). Goldberg (1982) also found P content of soil positively correlated with clay content.

4.3.6 Ellenberg's Indicator Values for the Studied Swamp Forests

Košir et al. (2013) stated that the Ellenberg's indicator values for soil nutrients play a significant role in the distribution of swamp forest species. In addition to this, nutrient-related parameters of soils according to Ellenberg's scale and hydrological regime as crucial drivers of compositional changes have already been determined at community level (Slezák et al. 2014). An evaluation of the Ellenberg indicator values (N) for some swamp forests has revealed that the species in Çakırlar and Galeriç forests prefer neutral and/or slightly acidic soils, while the species in Hacı Osman Forest develop on moderately alkaline soils with moderate levels of soil nitrogen (Sürmen et al. 2014). But a few species formed another group and this

Table 4.4 A comparison of the soil characteristics of some swamp forests from Turkey

	İğneada Floodplain Forests		Köyceğiz - Muğla	Bursa	Central Black Sea Region
	(Tecimen and Kavgacı 2010)		(Vural et al. 1995)	(Ozen 2010)	(Kutbay et al. 1998)
	0–5 cm	5–15 cm	0–30 cm	0–30 cm	0–30 cm
pH	5.2	5	6.89	7.12	6.92
CaCO3 (%)	0.31	0.26	2.8	0.85	3.65
Organic matter (%)	5.619	3.793	2.22	4.48	10.18
N (%)	0.297	0.213	0.225	0.224	0.49

group includes some herb species (i.e., *Carex* sp.). This group occurred in nitrogen-rich soils (Sürmen et al. 2014). This indicator value for soil N concentration is regarded as a good indicator in evaluating productivity and nutrient availability. The scale values indicate the degree of mobilization of nitrogen accumulated in the soil (Diekmann 2003; Vitousek et al. 2010).

The pH values of some swamp forests in Turkey range from 6 to 7, whereas soil nitrogen values range from 7 to 8 (Sürmen et al. 2014). The species found here are indicators of weakly acid to weakly basic and fertile soils with high bioactivity. They are alkaline with almost neutral pH (Sürmen et al. 2014). Ellenberg's indicator values for soil N concentration and pH in the present study are similar to those reported for other swamp forests (Slezák et al. 2012; Sürmen et al. 2014).

Based on the results pooled up, the swamp forest species have a wider soil pH amplitude, especially *Fraxinus angustifolia* ssp. *oxycarpa* has been reported to be able to tolerate higher soil pH, but can also grow on open soils with lower pH value (Pitman et al. 2014; Çiçek et al. 2010), pH has a major impact on the availability of soil nutrients. For example, the phosphorus availability declines with both a decrease and an increase of the soil pH (Sürmen et al. 2014). The differences lead to habitat heterogeneity in the soil in such forests (Rodríguez-Loinaz et al. 2008). For a sustainable management of these special and sensitive ecosystems, further studies will help in better characterization of these forests on local and global scales according to Ellenberg's indicator values (Kutbay 2001; Kutbay and Sürmen 2013; Sürmen et al. 2014).

4.4 Conclusions

The swamp forest ecosystems are characterized by favorable temperature and moisture regimes with the high supply of soil nutrients. These factors show favorable effects on the development of plant and animal populations, high biodiversity, and fast geochemical cycle (Vašíček 1985; Klimo et al. 2011). These forests contribute to the regulation of groundwater; provide habitats and ecological corridors for wildlife; and most importantly, supply drinking water for all living beings, especially human (Lima and Zakia 2000; Sampaio et al. 2012).

The saturation or submergence of the soil caused by an increase in the water table determines the floristic composition and structure of the swamp forests (Marques et al. 2003; Kurtz et al. 2013). The species richness and diversity of these forests in general is lower than that of adjacent or nearby forests inhabiting dry soils, swamp forests are therefore protected by the direct effect of the water table level because, swamp forests generally exhibit oligarchy or mono-dominance (Ivanauskas et al. 1997; Araujo et al. 1998; Scarano 2006).

Swamp forests are also the "climax" (sensu dynamic equilibrium) vegetation community of floodplain wetlands. A great deal of research has focused in the past 10 years or so on the nutrient processing and retention capacity of wetlands, both as riparian "buffers" and as direct recipients of contaminated waters from agriculture or industry (Brown et al. 1997; Mitsch and Gosselink 1993). The case for swamp forests in the lower reaches of eutrophic or polluted rivers subsequently used for human consumption is only just beginning to be realized (Brown et al. 1997). Ellenberg's indicator values are good predictors of ecological factors and they are essential for forest management, particularly for the choice of tree species adapted to natural site conditions. Swamp forests in Turkey usually had high Ellenberg's indicator values for soil N concentraion and soil pH. Other studies revealed that swamp forests occur in fertile soils (Otýpková 2009), and higher N values were associated with more mature and complex meso-hygrophilous communities (Sicuriello et al. 2014).

Conversion of swamp forests into agricultural and other land uses such as urban expansion and tree extraction, highway activities, as well as dam constructions are leading to a reduction of these forests, loss of their ecological functioning, and also interrupts in the ecosystem services such as flood abatement, biodiversity support, water quality improvement, and carbon management (Gore and Shields 1995; Zedler and Kercher 2005; Teixeira et al. 2008, 2011; Suchenwirth et al. 2012; Hanberry et al. 2015). In addition to these more or less natural processes including sediments at floods, heterogeneity of the soil environment of lowland alluvia is considerably affected by changes in the groundwater level, anthropogenic effects, particularly river channelization and various methods of management, particularly the regeneration of swamp forests and changes in their species composition (Klimo et al. 2011). In view of this, the restoration of swamp forests will also increase their resilience to extreme events of climate change (Groffman et al. 2014; Hanberry et al. 2015).

Although little is known about the effects of prehistoric land use on swamp forest development, recent evidence has shown that anthropogenic disturbances, such as selective cutting; grazing by domestic animals, burning, and deliberate seasonal flooding of wetlands, have played an important role in determining the structure of many swamp forests during the last millennium (Segerstrom et al. 1994, 1996; Hörnberg et al. 1998).

Swamp forests are vulnerable to alterations in hydrological regimes caused by river regulation or dam constructions, and at the same time vulnerable to plant invasions due to long-distance species dispersal, and intensive human pressures (Nilsson and Berggren 2000; Richardson et al. 2007; Erwin 2009; Kalusová et al. 2014; Douda et al. 2016).

The global applied land use type of wetlands is their conversion into farmlands which receive economical and political support on country basis (Aldous et al. 2005; Tecimen and Kavgacı 2010). The wetland biogeochemistry is mainly regulated by waterlogging and these areas function as CO_2 sinks in winter, but as a CO_2 emission source in summer. Denitrification as one of the main components of wetlands is receiving increased attention since its potential of alleviating environmental impacts of NO_3 (Ambus and Zechmeister-Boltenstern 2007; Tecimen and Kavgacı 2010). Methane emission from wetlands also causes global warming, which is induced particularly by the variables such as soil type, temperature, soil redox potential, water management, fertilization with organic carbon or nitrogen (Conrad 2002).

These ecologically sensitive and biologically rich swamp forests are important ecosystems which can easily be affected by the anthropogenic impacts (Tockner and Stanford 2002; Kavgacı et al. 2016). In fact like other countries these sensitive forests in Turkey are affected adversely by anthropogenic activities (Müller 1998; Efe and Alptekin 1989). Therefore, understanding ecological and biological richness of these systems is important not only for their sustainable management but also to restore and rehabilitate lost or degraded fields (Kavgacı et al. 2016).

To achieve greater sustainability of forest ecosystems to climate change, the establishment of mixed forest composition phytocoenoses is recommended. Raev et al. (1995) proposed that future research must encompass several directions. These should include: (1) studying changes in natural complexes; (2) studying the processes of water balance in the forest species; (3) monitoring the status forest, and (4) creating projects for afforestation with species resistant to climate change.

Forest protection and adaptation to climate change are specific activities related to the implementation of forestry activities in anticipation of adverse climatic effects. In these circumstances, preventive measures must be instituted to reduce the environmental risk to all forest areas threatened in this manner (Stoyanova and Stoyanov 2012).

Other swamp forests can be expected to show similar ecological characteristics, to which may be added the following functional values (Harper et al. 1997):

(**a**) The potential flood-protection role of alluvial forests (Brown 1997), which itself promotes the habitat and vegetation diversity of the floodplain. (**b**) The self-purification role which forest channels offer through the combination of additional channel bed area, discharge retention by debris dams and backwater pools, with microbial and invertebrate processing of particulate organic material. (**c**) The drinking water supply opportunities provided by alluvial gravels beneath forests relatively uncontaminated by agriculture. (**d**) The high ecological and economic value provided by floodplain meadows, which in many locations are part of the mosaic of habitats created out of partial forest clearance by a sustainable form of floodplain management practiced by humans for many centuries (Rychnovska 1993). (**e**) The high importance of riparian forests as nutrient "filters" between agriculture and river water (Olah and Olah 1996).

In addition, Stoyanova and Stoyanov (2012) have offered some suggestions: (**a**) clarifying the dynamics of climatic indices and determining risk areas for forests and wood biodiversity, (**b**) determination of unfavorable periods for tree species, revealed by depression of rainfall or high temperatures, (**c**) zoning within the catchment areas by degree of endangerment and the risk of climate change, (**d**) analyzing the health, performance, and the extent of problems suffered by forests affected by drought. This should then be compared with relatively preserved forests so that differences between them can be accurately defined, (**e**) compiling estimates for the resumption and development of woods, (**f**) optimizing the composition of forest phytocoenoses to reduce the stress level of future climate change.

Coupled with the sustainable management of floodplain agriculture, the restoration of floodplain forests could thus be one of the most effective strategies for the protection and enhancement of floodplain biodiversity in the managed lowland landscapes of Europe (Harper et al. 1997).

For these special ecosystems, natural resource management and conservation do not seem to be an easy task. As such, the first step for a better understanding of the multiple uses of these swamp forests and the socioeconomic conditions affecting these forests is to put forth the relevant protection measures and practices. This should be followed by management actions which are in balance and negotiable with the users of these forests. The use of forest resources can make a significant contribution toward increasing the income of local people and it can improve the protection measures (Sampaio et al. 2012).

Acknowledgments Our special thanks are due to Dr. Zeki Severoğlu from Marmara University (Turkey) for providing the photographs of the swamp forests.

References

Akman Y, Quézel P, Ketenoglu O, Kurt L (1993) Analyse syntaxinomique des forêts de *Liquidambar orientalis* en Turquie. Ecologia Mediterranea 19(1–2):49–57

Aldous A, McCormick P, Ferguson C et al (2005) Hydrologic regime controls soil phosphorus fluxes in restoration and undisturbed wetlands. Restor Ecol 13:341–347

Altay V (2015) An overview of the swamp forests of Turkey. In: Abstracts of the international conference applied ecology: problems, innovations, Tbilisi-Batumi, Georgia, 7–10 May, 2015

Ambus P, Zechmeister-Boltenstern Z (2007) Denitrification and N-cycling in forest ecosystems. In: Bothe H et al (eds) Biology of the nitrogen cycle. Elsevier, Amsterdam, p 452

Anşin R, Kutbay HG, Ok T (1997) A general view to the flora of Haci Osman Forest near Samsun. Karaca Arboretum 4:35–38

Araujo DSD, Scarano FR, Sa CFC et al (1998) Comunidades vegetais do Parque Nacional da Restinga de Jurubatiba. In: Esteves FA (ed) Ecologia das lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do município de Macaé (RJ). Universidade Federal do Rio de Janeiro, Rio de Janeiro, pp 39–62

Aydoğdu M (1988) A syntaxonomical analysis of the ash forest in the vicinities of Adapazarı. Commun Fac Sci Univ Ank Series C 6:85–90

Baričević D, Pernar N, Vukelić J et al (2009) Floristic composition as an indicator of destabilisation of lowland forest ecosystems in Posavina. Period Biol 111(4):443–451

Brown AG (1997) Biogeomorphology and stability in multiple-channel river systems. Global Ecol Biogeogr Lett 6:179–185

Brown AG, Harper D, Peterken GF (1997) European floodplain forests: structure, functioning and management. Glob Ecol Biogeogr Lett 6(3/4):169–178

Calhoun AJK (1999) Forested wetlands. In: Hunter ML Jr (ed) Maintaining biodiversity in Forest ecosystems. Cambridge University Press, Cambridge, pp 300–331

Çiçek E (2004) Subasar ormanların özellikleri ve Türkiye'nin subasar ormanları. İÜ Orman Fakültesi Dergisi Seri B 54(2):107–114

Çiçek E, Yilmaz F, Yilmaz M (2010) Effect of N and NPK fertilizers on early field performance of narrow-leaved ash, *Fraxinus angustifolia*. J Environ Biol 31:109–114

Conrad R (2002) Control of microbial methane production in wetland rice fields. Nutr Cycl Agroecosyst 64:59–69

Diekmann M (2003) Species indicator values as an important tool in applied plant ecology-A review. Basic Appl Ecol 4:493–506
Douda J, Boublik K, Slezák M et al (2016) Vegetation classification and biogeography of European floodplain forests and alder carrs. Appl Veg Sci 19:147–163
Efe A, Alptekin CU (1989) Önemli bir subasar ormanı: Hacıosman. İÜ Orman Fakültesi Dergisi Seri A 39(2):164–171
Erwin KL (2009) Wetlands and global climate change: the role of wetland restoration in a changing World. Wetl Ecol Manag 17:71–84
FAO (2006) Global Forest Resources Assessment 2005, FAO Forestry Paper 147, Food and Agriculture Organization of the United Nations, Rome, Italy
Fickert T, Gruninger F (2010) Floristic zonation, vegetation structure, and plant diversity patterns within a Caribbean mangrove and swamp forest on the Bay Island of Utila (Honduras). Ecotropica 16:73–92
Goldberg DE (1982) The distribution of evergreen and deciduous trees relative to soil type: an example from the Sierra Madre, Mexico, and a general model. Ecology 63:942–951
Gore JA, Shields FD (1995) Can large rivers be restored? Bioscience 45(3):142–152
Groffman PM, Kareiva P, Carter S et al (2014) Ecosystems, biodiversity, and ecosystem services. In: Melillo JM et al (eds) Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program, Washington, DC, pp 195–219
Güner A, Aslan S, Ekim T et al (2012) Türkiye Bitkileri Listesi (Damarlı Bitkiler), Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını, Istanbul-Türkiye
Hanberry BB, Kabrick JM, Hea HS (2015) Potential tree and soil carbon storage in a major historical floodplain forest with disrupted ecological function. Perspect Plant Ecol Evol Syst 17:17–23
Harper D, Mekotova J, Hulme S et al (1997) Habitat heterogeneity and aquatic ınvertebrate diversity in floodplain forests. Glob Ecol Biogeogr Lett 6(3/4):275–285
Hauenstein E, Gonzales M, Peña-Cortés F, Muñoz-Pedreos A (2005) In: Smith-Ramírez C et al (eds) Historia, biodiversidad y ecología de los bosques costeros de Chile. Editorial Universitaria, Santiago, pp 227–236
Hörnberg G, Zackrisson O, Segerstrom U et al (1998) Boreal Swamp Forests –biodiversity "hotspots" in an impoverished forest landscape. Bioscience 48(10):795–802
Hrivnák R, Košťál J, Slezák M et al (2013) Black alder dominated forest vegetation in the western part of central Slovakia – species composition and ecology. Hacquetia 12:23–37
Hseu Z-Y, Chen Z-S (2000) Monitoring the changes of redox potential, pH and electrical conductivity of the mangrove soils in Northern Taiwan. Proc Natl Sci Counc ROC(B) 24:143–150
Hüseyinova R, Kilinc M, Kutbay HG et al (2013) The comparison of Grime's strategies of plant taxa in Hacı Osman Forest and Bafra Fish Lakes in the central Black Sea region of Turkey. Turk J Bot 37(4):725–734
Imbert D, Bonhême I, Saur E, Bouchon C (2000) Floristics and structure of the *Pterocarpus officinalis* swamp forest in Guadeloupe, Lesser Antilles. J Trop Ecol 16:55–68
IUCN (2006) Red list of threatened species. http://iucn.org/places/medoffice/documentos/press-release-red-list.pdf. Accessed 01 Nov 2015
Ivanauskas NM, Rodrigues RR, Nave AG (1997) Aspectos ecologicos de um trecho de floresta de brejo em Itatinga, SP: floristica, fitossociologia e seletividade de especies. Rev Bras Bot 20:139–153
Kalusová V, Chytrý M, Peet RK, Wentworth TR (2014) Alien species pool influences the level of habitat invasion in intercontinental exchange of alien plants. Glob Ecol Biogeogr 23(12):1366–1375
Kavgacı A, Özalp G, Özhatay N (2007) Flora of İğneada floodplain forests (longozes) and their surroundings. J Fac For Istanbul Univ (JFFIU) 57(2):61–90
Kavgacı A, Čarni A, Tecimen HB, Ozalp G (2011) Diversity of floodplain forests in the İgneada region (NW Thrace-Turkey). Hacquetia 10:73–93
Kavgacı A, Yalçın E, Korkmaz H (2016) Numerical classification and ordination of the floodplain forests in the Euxine region of Turkey. Turk J Bot 40:164–175

Ketenoğlu O, Vural M, Kurt L, Körüklü T (2014) Vejetasyon. In: Güner A, Ekim T (eds) Resimli Türkiye Florası, vol 1. Ali Nihat Gökyiğit Vakfı, Flora Araştırmaları Derneği and Türkiye İş Bankası Kültür Yayınları, İstanbul

Klimo E (ed) (2008) Floodplain forests of the temperate zone of Europe. Publishing House for Forestry, Lesnická Práce

Klimo E, Hybler V, Lorencova H, Štykar J (2011) The heterogeneity of soil properties and biodiversity in floodplain forests of Southern Moravia in natural conditions and under antropogenic impacts. Ekologia (Bratislava) 30(3):296–314

Kopeć D, Ratajczyk N, Wolańska-Kamińska A et al (2014) Floodplain forest vegetation response to hydroengineering and climatic pressure-A five decade comparative analysis in the Bzura River valley (Central Poland). For Ecol Manag 314:120–130

Koponen P, Nygren P, Sabatier D et al (2004) Tree species diversity and forest structure in relation to microtopography in a tropical freshwater swamp forest in French Guiana. Plant Ecol 173:17–32

Korkmaz H, Mumcu U, Alkan S, Kutbay HG (2012) Gölardı (Terme/Samsun) yaban hayatı koruma alanının psammofil, higrofil ve orman vejetasyonu üzerine sintaksonomik bir araştırma. Ekoloji 21:64–79

Košir P, Čarni A, Marinšek A, Šilc U (2013) Floodplain forest communities along the Mura River (NE Slovenia). Acta Bot Croat 72:71–95

Kurtz BC, Gomes JC, Scarano FR (2013) Structure and phytogeographic relationships of swamp forests of Southeast Brazil. Acta Bot Bras 27(4):647–660

Kutbay HG (2001) Nutrient content in leaves in different strata of a swamp forest from northern Turkey. Pol J Ecol 49(3):221–230

Kutbay HG, Sürmen B (2013) Determination of Ellenberg's indicator values along an elevational gradient in Central Black Sea region of Turkey. Sains Malaysiana 42:1387–1393

Kutbay HG, Anşin R, Ok T (1997) Samsun-Hacıosman Tabiatı Koruma ormanının florası. Orman Mühendisliği Dergisi 34(3):22–26

Kutbay HG, Kılınç M, Kandemir A (1998) Phytosociological and ecological Structure of *Fraxinus angustifolia* subsp. *oxycarpa* forest in the Central Black Sea Region. Turk J Bot 22:157–162

Lima WP, Zakia MJP (2000) Hidrologia de matas ciliares. In: Rodrigues RR, Leitão-Filho HF (eds) Matas ciliares: conservação e recuperação. Editora da Universidade de São Paulo: Fapesp, São Paulo, pp 33–44

Marques MCM, Silva SM, Salino A (2003) Floristica e estrutura do componente arbustivo-arboreo de uma floresta higrofila da bacia do rio Jacare-Pepira, SP, Brasil. Acta Bot Bras 17:495–506

MEA (Millennium Ecosystem Assessment) (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC

Migeot J, Imbert D (2011) Structural and floristic patterns in tropical swamp forests: a case study from the *Pterocarpus officinalis* (Jacq.) forest in Guadeloupe, French West Indies. Aquat Bot 94:1–8

Mitsch WJ, Gosselink JG (1993) Wetlands. Van Nostrand Rheinhold, New York

Moffatt SF, McLachlan SM (2004) Understory indicators of disturbance for riparian forests along and urban-rural gradient in Manitoba. Ecol Indic 4:1–16

Müller N (1998) Effects of natural and human disturbances on floodplain vegetation. In: Müller N et al (eds) In: Proceedings of international symposium for river restoration, Tokyo, p 209

Nilsson C, Berggren K (2000) Alterations of riparian ecosystems caused by river regulation. Bioscience 50:783–792

Økland RH, Eilertsen O (1993) Vegetation-environment relationships of boreal coniferous forests in the Solhomfjell area, Gjerstad, S. Norway, vol 27, Botanical Garden and Museum, University of Oslo

Olah J, Olah M (1996) Improving landscape nitrogen metabolism in the Hungarian lowlands. Ambio 25:331–335

Otýpková Z (2009) The influence of sample plot size on evaluations with Ellenberg indicator values. Biologia (Bratislava) 64:1129–1128

Ozen F (2010) Yenikoy (Bursa) higrofil, orman ve maki vejetasyonunun sinekolojik ve sintaksonomik analizi. Ekoloji 19:50–64

Ozhatay N, Byfield A, Atay S (2003) Türkiye'nin Önemli Bitki Alanları. WWF Türkiye

Ozhatay N, Akalın E, Güler N et al (2013) Floristic richness and conservation priority sites in the northwest of European Turkey: Mt Yıldız-Kırklareli. Phytologia Balcanica 19(1):77–88

Ozturk M, Parks R, Coşkun F et al (2004) Vanishing tertiary genetic heritage in the East Mediterranean, *Liquidambar orientalis* Mill. Environ Forensic 10(4):6–8

Ozturk M, Celik A, Güvensen A, Hamzaoglu E (2008) Ecology of tertiary relict endemic *Liquidambar orientalis* Mill. Forests. For Ecol Manag 256:510–518

Paal J, Rannik R, Jeletsky EM, Prieditis N (2007) Floodplain forests in Estonia: typological diversity and growth conditions. Folia Geobot 42:383–400

Peña-Cortés F, Pincheira-Ulbrich J, Bertrán C et al (2011) A study of the geographic distribution of swamp forest in the coastal zone of the Araucanía Region, Chile. Appl Geogr 31:545–555

Pitman R, Benham S, Poole J (2014) A chronosequence study of soil nutrient status under oak and Corsican pine with Ellenberg assessed ground vegetation changes. Forestry 87:287–300

Poldini L, Vidalı M, Ganis P (2011) Riparian *Salix alba*: scrubs of the Po lowland (N-Italy) from an European perspective. Plant Biosyst 145(Suppl 1):132–147

Quezel P, Barbero M, Akman Y (1980) Contribution a l'etude de la Vegetation Forestiere d'Anatolie Septentrionale. Phytocoenologia 8:365–519

Raev I, Grozev O, Alexandrov V (1995) The issue of future climate change and erosion afforestation in Bulgaria (in Bulgarian). In: National Conference with International Participation 90 years Combating Soil Erosion in Bulgaria, Sofia, pp 84–93, 16–20 October 1995

Ramsar Convention Secretariat (2006) The Ramsar convention manual: a guide to the convention on wetlands (Ramsar, Iran, 1971), 4th edn. Ramsar Convention Secretariat, Gland

Richardson DM, Holmes PM, Esler KJ et al (2007) Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Divers Distrib 13:126–139

Rivera-Ocasio E, Aide TM, Rios-Lopez N (2007) The effects of salinity on the dynamics of a *Pterocarpus officinalis* forest stand in Puerto Rico. J Trop Ecol 23:559–568

Rodriguez-Loinaz G, Onaindia M, Amezega I et al (2008) Relationship between vegetation diversity and soil functional diversity in native mixed-oak forests. Soil Biol Biochem 40:49–60

Rychnovska M (ed) (1993) Structure and functioning of seminatural meadows. Elsevier, Amsterdam

Sampaio MB, Ticktin T, Seixas CS, dos Santos FAM (2012) Effects of socioeconomic conditions on multiple uses of swamp forests in Central Brazil. Hum Ecol 40:821–831

Scarano FR (2006) Plant community structure and function in a swamp forest within the Atlantic rain forest complex: a synthesis. Rodriguesia 57:491–502

Schmitt CB, Burgess ND, Coad L et al (2009) Global analysis of the protection status of the world's forests. Biol Conserv 142:2122–2130

Schnitzler A, Hale BW, Alsum E (2005) Biodiversity of floodplain forests in Europe and eastern North America: a comparative study of the Rhine and Mississipi Valleys. Biodivers Conserv 14:97–117

Schuck A, Parviainen J, Bücking W (1994) A review of approaches to forestry research on structure, succession and biodiversity of undisturbed and semi-natural forests and woodland in Europe. European Forest Institute Working Paper 3, Joensuu, p 64

Segerstrom U, Bradshaw R, Hornberg G, Bohlin E (1994) Disturbance history of a swamp forest refuge in northern Sweden. Biol Conserv 68:189–196

Segerstrom U, Hornberg G, Bradshaw R (1996) The 9000-year history of vegetation development and disturbance patterns of a swamp forest in Dalarna, Northern Sweden. The Holocene 6:37–48

Sicuriello F, De Nicola C, Dowgiallo G, Testi A (2014) Assessing the habitat conservation status by soil parameters and plant ecoindicators. For Biogeosci For 7:170–177

Slezak M, Hrivnak R, Petrašova A, Ditě D (2012) Variability of alder-dominated forest vegetation along a latitudinal gradient in Slovakia. Acta Soc Bot Pol 82:25–35

Slezák M, Hrivnák R, Petrášová A (2014) Numerical classification of alder carr and riparian alder forests in Slovakia. Phytocoenologia 44:283–308
Stoyanova N, Stoyanov D (2012) Forest conservation and improvement their adaptation to climate change in Bulgaria. Ekológia (Bratislava) 31(4):370–378
Suchenwirth L, Förster M, Cierjacks A et al (2012) Knowledge-based classification of remote sensing data for the estimation of below- and above-ground organic carbon stocks in riparian forests. Wetl Ecol Manag 20:151–163
Sürmen B, Kutbay HG, Kilic DD et al (2014) Ellenberg's indicator values for soil nitrogen concentration and pH in selected swamp forests in the Central Black Sea region of Turkey. Turk J Bot 38(5):883–895
Tecimen HB, Kavgaci A (2010) Comparison of soil and forest floor properties of floodplain and surrounding forests in Igneada, Turkey. J Environ Biol 31(1/2):129–134
Teixeira AP, Assis MA, Siqueira FR, Casagrande JC (2008) Tree species composition and environmental relationships in a Neotropical swamp forest in Southeastern Brazil. Wetl Ecol Manag 16:451–461
Teixeira AP, Assisb MA, Luizec BG (2011) Vegetation and environmental heterogeneity relationships in a Neotropical swamp forest in southeastern Brazil (Itirapina, SP). Aquat Bot 94:17–23
Tockner K, Standford JA (2002) Riverine flood plains: present state and future trends. Environ Conserv 29:308–330
Vašiček F (1985) Natural condition of floodplain forests. In: Penka M et al (eds) Floodplain forest ecosystem, vol 1. Academia, Praha, pp 13–29
Vitousek PM, Porder S, Houlton BZ, Chadwick OA (2010) Terrestrial phosphorus limitation: mechanisms, implications, and nitrogen-phosphorus interactions. Ecol Appl 20:5–15
Vural M, Duman H, Güner A et al (1995) The vegetation of Köyceğiz-Dalyan (Muğla) specially protected area. Turk J Bot 19(4):431–476
Yalçın E, Bilgin A, Kutbay HG, Kilinc M (2004) Relationships between community structure and soil properties of a swamp forest from Northern Turkey. Pol J Ecol 52(2):233–238
Yarcı C (1994) Longos (Subasar) Ormanlarının (İğneada-Kırklareli) Fitososyolojik Yapısı. In: 12. Ulusal Biyoloji Kongresi, Botanik Seksiyonu 1:125–132
Zedler JB, Kercher S (2005) Wetland resources: status, trends, ecosystem services, and restorability. Annu Rev Environ Resour 30:39–74

Chapter 5
Forest Fires and Sustainability in the Mediterranean Ecosystems

Hüseyin Barış Tecimen, Ali Kavgacı, and Orhan Sevgi

5.1 Introduction

Mediterranean ecosystems are mainly distributed in the northern Africa, southern Europe, Southwest of North America, Western South America, southern Australia, and the Aegean and Mediterranean regions of Turkey. The climate is a major determinant on plant diversity characteristics and ecosystem structure. According to Köppen-Geiger-Pohl system; the Mediterranean climate is coded as Cs within Csa and Csb sub-divisions, with a highest summer temperature as ≥10 °C and coldest winter temperature as ≤18 °C also above −3 °C (Encyclopaedia Britannica 2019).

This ecosystem harbors typical Mediterranean type flora. The composition and plant diversity are controlled by the competition and adaptation behaviors of plants. The plant species are mainly composed of scrubby type shrubs and trees accompanied by some pine species. The plant species ground cover characteristics, layer numbers of the plant cover, all affect the quality, conservation, and stabilization of soil. Accordingly, land-use type, plant composition, ecosystem production, plant diversity, and soil nutrient element cycles may differ from place to place (Ozturk et al. 2010a, b; Ozyigit et al. 2015; Altay 2019). In forest ecosystems with a high canopy shade, the ground flora may not be present, and the soil is generally covered by forest litter.

Looking at the ecosystem sustainability, reduction in the number of fires, controlling the severity of fires, treating the fuel material, and analysis of spatial features of the land are commonly applied solutions (Lee et al. 2009; Salis et al. 2016).

H. B. Tecimen (✉) · O. Sevgi
Soil Science and Ecology Department, Faculty of Forestry, Istanbul University-Cerrahpasa, Istanbul, Turkiye
e-mail: osevgi@istanbul.edu.tr

A. Kavgacı
Forest Botany Department, Faculty of Forestry, Karabuk University, Karabuk, Turkiye
e-mail: alikavgaci@karabuk.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_5

Most commonly appealed practice is to establish and generate models predicting the fire spreading rate, fire speed, direction, and ending time (Cruz et al. 2018). The conditions affecting the fires are weather which is responsible for the speed, severity, direction, extinguishing time by providing oxygen and driving force. The burning fuel material also determines the severity of the fire. In the Mediterranean ecosystems, structure and content of the burning materials fully support the forest fires with inclusion of etheric and phenolic oils, resins, and easily flammable materials. Forests, maquis, meadows, and agricultural lands especially close to urbanized locations are most frequently exposed to fires. Hammill and Bradstock (2006) have tested the severity of fire by remote sense utilizing tool models and satellite data within field fire residues such as burnt and unburnt branch and tree stem residues. They have concluded that the effect of vegetation type on fire severity is greater, for example, the forested areas and higher tree and biomass baring sites burn more severely than the sites with bushes, and less flammable biomass load.

Nevertheless, the geographical position like intersection of certain latitudes and longitudes, closeness to marine sites or terrain parts; the altitude – as the higher elevations are colder and the burning material flammability is lower whereas at lower elevations it is reverse; and the topographic situation makes inducive effect on fires by being under the wind current valleys, plain lands, or steep slopes where current blows away the fire or restricts it or decreases the fire speed. The geographical position is highly affected by the global climate change. Flannigan et al. (2000) sought a generalized model to apply to forest fires under changing climatic conditions. They criticized the previous models which manifest more severe fire with increased global climate change, with the description of the fire severity increasing conditions as wind, topography, burning material, drought, microtopography interactions, and collective function with temperature. These authors also highlight that the global climate change does not happen with sole parameter temperature, it includes the amount of annual precipitation, intense rain frequency, seasonality co-act together with the increasing temperatures (Flannigan et al. 2000). According to the model applied by these workers when the amount of CO_2 increase is doubled to its current conditions it results in 20–50% higher severe fires. The effect of vegetation has been expressed as an incorporated factor alike human intervention and topography (Flannigan et al. 2000). However, the model given by Lenihan et al. (2003) shows that even though the altered temperature scenario dictated the vegetation distribution shift from coniferous pine forests to deciduous leaf vegetation type, they confess the confused outputs of the model because of the lack of exact land use parameter data.

To obtain sustained and resilient ecosystems in the fire-prone Mediterranean region, the researchers focus on the management of vegetation, human intervention, conversion, and management of the land-use types to fire-resistant ones, reduction or control of the flammable vegetative residues, avoidance of extra-accumulation of ignitable material, and vegetation productivity. In this chapter, we are trying to answer the questions as; if it is possible to create sustainably managed Mediterranean ecosystems; how global climate conditions affect the sustainability; to what extent it is possible to protect these ecosystems from the disturbances of post-fire and the responses of vegetation vs vegetation management interpretation effects on fire severity and soil and ecosystem quality.

5.2 Fire Phenomenon in the Mediterranean Ecosystems

Wild or human-induced fires are part and parcel of the Mediterranean ecosystems with its intrinsic properties, such as vegetation, climate, and soil types (Uysal et al. 2008; Ozturk et al. 2010a, b). The question asked is whether the vegetation is adapted to fire, or fire most frequently occurs in this type of ecosystem. In one of ecological evolvement theory, the living organisms induce their environment to convert it more reliable for themselves and the other theory manifests that the environment affects the living organisms in it. The discussion can also be extended further and the content of adaptation might be questioned from the aspects of both living and nonliving things.

From the ecological point of view, the studies conducted at global scale via modeling to estimate the future reality with some literal scenarios, local studies to determine the effects of parameters of fire components reveal that effects of fire in the Mediterranean ecosystems have significant impacts regarding the variance of fire inducing factors such as vegetation type, vegetation structure, ignitability of material, land use, landform, geographical location, and climate (for long-term predictions)/weather conditions (for the fire synchronic assessments).

Post-fire part of the fire studies generally focuses on the rehabilitation, reconstruction, restoration of the ecosystem, recovery of the vegetation, post-fire succession, seed germination, soil improvement, soil degradation caused erosion, run-off water, and deteriorated soil water regime (Uysal et al. 2008). Within the fire; in addition to the exceeding concentration of CO_2 release; nitrous oxide and volatile gases are released from the soil when the vegetation cover is ignited. Abrupt conversion of soil organic matter to ash is a kind of natural fertilization of the soil in terms of high amounts of K, Ca, Na, and Mg. However, the effect of fire on the upper soil crust ends up with degradation of granular structure of soil which becomes less penetrable.

Fires can have temporary and permanent effects on soils. The kind of effect of fire depends on the features of fire, soil characteristics, and plant communities covering the soil (Neyişçi 1989). The intensity of fires does not reveal its direct impacts on soil, vegetation, and air instead, the fire temperatures reach the forest litter level, within the duration of fire following the trend as vegetation layer, forest litter layer, and mineral soil layer (Hartford and Frandsen 1992). Even there are conflicting thoughts on the definition of fire severity versus fire intensity. Keeley (2009) mentions that the fire intensity can be defined by the released energy measured by factors like fire strip length, temperature, and duration. He describes fire severity as the amount of ignited material at below and above ground levels. As a result of burned organic material below and above ground, initially there is an obvious loss of organic matter. The ignitable material mentioned here refers to the ignitable material that alters its surroundings physically and chemically by its energy released.

The soil quality and loss of soil nutrient material decrease soil microorganism activity; negative development in soil moisture regime, absence of vegetation cover, removal of soil organic matter layer, and dysfunction by over solar exposition have been stressed by many workers (Tecimen and Sevgi 2011). Some of the studies have focused on post-fire soil quality, including soil microorganisms-incorporated enzyme activities and biogeochemical cycles which are prominent indicators for soil quality. Hinojosa et al. (2019) have studied the impact of fire born drought effects on soil microbial populations following experimental treatments, they found that the functional soil microbial community composition is highly negatively affected by the drought and this continues up to 2 years related to the severity of fire, degree of the quality, and re-adjustment period for rains.

The post-fire vegetation is affected diversely depending on the severity of the fire, the pre-fire history of plant cover, the climatic conditions, landform type, and vegetation composition (Uysal et al. 2008; Ozturk et al. 2010a, b). The seed bank deposition trait for the potential catastrophes may re-arrange the dominancy of the vegetation associations. According to De Luis et al. (2006), the vegetation composition shifts from Fabaceae to Cistaceae family depending on the fire interval period which effects re-sprouting of species, seed bank capacity of the plants compared to each other, and early reproductivity potential of the shrubs. The hypothesis of autosuccession has been declined by De Luis et al. (2006), based on their results indicating that the seed bank potential, seed resistance to fire, fire-induced regeneration evoke seeds, and interval between two fires are controlling agents for the post-fire vegetation composition and dominancy rank, whereas the theoretical assumption of reverse impact of vegetation on fire severity, frequency, and recurring interval has been recalled. Kazanis and Arianoutsou (2004) have confirmed that, even though the post-fire vegetation composition remained as the preceding fire situation, the abundancy changes raise herbal population during the initial year following the fire, particularly notable is the presence of leguminous species, the dominancy of the sublayer in *Pinus halepensis* forest with belowground nutrient source baring species, and spatially expanded species in sequential years. The reactions of the vegetation type to high solar exposition, competence success at conquering the site by early sprouting and/or by fast growing, shape the new vegetation composition. The soil properties and actual water regime determine the first appearance of plants. Regarding the severity together with duration of fire, burned material, and extinguishing intervention, the belowground parts of the plants may remain undamaged or moderately or severely damaged. The soil properties do not show any significant difference between severely burned and unburned sites in terms of soil reaction and soil nutrient element concentrations, there is almost similar re-growth of post-fire vegetation which indicates the adaptability of current bushy vegetation and woodland of slash pine and dryland adapted oak forests to the fires and substantial disasters and harsh conditions.

The soil's physical properties are most crucial for ecosystem persistence and sustainability related to water regime and soil conservation. Among these, soil texture is the most significant feature, as the composition of soil particles defines the texture, determines the aeration, water holding capacity, water penetration, and water infiltration. It is a signature for the ecosystem resilience by its control on soil protection against erosion or other soil loss factors and guarantees the future productivity of the soil. The most frequently observed soil deterioration type is soil water repellency, which eventually is responsible for erosion. Soil water repellency has been described as the hydrophobic attitude of soil especially seen after fire occasions. The post-fire soil erosion by run-off water has been studied from the point of view of soil water repellency focusing on critical moisture content that repellency ceases, water repellency, soil sealing, or loss of soil cover (Larsen et al. 2009), several water precipitation treatments (Johansen et al. 2001) and soil protection applications such as mulching and various surface covering materials (Cerdà and Doerr 2008). Though majority of the studies agree on the disappearance of run-off, water repellency and erosion in between a year to a couple of years (Prosser and Williams 1998), soil physical, chemical, and biological properties are altered following the fire.

5.2.1 Soils as a Component of Ecosystems Affected from Fires

Fires as natural disasters have significant functions in ecosystems and at the same time contribute to the macronutrient cycles globally. The condition for fire initiation is the temperature in Mediterranean ecosystems while the ignitable material becomes a dominant factor for the regions where cold climate dominates. Especially in South European Mediterranean ecosystems, fire is regarded as the primary forest damage factor. In recent years, the number of fires has increased within decreased aerial magnitudes. Technological and scientific developments have assisted to detect the fires prior to their devastation. Observation of fires remotely, programs for forest fire monitoring (Ayanz et al. 2002), and monitoring the fires by satellites (López et al. 2002) have enabled to gain knowledge about the projection of fires and to take precautions against the fire progression direction. The mathematical and software-based smart modelings have increased the precision at the estimations for fires. The global climate change phenomenon induced altered precipitation regimes and temperature anomalies have created confusion and misestimations of fires in terms of expected time, duration, initiation location, or any progress (Dale et al. 2001a). The possible fires in taiga and tundra ecosystems such as subarctic regions in Canada and Russia are out of over summer-drought regions with potentially bare higher risks (Stocks et al. 1998). Even though the fires in tropical and sub-tropical regions are not initiated by human beings, the losses in biodiversity and biomass do reflect major threat for the future. The forest fires have been accounted as the top factors on carbon sequestration or release.

The soils are full of living organisms, but they are exposed to various effects of fire which interferes its physico-chemical as well as biological aspects. A comprehensive account on the properties of soils is required prior to jumping to the effects of fires on soils. The soil can be defined briefly as crust of earth, possessing different characteristics at different depths. According to soil scientists; soil is a layer of outer part of earth exposed to physical, chemical and biological degradation and disintegration, and weathering, covering the processes of humus production, clay minerals as well as sesquioxides and formed of layered horizons by vertical elusion, eluviation, and transport of minerals (Irmak 1972).

Organisms, landscape, parent rock/material, climate, and time are the factors responsible for the formation of soils. Out of these the forest soils are covered by litter which is prone to fire. The forest litter layer is composed of degraded or semi-degraded or to be degraded particles of dead or shed parts of living organisms. This layer mainly includes leaves (L), fermentated materials (F), and humus (H) layers (Çepel 1995). Leaf layer includes freshly shed leaves from the trees and the branches, twig pieces, cones, carpels, and other undeformed and undegraded plant residues. In the F layer, the pieces of to-be-degraded parts can still be recognized but apparently has lost its original form, color, shape, and structure at a level where they reveal their origin. Humus layer is composed of macromolecular forms of the material coming from the decomposed fermentation layer.

The most frequent forest litter type found in the Mediterranean type ecosystems is mull-type humus, with very thin and decomposed leaf and fermented layers, a humus layer mostly mixed with upper parts of mineral soil. The forest ecosystems consist of one or multilayers of trees, the shrub layers which are not higher than the bottom of the crown canopy, and herbal and mossy layers attributed to the organic layer of the forest. All provide a multilayered utilization capacity both above as well as below the soil. The organic layer of the forest is dependent on the amount of light, water, and nutrient elements allowed by the dominant forest tree species and shrub vegetation layer. Even the organic layer is dependent on the forest tree species as living source, which have remarkable impact on the water cycle and biological (affecting the microorganisms by root exuded enzymes), physical (granularity, permeability, and resistance), and chemical (pH, absorbance, and release of cations and nutrient elements) properties of soils.

In mature soils, various forms of remarkable layers of horizons coded by A, B, and C layers can be detected. The soil horizons are defined as horizontally stratified layers differing in the color, structure, root density, staining, humidity, and stoniness. The horizons not recognizable are defined as unique horizons or transition horizons named with combined letters of distinctive horizons like AB or BC.

Fire has various degrees of effects on soils depending on its duration, severity, and intensity. The permeability and infiltration of water to the soil is highly negatively affected by the fire leading to deformation of structure of soils (Çepel 1985). Soils perform functions providing living environment for vegetation components. The most distinct feature of soil is forming a physically erecting and standing base and a pool of water and nutrient elements. The nutrient elements originate from the decomposition of organic materials coming from the forest litter layer and decomposition of parent rock/material. The availability of plant nutrient elements is dependent upon the water movement in well-aerated soil pores and presence of electron receptors to release and exchange the nutrient elements captured as exchangeable forms in between the clay minerals, soil colloids, and organic molecules. The well-granulated form of the upper soil layer is a prerequisite for the sufficient water and air circulation in the soil matrix. Nutrient element uptake by plants is dependent on the presence of water for both transport of nutrient elements and providing available nutrient element forms since it is one of the most important media for uptake of available elements.

The microorganisms in soils are in relation with plants occurring in the physical–biochemical soil environment. The chemical environment of the soil is determined by nutrient elements, pH, aeration, parent rock, plant communities, soil microbiome, and soil nutrient elements cycle. Soil pH is determined by the release or fixation of H^+ ions in the soil water solution. The exchangeable nutrient elements are held by the clay minerals that are also called macronutrient elements such as Na^+, K^+, Ca^{+2}, and Mg^{+2}, known as potential pH buffering elements as they replace with H^+ in the soil water solution.

In the estimation and approaches to assess the total carbon sequestration, the distribution of carbon in forest ecosystems in above and belowground parts together with carbon fluxes has not been studied fully but the attempts are going on (Hao et al. 1990; Kuhlbusch and Crutzen 1995; Kuhlbusch et al. 1995). The larger part of the carbon in forest ecosystems is deposited in the belowground part of the plants and as organic matter in soil (Jandl et al. 2007). The soil is exposed to physical, chemical, and biological alterations, structural deformations and losses (Hogg et al. 1992; Neff et al. 2005; Neary et al. 1999). The scientific studies have focused on the estimation of disturbance of soil following fire (Johansen et al. 1984; Gutknecht et al. 2010), restoration of soil (Meyer et al. 2004), and recording data under experimental fire applications (Bilgili and Saglam 2003). The intrinsic features of the Mediterranean type ecosystems require novelties in approaches to understand the vegetation types and dynamics, geomorphological structure and features, the reflections of soils to fire and post-fire processes, and the ecosystem recovery potential. These ecosystems are sensitive because of summer drought and fire threats, face higher ecological pressure created by insect and fungal attacks, human pressure, and improper land-use activities. Following the degradation of ecosystem and soil, the ecosystem is unable to recover itself and its productivity and primary production potential is lost enormously.

5.2.2 Post-fire Soil Erosion, Impact, Mitigation, Estimation Models and Prospects

In the undegraded soils in the Mediterranean forests and shrubby lands, a definable water holding capacity is found under the canopy shelter with several protective layers like tree canopy, shrubby, and herbal layer and forest litter preventing the erosion priming effect such as splashing force or particle detachment from the uppermost soil crust. Several researchers (DeBano 2000; Doerr et al. 2000; Bisdom et al. 1993) have stated that soil repellency initiated by fires causes too light or severe erosion related to the severity of fire, geomorphological structure, soil texture, and intensity of rain. For a better understanding of the phenomenal aspects of fire-induced erosion, artificial erosion generating storm experiments and natural wild-fire exposed soils/forest lands have been investigated and studied for gaining comprehensive knowledge. DeBano (2000) has evaluated the water repellency problem from a historical point of view starting from 1968. He mentions that the interest on water repellency of soils starts first by re-distribution and situation of water not penetrating the soil, with a peripheral extension to the aggregate stability and water production relations in fragile arid ecosystems. According to Doerr et al. (2000), the mechanism of water repellency in soils is described within factors incorporated such as reaction of solid surfaces to liquids by adhesive and cohesive forces, electro-chemical composition of water molecules, the hydrophilicity or hydrophobicity of the surface of solid material, classification of water repellency rank, and vegetation composition. He concludes with the information lacking research results on such as (i) the identification of the water repellency influence on soil erosion from co-working factors; (ii) the detection of the factors affecting the water erosion gullies such as soil properties (texture, organic matter content, clay mineral distribution, vegetation type, inorganic components causing water repellency) and understanding the co-relations in between those factors.

The post-fire erosion severity is supposed to be accelerated by fires and this is thought to be relevant to the intensity of the fire. This approach is dominantly agreed by most of the workers, but some are contradicting with questions summarized from the studies. In the study by Benavides-Solorio and MacDonald (2001), a comparison of post-fire sediment yield reveals that it is related to the inherent repellency of soils and thus the severity of fire only shows 15–30% higher runoff, and regardless of the fire severity, the actual soil moisture has been detected as the primary factor for runoff amount.

Erosion inducing stormy rains, amount, duration, repeated rains, the time of the rain following the fire, existence of potential vegetation, vegetation growth for covering the ground as a protecting agent for the soil surface, the geographical position of the fire burnt area; which will determine the re-growth of vegetation; all together determine the soil loss caused by rain at a post-fire period. The report of Robichaud (2000) has revealed that post-fire erosion varies from 0.01 to 110 t/ha/year during the first year following the fire depending on the inclination, revegetation, rain intensity, and soil properties. During the 4 years following the first one, erosion may have disappeared and not noticed anymore (Robichaud 2000). So, the immediate post-fire erosion mitigation interventions are the most effective applications where the timeliness provides more efficient soil protection within economical benefits. The most common runoff protection methods applied are actually: mulching, revegetation (seeding, plantation), protective fence applications, barrier fences, sectioning of the land with crossing shields, and others.

5.3 Ecosystem Recovery, Resilience and Sustainability Possibilities

5.3.1 Ecosystem Regeneration

The response of the ecosystem to a natural or anthropogenic disturbance; regarding its intensity, severity, and persistence; is called the recovery or ecosystem adaptation. According to Kelly and Harwell (1990), the disturbance source acting as a degrading agent may have various effects on the ecosystem regarding its intensity, frequency, and duration. Ecosystem recovery time has been described as the time required to set the disturbed ecosystem back to its pre-degraded status (Peterson et al. 1998). The shorter period is regarded as the resilience of the ecosystem, while the long period demanding recovery situation or alteration of the ecosystem to a different type compared to the previous state without accomplishment of recovery properly, the situation is defined an acute degradation (van de Leemput et al. 2018).

The most profound impacts on ecosystem disturbance are disappearance or damage of production systems such as vascular plants, removal of soil protection and exposure to erosion threat, loss of nutrient elements by erosion, and loss of seed banks for further regeneration of the flora. According to Cromack et al. (2000), removal of nutrient elements occurs by ignition of nutritional leaves on the trees and the translocation of nutrient and organic matter rich upper organic and organomineral layer of soil by runoff water. The low evaporation temperature bearing nutrient elements like C, N, P, S, and K are lost most highly and are the key nutrient elements reloaded during post-fire period as these are present in the upper organic and organomineral layers of soil (Johansen et al. 1984). The removal of nutrient elements from upper soil horizons hampers the renovation of ecosystem and causes accumulation of unintended nutrient element load in the neighboring ecosystems. To re-gain the ecosystem sustainability, a fire-prone ecosystem has to be handled from diverse aspects such as plant community adaptation and revegetation; soil protection; climate change effects, and human interference to provide the precautionary suggestions to reduce the fire disturbance effects and establish a sustainable ecosystem (Fig. 5.1).

The vegetation layers are combustible material and heat source altering the structure of soil surface, which is also a seed germination media for the plants. Following the fire, soil becomes ultimately exposed to open air impacts and the nutrient element pool in ash form is encountered with the risk of removal toward the most convenient lower level watershed regions with the first runoff water. The seeds of the post-fire vegetation may either be supplied by the previous vegetation that bears fire-resistant seeds or by the translocation of the seeds from surrounding sources with either wind or rain. Vegetation in the Mediterranean ecosystems has fire-resistant seeds with germination ability following the exposition to high temperature. The most challenging grade of the ecosystem regeneration has been pointed as the re-establishment of the floral communities, where the dominancy of the species leads to the composition of new flora; the species composition; the growth and

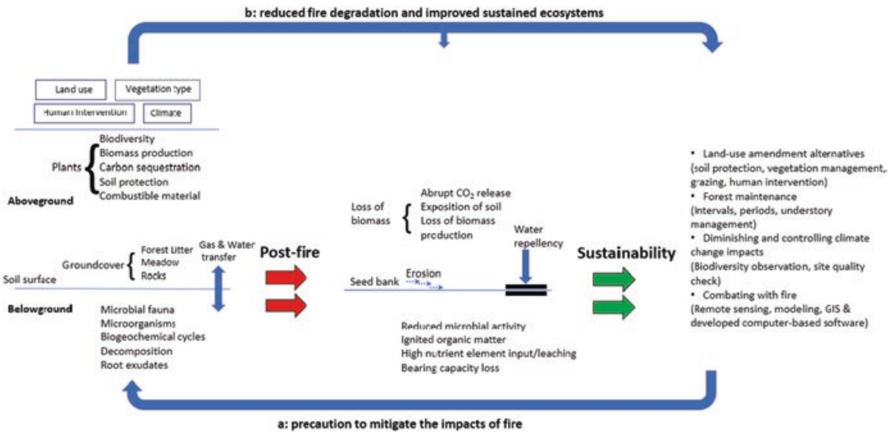


Fig. 5.1 Conceptual framework for ecosystem functions, fire hazards, and possible precautions. Arrow (**a**) implies the effects of precautions that create a more resistant ecosystem to fire and further natural hazards; arrow (**b**) indicates the improved ecosystems which suffer comparably less to unprotected ecosystems and finally a consolidation for sustainability could be established

spreading performance of the species reveals important information on the recovery of the ecosystem (Bonet 2004; Soares et al. 2006; Capitano and Carcaillet 2008; Kavgacı et al. 2010a).

The satellite monitoring opportunity provides convenience at making decisions on these issues (Viedma et al. 1997). To promote the ecosystem resilience following a fire occasion, mulching, intensive pruning of brushes ,and vegetation removal have been applied to anticipate better germination performance in native sprouting species in competition with abandoned agricultural lands and repetitive fire occurrence induced brush community composition (Valdecantos et al. 2009). The trials have been established with narrow spaces with seedlings receiving less sunlight and lower soil temperature, higher soil moisture at mulching + narrow space holes than unmulched ones; mulching provided higher survival performance for *P. lentiscus*. The relation between the fire and the vegetation depends on the intrinsical existence of fire in an ecosystem, frequency, intensity, character, and those features of the fire which have an influence on the vegetation type from several aspects (Urretavizcaya and Defossé 2004; Pausas et al. 2004a; Capitanio and Carcaillet 2008; Esposito et al. 2006). Re-sprouting of branches and the resistance of seeds against fire are the prominent features of the fire adaptation (Pausas et al. 2004a); however, the heritable characteristics of the plant species enhance the competition with the co-existing individuals while combatting with fire and is expected that during the coming fire cases the next competition challenges will appear. The predominance against the competitive individual at seedling stage of the plants may vary depending on the absorbed water, nutrient element of the seed from soil, and its root development (Soares et al. 2006). Thus, the natural historic background of the plant-soil interactions encourages the ecosystem resilience, plant diversity, and new generation currents at global element cycles (Sardans and Peñuelas 2013).

Post-fire succession has been an important issue because of its effects during the future fire regimes, and also the effects on hydrological, structural, and biological situation of the forests in the Mediterranean ecosystems. De Luis et al. (2006) researched the effects of dominancy on auto-successional progress of Mediterranean gorse species. Their results revealed that dominant Mediterranean gorse species did not reach to pre-fire population as had been expected, and instead, Fabaceae family including majority of the Mediterranean gorse species (only 25% germination) has been replaced by Cistaceae (mostly as *Cystus albidus*) expressed as 63% germination ratio against the former species.

Re-establishment of the post-vegetation may be supported by either internal seed immigration or by the seed bank deposited in the soil. The magnitude of the fire is deterministic in the possibility option and the duration of seed arrival to the burned land area from the surrounding ecosystem sources. The soil seed bank support is dependent upon the length of the fireless years and or the interval between fire occurrence and the abundant seed year (Zammit and Zedler 1988). The more the years without any fire case, the more the combustible material accumulates which causes a boost up in the intensity of the forthcoming fires. When the number and the spatial magnitude of the contemporary fires increase it reduces the soil quality and increases the nutrient loss that makes harder to maintain the sustainability of the ecosystems (Johansen et al. 2001).

The actual quality of a given forest ecosystem in the Mediterranean region depends on the factors of climatic parameters, vegetation dynamics, and land-use policy. The human intervention or utilization of the ecosystem is deterministic in the management strategies of an ecosystem. The social pressure is one of the most important factors on the forests and is one of the most prominent fire inducing factors as well. Controls on the ecosystem parameters such as vegetation utilization of woody material for market demands; effects on soil such as grazing/agricultural activities/clear-cutting of forest/alteration of vegetation type from forest to maquis land (forest degradation), all alter the fire patterns in a generally negative way. The 50–100 year regular fire cycles in Wyoming sagebrush ecosystem have been interrupted by change in plant biodiversity and domination of natural plant composition with unintended invading species; climate change and the increased legal permissions to intensive grazing have added to this (Ellsworth et al. 2016). Regarding the vegetation type and land cover, the severity and relatedly the recovery of the ecosystem may be re-established from scratch or may require a gentle touch within a considerable period. The vegetation unit member responses following a fire have shown variance at re-sprouting such as more tree species (more than 84%) were detected to be re-sprouting compared to shrub taxa (approximately 50%), although the studied ecosystems were occupied dominantly by shrubs (64%) (Clarke et al. 2015). The impact of climate patterns on fire-prone ecosystem resilience has been investigated at length. The results have revealed that the soil productivity status, the temperature extremes, and the precipitation occasions in dry seasons are most efficient and associated factors in ecosystem recovery (Wilson et al. 2015). Mediterranean ecosystems are the vulnerable ones and require a subjection to more critical management strategies. Repeated fire disturbances in these ecosystems bear historical experience at ecosystem scale which may be a characteristic of the Mediterranean type ecosystems. The fire-prone ecosystems like the Mediterranean ones harbor adapted species which are able to basal or epicormic sprouting following a fire, reserve more seeds to soil as a seed bank, possess fire-induced seed germination physiology or seritony (seed reserving on the tree canopy – mostly seen in the fire-prone tree species) (Lamont and Enright 2000). The history of an ecosystem experiencing fire disturbances is managed to response against the fire by either biotic components (like adaptability to fire, re-sprouting trait) or subjective components (like plant physiology, seed formation) which is defined as the concept of ecosystem memory to explain the adaptation/recovery/alteration/disturbance issues (Johnstone et al. 2016).

5.3.2 Climate Change Impact

The debates on the effects of climate change on the disturbance regimes, particularly on the fire cases, have increased based on the future estimation scenarios, risk evaluations, and global climate models. According to Dale et al. (2001b), the disturbances including the fire have direct and indirect effects on forests as fires for the fire-case disturbance and alteration of forest species composition, and traits for migration. The global climate change has an impact on the disturbance regimes influencing its frequency, duration, and severity. Fire is a function of temperature, burning material, and the oxygen availability. Thus, the usual circulations of the climatic parameters and events are known and adapted with the current vegetation type. The responses of the climate change vary from drought-precipitation regime alterations to sub-weather conditions such as humid days, the extreme temperatures, wind occurrences, and subsequent weather incidents. Fire may also be perceived as an adaptation method of the vegetation to changing climate. The frequency, duration, and the severity of the fires create an emerged situation on the ecosystem elements including the living organisms, organic matter and biomass accumulation; inorganic elemental flows, and physical environment.

Forest stressors such as increased CO_2 concentration; changed temperature and precipitation patterns and nitrogen deposition + ozone parameters have been discussed in an integrated relation questioning whether (i) the increased temperature causes drought thereby reducing the stomatal conductance and mitigates the ozone uptake pollution; (ii) increased CO_2 cc has been responded by reduced stomatal conductance and mitigation of the ozone uptake pollution; (iii) increased nitrogen deposition may enhance the photosynthesis and leaf stomatal conductance still the biomass increase continues; (iv) and the negative feedback of ozone uptake decreases tree growth leading to an increase in N deposition and subsequent pollution in freshwater systems (Aber et al. 2001).

The analysis of the impacts of climate change on fire events has been studied by Pausas (2004). He reached the conclusion with obvious summer and annual temperature increase; slightly decreased summer rainfall; with increase in the annual record of fire events, and burned area for last century; increase at 3 decadal record of fire events but burned area increase was not significant; and the correlation was strong between the summer rains and reduced fire events.

5.3.3 Vegetation Recovery

Fire is an essential component of the Mediterranean type ecosystems, with a determinant role on floristic composition and vegetation type with differentiations in the drought effect of climate and soil characteristics (Trabaud 1994). Besides these ecological factors, the anthropogenic interventions by humans are highly efficient on the formation of actual landscape of Mediterranean-type ecosystems (Pausas and Vallejo 1999; Beatriz and Vallejo 2008; Pausas et al. 2008). Mankind has used the fire as a tool for conversion of forest lands into agricultural production, urbanization, or open a field for grazing and have influenced the alteration of fire regime in the region.

The effect of fire as an ecological principal element may either act as a reconstructional process that has an amendment effect following a post-fire (Doussi and Thanos 1994), or terminate with the degradation of ecosystem and current floristic composition and delineation from the actual properly functioning ecosystem situation (Moreira and Vallejo 2009). The commonly admitted perspective for the post-fire vegetational succession has faced rejection of classical secondary succession principals; it deviates from the prevalent succession where the vegetation substitutes temporally (Hanes 1971; Whelan 1995; Vallejo 1999; Tavşanoğlu and Gürkan 2009). Several hypotheses have been submitted regarding post-fire vegetation dynamics. The most widely accepted model is: Mediterranean type ecosystems re-establish with auto-successional process following a fire and are re-shaped in time (Trabaud 1994). Within the re-establishment process; majority of the obligatory seeded, pre-fire existing and the species with obligate resprouting occupy the burned area in following 2 years following the fire and primary variation of the vegetation is observed at the distribution density of those species and the reconstruction of shrub and the tree layers (Arianoutsou and Ne'eman 2000). The initial species filling the burned area during the 1st year following the fire provide the species pool function (Kavgacı et al. 2010a) (Fig. 5.2). The floral members timely leave from or join to this pool. The post-fire succession becomes more the differentiation of the existence density of current species composition than temporal change of species composition (Hanes 1971; Kazanis and Arianoutsou 2002; Götzenberger et al. 2003).

The flora of Mediterranean type ecosystems has adaptation abilities to the fire. However; they adapt to a certain fire regime rather than the "fire" (Sugihara et al. 2006; Keeley et al. 2011). There exists a mutual interrelation between the vegetation and the fire, as the profile of the fire relies on the vegetation type. Likewise, the vegetation is able to tolerate the fire regime to some extent relevantly to the adaptation capacity of the vegetation members (Sugihara et al. 2006). So, if the fire regime

Fig. 5.2 The revegetation of the post-fire field with the obligate seeding, seeds provided by soil seed bank and Calabrian pine from crown seed bank (1 and 2)

changes, the destiny of the vegetation which had already possessed an adaptation ability to a certain fire regime may face a risk (Keeley et al. 2011).

The most prominent adaptation capability of the Mediterranean type of ecosystem vegetation members to fire is obligate resprouting and obligate seeding (Pausas et al. 2004b). The plant species have four major paths while occupying the post-fire ecosystems: (a) obligate resprouting; (b) facultative species; (c) obligate seeding; and (d) colonizing species. Majority of the obligate resprouting species re-occupy following the fire and large numbers of these species from Calabrian pine individuals as well as maquis shrubland species re-vegetate in the post-fire lands. For instance, kermes oak, gall oak, olive, gum tree, terebinth tree, and locust species re-appear in post-fire lands by obligate resprouting. As against this, the species lacking obligate resprouting capability appear in those habitats following a seed germination which is possible with soil or crown seed bank. Calabrian pine and Aleppo pine rely on the canopy seed bank while Fabaceae family and *Cistus* sp. members depend on soil seed banks respectively. While the population of obligate resprouting species remains stable for a long time, the number of obligate seeding species shows an increase in the population during first year following the fire, they diminish with time and slightly increase through the maturation of the stand (Fig. 5.3 – Kavgacı et al. 2010b). The most frequently recorded facultative species are *Calicotome villosa* and *Erica* species which increase at the initial year following the fire but decrease temporally (Tavşanoğlu 2008). The other seeding species colonizing the fire area without the stimulation of fire during the early stages of the recovery are attributed as the opportunistic species in these ecosystems.

The existence of the obligate seeding species is dependent on the formation of post-fire vegetation. The severity of the fire may obscure the revegetation of obligate seeding species by depleting the canopy and soil seed bank deposits, inducing a dominancy in obligate resprouting species (Pausas et al. 2003). This may alter the vegetation structure and prevent the auto-succession. Indeed, recent studies have

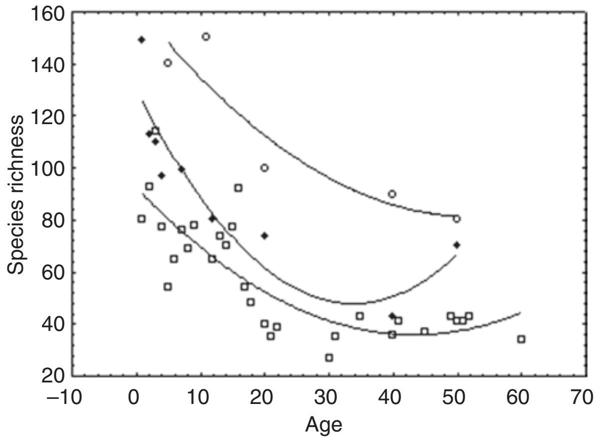


Fig. 5.3 Post-fire differentiation of (α-diversity) species diversity in the East Mediterranean Calabrian pine and Aleppo pine forests (from Kavgacı et al. 2010b). Israel (circle), Greece (filled square), and Turkey (square). Israel: $r = -0.9050$; $p < 0.05$, Greece: $r = -0.7402$; $p < 0.01$, Turkey: $r = -0.7883$; $p < 0.05$)

concluded that auto-succession is not the only method of the post-fire succession and fire frequency, fire intensity, fire severity, and pre-fire vegetation type may dictate the post-fire vegetation dynamics. In the Aleppo pine and

Calabrian pine forests in the Mediterranean basin, the occurrence of the fire event do not allow formation of sufficient seed, thus the post-fire vegetation is more inclined to turn to maquis shrubland. Kavgacı et al. (2016) have verified that a juvenile (13 year old) Calabrian pine stand exposed to fire is replaced by maquis shrubland with obligate resprouting species, while the mature stands return to a re-established Calabrian pine forest. However, even in the mature stands, the trends of species richness, species diversity, seedling density, and family spectrum differ in relation to the differences of fire parameters like fire severity and topographical factors (Kavgacı et al. 2016). This indicates, even if the obligate seeding species dominate the vegetation recovery in the fire area, post-fire successional processes may not follow same dynamics and show differences according to the fire components.

5.4 Conclusions

Fire phenomenon has been widely perceived as a natural and essential component of Mediterranean type ecosystems and has received much attention related to the aspects of (i) investigation of fire characteristics such as severity, duration, frequency, time, modeling the future fire features, and potential disturbance risk; (ii) the effects efficient in the fires; land use, vegetation type, human interference, climatic components, ignitable material load, forest management strategies; and (iii) post-fire assessments; revegetation, vegetation formation, species composition, soil disturbance, ecosystem recovery, ecosystem resilience, and disturbance level. The uncertainties on the indirect effects of global climate change still are not revealed well, because of the complicacy of the ecosystem functions, adaptation inclinations of plants and interrelations between the impacts and responses (positive/negative feedbacks; circulated effects of functions and unpredicted co-effects/implication of the responses). While the up-to-date models attempt to estimate global climate change impacts, the synchronically occurring changes in the environment suppress the unraveling of the actual consequences of the climate effects on fire. One of the most vulnerable ecosystems on the world with drought reigning climate regime, shallow soil, harsh water content conditions and limited nutrient element contents and fire-adapted sensitive vegetation – the Mediterranean ecosystems – has evolved to contemporary adaptation period. However, the precautions to prevent the greenhouse gas release, controls on industrial exhaust, and legislative limitations on carbon emission promise to proceed toward more regulated climate regime globally and in the Mediterranean climates.

References

Aber J, Neilson RP, McNulty S et al (2001) Forest processes and global environmental change: predicting the effects of individual and multiple stressors: we review the effects of several rapidly changing environmental drivers on ecosystem function, discuss interactions among them, and summarize predicted changes in productivity, carbon storage, and water balance. Bioscience 51(9):735–751

Altay V (2019) Ecology of *Pinus sylvestris* L. Forests – a case study from Istanbul (Turkey). Pak J Bot 51(5):1711–1718

Arianoutsou M, Ne'eman G (2000) Post-fire regeneration of natural *Pinus halepensis* forests in the East Mediterranean Basin. In: Ne'eman G, Trabaud L (eds) Ecology, biogeography and management of *Pinus halepensis* and *P. brutia* forest ecosystems in the Mediterranean Basin. Bacjhuys Publishers, pp 269–289

Ayanz SM, Barbosa P, Schmuck G et al (2002) Towards a coherent forest fire information system in Europe: the European Forest Fire Information System (EFFIS). In: Viegas DX (ed) Forest fire research and wildland fire safety: Proceedings of IV International Conference on Forest Fire Research 2002 Wildland Fire Safety Summit, Luso, Coimbra, Portugal, 18–23 November 2002

Beatriz D, Vallejo VR (2008) Land use and fire history effects on post-fire vegetation dynamics in eastern Spain. J Veg Sci 19:97–108

Benavides-Solorio J, MacDonald LH (2001) Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range. Hydrol Process 15(15):2931–2952

Bilgili E, Saglam B (2003) Fire behavior in maquis fuels in Turkey. For Ecol Manag 184(1–3):201–207

Bisdom EBA, Dekker LW, Schoute JT (1993) Water repellency of sieve fractions from sandy soils and relationships with organic material and soil structure. In: Brussaard L, Kooistra MJ (eds) Soil structure/soil biota interrelationships. Elsevier, pp 105–118

Bonet A (2004) Secondary succession of semi-arid Mediterranean old-fields in South-Eastern Spain: insights for conservation and restoration of degraded lands. J Arid Environ 56:213–233

Capitanio R, Carcaillet C (2008) Post-fire Mediterranean vegetation dynamics and diversity: a discussion of succession models. For Ecol Manag 255:431–439

Çepel N (1985) Toprak Fiziği. İstanbul Üniversitesi Yayın No: 3313, Orman Fakültesi Yayın No: 374, Istanbul
Çepel N (1995) Orman Ekolojisi, İÜ Orman Fak. Yayınları, Istanbul
Cerdà A, Doerr SH (2008) The effect of ash and needle cover on surface runoff and erosion in the immediate post-fire period. Catena 74(3):256–263
Clarke PJ, Lawes MJ, Murphy BP et al (2015) A synthesis of postfire recovery traits of woody plants in Australian ecosystems. Sci Total Environ 534:31–42
Cromack K Jr, Landsberg JD, Everett RL et al (2000) Assessing the impacts of severe fire on Forest ecosystem recovery. J Sustain For 11(1–2):177–228
Cruz MG, Alexander ME, Sullivan AL et al (2018) Assessing improvements in models used to operationally predict wildland fire rate of spread. Environ Model Softw 105:54–63
Dale VH, Joyce LA, McNulty et al (2001a) Climate change and forest disturbances. Bioscience 51(9):723–734
Dale VH, Joyce LA, McNulty et al (2001b) Climate change and forest disturbances: climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. Bioscience 51(9):723–734
De Luis M, Raventós J, González-Hidalgo JC (2006) Post-fire vegetation succession in Mediterranean gorse shrublands. Acta Oecol 30(1):54–61
DeBano LF (2000) Water repellency in soils: a historical overview. J Hydrol 231:4–32
Doerr SH, Shakesby RA, Walsh R (2000) Soil water repellency: its causes, characteristics and hydro-geomorphological significance. Earth-Sci Rev 51(1–4):33–65
Doussi MA, Thanos CA, (1994) Postfire regeneration of hardseeded plants: Ecophysology of seed germination. In: Proceedings of the 2nd international conference of forest fire research, Coimbra, Vol II, D 25, p 1035–1044
Ellsworth LM, Wrobleski DW, Kauffman JB, Reis SA (2016) Ecosystem resilience is evident 17 years after fire in Wyoming big sagebrush ecosystems. Ecosphere 7(12):e01618
Encyclopaedia Britannica (2019) Mediterranean climate. Encyclopaedia Britannica Inc. https://www.britannica.com/science/Mediterranean-climate. Accessed on 09 Dec 2019
Esposito A, Strumia S, Caporaso S, Mazzoleni S (2006) The effect of fire intensity on soil seed bank in Mediterranean macchia. For Ecol Manag 234S:S207
Flannigan MD, Stocks BJ, Wotton BM (2000) Climate change and forest fires. Sci Total Environ 262(3):221–229
Götzenberger L, Ohl C, Hensen I, Gómez PS (2003) Postfire regeneration of a thermo-Mediterranean shrubland area in South-Eastern Spain. Ann Biol 25:21–28
Gutknecht JL, Henry HA, Balser TC (2010) Inter-annual variation in soil extra-cellular enzyme activity in response to simulated global change and fire disturbance. Pedobiologia 53(5):283–293
Hammill KA, Bradstock RA (2006) Remote sensing of fire severity in the Blue Mountains: influence of vegetation type and inferring fire intensity. Int J Wildland Fire 15(2):213–226
Hanes TL (1971) Succession after fire in the chaparral of Southern California. Ecol Monogr 41:27–52
Hao WM, Liu M-H, Crutzen PJ (1990) Estimates of annual and regional releases of CO_2 and other trace gases to the atmosphere from fires in the tropics based on the FAO statistics for the period 1975-1980. In: Goldammer JG (ed) Fire in the tropical bioto. Springer-Verlag, Berlin, pp 440–462
Hartford RA, Frandsen WH (1992) When it's hot, it's hot … or maybe it's not (surface flaming may not portend extensive soil heating). Int J Wildland Fire 2:139–144
Hinojosa MB, Laudicina VA, Parra A et al (2019) Drought and its legacy modulate the post-fire recovery of soil functionality and microbial community structure in a Mediterranean shrubland. Glob Chang Biol 25(4):1409–1427
Hogg EH, Lieffers VJ, Wein RW (1992) Potential carbon losses from peat profiles: effects of temperature, drought, cycles, and fire. Ecol Appl 2(3):298–306

Irmak A (1972) Toprak İlmi. İstanbul Üniversitesi Yayın No: 1268, Orman Fakültesi No: 121, Istanbul

Jandl R, Lindner M, Vesterdal L et al (2007) How strongly can forest management influence soil carbon sequestration? Geoderma 137:253–268

Johansen JR, St Clair LL, Webb BL, Nebeker GT (1984) Recovery patterns of cryptogamic soil crusts in desert rangelands following fire disturbance. Bryologist 83:238–243

Johansen MP, Hakonson TE, Breshears DD (2001) Post-fire runoff and erosion from rainfall simulation: contrasting forests with shrublands and grasslands. Hydrol Process 15(15):2953–2965

Johnstone JF, Allen CD, Franklin JF et al (2016) Changing disturbance regimes, ecological memory, and forest resilience. Front Ecol Environ 14(7):369–378

Kavgacı A, Başaran S, Başaran MA (2010a) Kızılçam ormanlarında yangın sonrası vejetasyonun zamansal ve yapısal değişimi. TUBITAK – TOVAG – Slovenya 106O487 proje sonuç raporu, 78 p

Kavgacı A, Čarni A, Başaran S et al (2010b) Long-term post-fire succession ofinus brutiaforest in the East Mediterranean. Int J Wildland Fire 19:599

Kavgacı A, Örtel E, Torres I, Safford H (2016) Early postfire vegetation recovery of *Pinus brutia* forests: effects of fire severity, prefire stand age, and aspect. Turk J Agric For 40(5):723–736

Kazanis D, Arianoutsou M (2002) Long term post-fire dynamics of *Pinus halepensis* forest of Central Greece: plant community pattern. In: Viergas (ed) Forests fire research and wildland fire safety. Millpress, Rotterdam, pp 1–12

Kazanis D, Arianoutsou M (2004) Long-term post-fire vegetation dynamics in *Pinus halepensis* forests of Central Greece: a functional group approach. Plant Ecol 171(1–2):101–121

Keeley JE (2009) Fire intensity, fire severity and burn severity: a brief review and suggested usage. Int J Wildland Fire 18:116–126

Keeley JE, Pausas JG, Rundel PW et al (2011) Fire as an evolutionary pressure shaping plant traits. Trends Plant Sci 16:406–411

Kelly JR, Harwell MA (1990) Indicators of ecosystem recovery. Environ Manag 14(5):527–545

Kuhlbusch TAJ, Crutzen PJ (1995) Toward a global estimate of black carbon in residues of vegetation fires representing a sink of atmospheric CO_2 and a source of O_2. Global Biogeochem Cycles 9(4):491–501

Kuhlbusch TAJ, Andrea MO, Cachier H et al (1995) Black carbon formation by savanna fires: measurements and implications for the global carbon cycle. J Geophys Res 101(19):23651–23665

Lamont BB, Enright NJ (2000) Adaptive advantages of aerial seed banks. Plant Species Biol 15(2):157–166

Larsen IJ, MacDonald LH, Brown E et al (2009) Causes of post-fire runoff and erosion: water repellency, cover, or soil sealing? Soil Sci Soc Am J 73(4):1393–1407

Lee SW, Lee MB, Lee YG et al (2009) Relationship between landscape structure and burn severity at the landscape and class levels in Samchuck, South Korea. For Ecol Manag 258(7):1594–1604

Lenihan JM, Drapek R, Bachelet D, Neilson RP (2003) Climate change effects on vegetation distribution, carbon, and fire in California. Ecol Appl 13(6):1667–1681

López AS, San-Miguel-Ayanz J, Burgan RE (2002) Integration of satellite sensor data, fuel type maps and meteorological observations for evaluation of forest fire risk at the pan-European scale. Int J Remote Sens 23(13):2713–2719

Meyer VF, Redente EF, Barbarick KA et al (2004) Plant and soil responses to biosolids application following forest fire. J Environ Qual 33(3):873–881

Moreira F, Vallejo R (2009) What to do after fire? Post-fire restoration. In: Birot Y (ed) Living with Wild fires: What science can tell us, A contribution to the science – Policy dialoque, EFI discussion paper, 15:53–58

Neary DG, Klopatek CC, DeBano LF, Ffolliott PF (1999) Fire effects on belowground sustainability: a review and synthesis. For Ecol Manag 122:51–71

Neff JC, Harden JW, Gleixner G (2005) Fire effects on soil organic matter content, composition, and nutrients in boreal interior Alaska. Can J For Res 35:2178–2187

Neyişçi T (1989) Kızılçam Orman Ekosistemlerinde Denetimli Yakmanın Toprak Kimyasal Özellikleri ve Fidan Gelişimi Üzerine Etkileri. Ormancılık Araştırma Enstitüsü Teknik Bülten No: 205

Ozturk M, Gucel S, Kucuk M, Sakcali S (2010a) Forest, climate change & forest fires in the Mediterranean Region of Turkey. J Environ Biol 31(SI):1–9

Ozturk M, Gucel S, Ozkan K et al (2010b) Journal of Environmental Biology Special Issue-Forests-Forestry-Environment in Turkey. Dalela Publishing 31(01/02):245 p

Ozyigit S, Altay V, Ozyigit II, Yarci C (2015) Vegetation ecology of the Princes' Islands, Istanbul-Turkey. J Environ Biol 36(1):113–120

Pausas JG (2004) Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). Clim Chang 63(3):337–350

Pausas JG, Vallejo VR (1999) The role of fire in European Mediterranean ecosystems, In: Chuvieco E (ed) Remote sensing of large wildfires in the European Mediterranean Basin, Springer Verlag, p 3–16

Pausas JG, Ouadah N, Ferran A et al (2003) Fire severity and seedling establishment in *Pinus halepensis* woodlands, eastern Iberian Peninsula. Plant Ecol 169:205–213

Pausas J, Bradstock AR, Keith AD, Keeley EJ (2004a) GCTE (global change of terrestrial ecosystems) fire network, plant functional traits in relation to fire in crown-fire ecosystems. Ecology 85:1085–1100

Pausas JG, Bradstock RA, Keith DA et al (2004b) GCTE (global change of terrestrial ecosystems) fire network – plant functional traits in relation to fire in crown-fire ecosystems. Ecology 85(4):1085–1100

Pausas JG, Llovet J, Rodrigo A, Vallejo R (2008) Are wildfires a disaster in the Mediterranean basin? – A review. Int J Wildland Fire 17:713–723

Peterson G, Allen CR, Holling CS (1998) Ecological resilience, biodiversity, and scale. Ecosystems 1(1):6–18

Prosser IP, Williams L (1998) The effect of wildfire on runoff and erosion in native *Eucalyptus* forest. Hydrol Process 12(2):251–265

Robichaud PR (2000) Fire and erosion: evaluating the effectiveness of a post-fire rehabilitation treatment, contour-felled logs. In: Watershed management and operations management. American Society of Civil Engineers, Reston, pp 1–11

Salis M, Laconi M, Ager AA et al (2016) Evaluating alternative fuel treatment strategies to reduce wildfire losses in a Mediterranean area. For Ecol Manag 368:207–221

Sardans J, Peñuelas J (2013) Plant-soil interactions in Mediterranean forest and shrublands: impacts of climatic change. Plant Soil 365:1–33

Soares JJ, Souza MHAO, Lima MIS (2006) Twenty years of post-fire plant succession in a "Cerrado", São Carlos, sp, Brazil. Braz J Biol 66(2B):587–602

Stocks BJ, Fosberg MA, Lynham TJ et al (1998) Climate change and forest fire potential in Russian and Canadian boreal forests. Climate Change 38:1–13

Sugihara NG, van Wagtendonk JW, Fites-Kaufman J (2006) Fire as ecological process. In: Sugihara NG, van Wagtendonk JV, Shaffer KE et al (eds) Fire in California's ecosystems. University of California Press, Berkeley, pp 58–74

Tavşanoğlu Ç (2008) Marmaris çevresi *Pinus brutia* (Kızılçam) ormanlarında yangın sonrası vejetasyon dinamikleri. Phd thesis, Hacettepe University

Tavşanoğlu Ç, Gürkan B (2009) Post-fire regeneration of a *Pinus brutia* (Pinaceae) forest in Marmaris National Park, Turkey. Int J Bot 5:107–111

Tecimen HB, Sevgi O (2011) Heating induced changes in mineral nitrogen and organic carbon in relation with temperature and time. J Environ Biol 32(3/4):295–300

Trabaud L (1994) Post fire plant community dynamics in the Mediterranean Basin. In: Moreno JM, Oechel WC (eds) The role of fire in the Mediterranean-type ecosystems. Springer Verlag, New York, pp 1–15

Urretavizcaya MF, Defossé GE (2004) Soil seed bank of *Austrocedrus chi*lensis (D. Don) Pic. Serm. et Bizarri related to different degrees of fire disturbance in two sites of southern Patagonia, Argentina. For Ecol Manag 187(2–3):361–372
Uysal I, Guvensen A, Celik S et al (2008) The post fire plant diversity of Gallipoli National Park (Turkey). Malaysian Forester 71:39–55
Valdecantos A, Baeza MJ, Vallejo VR (2009) Vegetation management for promoting ecosystem resilience in fire-prone Mediterranean shrublands. Restor Ecol 17(3):414–421
Vallejo VR (1999) Post-fire restoration in Mediterranean ecosystems. In: Eftichidis G, Balabanis P, Ghazi A (eds) Wildfire management – proceedings of the advanced study course held in Marathon, Greece, 6–14 October 1997. Algosystems SA & European Commission DGXII, Athens, pp 199–208
van de Leemput IA, Dakos V, Scheffer M, van Nes EH (2018) Slow recovery from local disturbances as an indicator for loss of ecosystem resilience. Ecosystems 21(1):141–152
Viedma O, Meliá J, Segarra D, García-Haro J (1997) Modeling rates of ecosystem recovery after fires by using Landsat TM data. Remote Sens Environ 61(3):383–398
Whelan RJ (1995) The ecology of fire. Cambridge University Press, Cambridge
Wilson AM, Latimer AM, Silander JA (2015) Climatic controls on ecosystem resilience: Postfire regeneration in the Cape Floristic Region of South Africa. Proc Natl Acad Sci 112(29):9058–9063
Zammit CA, Zedler PH (1988) The influence of dominant shrubs, fire, and time since fire on soil seed banks in mixed chapparal. Vegetatio 75:175–187

Chapter 6
Turkey's Wild Orchids

Nazli Turkmen

6.1 Introduction

Orchidaceae family is the largest family of flowering plants and it is reported that the origin of wild orchids dates back to 120 million years ago (Hossain 2011). However, the evidence of the existence of these plants was first encountered in the herbal writings of Japan and China 3000–4000 years ago (Gabel 2005). Wild orchids are grown all over the world, except Antarctica and deserts, but are mostly found in tropical and sub-tropical regions (Hossain 2011).

Turkey in terms of wild orchids is one of the richest countries in Europe and the Middle East. These plants belong to the *Orchidaceae* family and are found in almost every region of Turkey. Wild orchids are perennial herbaceous plants and each plant usually carries 2 tubers. One of these tubers is the old tuber formed in the previous year and the other is the newly formed tuber. The locals generally name wild orchids as "salep" or "salep grass" since the salep is produced from the tubers of these plants.

The importance of wild orchids has probably emerged with the use of their tubers for medicinal purposes. Wild orchid tubers have been used for their therapeutic effects for centuries (Hossain 2011) all over the world. In Turkey, however, salep is primarily used in the production of Maraş ice cream which is a traditional dairy product and a hot beverage called salep. According to Sandal and Söğüt (2010) approximately 10–20 million wild orchid tubers are collected from their habitats annually, but the number estimated by other authors is reported as 30 million (Özhatay 2002) and 40 million (Sezik 2002). Approximately 1000 to 4000 tubers, weighing 0.25 to 1 g, are needed to obtain 1 kg of salep (Tekinşen and Güner 2010). In contrast to governmental prohibition and strong legal sanctions for unauthorized gatherers, there is an ongoing annihilation of millions of individuals annually.

N. Turkmen (✉)
Faculty of Agriculture, Department of Dairy Technology Diskapi, Ankara University, Ankara, Turkey
e-mail: nazli.turkmen@ankara.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_6

Removal of newly formed tubers during the harvesting of wild orchids is greatly destroying the population level as these are responsible for the following generation (Tamer et al. 2006). Sezik (2002) has indicated that salep harvesting affects 85% of wild orchid species in Turkey. In addition to intense harvesting of tubers of wild orchids, habitat loss, increased land use for agriculture (Şekercioğlu et al. 2011; Yilmaz 1997), overgrazing (Özhatay et al. 2013), and tourism are threatening Turkey's wild orchid flora (Kasparek and Grimm 1999; Sezik 2002; Tecimen et al. 2010).

6.2 Distribution Areas of Wild Orchid Species in Turkey

The presence of 80 species belonging to 10 genera of wild orchids has been reported from Turkey (Anonymous 2014). According to Sandal and Söğüt (2010) this number is 24 genera and 90 species, whereas Sezik (2002) has reported that a total of 150 species grow in Turkey. In general, there are more than 20,000 different species belonging to the Orchidaceae family placed under 900 genera in the world (Gabel 2005) and an important part of the species of this family, 28 species from 5 genera, grow in Turkey as endemics (Sandal and Söğüt 2010).

Turkey is very rich in the wild orchid diversity, and these are grown in almost every region, especially in the southwest of the country, the Mediterranean and the Aegean Regions, and mostly in the province of Muğla. Approximately half of the total number of wild orchid species in Turkey grow in Muğla (Sezik 1984; Kreutz 2002). A general view of some different wild orchid species growing in various regions of Turkey is shown in Fig. 6.1.

Wild orchids are usually found in pine forests and meadows, but depending on the needs of each species, soil types and altitudes vary considerably. For example, the *Comperia comperiana* is not seen below an altitude of 500 m, while *Orchis mascula* ssp. *pinetorum* can be seen at almost any altitude up to 2500 m. *Serapias* species are more likely to be encountered on the slopes of the hills which are very close to the coasts (Sezik 1984).

The conservation status of native orchids in Turkey is largely unknown. Most of the species have not been evaluated according to the criteria of IUCN's (International Union for the Conservation of Nature and Natural Resources) global Red List of Threatened Species, nor nationally assessed. Considering the hazard classes listed in the IUCN, there are 3 (2 endemics) endangered species (*Ophrys isaura, O. lycia*, and *Serapias parviflora*), 3 endemic species (*O. cilicica, O. phrygia*, and *O. transhyrcana* ssp. *amanensis*) under threat, and 11 (2 endemics) species (*O. holoserica* ssp. *heterochila, O. reinholdii* ssp. *leucotaenia, Barlia robetiana, Dactylorhiza incarnata, Listera cordata*, *Ophrys attica*, *O. holoserica* ssp. *candica, O. oestrifera* ssp. *heldreichii, O. omegaifera*, *Orchis lactea*, and *O. stevenii*) are vulnerable (Ekim et al. 2000).

Fig. 6.1 Different species of wild orchids from different regions of Turkey. (**a**) Burdur, (**b**) Manisa, (**c**) Muğla, (**d**) Yozgat. (Turkmen Nazli, personal archive)

6.3 Wild Orchids and Salep

Despite the rapid loss of wild orchids, awareness among the general public and within the relevant authorities is lacking in Turkey. A survey conducted with salep collectors from different regions of Turkey has revealed interesting data which prove that the number of wild orchid species is decreasing day by day. A detailed study has been carried out by Sandal Erzurumlu and Doran (2011), questioning 103 salep collectors in a wide area covering Mersin, Adana, Kahramanmaraş, and Karaman provinces between 2005 and 2007. The interviews point out that 70.9% of the collectors report to have collected 1–5 kg, 24.2% 5–10 kg, and 4.9% 10–15 kg of wild orchid tubers per year. 51.4% of the collectors, who are also farm animal owners, stated that the animals harmed the wild orchids and the collectors reported that they could not find wild orchids in their habitats anymore. 65% of the respondents stated that the measures to be taken for the protection of these plants should be explained to the local people and 72.9% of them stated that they would participate unconditionally in these protection activities.

Interestingly, it is recognized that wild orchids growing within graveyards offer a potential in conservation of wild orchids in Turkey (Kaya et al. 2008; Kreutz and Çolak 2009). A recent field study has demonstrated that salep is harvested even from Turkish graveyards (Löki et al. 2015). In another study, it was reported that some wild orchid species are highly affected from salep harvesting in these areas especially due to collection during early flowering stages (Molnár et al. 2017).

Considering the efforts on the propagation of wild orchids, the most extensive work in Turkey is "Salep Action Plan" carried out by the General Directorate of Forestry of the Republic of Turkey Ministry of Forestry and Water Affairs. Within the scope of "2014–2018 Salep Action Plan", establishment of gene-source seed gardens, extending the distribution areas by transferring wild orchid individuals raised in nurseries to their natural environment, and also preservation and propagation of the species in their natural environment are aimed. According to the results of the research on the propagation of wild orchid individuals in the culture medium, *Serapias vomeracea*, *Orchis sancta*, and *Ophrys bombylifera* were the most promising species considering their tubing ability, and it was indicated that the first two of these species were the most convenient species considering their adaptation to medium culture conditions and widespread availability. The species of *Orchis morio*, *Orchis italica*, and *Orchis anatolica* were also reported as promising species (Anonymous 2014). Unfortunately, the final report of "2014–2018 Salep Action Plan" was not available during preparation of the present study.

Many other studies (Çağlayan et al. 1998; Gümüş 2009; Kısakürek and Arpacı 2010; Bulunuz Palaz et al. 2012; Tutar et al. 2013; Kemeç et al. 2015; Bektaş 2016; Çığ and Yılmaz 2016, 2017; Gümüş et al. 2017; Bozdemir et al. 2018; Kemeç Hürkan et al. 2018) have been carried out in order to enlighten the number of wild orchid species facing the danger of extinction. These studies are mostly focused on the cultivation of wild orchids in the culture medium. In these studies, germination and protocorm formation could be achieved, but some problems were encountered in transformation to the plant and transferring the plant to external conditions.

Therefore, it is possible to say that the results obtained from the studies conducted regarding the reproduction of wild orchids growing in Turkey lack qualification that can be used in practice. The main reasons for this are: lack of continuity in the institutions working on the subject, inability to provide adequate communication between the institutions, and especially very different needs of even the different genotypes of the same wild orchid species under in vitro conditions (Gümüş and Ellialtıoğlu 2012). Therefore, it is thought that the studies to be carried out on as many different species of wild orchids as possible should have continuity. It is only possible to maintain the plant diversity in this way.

The tubers of 85% of the wild orchids growing in Turkey are used for salep. The tubers of the plants may differ in color, size, and shape according to the species. Figure 6.2 shows the tubers of different species that differ in size and shape.

Salep is obtained by washing the tubers in water (milk or ayran in some regions) in order to stop the enzymatic activity and to gain the specific aroma, drying the tubers in the shade and then milling them into powder (Sezik 1984).

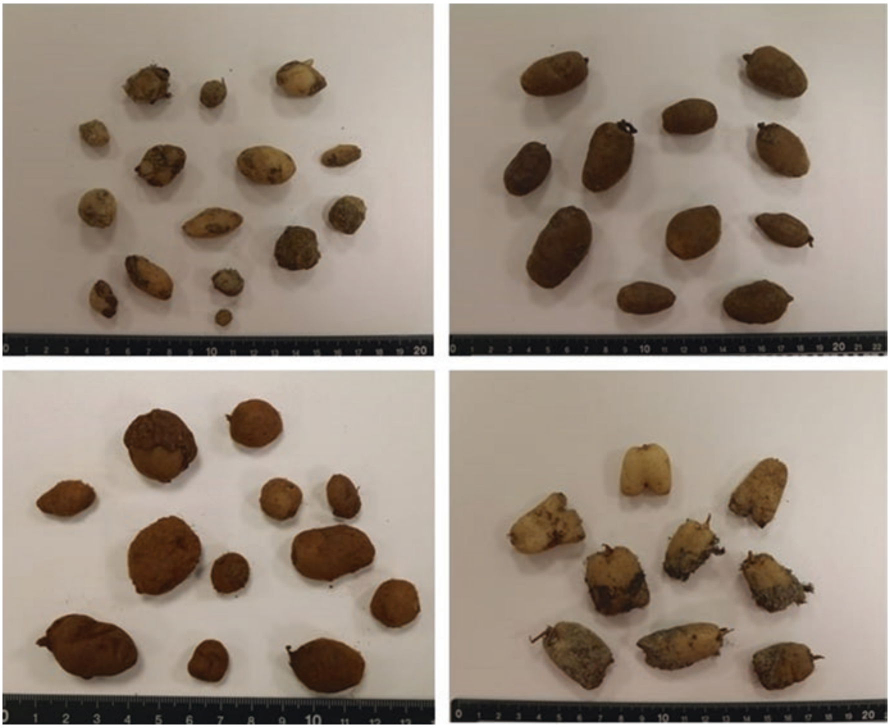


Fig. 6.2 Tubers with different sizes and shapes (Turkmen Nazli, personal archive)

Wild orchids often have two tubers, one is shrunken, darker colored which belongs to the previous year and the other one is currently formed. However, there are also some wild orchid individuals which possess more than 2 or even 4–5 tubers. Figure 6.3 shows the tuber remained from the previous year and the newly formed tubers belonging to different species. The tubers used to obtain salep are newly formed tubers.

Salep obtained from these newly formed tubers has been used for different purposes in Turkey and has been exported to other countries for centuries. According to European sources, in the 1700s, salep was obtained from Izmir in particular, and also from Muğla, Milas, and Kastamonu. These sources report that the amount of salep exported is reported to be approximately 6.5 tons per year. Salep exports continued for centuries and the amount of salep exported increased to 15 tons per year. Considering the warnings made later, the Republic of Turkey Ministry of Agriculture has prohibited the export of salep to abroad (Sezik 1984) and this ban is still ongoing.

As mentioned above, wild orchids have been collected and their tubers used for different purposes for centuries in Turkey. It is known that salep has been mentioned in medicinal books since ancient times. In Ibn Sina's writings, there is extensive information about salep and the pastes containing salep were described as having aphrodisiac, appetizing, and refreshing effects. Salep was described as a drug with

Fig. 6.3 The tubers of different species of wild orchids (the shrunken tuber from the previous year and the newly formed tubers). (Turkmen Nazli, personal archive)

similar effects in also many other medical books and it was stated that besides tuberculosis it is good for almost all diseases. Other records mention that salep was used for making hot drinks and ice cream and it was included in the composition of the pastes prepared for the sultans in the Ottoman Palace (Sezik 1984).

Today salep is mostly used in salep beverage and Maraş ice cream production in Turkey. Maraş ice cream was registered as a PDO (Protected Designation of Origin) in 2018 and it was stated that the product content consists of a mixture of salep and the milk of goats fed with flowers such as thyme, hyacinth, and crocus within the borders of Kahramanmaraş province. Maraş ice cream has many distinctive features besides it has own taste and aroma. The product has a chewable elastic structure, homogeneous white color, lower overrun, and it is more resistant to melting than other ice creams, and it also maintains its properties at −18 °C or lower temperatures for a longer time (Anonymous 2018).

Maraş ice cream owes these properties especially to salep. Salep contains glucomannan and starch in different ratios according to the wild orchid species. Glucomannan is the major component of Maraş ice cream which provides the unique flavor to the product and its late-melting and knife-cutting structure and starch, which is a polysaccharide, is characterized by its swelling property as an adjunct to glucomannan in the formation of this structure (Sezik 1984).

Glucomannan is a polysaccharide belonging to the mannan family contained in the roots, tubers, and bulbs of many plants in nature. The best-known source of glucomannan in the world is the tubers of the species belonging to *Araceae* family and *Amorphophallus* genera, also known as the konjac plant which is the most commonly cultivated, and therefore the most commonly used source. Regardless of which source, glucomannan consists of D-mannose and D-glucose monomers combined with β-1,4 bond. However, the rate of mannose/glucose may vary depending on the source from which glucomannan is obtained. For example, this ratio is 1.6:1

or 3:2 in konjac glucomannan, while it is 2.1:1 in Scotch pine glucomannan and 3.6:1 in wild orchid glucomannan (Tekinşen et al. 2009; An et al. 2010). Many scientific studies have shown that glucomannan helps weight control, reduces stress on the pancreas, helps to prevent blood sugar abnormalities such as hypoglycemia, and helps to normalize blood sugar (Walsh et al. 1984; Hozumi et al. 1995; Vuksan et al. 1999).

Despite the large number of wild orchid species growing in Turkey, very few studies (Tekinşen and Güner 2010; Çitil and Tekinşen 2011; Bulut Solak et al. 2017; Şen et al. 2018) have focused on the glucomannan and starch contents and other properties of salep. With the determination of the characteristics of more wild orchid species, the species which are more suitable for the production of salep beverage and Maraş ice cream will prove fruitful and at the same time, the main reasons of collecting from nature can be revealed. It seems possible to reduce the collection of these plants from nature by further research on the cultivation of wild orchids in culture media.

6.4 Conclusions

Turkey is still one of the richest countries in Europe and the Middle East considering the wild orchid existence today. However, many species of wild orchids in Turkey are under threat. These are harvested from nature mainly for salep production. Salep is used in the production of salep beverage and traditional Maraş ice cream. Although it is known that some species are not suitable for ice cream production, suitability of species needs to be addressed. The salep obtained from every wild orchid species cannot be used in Maraş ice cream production. It is thought that it is possible to prevent the collection of many wild orchids from nature by determining the wild orchid species which are suitable for Maraş ice cream production and by focusing on the studies related to the propagation of these species in culture medium.

Acknowledgment The author would like to thank Dr. Halit Kanca for his technical assistance.

References

An NT, Thien DT, Dong NT et al (2010) Characterization of glucomannan from some Amorphophallus species in Vietnam. Carbohydr Polym 80:308–311

Anonymous (2014) Salep action plan. the General Directorate of Forestry of the Republic of Turkey Ministry of Forestry and Water Affairs, 32, Ankara

Anonymous (2018) Maraş dondurması. No:344 - Mahreç işareti. Türk Patent Enstitüsü, 5, Ankara

Bektaş E (2016) *Dactylorhiza urvileana*'nın in vitro asimbiyotik çimlendirilmesi ve fidelerinin oluşturulması. Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi 17(1):89–95

Bozdemir H, Çığ A, Türkoğlu N (2018) Effects of different concentrations of carbohydrate forms on *Orchis sancta* L. propagation in vitro. Appl Ecol Env Res 16(4):4849–4864
Bulunuz Palaz E, Özdemir A, Kaya Y (2012) Bazı salep orkide türlerine ait tohumların asimbiyotik çimlendirilmesi üzerine yapılan araştırmalar. Türkiye 2. Orkide ve Salep Çalıştayı, 25–26 April 2012, Proceeding Book, 293–300, İzmir
Bulut Solak B, Alonso-Miravalles L, O'Mahony JA (2017) Composition, morphology and pasting properties of *Orchis anatolica* tuber gum. Food Hydrocoll 69:483–490
Çağlayan K, Özavcı A, Eskalen A (1998) Doğu Akdeniz Bölgesinde yaygın olarak yetişen bazı salep orkidelerinin embriyo kültürü kullanılarak in vitro koşullarda çoğaltılmaları. Turk J Agric For 22:187–191
Çığ A, Yılmaz H (2016) Determination of in vitro plantlet formation potential of some terrestrial orchid species. In: Efe R, Matchavariani L, Yaldir A, Lévai L (eds) Development in science and engineering. St. Kliment Ohridski University Press, Sofia, pp 31–42
Çığ A, Yılmaz H (2017) In vitro symbiotic culture studies of some orchid species. J Agric Sci 23:453–463
Çitil OB, Tekinşen KK (2011) A comparative study on fatty-acid composition of salep obtained from some *Orchidaceae* species. Chem Nat Compd 46(6):943–945
Ekim T, Koyuncu M, Vural M et al (2000) Türkiye Bitkileri Kırmızı Kitabı. Türkiye Tabiatını Koruma Derneği, 246, Ankara
Erzurumlu GS, Doran İ (2011) Türkiye'de salep orkideleri ve salep kültürü. Harran Üniversitesi Ziraat Fakültesi Dergisi 15(1):29–34
Gabel R (2005) The role of CITES in orchid conservation. Endangered Species Bull xxx(2):14–15
Gümüş C (2009) Batı Karadeniz Bölgesi'nde salep elde edilmesinde kullanılan bazı orkide türlerinin (*Orchidaceae*) çoğaltım yöntemleri üzerinde araştırmalar. PhD Thesis, Ankara University, Ankara
Gümüş C, Ellialtıoğlu Ş (2012) Salep bitkisinin doku kültürü ile çoğaltılması ve arazi koşullarına aktarma çalışmaları. Türkiye 2. Orkide ve Salep Çalıştayı, 25-26 April, Proceeding Book, İzmir, p 259-267
Gümüş C, Ellialtıoğlu ŞŞ, Eman ŞB (2017) Studies for obtaining the protocorms and plantlets in *Orchis pinetorum, Anacamptis pyramidalis*, and *Dactylorhiza nieschalkiorum* under in vitro conditions. Int J For Hort 3(3):28–36
Hossain MM (2011) Therapeutic orchids: traditional uses and recent advances – an overview. Fitoterapia 82:102–140
Hozumi T, Yoshida M, Ishida Y et al (1995) Long-term effects of dietary fiber supplementation on serum glucose and lipoprotein levels in diabetic rats fed a high cholesterol diet. Endocr J 42(2):187–192
Kasparek M, Grimm U (1999) European trade in Turkish salep with special reference to Germany. Econ Bot 53(4):396–406
Kaya E, Varol Ö, Aytepe HA (2008) Urban flora of Muğla (Muğla, Turkey). Flora Mediterranea 18:127–148
Kemeç Hürkan Y, Hürkan K, Akı C (2018) Comparative growth media performances on in vitro propagation of some salep orchids. Anadolu Üniversitesi Bilim ve Teknoloji Dergisi C-Yaşam Bilimleri ve Biyoteknoloji 7(1):52–62
Kemeç Y, Hürkan K, Akı C (2015) In vitro pollen germination of orchids traditionally used to produce salep. Eur J Environ Sci 5(2):148–152
Kısakürek Ş, Arpacı BB (2010) Kahramanmaraş doğal florasında bulunan bazı salep orkidelerinin kültüre alınabilme olanakları. BAHÇE 39(2):9–16
Kreutz KCAJ (2002) Türkiye'nin orkideleri, salep, dondurma ve katliam. Yeşil Atlas 5:98–109
Kreutz KCAJ, Çolak AH (2009) Türkiye orkideleri: Botanik özellikleri, ekolojik özellikleri, doğal yayılış alanları, yaşam tehditleri, koruma önlemleri. Rota Yayınları, 848, Istanbul
Löki V, Tökölyi J, Süveges K et al (2015) The orchid flora of Turkish graveyards: a comprehensive field survey. Willdenowia 45:231–243

Molnár VA, Löki V, Máté A et al (2017) The occurrence of *Spiraea crenata* and other rare steppe plants in Pannonian graveyards. Biologia 72(5):500–509

Özhatay N (2002) Diversity of bulbous monocots in Turkey with special reference. Chromosome numbers. Pure Appl Chem 74(4):547–555

Özhatay N, Koçyiğit M, Yüzbaşıoğlu S, Gürdal B (2013) Mediterranean flora and its conservation in Turkey: with special reference to monocot geophytes. Flora Mediterranea 23:195–208

Sandal G, Söğüt Z (2010) Türkiye orkideleri (salepler). Mediterr Agric Sci 23(2):109–116

Şekercioğlu ÇH, Anderson S, Akçay E et al (2011) Turkey's globally important biodiversity in crisis. Biol Conserv 144(12):2752–2769

Şen MA, Palabiyik İ, Kurultay Ş (2018) Composition, viscosity and solubility of saleps from twenty different orchid (*Orchidaceae*) species. J Food Meas Char 12:1334–1339

Sezik E (1984) Orkidelerimiz. Türkiye'nin Orkideleri. Sandoz Kültür Yayınları No:6. Güzel Sanatlar Matbaası, 166, İstanbul

Sezik E (2002) Turkish orchids and salep. Acta Pharmaceutica Turcica 44:151–157

Tamer CE, Karaman B, Copur OU (2006) A traditional Turkish beverage: Salep. Food Rev Int 22:43–50

Tecimen HB, Sevgi O, Kara O et al (2010) The problems of salep species of Turkey and solution suggestions. J West Mediter Fores Inst 10:1–30

Tekinşen KK, Güner A (2010) Chemical composition and physicochemical properties of tubera salep produced from some *Orchidaceae* species. Food Chem 121(2):468–471

Tekinşen KK, Güner A, Uçar G (2009) Dondurma üretiminde konjak sakızının kullanılabilme imkanları. TÜBİTAK Project No: 1070461, Konya

Tutar M, Çiçek F, Sarı AO et al (2013) Ege Bölgesinde doğal yayılış gösteren bazı orkide türlerinin kültüre alınması. 5. Süs Bitkileri Kongresi, 6-9 May, Proceeding Book, Yalova, 74–83

Vuksan V, Jenkins DJ, Spadafora P et al (1999) Konjac- mannan (glucomannan) improves glycemia and other associated risk factors for coronary heart disease in type 2 diabetes. A randomized controlled metabolic trial. Diabetes Care 22(6):913–919

Walsh DE, Yaghoubian V, Behforooz A (1984) Effect of glucomannan on obese patients: a clinical study. Int J Obes 8(4):289–293

Yilmaz KT (1997) Ecological diversity of the eastern Mediterranean region of Turkey and its conservation. Biodivers Conserv 7(1):87–96

Chapter 7
Agrodiversity in Turkey: Case Study on Rice

Münir Öztürk, Khawar Jabran, and Mirza Hasanuzzaman

7.1 Introduction

Rice stands among the top cereals of the world which importantly ensure food security at the global level. Importance of rice is not limited to a food crop, it has a worth owing to its cultural, food, feed, medicinal, and industrial values (Sardar et al. 2018; Nada and Abogadallah 2018; Ali et al. 2019; Fei et al. 2020; Rehman et al. 2020; Ruqia et al. 2020; Sajid et al. 2020).

Rice probably originated from the Himalayan plains which include the today's Pakistan and India (Fig. 7.1). Two species of rice (*Oryza sativa* L. and *Oryza glaberrima* Steud.) are currently under cultivation throughout the world. *O. glaberrima* is grown in Africa (also called African rice) and *O. sativa* in Asian countries and rest of the world (Khush 1997).

Although rice is grown on all the continents of the world where humans cultivate the soils, more than 90% of the world rice is produced from Asian rice fields. China, India, Indonesia, Vietnam, and Thailand are the leading rice-producing countries which contribute more than ¾ of the total rice grain production in the world (Seck et al. 2012). Pakistan and India are important for growing extra-long, high-quality, and fragrant-grained rice (Calingacion et al. 2014).

The rice acreage, total production, and yield in the world have witnessed a consistent improvement over several decades. For example, during 1960s, total rice production in the world was nearly 313 million tons, but has now reached to almost

M. Öztürk (✉)
Botany Department & Centre for Environmental Studies, Ege University, Izmir, Turkey

K. Jabran
Faculty of Agriculture, Düzce University, Merkez/Düzce, Turkey

M. Hasanuzzaman
Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_7

Fig. 7.1 Rice field plantation – a view from Kashmir

698 million tons. The current rice acreage is more than 150 million ha with an average paddy yield of over 4 t ha^{-1}; almost double to the rice yield in the 1960s.

Aerobic rice is a system of growing rice which need less labor and lower water input than the conventional system (Bhushan et al. 2007). In this system, the rice seeds are sown on well prepared soil either manually or using a seed drill (Joshi et al. 2013). Mostly, the aerobic rice is grown on flat lands. Further, in the system of aerobic rice, either furrow-beds or furrow-ridges are made to sow rice seeds on the top of bed or among the ridges. Aerobic rice can also be grown while adopting the conservation agriculture systems. Under such situations, the aerobic rice is sown on a no tilled soil using zero tillage rice sowing drill (Jabran et al. 2013; Mahajan et al. 2013).

As lower water inputs are provided to the aerobic rice systems than the conventional systems, the lower soil moisture contents can result in drought conditions (Kato and Okami 2011; Serraj et al. 2011). Hence, proper water management is especially important for the aerobic rice systems. Further, the moisture stress can be intensified owing to higher moisture evaporation rates caused by higher summer temperatures (Nie et al. 2012). The situation demands a management which can improve the soil moisture retention in the soil. Ground covers or mulches can be applied to improve for higher soil moisture retention. Plastic and straw mulches are important in this regard (Davies et al. 2011).

Poor fertilizer and pest management are the factors which can reduce the aerobic rice productivity. Diseases and weeds are most critical among the pests of aerobic rice. For example, the weeds can even lead to total destruction of the aerobic rice crop (Chauhan and Johnson 2011; Jabran et al. 2012a). Similarly, the disease intensity increases when rice is grown under aerobic conditions. Hence, weeds and disease management need special attention for harvesting higher yields of aerobic rice.

In this chapter, we summarize the most important aerobic rice cultivars along with the explanations regarding the seed rate to harvest highest paddy yields. This chapter also discusses the important sowing methods for aerobic rice, the ways for enhancing the soil water retention, the water management, fertilizer management, and pest management. Further, the implications regarding the harvesting and yield, and the molecular aspects of aerobic rice cultivation have also been discussed.

7.2 Cultivars and Seed Rate

The crop environment changes by shifting from the conventionally puddled flooded rice to the aerobic rice; hence, growing rice under this system requires cultivars different than the ones grown in the conventional system. The cultivars which can establish a good crop stand and possess a quick early growth may be more suitable for growing aerobic rice. Several studies have evaluated the suitability of different rice cultivars for aerobic rice growing. For instance, in China, special cultivar named as "Han Dao" has been used to plant the aerobic rice. Two aerobic rice cultivars (HD 502 and HD597) and one lowland cultivar (JD305) have been grown both under the flooded and aerobic conditions. JD305 has yielded higher under the flooded conditions than the aerobic environment (Xiaoguang et al. 2005). Similarly, with a water supply of 650 mm, HD502 has given a yield of 5.3–5.7 t ha^{-1} while HD297 has given 4.7–5.3 t ha^{-1} (Xiaoguang et al. 2005). Han Dao 502, Han Dao 297, and Han Dao 277 are some of the other aerobic rice cultivars which have been grown in China (Wang et al. 2002). Likewise, Apo is the other cultivar which is specified for growing under aerobic conditions. The cultivar yields are higher when grown as aerobic rice, and it has been under practice in the Philippines and some other rice-growing countries (Bouman et al. 2005).

In a study conducted in India, Pusa Basmati-1 and Basmati-386 have been evaluated for aerobic rice cultivation. Pusa Basmati-1 has been found to yield higher (2.24 t ha^{-1}) than Basmati-386 (2.10 t ha^{-1}) (Yadav et al. 2007). Another study from India has compared 12 cultivars for their suitability to grow under the aerobic conditions. PMK 3, ASD 16, and MDU 3 were found as the high-yielding rice cultivars under the aerobic conditions with respective yields of 3.7, 3.1, and 2.9 t ha^{-1} (Martin et al. 2007).

A variable quantity of seed has been reported on aerobic rice in different parts of the world. Seed rate can vary depending on the grain size, cultivar type, seed germination percentage, seed viability, sowing conditions, sowing method, field conditions, and weather. A survey of farmers in Sri Lanka indicated that the seed rate used by different farmers was greatly variable where 71–220 kg ha was being used by different growers (Weerakoon et al. 2011). A study evaluated three seed rates (30, 40, and 50 kg ha^{-1}) for sowing the aerobic rice. The lowest seed rate among the investigated ones – 30 kg ha^{-1} attained the higher number of effective tillers (376 no. m^{-2}) and grain yield (2.27 t ha^{-1}) that had higher seed rates, i.e., 40 and 50 kg ha^{-1} (Yadav et al. 2007). A study from Bangladesh has evaluated five seed rates for aerobic rice (20 to 100 kg ha^{-1} with a difference of 20 kg) for two years, and concluded that the higher crop yields (5.15 t ha^{-1}) are obtained with seed rate 40 kg ha^{-1} (Ahmed et al. 2014). Conversely, a study conducted in the Philippines during two seasons (wet and dry) has used three seed rates (40, 80, and 160 kg ha^{-1}). During the wet season, the three seed rates had the same yield while during dry season, higher seed rates were found to give higher yield (Phuong et al. 2005). The seed rates of 40, 80, and 160 kg ha^{-1} had a yield of 1.32, 2.5, and 3.3 t ha^{-1}, respectively (Phuong et al. 2005). A study, where seed rates have been evaluated in a range (15–125 kg ha^{-1}) for aerobic rice, clearly demonstrates the most suitable seed rates for either the hybrids or in-bred cultivars. For cultivars, a seed rate between 48 and 80 kg ha^{-1} is sufficient to harvest highest yield of aerobic rice, while for hybrids, a seed rate between 95 and 125 kg ha^{-1} is more suitable (Chauhan et al. 2011).

Several cultivars have been evaluated for growing aerobic rice. Many of the cultivars yield higher under aerobic conditions, such as Apo and Han Dao cultivars. Moreover, diverse results have been obtained regarding the seed rate of aerobic rice, which means seed rate can be adjusted according to the specific conditions of the sowing site. However, a seed rate of above 40 kg ha^{-1} and below 80 kg ha^{-1} might be suitable under most conditions.

7.3 Water Management

Aerobic rice possesses a particular significance for the water shortage areas of the world where rice is grown. Hence, appropriate water management is very critical for growing rice under such environments. The water management is done to achieve objectives such as improving water productivity and saving water (i.e., reducing water input). These objectives are realized by irrigating the crop with what it desires for evapo-transpiration, and avoiding the water inputs which are lost in the form of evaporation, seepage, and leaching.

For aerobic rice at farmer's level, water-saving and higher water productivity can be obtained by closely watching the soil water requirements, and watering the crop at moisture depletion. Farmers can set an interval for irrigating the aerobic rice crop; for this purpose an interval between 5 and 10 days may be suitable for most of the farms. However, such intervals should be flexible according to the soil and weather conditions. Use of cultivars which are efficient to draw water, especially the ones with long roots, can help to harvest more rice with less water.

Similarly, the productivity of applied water can be increased by improving its retention in the field, the techniques of mulching to harvest will prove beneficial as discussed above. Moreover, organic matter may be applied to the aerobic rice fields in the form of compost to enhance the moisture retention. Although some chemicals which prolong the water retention in the soil are being sold in markets, no sound report describes the utility of such products.

The conventional rice requires higher water quantities (1000–1500 mm, or even higher) than the aerobic rice. However, the latter can be grown with limited water supply. For example, the result of study on aerobic rice indicates that a total water input of 688 mm helps to obtain a yield of 4.5 t ha^{-1} for HD297 cultivar (Xue et al. 2008b). Similarly, the study conducted by Xiaoguang et al. (2005) indicates that yields equal to 3–3.5 t ha^{-1} are harvested by irrigating the crop with 450–500 mm water, while this yield increases to 4.7–5.3 t ha^{-1} with 650 mm of applied water. In another study, applying approximately 600–800 mm water to aerobic rice shows that it yields more than 6 t ha^{-1} of paddy grains (Xue et al. 2008a). One study has compared the aerobic rice grown on beds with the conventionally grown rice. The aerobic rice on beds needed 930 mm water compared to 1600 mm required to grow rice under the conventional system (Choudhury et al. 2007). However, yields are lower for bed planted aerobic rice (3.2 t ha^{-1}) than the conventional system (5.5 t ha^{-1}) (Choudhury et al. 2007). Nevertheless, nearly 40% water-saving has been recorded when aerobic rice was grown in a furrow-bed system.

The use of sophisticated irrigation systems like sprinkler and drip irrigation for growing aerobic rice can result in a significantly increased water-saving and improved water productivity. Such management options are being evaluated in different parts of the world, and if workers are successful, it will help to produce higher rice quantities with lower water inputs.

7.4 Fertilizer Management

Approximately, half of the yield potential of a crop is realized if the plants are fertilized properly. Poor fertilizer management is among the major reasons which reduce the aerobic rice yields. Majority of farmers do not follow the recommendations regarding the quantity and timing of fertilizer application in aerobic rice production (Weerakoon et al. 2011). The nutrient recovery has been found poorer in aerobic than conventional rice (Belder et al. 2005). The packages for nutrient management for aerobic rice are still under development; hence, current literature does not provide much information regarding the nutrient management in aerobic rice. A precise fertilizer management is required to have a healthier rice crop under aerobic environment. The new aerobic rice cultivars are responsive to applied fertilizers, which can lead to a healthier crop and high yields.

Nitrogen is among the essential nutrients deficient in most soils. The studies on aerobic rice regarding fertilizer application mostly elaborate about nitrogen application. Nitrogen applied at 150 kg ha^{-1} results in a yield of 4.2–6.3 t ha^{-1} of paddy grains when grown using Apo cultivar in the Philippines (Belder et al. 2005). The same N rate (i.e., 150 kg ha^{-1}) has helped to achieve the highest yield of aerobic rice (5.39 t ha^{-1}) in a study conducted in India (Mahajan and Timsina 2011). The timing and rates of N application have also been evaluated for the aerobic rice. Among four experiments; in one site N at 90 kg ha^{-1} was sufficient to harvest the highest rice grain yield (4.64 t ha^{-1}); at the second site, the rice crop yielded highest (4.28 t ha^{-1})

in response to applied N of 120 kg ha^{-1} while on the other two sites, a response to applied N was noted up to 150 kg ha^{-1} (Lampayan et al. 2010). The higher rates result in rice crop lodging. The recommendation can be given as to apply N in more in one split (Lampayan et al. 2010). The aerobic rice with an N rate of 120 kg ha^{-1} has yielded 4.9 t ha^{-1} but reached to 5.5 t ha when N was given at 180 kg ha^{-1} (Yadav 2004). A study from India has elaborated information regarding fertilizer use in aerobic rice. Four N rates, i.e., 0, 60, 120, and 180 kg ha^{-1} with and without application of potassium and phosphorus have been evaluated (Mahajan et al. 2012). Fertilizer application has improved the leaf area index, number of panicles, grain yield and decreased the panicle sterility of aerobic rice. The highest effect of N has been realized in terms of leaf area, panicle numbers, and paddy yield up to a level of 120 kg ha^{-1}. Similarly, the decrease in panicle sterility witnessed a positive influence until a level of 120 kg ha^{-1}. N uptake and the yield parameters have been stagnant with an N application of more than 120 kg ha^{-1} (Mahajan et al. 2012). Higher growth, N uptake and paddy yield, and lower panicle sterility have been noted when N was applied in combination with phosphorus and potassium than alone (Mahajan et al. 2012).

Phosphorus is an essential element for crops important after the N. Its availability can be a problem on some paddy soils. Moreover, shifting from conventional to aerobic rice can cause a phosphorus deficiency in paddy soils. Hence, phosphorus management in aerobic rice needs special care. Chinese scientists have indicated that phosphorus addition at 70 kg ha^{-1} is the most appropriate quantity for the aerobic rice cultivation (He et al. 2005).

The fertilizer management needs special care as aerobic rice is a new way of growing rice. N application at the rate of about 120 kg ha^{-1} helps to harvest high yields. The application of N in combination with K and P has a synergistic effect on the growth and yield of aerobic rice.

7.5 Pest Management

Among the rice pests, weeds most importantly infest the crop when grown by the aerobic method. Although the disease intensity may be higher in aerobic than conventional rice, the weeds are a major cause of aerobic rice crop failure. In the case of conventional rice plantation, the weeds are destructed by puddling while transplanting the 3 to 5 weeks seedlings provides rice plants an advantage over the weeds. However, the weeds are abundant with profuse growth when the fields are sown with aerobic rice. A study from Pakistan has shown that weeds cause more than 75% yield losses in aerobic rice (Jabran et al. 2012a). Only integrated weed management (IWM) can successfully manage the weeds in aerobic rice (Rao et al. 2007; Mahajan et al. 2009). Different techniques can be combined in 4–5 steps to suppress weeds sustainably.

In the first step, the weeds can be avoided to add to the already prevailing weed density in the field by following the principles of prevention (Rao et al. 2007). For aerobic rice, the preventive weed control may include sowing of weed-seed free rice seed, irrigating the crop with weed-seed free water, keeping the field bunds free of weeds, and cleaning the tractor and other agri-equipments before entering to a new field for carrying out different operations (Shibayama 2001; Gibson et al. 2002; Rodenburg and Johnson 2009; Farooq et al. 2011b).

The second step for managing weeds in aerobic rice includes practicing the cultural operations to keep low the weed intensity. Most important of such practices includes intercropping (e.g., aerobic rice + legumes, or aerobic rice + *Sesbania* spp.), sowing crop with higher seed rate (e.g., 70 kg ha^{-1} or higher), sowing crop keeping the rows closer, changing the sowing time (e.g., sowing the rice crop earlier or later than the recommended time), preparing a stale seedbed, sowing of allelopathic cultivars, and crop rotation (Shibayama 2001; Phuong et al. 2005; Rodenburg and Johnson 2009; Chauhan and Johnson 2011; Farooq et al. 2011a).

The third step is the use of either preemergence or postemergence herbicides. Most important aerobic rice preemergence herbicides are pendimethalin, butachlor, pretilachlor, while early postemergence or postemergence herbicides are penoxulam, bispyribac-sodium, cyhalofop-butyl, ethoxysulfuron, and 2,4-D (Mann et al. 2007; Singh et al. 2008; Akbar et al. 2011; Mahajan and Timsina 2011; Jabran et al. 2012a, 2012b; Mahajan and Chauhan 2013). Herbicides can be selected according to the nature of weeds and keeping in mind the feasibility of integration of chemical control with other methods.

The fourth step in executing the IWM in aerobic rice is employing the mechanical methods of weed suppression. Such methods include a wide range of equipments ranging from hand tools to the modern motor weeders. The kind of tool required to be used can be decided according to crop stage, field conditions, and weeds prevalence. Probably, hand tools are suited for small-scale operation while large-scale operation may require tractor-operated tool or modern weeder. Hand weeding may also be employed as a step of IWM, if some weeds are left there after implementing the first four step of IWM. Integrated practice of steps in IWM is the most reliable way to suppress weeds in aerobic rice.

7.6 Harvesting and Yield

Aerobic rice can probably mature earlier than conventional rice. The harvesting of rice sown under aerobic conditions may be easier to harvest than the rice sown by the conventional method. The rice grown by the conventional method is applied with higher water quantities than the aerobic rice; hence, the conventional rice fields may be saturated at the harvesting time. Further, the stems of rice plants in the conventional system may contain higher moisture than the rice plants under aerobic conditions. The higher soil and plant moisture contents can hinder or slower the process of mechanical rice harvesting.

High crop yields can be harvested from the aerobic rice if the crop is managed appropriately. The studies carried out for 6 seasons have compared the paddy yield of aerobic rice among the seasons. The paddy yields have been recorded as above 5 t ha^{-1} for most of the cases (Bouman et al. 2005). The aerobic rice grown in Sri Lanka has been found to have a yield of 3.3 to 5 t ha^{-1}; however, higher yields (5–8 t ha^{-1}) can be obtained if the crop management is precise (Weerakoon et al. 2011). A study from Bangladesh has indicated that yields up to 5.2 t ha^{-1} can be harvested from aerobic rice (Ahmed et al. 2014).

7.7 Rice Cultivation in Turkey

The rice production area in Turkey varies between 50.000 and 60.000 ha. It depends on the availability of irrigation water. The rice-growing area was over 70.000 ha in 1980s, but went up to 77.000 ha in 1982. However, it decreased tremendously during the later years. The reason for this was shortage of irrigation water subsequent to the drought period which prevailed between 1985 and 1994. There were also some limitations on rice importation before 1984. These were lifted or reduced in 1984, which made rice import easier and at lower costs. The production costs were higher than that of imported rice. This too proved effective in this connection. Many farmers left rice cultivation because of irrigation water shortage as well as higher production costs. In some areas of Turkey, rice cultivation was forbidden during the drought period so that the available water could be used for irrigating other crops, like cotton, maize, and vegetables. However, the rice-growing area started to increase again in 1995: from 41,000 ha in 1994 to 58.000 in 1995; and more than 60.000 ha was recorded in 1996. This increase was due to an increase in the rainfall providing more available irrigation water (Surek 1997).

The total milled rice production in Turkey varies between 150.000 and 200.000 tons. This is not enough for domestic consumption. The consumption per capita in the country is 4–5 kg, and the total milled rice consumption is around 300.000 tons. In view of this situation, the milled rice is imported to meet the domestic consumption. The rice imports have increased in the country just in parallelity with the decrease in domestic rice production. The average rough rice yield in Turkey is 5 tons/ha, it has slightly increased (Surek 1997).

Turkey has seven geographical regions and rice can be cultivated in all these regions. However, the main rice-growing regions are the northwestern (Marmara-Thrace) and the northern parts of the country (Black Sea region). The Marmara-Thrace region has the largest rice-growing area and production, followed by the Black Sea region. Although the rice yields have been affected by drought in all the regions, the decreases have been more significant in some regions (e.g., the Mediterranean and Aegean regions). Rice production had been forbidden in the Aegean region because of the shortage of irrigation water. Its cultivation in the micro- and macro-climatic regions of the country provides a fairly good income because rice allows a very high gross profit per unit area. In these regions, there is no alternative crop providing such high income as rice as such rice growing still prevails. In regions where there are alternative high-profit crops (e.g., cotton and maize) or in the case of a drop in rice prices or of water shortage, farmers prefer to grow other crops (Surek 1997).

The rice varieties grown in some regions in Turkey are as follows (Ozturk et al. 1989; Surek 1997): Rocca, Baldo, Sürek-95, Ergene, Veneria, Trakya, Meriç, Ipsala, and Serhat-92 in the Marmara-Thrace region; Ribe, Krasnodarsky-424, Rocca, Serhat-92, and local varieties in the Black Sea region; local varieties in the South-East Anatolia region; Krasnodarsky-424, local varieties in the Central Anatolia region; Rocca, Baldo, Ergene, and local varieties in the Mediterranean region; local varieties in the East Anatolia; and Rocca, Baldo, Veneria, Ribe, Krasnodarsky-424, Maratelli, and some local varieties Rocca, Veneria, and Baldo in the Aegean region.

The Rocca variety occupies the largest growing area in Turkey, followed by Baldo. Local varieties are mostly cultivated in the South-East and East Anatolia regions (Ozturk et al. 1989; Surek 1997). In addition to these, 21 rice cultivars of Turkish origin and 11 rice cultivars from Bulgaria, France, Italy, and Russia (such as Sürek-95, Serhat-92, Rocca, Osmancık 97, Altınyazı, Veneria, Ece, Bonni, Ergene, Akçeltik, Ribe, Europa, Krosnodarsky, Delta, Trakya, Kargı, Gönen, Baldo, Kırkpınar, Neğiş, Demir, Ipsala; 8203-TR413–6–1-1, 82,060-TR470–6–1-1, Balilla, Balilla-28, Lido, Halil Bey, Meric¸ Yavuz; Kıral and 80,110-TR253–4–1-1) have been genetically analyzed by Bal and Bay (2010).

Compared with other temperate countries, such as Spain, Italy, Japan, and South Korea, Turkey's rice yield, which is about 5 tons/ha, seems to be low. It can be increased through the adoption of developed modern rice varieties and new growing techniques used in the above countries with similar rice-growing conditions. Increasing the rice cultivation area in Turkey depends on irrigation water. Since the climate and the soil structure are suitable for rice cultivation in many micro- and macro-climatic regions, if the irrigated area is increased, it will be possible to increase the rice area as well. Some irrigation projects have been conducted, especially in South East Anatolia, and are intended to increase the rice area (Surek 1997).

Turkey is not a primary rice producer, and the country cannot meet the demands of the country's growing rice consumption. In short in order to reduce reliance on foreign rice imports, increased rice production is necessary and aerobic rice growing should also be undertaken (Ozturk et al. 1989; Bal and Bay 2010).

7.8 Conclusions

Higher paddy yields can be harvested with good management of aerobic rice. Several high-yielding aerobic rice cultivars are available in different rice-growing countries of the world. Depending on seed type and environment, a seed rate between 40 and 80 kg ha^{-1} may be suitable for growing aerobic rice. However, higher seed rate may be used to achieve certain objectives, such as suppressing weeds or compensating the poor germination. Drill and manual sowing are among the most important aerobic rice sowing methods; however, methods like furrow-bed and furrow-ridge aerobic rice cultivation methods are also gaining popularity. Water management is very crucial for aerobic rice due to lower water inputs, while mulches can be used to improve soil moisture retention. Fertilizers added at rates like N ~ 120 kg ha^{-1}, P_2O_5 ~ 70 kg ha^{-1} are probably the most suitable rates for the good growth and realizing the yield potential. Diseases and weeds are the most important pests infesting the aerobic rice crop. These two pests can be best tackled by following the principles of integrated pest management.

Aerobic rice can be harvested as higher yields have been reported for aerobic rice from across the world.

Acknowledgments TUBITAK (The Scientific and Technological Research Council of Turkey) is acknowledged for supporting the studies of one of us (Khawar Jabran).

References

Ahmed S, Salim M, Chauhan BS (2014) Effect of weed management and seed rate on crop growth under direct dry seeded rice systems in Bangladesh. PLoS One 9(7):e101919

Akbar N, Ehsanullah JK, Ali MA (2011) Weed management improves yield and quality of direct seeded rice. Aust J Crop Sci 5:688–694

Ali S, Rizwan M, Noureen S et al (2019) Combined use of biochar and zinc oxide nanoparticle foliar spray improved the plant growth and decreased the cadmium accumulation in rice (*Oryza sativa* L.) plant. Environ Sci Pollut Res 26(11):11288–11299

Bal EBB, Bay S (2010) Genetic analysis of Turkish rice varieties (*Oryza sativa* L.) using seed storage proteins and RAPD markers. Eur Food Res Technol 230(4):609–617

Belder P, Bouman B, Spiertz J et al (2005) Crop performance, nitrogen and water use in flooded and aerobic rice. Plant Soil 273:167–182

Bhushan L, Ladha JK, Gupta RK et al (2007) Saving of water and labor in a rice-wheat system with no-tillage and direct seeding technologies. Agron J 99:1288–1296

Bouman B, Peng S, Castaneda A, Visperas R (2005) Yield and water use of irrigated tropical aerobic rice systems. Agric Water Manag 74:87–105

Calingacion M, Laborte A, Nelson A et al (2014) Diversity of global rice markets and the science required for consumer-targeted rice breeding. PLoS One 9:e85106

Chauhan BS, Johnson DE (2011) Row spacing and weed control timing affect yield of aerobic rice. Field Crop Res 121:226–231

Chauhan BS, Singh VP, Kumar A, Johnson DE (2011) Relations of rice seeding rates to crop and weed growth in aerobic rice. Field Crop Res 121:105–115

Choudhury B, Bouman B, Singh A (2007) Yield and water productivity of rice-wheat on raised beds at New Delhi, India. Field Crop Res 100:229–239

Davies W, Zhang J, Yang J, Dodd I (2011) Novel crop science to improve yield and resource use efficiency in water-limited agriculture. J Agric Sci 149:123–131

Farooq M, Jabran K, Cheema ZA et al (2011a) The role of allelopathy in agricultural pest management. Pest Manag Sci 67:493–506

Farooq M, Siddique KH, Rehman H et al (2011b) Rice direct seeding: experiences, challenges and opportunities. Soil Tillage Res 111:87–98

Fei M, Jin Y, Jin L et al (2020) Adaptation of rice to the nordic climate yields potential for rice cultivation at most northerly site and the organic production of low-arsenic and high-protein rice. Front Plant Sci 11:329

Gibson K, Fischer A, Foin T, Hill J (2002) Implications of delayed *Echinochloa* spp. germination and duration of competition for integrated weed management in water-seeded rice. Weed Res 42:351–358

He Y, Shen Q, Kong H et al (2005) Effect of soil moisture content and phosphorus application on phosphorus nutrition of rice cultivated in different water regime systems. J Plant Nutr 27:2259–2272

Jabran K, Ehsanullah HM, Farooq M et al (2012a) Application of bispyribac-sodium provides effective weed control in direct-planted rice on a sandy loam soil. Weed Biol Manage 12:136–145

Jabran K, Farooq M, Hussain M et al (2013) Aerobic rice in reduced tilled fields fetches higher yield and net economic returns. In: Proceedings of 3rd international Conference 'Frontiers in agriculture' held at Dankook International Cooperation on Agriculture, Dankook University, Cheonansi, Republic of Korea during October 3–5, 2012. Dankook University, Cheonansi, pp 5–8

Jabran K, Farooq M, Hussain M et al (2012b) Efficient weeds control with penoxsulam application ensures higher productivity and economic returns of direct seeded rice. Int J Agric Biol 14:901–907

Joshi E, Kumar D, Lal B et al (2013) Management of direct seeded rice for enhanced resource-use efficiency. Plant Knowl J 2:119

Kato Y, Okami M (2011) Root morphology, hydraulic conductivity and plant water relations of high-yielding rice grown under aerobic conditions. Ann Bot 108:575–583

Khush GS (1997) Origin, dispersal, cultivation and variation of rice. In: Oryza: from molecule to plant. Springer, Dordrecht, pp 25–34

Lampayan R, Bouman B, de Dios J et al (2010) Yield of aerobic rice in rainfed lowlands of the Philippines as affected by nitrogen management and row spacing. Field Crop Res 116:165–174

Mahajan G, Chauhan B, Gill M (2013) Dry-seeded rice culture in Punjab State of India: lessons learned from farmers. Field Crop Res 144:89–99

Mahajan G, Chauhan B, Johnson D (2009) Weed management in aerobic rice in northwestern indo-Gangetic Plains. J Crop Improv 23:366–382

Mahajan G, Chauhan B, Timsina J et al (2012) Crop performance and water-and nitrogen-use efficiencies in dry-seeded rice in response to irrigation and fertilizer amounts in Northwest India. Field Crop Res 134:59–70

Mahajan G, Chauhan BS (2013) The role of cultivars in managing weeds in dry-seeded rice production systems. Crop Prot 49:52–57

Mahajan G, Timsina J (2011) Effect of nitrogen rates and weed control methods on weeds abundance and yield of direct-seeded rice. Arch Agron Soil Sci 57:239–250

Mann RA, Ahmad S, Hassan G, Baloch MS (2007) Weed management in direct seeded rice crop. Pak J Weed Sci Res 13:219–226

Martin G, James Padmanathan P, Subramanian E (2007) Identification on suitable rice variety adaptability to aerobic irrigation. J Agric Bio Sci 2:1–3

Nada RM, Abogadallah GM (2018) Root-favoured biomass allocation improves growth and yield of field-grown rice (*Oryza sativa* L.) plants only when the shoot sink is expandable. Acta Physiol Plant 40(6):123

Nie L, Peng S, Chen M et al (2012) Aerobic rice for water-saving agriculture. A review. Agron Sustain Dev 32:411–418

Ozturk M, Pirdal M, Türkan I (1989) Ecology of rice in the Aegean region. In: V International congress of ecology, August 23–30 1990, Yokohama

Phuong L, Denich M, Vlek P, Balasubramanian V (2005) Suppressing weeds in direct-seeded lowland rice: effects of methods and rates of seeding. J Agron Crop Sci 191:185–194

Rao A, Johnson D, Sivaprasad B et al (2007) Weed management in direct-seeded rice. Adv Agron 93:153–255

Rehman R, Tarıq A, Haq N et al (2020) Chapter 5: Mutations leading to a better tomorrow in the production of improved crop varieties. In: Cambridge Scholar, (in press)

Rodenburg J, Johnson D (2009) Weed management in rice-based cropping systems in Africa. Adv Agron 103:149–218

Ruqia S, Haq SN, Ilyas M et al (2020) Chapter 9: Plant metabolomics: role in crop improvement. In: Cambridge Scholar, (in press)

Sajid A, Abbasi A, Gul A et al (2020) Chapter 17: Structural and functional genomics of rice. In: Cambridge Scholar, (in press)

Sardar MF, Ahmad HR, Zıa-Ur-Rehman M et al (2018) Absorption of foliar-applied lead (Pb) in rice (*Oryza sativa* L.): a hydroponic experiment. Fresenius Environ Bull 27(10):6634–6639

Seck PA, Diagne A, Mohanty S, Wopereis MC (2012) Crops that feed the world 7: Rice. Food Sec 4:7–24

Serraj R, McNally KL, Slamet-Loedin I et al (2011) Drought resistance improvement in rice: an integrated genetic and resource management strategy. Plant Product Sci 14:1–14

Shibayama H (2001) Weeds and weed management in rice production in Japan. Weed Biol Manage 1:53–60

Singh S, Ladha J, Gupta R et al (2008) Weed management in aerobic rice systems under varying establishment methods. Crop Prot 27:660–671

Surek H (1997) Rice production and research activities in Turkey. In: Chataigner J (ed) Activités de recherche sur le riz en climat méditerranéen. CIHEAM, Montpellier, pp 165–174. (Cahiers Options Méditerranéennes 24(2))

Wang H, Bouman BAM, Dule Z et al (2002) Aerobic rice in northern China: opportunities and challenges. In: Bouman BAM, Hengsdijk H, Hardy B et al (eds) Water-wise rice production. Proceedings of the International Workshop on water-wise rice production, 8–11 April 2002. International Rice Research Institute, Los Banos, pp 143–154

Weerakoon W, Mutunayake M, Bandara C et al (2011) Direct-seeded rice culture in Sri Lanka: lessons from farmers. Field Crop Res 121:53–63

Xiaoguang Y, Bouman B, Huaqi W et al (2005) Performance of temperate aerobic rice under different water regimes in North China. Agric Water Manag 74:107–122

Xue C, Yang X, Bouman BA et al (2008a) Optimizing yield, water requirements, and water productivity of aerobic rice for the North China Plain. Irrig Sci 26:459–474

Xue CY, Yang XG, Bouman B et al (2008b) Effects of irrigation and nitrogen on the performance of aerobic rice in northern China. J Integr Plant Biol 50:1589–1600

Yadav R (2004) Enhancing efficiency of fertilizer N use in rice–wheat systems of indo-Gangetic Plains by intercropping *Sesbania aculeata* in direct seeded upland rice for green manuring. Bioresour Technol 93:213–215

Yadav S, Gill M, Kukal S (2007) Performance of direct-seeded basmati rice in loamy sand in semi-arid sub-tropical India. Soil Tillage Res 97:229–238

Chapter 8
Agrodiversity in West Asia: Pepper

Esra Koç and Belgizar Karayiğit

8.1 Introduction

The homeland of pepper (*Capsicum*), a member of the Solanaceae family, is central and South America. It is listed among the first plants cultivated in the Americas. There are at least 30 species but *C. annuum, C. frutescens*, *C. chinense*, *C. pubescens*, and *C. baccatum* all belonging to the *Capsicum* stock, are the most widely cultivated native species globally (FAOSTAT 2013). Origin of hot and sweet peppers (*C. annuum*) is Mexico, the origin of aromatic hot peppers (*C. chinese*) is the Amazon Basin, and the origin of the bird pepper (*C. frutescens*) is the coastal regions in the southern parts of tropical South America. Apart from *C. annuum* others are economically cultivated as vegetables only in the central and southern parts of the USA (Abak and Pitrat 1981). Taking into account the fruit and flower characteristics, *C. annuum, C. frutescens*, and *C. chinese* are different from each other and considered as three types; however, these taxa may have shared the same ancestor gene pool through a gene flow between these species, and some morphological characters of taxonomic similarity have created doubts about whether they are different (Grubben and Denton 2004).

Following the discovery of America peppers both sweet and hot were brought to Portugal and Spain. These got scattered throughout the tropical regions of the world from here and were cultivated as a source of vegetable and spice in the late seventeenth century. The hot type of *C. annuum* became more popular than the sweet one. The hot one is also called paprika and bell pepper and is consumed more as a spice in African countries. In Europe, sweet pepper is preferred because it provides more adaptation to the temperate climate. The species *C. baccatum* and *C. pubescens* are native species especially cultivated in Latin America. The commercial species of *C. baccatum* are mainly cultivated in Asian countries, and cold-resistant

E. Koç (✉) · B. Karayiğit
Faculty of Science, Department of Biology, Ankara University, Ankara, Turkey
e-mail: ekoc@science.ankara.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_8

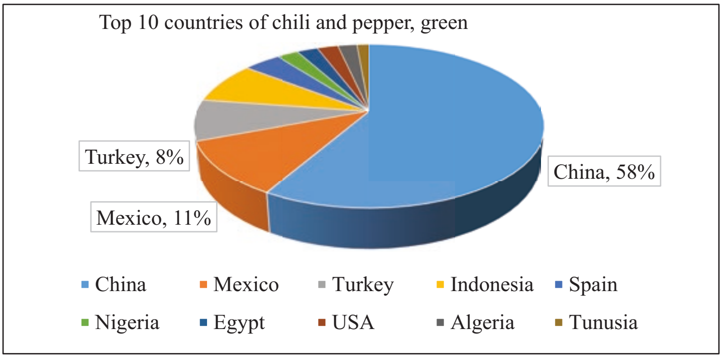


Fig. 8.1 Top 10 countries with production of chilies and peppers, green. (Based on: FAOSTAT data 2018)

C. pubescens, on the other hand, is cultivated in countries with high mountainous regions (Grubben and Denton 2004).

Pepper is an important vegetable in many tropical, subtropical, and temperate climates of the world. Hot peppers are spicy or salty food additives commonly used around the world. It has high value due to its color, flavor, and tanginess features (Barbero et al. 2016). The pepper is reported to be cultivated on a total area of 3.8 million hectares. The most pepper growing areas lie in Asia with 2.5 million hectares, followed by Africa with 0.8 million hectares (FAOSTAT 2013). The data published by FAO reveal that it is included in the ten most produced vegetables in the world with a production of approximately 34 million tons. In global fresh vegetable exports, pepper is second with an export value of 4.5 billion dollars (URL-1). In addition to its economic importance, pepper is also an agricultural product used in pharmacology and medicine because of its biological and functional compounds such as antioxidants, vitamins, and secondary metabolites (URL-2). The secondary metabolite mainly responsible for the bitterness of pepper is capsaicin, which is used in the treatment of low back pain (lumbago), neuralgia (nerve pain) and rheumatic diseases, kidney pain, cancer, Parkinson's, and coronary heart diseases (Antonious 2018).

China ranks first in the production of peppers in the world, followed by Turkey and Mexico (Penella and Calatayud 2018; FAOSTAT 2018) (Fig. 8.1).

8.2 Pepper in Turkey

With diverse terrains and climatic features, we come across ecological differences in different geographical regions of Turkey (Ozturk et al. 2013, 2017a, 2018a, b, c, d; Kafi et al. 2018). There are vast and fertile agricultural lands suitable for the production of new and different types of fruits and vegetables with good quality in the country. It is a major vegetable producer with an annual production of 22.7 million tons (FAOSTAT 2013) a year. Pepper is the third most grown vegetable with 2.6 million tons of production, while green pepper is the most exported vegetable (TUIK 2017; FAOSTAT 2018) (Fig. 8.1).

It links the continents of Europe, Asia, and Africa, possessing different ecosystems inhabited by varying plants and animals, a rich biodiversity, and species endemism (Tan 1998; Uzun and Bayır 2009; Ozturk et al. 2012a, b, 2016; Altay et al. 2013, 2016a, b, 2017). It is also one of the rare countries in terms of plant diversity (Balkaya and Karaağaç 2006; Küçük 2003; Ozturk et al. 2012a, 2016). However, the rich diversity is decreasing or disappearing due to anthropogenic impacts. Turkey is a source of genes for many plants, especially Solanaceae family, and is a micro-gene center as well. The landraces are grown by farmers in almost all regions. Over 1500 accessions of Solanaceae have been collected since 1964. Seeds are preserved in the cold storage gene bank at the Aegean Agricultural Research Institute. The institute has records based on the study covering the years 1964–2000 (ex situ collections of Solanaceae), *C. annuum* is the most common type of pepper in Turkey cultivated currently in nearly 60 provinces: *C. annuum-grossum* in Aksaray, Antalya, Bolu, Kocaeli, Konya, and Sakarya, *C. annuum-longum* in Aksaray, Antalya, Karaman, and Konya, *C. frutescens* in the provinces of Afyon, Balikesir, Bilecik, Burdur, Bursa, Canakkale, Eskisehir, Isparta, Izmir, Manisa, and Usak (Küçük 2003). The local cultivars of pepper grown widely in Turkey are: table green pepper ('Acı Sivri Biber-Bursa', Ayaş, Cuma Ovası, 'Ege-91', 'Finli Biber', 'Şahnalı Biber', 'Sera Demre', 'Tatlı Kıvırcık Biber', 'Yalova Biber', 'Yalova Tatlı Sivri Biber', etc.), banana pepper ('Çarliston Biber-Bursa', 'Yalova Çarliston 341', etc.), bell pepper ('Acı Biber-Gaziantep', 'Domat Biberi- Bursa', 'Dolmalık yeşil-Bursa', 'Kale', etc.), capia (for oil), local peppers for drying, gravy ('Yalova yağlık biber', 'Salçalık biber-Bursa', 'Salçalık biber-Gaziantep'), pickling peppers, chilies, and ornamental peppers (such as Cayenne pepper). Lately, besides traditional types like Demre green pepper, banana pepper, bell pepper, and capia pepper, the Hungarian pepper with low production potential as well as 'Jalapeno', 'California Wonder', 'Greek Charlie', Chili, 'Hungarian bell peppers' to some extent are grown in greenhouses for export purposes (Frary et al. 2008; UİB 2017).

Gene banks are ex situ conservation places used to protect genetic resources (Hameed et al. 2019). There are many challenges encountered in gene banks, for example, regular re-plantation and limited biodiversity conservation areas. They are very expensive for biodiversity-rich countries in particular in the third world nations, due to marking and cataloging problems (Hameed et al. 2019). In 1999, in situ (on-farm) conservation studies were started in a selected pilot area in the northwestern transitional zone in Turkey. Sakarya valley is one of the important transitional regions for such landraces as many vegetables are grown here, including Solanaceae (Küçük 2003). In situ conservation increases genetic diversity as it allows evolution to continue, and hence the gene flow. Many international organizations report that it is important to preserve some areas of high genetic diversity for growing traditional and local agricultural crops (Khoury et al. 2010; Hameed et al. 2019).

In Turkey, in some regions of Kahramanmaras, Gaziantep, Urfa, Diyarbakir, Bursa, Adiyaman, and Hatay provinces there are places set aside in field for such agricultural practices whereas, Antalya, Mersin, Mugla, and Izmir provinces follow greenhouse production in this connection (Üstün 1990). Later includes production in plastic or glass-covered greenhouses and under plastic tunnels. Antalya province and Kumluca District are important centers in Turkey where greenhouse pepper cultivation and exports are realized (FAO 2018). A large part of the green pepper cultivation in greenhouses is observed in the Mersin province (Anonymous 2016). This type of production requires a labor force but also creates employment. It has been a source of livelihood for the people living in these regions and engaged in farming. A majority of the greenhouse plants are grown in soil, but there is growing interest in the use of landless culture techniques to overcome soil-specific problems, with tomato and pepper production in these areas making up the top two (Tüzel and Öztekin 2018).

8.3 Pepper Cultivation in Other West Asian Countries

Cyprus is the third largest island in the Mediterranean region, its coastal geographical location and climatic features (hot and arid summers with rainy winters) are convenient for the growth of plants. The island has a rich genetic diversity and flora (Ozturk et al. 2013, 2014, 2019a). The program for protection and collection of genetic resources has been launched in Cyprus. Although there are variations in many plant varieties, sweet pepper production is still ongoing (Della 1999).

Drought, desertification, semi-arid areas, groundwater depletion, hot sand storms, besides harsh climatic conditions such as reduced rainfall, population growth, inefficient agricultural water use have greatly reduced the biodiversity in Syria (Mourad and Berndtsson 2012). The problems like political instability have damaged the water pumps and water channels used in the irrigation-based agriculture in the country, leading to reduced water supplies. With climate simulation models to assess the impact of climate change and identify potential threats in the future, providing quantitative forecasts, it is predicted that rainfall will decrease further, drought and temperature will increase in Syria in the future (De Châtel 2014). These negative factors have limited the cultivation of hot Aleppo pepper and the sweet Haskoria pepper in the Al-Hasakah region, which is named after the Syrian city of Aleppo, one of the most important parts of Syria in terms of Agriculture and has become a symbol of the city (Nabhan 2010; Anjarini 2014; Akhmedkhodjaeva 2015; URL-3). This type of pepper, which has originated from Syria is loved and consumed in many countries in the world. Aleppo pepper has not been used in countries other than neighboring countries for many years, and political reasons that still persist today have made it difficult to export these to the other countries. Aleppo pepper is not consumed much without being dried and ground. This type of pepper is called flaked red pepper in Turkey, while in Armenia it is called Aleppo pepper (Anderson 2016).

Armenia abounds in high plateaus and mountains, exhibiting different climatic features such as dry subtropical, cold highland climate due to its location (Avetisyan

2010). Because of these characteristics, it is home to many regional endemic and rare plant species and is also considered an endemism center for wild relatives of economically important agricultural crops (Chemonics International Inc 2000). Hot and sweet peppers are among the most important vegetables in Armenia. *C. annum grossum* and *C. annum* var. *longum* are the most cultivated peppers after eggplant and tomatoes in the Armavir region and in the Ararat Valley which is an agricultural center in the country with an average monthly temperature changing between 24 and 26 °C. Scientific Center of Vegetables and Industrial Crops has made several efforts to develop hybrid and new varieties of pepper, eggplant, and tomato all from the Solanaceae family. After developing these hybrid and new varieties, these are distributed in different parts of the country (Sarikyan 2003). Between 2000 and 2004, 'Aik', 'Arevaam', 'Arevashog', 'Nush-78', and 'Nush-83' varieties have been adapted to the special growth conditions, and between 2010 and 2012 sweet pepper varieties named 'Natali', 'Mili', 'Emili', and chili pepper varieties named 'Gita', 'Zspanak', 'Kon', and 'Punj' have been released (Lin et al. 2013). These new varieties are unique, with good marketable valuable features (high yield, fruit quality, etc.), enabling farmers to sell the product directly to the consumer (Aslanyan and Lokyan 2006).

Georgia too is rich in bio as well as genetic diversity. The most important reasons for this situation are the location of this country lying at the intersection of Asia and Europe. There are three different soil types and annual rainfall is very high. Since ancient times, the seeds of different plants from many countries of the world have been brought to Georgia and different plant varieties have been cultivated here. The black pepper has come from India, and green pepper from America (Akhalkatsi et al. 2017). The varieties of peppers grown in Georgia are *C. annuum*, black pepper, sweet Bulgarian pepper, sweet pepper, and chili pepper (FAO 2008). In addition to their use as food, *C. annuum* is used to treat diseases such as colds and flu (Bussmann et al. 2016). The 'Georgian Research Institute of Crop Husbandry' (GRICH) has done breeding studies for the cultivation of many vegetables such as cucumber, tomato, eggplant, pepper (Hot pepper: 'Kutai', 'Swenet', semi-hot 'slonoviy hobot'), and developed new varieties (Saralidze et al. 2006).

Azerbaijan experiences a subtropical climate (Ali et al. 2004). Many factors such as constant change of crops, increasing population, intensive urbanization, increasing abiotic and biotic stresses, pollution, climate change, intensive grazing, and excessive irrigation have led to a decrease in the genetic diversity of plants in the country (Ozturk et al. 2018e, f). It is very important that the native genetic resources of vegetables should be protected here in various gene banks and facilities. *C. annum* is among the species protected at the Vegetable Growing Research Institute. The studies are carried out in these institutes on the development of higher quality, efficient, and disease-resistant varieties. In all, 300 accessions of hot and sweet peppers have been preserved in the country, but varieties of sweet peppers such as 'Muradi', 'Shafa', 'heirloom' and 'Nakhichevanskiy mestnii' and 'Gekgel' hot peppers and 'apsheronskiy mestnii'; which are bitter and sweet; have been developed and released to the market (FAO 2006; Sadikhova 2006). The Solanaceae members are widely grown in Ganja-Kazakh, Guba-Khachmaz, Lenkoran-Astara, and Absheron peninsula (Desbiez et al. 2019) in the country. The importance of high quality and productive varieties from European countries has been one of the most important factors in the development of Azerbaijan vegetable crops and currently. The country can produce own vegetables throughout the year and exports these to other countries as well (Sadikhova 2006).

Iran has arid as well as semi-arid features with water shortages. The regions receiving rainfall have harsh climatic conditions (Abbaspour et al. 2009; Ozturk et al. 2018e, f, 2019b; Younessi-Hamzekhanlu et al. 2020). The south of country is more arid than north and suffers from water shortages. Therefore, majority of farms are restricted in the northern areas, closer to freshwater sources. Much of the agriculture is carried out by irrigation or on rainwater-fed lands or arid lands (Ministry of Jihad-e-Agriculture 1997; Anonymous 2014). Groundwater is used in grain and fruit cultivation. Iran has over 4000 hectares of pepper cultivation, and is ranked 35th among the leading countries in pepper production (Bagheri et al. 2017). The sweer *C. annuum* type is an important economic agricultural crop in the country. It is cultivated especially in open lands and under greenhouse conditions (*C. annuum* green-yellow-red bell pepper in Isfahan, etc.) (Abdi et al. 2015). *C. annum* hot (Chili) peppers are grown for use as both fresh vegetables and spices. These are used to aid in digestion (Parsa 1959; Osdaghi et al. 2016). *C. frutescens* is grown commercially in different regions in northern Iran and in Karaj, Shahriyar, and Varamin districts of Tehran (Sokhansanj et al. 2012).

Iraq is one of the other countries suffering from water scarcity in West Asia. The summers are very hot and winters very cold. Although rainfall in the northern Iraq is sufficient for agriculture, agriculture in the central and southern regions is done with irrigation water. The country includes different regions such as lower Mesopotamia, desert areas, high plateaus, and mountainous areas. The rainfall in the desert region is very low and temperature is high, while in the mountainous areas the temperature decreases to minus degrees which gives this country a rare position. Later has enabled increased agricultural diversity, enabling the cultivation of many agricultural crops such as wheat, corn, rice, beans, sunflowers, sesame, tomatoes, and peppers (only *C. annuum* and *C. frutescens*) (FAO 2007; Al-Snafi 2015).

Jordan is among the countries suffering the most water shortages and water stress in the world (MWI 2016). The water needed for irrigation is supplied from groundwater and spring water. The amount allocated for agriculture has got reduced by 17% in 2017 compared to 2008, as much of the water resources are used in industry and cities to meet the needs of the growing population in the country (MOA 2017). The water source of many vegetables, including bell pepper (*C. annum*) grown in Jordan in the Jordan Valley, is rainwater and deep wells. Although all kinds of vegetable farming are done in this valley without depending on the season, it is one of the biggest problems that the requested water is not provided at the desired rate (Shammout et al. 2018). In addition, important vegetables such as tomatoes, peppers, cucumbers, and lettuce are grown in the large greenhouses in this valley. Sensitive to water stress, bell pepper is an important vegetable that gives very good yield when irrigation is done in greenhouses and forms approximately 11% of vegetable exports to countries such as Kuwait, United Arab Emirates, Bahrain, and Qatar (MOA 2017).

More than half of Israel's surface area has a dry and semi-arid climate. In view of this, because of the lack of rainfall and other water resources, both fertilization and irrigation are required to grow agricultural crops and increase productivity (Imas 1999). According to the FAO 2012 data, Israel is 17th in bell and chili pepper production in the world (FAOSTAT 2012). Dombrovsky et al. (2010) have reported that peppers are grown in large areas all year round for local and export markets in Israel. Arava Valley which is located in the south of the country is one of the most important pepper cultivation areas. The area of pepper cultivation in this valley is approximately 2000 hectares, sweet bell pepper is one of the most important types produced and exported during the fall and winter months. However, drought due to lack of water, increased salinity due to high evaporation and low rainfall are serious problems causing a loss in pepper cultivation, yield, and quality (Yasour et al. 2017; Rameshwaran et al. 2015; Fallik et al. 2019; URL-4).

Another important pepper cultivating region, due to its geopolitical location, abundance of water resources, and enormous plant diversity, is the Jordan Valley. It is one of the most important parts where agriculture is practiced in Jordan, Palestine, and Israel. Bell pepper (*C. annuum*) is grown in the Jordan Valley using a Spanish cage system (Joshi et al. 2019), and hot peppers have been cultivated with a production of 134.000 tons in 2000. In 2010, the production has increased to approximately 294.000 tons. Comparison of 2000 and 2009 points out that, there has been a significant increase in both the area harvested and the amount of bell peppers and hot peppers exported from Israel, and the amount of pepper exported has reached 140.000 tons (Ignat 2012). Sweet pepper such as bell pepper, elongated green pepper, and chili has been the second-largest exported vegetable after potatoes in Israel (Fallik et al. 2008; Fallik 2015).

Agriculture holds an important place for the Palestinian economy. Jordan Grift Valley is one of the most important irrigated agricultural areas with an arid climate. It is heavily cultivated by Israeli settlers. The Gaza Strip, Tulkarm, and Jenin are other areas where irrigated agriculture is mostly based on wells and spring waters. In the remaining regions, farming with rainwater accounts for approximately 90% of the cultivated areas, while production varies according to the amount of rainfall (CBD 2015). Cucumber, onion, broad beans, and hot pepper (sweet pepper is less) are the products with the most cultivated area (Leipzig 1996). Following Israel's unilateral separation from the Gaza Strip in 2005, Palestinians have produced 8.400 metric tons of cherry tomatoes, peppers, cucumbers, and strawberries in Israeli former settlers' greenhouses in 2006 (UNDP 2009). In addition, the village of Frush Beit Dajan in the North West Bank is trying to produce hot and sweet peppers that are adapted to different climatic conditions.

Agricultural biodiversity in Kuwait has not developed much, the reason being scarcity of rainfall. The water used in the irrigation of crops is of saline nature, under extremely harsh climatic conditions (high temperatures in summer and low temperatures in winter). Agriculture is practiced in the areas like Wafra, Abdally, Jahraa, and Sulaibiya. It is only done in certain areas with greenhouses and very few on open land. Irrigation is done with very small amounts of freshwater using the trickle method. Only potatoes, onions, tomatoes, bell peppers, cucumbers, and eggplants are grown in Kuwait. Vegetable yield is low, much due to plant pathogens and unfavorable soil. The least grown vegetable among these is the bell pepper because it needs a lot of water (Leipzig 1996).

Although Oman is referred to as an industrial and oil city, agriculture also constitutes one of the major sources of income. Agriculture has been a major source of employment, especially for people living in rural areas (Hussain et al. 2006). Oman comprises 74% deserts, 15% mountains, and 8% agricultural areas. Although the area suitable for agriculture in Oman is 2.223 million hectares, the irrigable area is 72.820 hectares (CBD 2014). Batinah has high rainfall and humidity, and is one of the regions with the most important production potential. Agricultural practices are also followed in Sallalah, Jebel akhdar, and in the mountainous areas (Hussain et al. 2006; Al Bakri et al. 2008). River and canal systems are not available in Oman, so an automatic water pumping system has been developed in order to make irrigation easier. Since rainfall in the country is insufficient and seawater is not suitable for use in agriculture, the cultivation of vegetables and fruits with less water requirement are preferred (Hussain et al. 2006). The most widely grown vegetables in Oman are onions, potatoes, cucumbers, garlic, parsley, eggplant, lettuce, radish, and red pepper (*C. annuum*). Red pepper is used both as a spice and as a medicinal plant. In October–March, exotic sweet peppers are also grown in Oman (Gebauer et al. 2007). However, red pepper is planted in 0.4% of the agricultural area, while exotic sweet pepper is planted in very restricted area (Zekri et al. 2007). These are mainly exported to Arab and Gulf countries.

The land and soil conditions of Yemen too are unfavorable and rainfall is limited, affecting agriculture in a negative way. However, the fertile land in the west is among its main natural resources. The agriculture is spread in this region because it is suitable following seed adaptation techniques and as such many fruits and vegetables are grown including *C. annuum* (Wahyuni 2014).

Bahrain has a generally desert climate, with two seasons, summer and winter (Alnaser and Merzaa 2003). It has more freshwater resources than any other Arab country, but the existing freshwater resources are not sufficient for consumption. Majority of the freshwater required is obtained from seawater. The country imports pepper, black pepper, Pimenta, or *Capsicum* from Vietnam (Trading Economics 2018). Chili peppers are very important commercially. The Chili (*C. annuum*) pepper produced in India is imported mainly to Bahrain (Reddy 2010).

Although Saudi Arabia has the least rainfall in the world and extensive desert areas, it has made great progress in agriculture by turning desert areas into agricultural areas. There are more than 200 dams. The water is primarily used in agriculture and is distributed to farmlands through irrigation canals and troughs extending throughout the country (Abderrahman 2001). Bell pepper (*C. annuum*) besides being commercially important, plays a very important role in the country's agriculture. There are nearly 70 viruses and bacteria responsible for the disease in pepper plants, pepper production has greatly reduced globally (Kamran et al. 2018). Varieties of Jalapeno and red or green pepper are produced in the Arabian Gulf countries (Moitra 2010). Three commercial hybrid pepper varieties called ‘Boogie’, ‘Romica’, and ‘Zamboni’ are grown in greenhouses at the experimental agricultural research institute in Riyadh (Alsadon et al. 2013). In addition, piper peppers, paprika, and Pimenta peppers from Ethiopia (Moitra 2010), and chili peppers (filfil harr, akhdar) from India are imported to Saudi Arabia (Trading Economics 2016).

Qatar too has two seasons, hot and cold, but has a unique and diverse habitat, biodiversity which is gradually declining due to urbanization, population growth, and wrong land use. The vegetables are imported from other countries. The pepper is imported from India (URL-5). However, Qatar has established gene banks to maintain and increase existing biodiversity and has developed the National Biodiversity Strategy and action plan, which is in full operation (Elazazi and Al-Kuwari 2016).

Vegetable farming in Lebanon is carried out in four regions: coastal areas where there are plenty of greenhouses, mountain areas, Northern Lebanon-Akkar Plain-Mount Lebanon, and Bekaa Valley. The Bekaa Valley, Baalbeck-Hermel, and Aakka regions are the areas with the most vegetable production in the country due to their favorable climate, fertile soil, and adequate irrigation (Ruijs 2017). In these regions, tomato, cucumber, potato, eggplant, and bell pepper (*C. annum*) are most cultivated; however, chili and green pepper are the least cultivated in the fields and greenhouses (Machlab 2001; Ruijs 2017).

8.4 Conclusions

Water scarcity, drought, aridness, reduced rainfall, reduction in groundwaters resulting from global climate change, and population growth are destroying our genetic resources (Letchamo et al. 2018; Ozturk et al. 2012b, 2017b, 2018g, 2020). These are increasing international disputes, internal political conflicts. All these are the main factors leading to a decrease in biodiversity in West Asian countries which in fact has a large biodiversity due to its geographical positions (Ozturk et al. 2019b). The source of irrigation water used for agriculture in West Asia is the major rivers including Tigris and Euphrates. Rising temperatures and decreasing rainfall due to climate change are reducing the flow and amount of water in the Euphrates and Jordan Rivers, which are important for agriculture in the countries such as Iraq, Syria, Lebanon, Jordan, and Palestine (UNEP 2010). Protected areas in the region are quite limited, so in most countries, these areas need to be expanded.

Pepper, especially *C. annuum* is a plant that is susceptible to water deficiency and excessive amounts of salt (Penella and Calatayud 2018). Therefore, there is a need for the establishment of purification plants which can reduce soil salinity resulting from decreasing rainfall and water scarcity. An increase in the efficiency of the use of rainwater will increase the number of taxa, yield, and quality. The conservation of diversity in genetic resources and the conservation of collected materials in gene banks are important for the sustainability of agricultural products with economic value, such as pepper. Many West Asian countries such as Turkey, Azerbaijan, Georgia, and Armenia are aware of the decrease in plant diversity, and are trying to conserve their plant resources by establishing gene banks. Countries such as Jordan, Lebanon, United Arab Emirates, and Yemen are organizing various organizations to raise people's awareness about biodiversity conservation (UNEP-WCMC 2016). In addition to these, efforts are made to develop more efficient, durable, and high-quality varieties that can adapt to the negative conditions of the region in order to reduce the dependence on agriculture and to export their agricultural products to other countries. There is a need for new strategies which should be developed and action plans implemented at a faster speed.

References

Abak K, Pitrat M (1981) Biberlerde kök boğazı yanıklığı (*Phytophthora capsici* Leon.) hastalığına dayanıklılık üzerinde bir araştırma. AÜZF Yıllığı 29(2–3-4):943–947

Abbaspour AC, Faramarzi M, Seyed Ghasemi S, Yang H (2009) Assessing the impact of climate change on water resources in Iran. Water Resour Res 45:W10434

Abderrahman WA (2001) Water demand management in Saudi Arabia. Water Manag Islam 1(21):61

Abdi MR, Rezaee-Ebrahim-Saraee K, Fard MR, Baradaran-Ghahfarokhi M (2015) Potential health concerns of trace elements and mineral content in commonly consumed greenhouse vegetables in Isfahan, Iran. Adv Biomed Res 4:214

Akhalkatsi M, Otte A, Togonidze N et al (2017) Agrobiodiversity and genetic erosion of crop varieties and plant resources in the Central Great Caucasus. Ann Agrarian Sci 15(1):11–16

Akhmedkhodjaeva N (2015) Drought in Syria. Culture 22:16–14

Al Bakri AN, Lawati AA, Nadaf SK et al (2008) The state of plant genetic resources for food and agriculture in Oman, Ministry of Agriculture, Oman. pp 4–34

Ali M, Akparov ZI, Entwistle A et al (2004) Century study on biodiversity of Republic of Azerbaijan – first national report to convention on biological diversity. Azerbaijan National Academy of Sciences, Azerbaijan

Alnaser WE, Merzaa MK (2003) Profile of the climate change in the Kingdom of Bahrain. Environmetrics 14(8):761–773

Alsadon A, Wahb-Allah M, Abdel-Razzak H, Ibrahim A (2013) Effects of pruning systems on growth, fruit yield and quality traits of three greenhouse-grown bell pepper (*Capsicum annuum* L.) cultivars. Aust J Crop Sci 7(9):1309

Al-Snafi AE (2015) The pharmacological importance of *Capsicum* species (*Capsicum annuum* and *Capsicum frutescens*) grown in Iraq. J Pharm Biol 5(3):124–142

Altay V, Ozyığıt II, Keskin M et al (2013) An ecological study of endemic plant *Polygonum istanbulicum* Keskin. Pak J Bot 45:455–459

Altay V, Karahan F, Ozturk M et al (2016a) Molecular and ecological investigations on the wild populations of *Glycyrrhiza* L. taxa distributed in the East Mediterranean Area of Turkey. J Plant Res 129(6):1021–1032

Altay V, Gulyanar Ş, Ozyıgıt II (2016b) Autecology of *Cephalaria taurica* Szabó, a narrow endemic from Turkey: plant-soil interactions. IOSR J Environ Sci Toxicol Food Technol (IOSR-JESTFT) 10(9):90–94

Altay V, Daloğlu MY, Ozturk M (2017) Edaphic relations of *Cirsium cassium* Davis & Parris (Asteracee), a local endemic from Hatay (Turkey). Anatolian J Bot 1(2):41–44

Anderson HA (2016) Chillies: a global history. Reaktion Books, London

Anjarini S (2014) Syria: drinking water and war profiteers in Aleppo. http://english.al-akhbar.com/node/20189. Accessed on 10 Feb 2020

Anonymous (2014) Agricultural Statistics, Vol 1. 2012–2013 Cropping Seasons. Tehran, Iran, Ministry of Jihade-Agriculture (in Persian), p 156

Anonymous (2016) Ministry of food, agriculture and livestock Mersin provincial directorate records (in Turkish). Mersin

Antonious GF (2018) Chapter 2: Capsaicinoids and vitamins in hot pepper and their role in disease therapy. In: Capsaicin and its human therapeutic development. IntechOpen, London, pp 13–35

Aslayan GG, Lokyan AB (2006) Research and development of the vegetable system in Armenia. In: Lokyan Kuo CG, Mavlyanova RF, Kalb TJ (eds) Increasing market-oriented vegetable production: in Central Asian and the Caucasus through collaborative research and development, vol 6, no. 679, AVRDC-World Vegetable Center, pp 15–21

Avetisyan SS (2010) Agriculture and food processing in Armenia. Limush Publishing House, Yerevan, 138 p

Bagheri G, Zahedi B, Darvishzadeh R, Hajiali A (2017) Investigation on morphological and physiological variation of some sweet pepper ecotypes (*Capsicum annuum* L.). J Hortic Sci 31:140–157

Balkaya A, Karaağac O (2006) Vegetable genetic resources of Turkey. J Veg Sci 11(4):81–102

Barbero GF, Liazid A, Azaroual L et al (2016) Capsaicinoid contents in peppers and pepper-related spicy foods. Int J Food Prop 19:485–493

Bussmann RW, Paniagua Zambrana NY, Sikharulidze S et al (2016) Medicinal and food plants of Svaneti and Lechkhumi, Sakartvelo (Republic of Georgia), Caucasus. Med Aromat Plants 5(266):2167–0412

CBD (2015) State of Palestine fifth national report (CBD) to the convention on biological diversity

CBD (Convention on Biological Diversity) (2014) 5th National Report to the Convention on Biological Diversity, National Environment Management Authority, Kampala-Uganda. https://www.cbd.int/doc/world/om/om-nr-05-en.pdf. Accessed 25 Feb 2020

Chemonics International Inc (2000) Biodiversity assessment for Armenia. Task order under the Biodiversity & Sustainable Forestry IQC (BIOFOR). Washington, DC, February 2000

De Châtel F (2014) The role of drought and climate change in the Syrian uprising: untangling the triggers of the revolution. Middle East Stud 50(4):521–535

Della A (1999) Conserving plant genetic resources in Cyprus. In: Genetic resources of Mediterranean pasture and forage legumes. Springer, Dordrecht, pp 231–234

Desbiez C, Verdin E, Moury B et al (2019) Prevalence and molecular diversity of the main viruses infecting cucurbit and solanaceous crops in Azerbaijan. Eur J Plant Pathol 153(2):359–369

Dombrovsky A, Glanz E, Pearlsman M et al (2010) Characterization of pepper yellow leaf curl virus, a tentative new Polerovirus species causing a yellowing disease of pepper. Phytoparasitica 38(5):477–486

Elazazi EM, Al-Kuwari SD (2016) The Role of gene banks to preservation plant genetic resources for combat food in security in Qatar. In: Qatar foundation annual research conference proceedings, vol 2016, no. 1, p EEPP2250, Hamad bin Khalifa University Press (HBKU Press)

Fallik E (2015) Postharvest practices of peppers in Israel. 15 years of Research. https://issuu.com/horticulturaposcosecha/docs/141021pepper_postharvest_c7d3229b1056d4. Accessed on 05 Feb 2020

Fallik E, Alkalai-Tuvia S, Parselan Y et al (2008) Can colored shade nets maintain sweet pepper quality during storage and marketing?. In: Proceedings of the IV Balkan symposium on vegetables and potatoes, Plovdiv, Bulgaria, 9–12 September 2008, pp 37–44

Fallik E, Alkalai-Tuvia S, Chalupowicz D et al (2019) How water quality and quantity affect pepper yield and postharvest quality. Horticulturae 5(1):4

FAO (2006) Country report on the state of plant genetic resources for food and agriculture. National report on the state of plant genetic resources for food and agriculture in Azerbaijan. Baku

FAO (2007) Iraq: country report to the FAO international technical conference on plant genetic resources. In: Abdul S, Baghdad WA-S (eds) Focal point for country report to the FAO, International Technical Conference On Plant Genetic Resources, October 2007

FAO (2008) National report on the state of plant genetic resources for food and agriculture in Georgia. Georgian report on State of PGR Sep 29, Georgia. Accessed 21 Feb 2020

FAO (2018) Biodiversity of Turkey. Contribution of genetic resources to sustainable agriculture and food Systems. Ankara, 222 p

FAOSTAT (2012). http://faostat.fao.org. United Nations, Food and Agriculture Organization. Accessed 10 Feb 2020

FAOSTAT (2013). http://www.fao.org. Accessed 10 Feb 2020

FAOSTAT data (2018) Countries by commodity. http://www.fao.org/faostat/en/#rankings/countries_by_commodity. Accessed 22 Feb 2020

Frary A, Keceli MA, Ökmen B et al (2008) Water-soluble antioxidant potential of Turkish pepper cultivars. HortScience 43(3):631–636

Gebauer J, Luedeling E, Hammer K et al (2007) Mountain oases in northern Oman: an environment for evolution and in situ conservation of plant genetic resources. Genet Resour Crop Evol 54(3):465–481

Grubben GJH, Denton OA (2004) Plant Resources of Tropical Africa 2. Vegetables. PROTA Foundation, Wageningen Netherlands. Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen Netherlands

Hameed M, Ahmad MSA, Ashraf M et al (2019) Plant genetic resources of major and minor crops: origin, sustainable use and, conversation. In: Ozturk M, Hakeem KR, Ashraf M, Ahmad MSA (eds) Crop production technologies for sustainable use and conservation: physiological and molecular advances. CRC Press, Florida, USA

Hussain N, Al-Wahaibi NS, Habsi SSA, Al-Bakri A (2006) Hydro-economical localization of Oman agriculture. In: Proceedings of the international conference on economic incentives and demand management, 8–22 March 2006, Muscat, Oman, pp 18–22

Ignat T (2012) Non-destructive methods for determination of quality attributes of bell peppers. PhD thesis, Department of Physics-Control, Faculty of Food Science, Corvinus University of Budapest

Imas P (1999) Recent techniques in fertigation of horticultural crops in Israel. In: Workshop on recent trends in nutrition management horticultural crops. Dapoli, Maharashtra, pp 11–12

Joshi NC, Ratner K, Eidelman O et al (2019) Effects of daytime intra-canopy LED illumination on photosynthesis and productivity of bell pepper grown in protected cultivation. Sci Hortic 250:81–88

Kafi M, Kamili AN, Husaini AM et al (2018) Chapter 4: An expensive spice – Saffron (*Crocus sativus* L.) – case study from Kashmir, Iran and Turkey. In: Munir Ozturk et al (eds) Global perspectives on underutilized crops, Cham Springer International Publishing AG, part of Springer Nature, p 109–149

Kamran A, Lotos L, Amer MA et al (2018) Characterization of Pepper leafroll chlorosis virus, a new polerovirus causing yellowing disease of bell pepper in Saudi Arabia. Plant Dis 102(2):318–326

Khoury C, Laliberté B, Guarino L (2010) Trends in *ex situ* conservation of plant genetic resources: a review of global crop and regional conservation strategies. Genet Resour Crop Evol 57(4):625–639

Küçük SA (2003) *Solanaceae* genetic resources activities in Turkey. In compilers. *Solanaceae* genetic resources in Europe. Report of two meetings-21 September 2001, Nijmegen, The Netherlands/22 May 2003, Skierniewice, Poland. International Plant Genetic Resources Institute, Rome, Italy, vol 472, pp 39

Leipzig (1996) PIALES (The Palestinian Institute for Arid Land and Environmental Studies). Palestine: Country report to the FAO international technical conference on plant genetic resources

Letchamo W, Ozturk M, Altay V et al (2018) Chapter 2: A alternative potential natural genetic resource: Seabuckthorn [*Elaeagnus rhamnoides* (syn.: *Hippophae rhamnoides*)]. In: Ozturk M et al (eds) Global perspectives on underutilized crops, Springer International Publishing AG, part of Springer Nature 2018, p 25–82

Lin SW, Chou Y, Shieh HC et al (2013) Pepper (*Capsicum* spp.) germplasm dissemination by AVRDC – The World Vegetable Center: an overview and introspection. Chron Hortic 53(3):21–27

Machlab H (2001) Focus on seed programs. The Lebanon Seed Industry, Aleppo

Ministry of Jihad-e-Agriculture (1997) Agriculture of Iran: a brief look. Under-secretariat of planning and budget. Center for Agricultural Planning and Economic Studies, Iran, p 94

MOA (2017) Annual report of fruits and vegetable exports. Ministry of Agriculture, Amman, p 2017

Moitra CA (2010) The Arabian nights cookbook: from lamb kebabs to baba ghanouj, delicious homestyle Arabian cooking. Tuttle/Publishers Group UK, Clarendon/Enfield

Mourad KA, Berndtsson R (2012) Analysis of agricultural production in Syria from a virtual water flow perspective. J Agric Sci Appl 1(3):60–66

MWI (2016) Water sector capital investment plan 2016–2025. Ministry of water and irrigation, Amman

Nabhan G (2010) Drought drives Middle Eastern pepper farmers out of business, threatens prized heirloom Chiles. Climate change and food culture. Grist. http://grist.org/food/2010-01-15drought-drives-middle-eastern-peppers/. Accessed on 15 May 2015

Osdaghi E, Taghavi SM, Hamzehzarghani H, Lamichhane JR (2016) Occurrence and characterization of the bacterial spot pathogen *Xanthomonas euvesicatoria* on Pepper in Iran. J Phytopathol 164(10):722–734

Ozturk M, Altay V, Gucel S, Aksoy A (2012a) Aegean Grasslands as endangered ecosystems in Turkey. Pak J Bot 44:7–18

Ozturk M, Gucel S, Altay V, Altundağ E (2012b) Alliums, an underutilized genetic resource in the East Mediterranean. Proceedings of 6th IS on Edible Alliaceae. Acta Horticulturae, 969 (ISHS 2012), pp 303–309

Ozturk M, Guvensen A, Gucel S, Altay V (2013) An overview of the atmospheric pollen in Turkey and the Northern Cyprus. Pak J Bot 45:191–195

Ozturk M, Altay V, Gucel S, Guvensen A (2014) Halophytes in the East Mediterranean-their medicinal and other economical values. In: Sabkha ecosystems: volume IV: cash crop halophyte and biodiversity conservation tasks for vegetation science, vol 47. Springer Science+Business Media, Dordrecht, pp 247–272

Ozturk M, Altay V, Aksoy A (2016) Ecology of some endangered endemic plant taxa of Turkiye in relation to climate change. Conservation and Sustainable use of genefund of plant world in Eurasia at the present stage - International Scientific conference within "Day of Kazakhstan", at EXPO 2016, Antalya-Turkey, pp 12–15

Ozturk M, Saba N, Altay V et al (2017a) Biomass and bioenergy: an overview of the development potential in Turkey and Malaysia. Renew Sust Energ Rev 79:1285–1302

Ozturk M, Altay V, Hakeem KR, Akçiçek E (2017b) Liquorice from botany to phytochemistry. Springer briefs in plant science. Springer, Cham. https://doi.org/10.1007/978-3-319-74240-3

Ozturk M, Altay V, Latiff A et al (2018a) Chapter 9: A comparative analysis of the medicinal pteridophytes in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 349–390

Ozturk M, Altay V, Latiff A et al (2018b) Chapter 11: A comparative analysis of the medicinal plants used for diabetes mellitus in the traditional medicine in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 409–461

Ozturk M, Altay V, Latiff A et al (2018c) Chapter 16: Potential medicinal plants used in the hypertension in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 595–618

Ozturk M, Gökler I, Altay V (2018d) Chapter 8: Medicinal bryophytes distributed in Turkey. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 323–348

Ozturk M, Altundağ E, Ibadullayeva SJ, Altay V, Aslanıpour B (2018e) A comparative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343

Ozturk M, Altay V, Altundağ E, Ibadullayeva SJ, Aslanipour B, Gönenç TM (2018f) Chapter 6: Herbals in Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer, Cham, pp 197–266

Ozturk M, Altay V, Orçen N et al (2018g) Chapter 3: A little known and a little consumed natural resource: *Salicornia*. In: Ozturk M et al (eds) Global perspectives on underutilized crops, Springer International Publishing AG, part of Springer Nature, Cham p 83–108

Ozturk M, Gucel S, Altay V et al (2019a) Clustering of halophytic species from Cyprus based on ionic contents, biochemical attributes and micro-nutrients. Phyton Int J Exp Bot 88(1):63–68

Ozturk M, Altay V, Guvensen A (2019b) Chapter 11: Sustainable use of halophytic taxa as food and fodder – an important genetic resource in Southwest Asia. In: Hasanuzzaman M, Nahar K, Öztürk M (eds) Ecophysiology, abiotic stress responses and utilization of halophytes. Springer, Singapore, pp 235–257

Ozturk M, Altay V, Kucuk M et al (2020) Preservation and ecology of a living relict shrub in South Caucasus as a eco-genetic heritage from Tertiary: *Epigaea gaultherioides* (Boiss. & Bal.) Takht. J Environ Biol 41:279–284

Parsa A (1959) Medicinal plants and drugs of plant origin in Iran II. Qualitas Plantarum et Materiae Vegetabiles 6(1):69–96

Penella C, Calatayud A (2018) Chapter 7: Pepper crop under climate change: grafting as an environmental friendly strategy. In: Shanker A, Shanker C, Srinivasarao C (eds) Climate resilient agriculture: strategies and perspectives. BoD-Books on Demand, pp 129–155

Rameshwaran P, Tepe A, Yazar A, Ragab R (2015) The effect of saline irrigation water on the yield of pepper: experimental and modelling study. Irrig Drain 64:41–49

Reddy PP (2010) Fungal diseases and their management in horticultural crops. Scientific Publishers, Jodhpur

Ruijs M (2017) Value chain analysis of (greenhouse) vegetables in Lebanon. Strengthening Lebanese water and agriculture sector component 5: adaptive greenhouse; Work package. Wageningen Economic Research Wageningen

Sadikhova L (2006) Research and development of the vegetable system in Azerbaijan. In: Lokyan Kuo CG, Mavlyanova RF, Kalb TJ (eds) Increasing market-oriented vegetable production: in Central Asian and the Caucasus through collaborative research and development, Vol. 6, No. 679, AVRDC-World Vegetable Center, Tashkent, Uzbekistan, p 25–35

Saralidze A, Kakabadze N, Nozadze L et al (2006) Research and development of the vegetable system in Georgia. In: Lokyan Kuo CG, Mavlyanova RF, Kalb TJ (eds) Increasing market-oriented vegetable production: in central Asian and the Caucasus through collaborative research and development, Vol. 6, No. 679, AVRDC-World Vegetable Center, Tashkent, Uzbekistan, p 43–45

Sarikyan K (2003) *Solanaceae* genetic resources in Europe. *Solanaceae* genetic resources in Armenia. In: Daunay MC, Maggioni L, Lipman E (eds) Solanaceae genetic resources in Europe. Report of two meetings – 21 September 2001, Nijmegen, The Netherlands, 22 May 2003, Skierniewice, Poland. International Plant Genetic Resources Institute, Rome, pp 10–13

Shammout MAW, Qtaishat T, Rawabdeh H, Shatanawi M (2018) Improving water use efficiency under deficit ırrigation in the Jordan Valley. Sustainability 10(11):4317

Sokhansanj Y, Rakhshandehroo F, Pourrahim R (2012) First report of Tomato ringspot virus infecting pepper in Iran. Plant Dis 96(12):1828–1828

Tan A (1998) Current status of plant genetic resources conservation in Turkey. In: Zencirci N, Kaya Z, Anikster Y, Adams WT (eds) Proceedings of international symposium on in situ conservation of plant genetic diversity, 4–8 November 1996, Antalya, Turkey. Central Research Institute for Field Crops, Ankara, pp 5–16

Tradings Economics (2016) Ethiopia exports to Saudi Arabia of pepper, genus piper, genus capsicum or Pimenta. https://tradingeconomics.com/ethiopia/exports/saudarabia/pepper-genus-piper-genus-capsicum-pimenta. Accessed 05 Feb 2020

Tradings Economics (2018) Bahrain imports from Vietnam of pepper, genus piper, genus capsicum or Pimenta. https://tradingeconomics.com/bahrain/imports/vietnam/pepper-genus-piper-genus-capsicum-pimenta. Accessed 05 Feb 2020

TUIK (2017) https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr. Accessed on 05 Feb 2020

Tüzel Y, Öztekin GB (2018) Protected cultivation in Turkey. XXX. International Horticultural Congress. 12–16 August 2018, İstanbul, Turkey

UİB (2017) Uludağ İhracatçı Birlikleri Genel Sekreterliği, ARGE, Biber Raporu. http://www.uib.org.tr/tr/kbfile/biber-raporu-2017. Accessed 20 Jan 2020

UNDP (United Nations Development Program) (2009) Climate change adaptation strategy for the occupied Palestinian territory. Principal Consultant: Dr Michael Mason (London School of Economics and Political Science, UK)

UNEP (United Nations Environment Programme) (2010) State of biodiversity in West Asia. http://www.unep.org/delc/portals/119/Stateofbiodiv-westasia.pdf. Accessed on 05 Jan 2020

UNEP-WCMC (The United Nations Environment Programme World Conservation Monitoring Centre) (2016) The state of biodiversity in West Asia: A mid-term review of progress towards the Aichi biodiversity targets. Cambridge, UK

URL-1. http://www.fao.org/faostat/en/#data/QC. Accessed 20 Jan 2020

URL-2. https://ticaret.gov.tr/data/5b8700a513b8761450e18d81/Yas_Meyve_ve_Sebze.pdf. Accessed 20 Jan 2020

URL-3 Tonnemaker's 2018 pepper varieties. https://docplayer.net/88823725-Tonnemaker-s-2018-pepper-varieties.html. Accessed 05 Feb 2020

URL-4 Peppers remain the star product of Israel's horticultural business in 2007/2008. https://www.agrisupportonline.com/Articles/gworing_pepper_in_israel.htm. Accessed 05 Feb 2020

URL-5. https://www.infodriveindia.com/india-export-data/black-pepper-export/fc-qatar-report.aspx. Accessed 05 Jan 2020

Üstün AS (1990) Biberlerde kök boğazı yanıklığı (*Phyhophtora capsici* Leon.) hastalığına dayanıklılığın nedenlerinin fizyolojik ve biyokimyasal olarak incelenmesi. PhD thesis, Ankara University, Ankara, Turkey

Uzun I, Bayır A (2009) Horticultural biodiversity in Turkey. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture 66(2):536–543

Wahyuni Y (2014) Breeding for pepper fruit quality: a genitical metabolomics approach. PhD thesis, Wageningen University, Wageningen, NL

Yasour H, Tamir G, Stein A et al (2017) Does water salinity affect pepper plant response to nitrogen fertigation? Agric Water Manag 191:57–66

Younessi-Hamzekhanlu M, Ozturk M, Altay V et al (2020) Ethnopharmacological study of medicinal plants from Khoy city of West Azerbaijan-Iran. Indian J Tradit Knowl 19(2):251–267

Zekri S, Al Said FA, Khan IA (2007) Profitability analysis of selected farms in the Batinah region of Oman. J Agric Mar Sci 12:1–12

Chapter 9
Promising Small Molecules Against Cancer from *Ganoderma* Genus

Mehmet Öztürk, Gülsen Tel-Çayan, Fatih Çayan, and Mehmet Emin Duru

9.1 Introduction

Cancer is commonly known as an irregular division and proliferation of cells in an organ or tissue. It is a disease frequently discussed lately, one of the most common causes of death and scientists are searching for its cures (Masoodi et al. 2020). In Europe and Turkey, the death rates from cardiovascular and cancer diseases are about 38 and 29%, respectively. The most diagnosed cancers in the world are lung (13.0%), breast (11.9%), prostate (15.0%), and colon (9.7%). Accordingly, the cancer deaths are mostly because of lung (19.4%), breast (18.1%), and prostate (14%) (Globocan 2012). According to the 2014 World cancer report, out of 14 million cancer cases, 8 million cancer-related deaths were recorded in 2012 (World Cancer Report 2014). International Cancer Agency has highlighted the increase in breast cancers, which has the most incidence in women. The rate of breast cancer incidence is increasing by 20% every year (Globocan 2012). The WHO joint report from 2013 points out that the number of breast cancer cases has been rising fast. Every year new breast cancer develops in more than a million women and 370.000 women die. In Europe, 340.000 new cases of breast cancer are observed each year. In USA, 184.000 new breast cancers are observed annually and are reported as second death cause with 18% among all cancer deaths (World Health Organization (WHO) 2013; Siegel et al. 2017). World Health Organization reports that lung

M. Öztürk (✉) · M. E. Duru
Faculty of Science, Department of Chemistry, Muğla Sıtkı Koçman University, Muğla, Turkey
e-mail: mehmetozturk@mu.edu.tr

G. Tel-Çayan · F. Çayan
Faculty of Science, Department of Chemistry, Muğla Sıtkı Koçman University, Muğla, Turkey

Muğla Vocational School, Department of Chemistry and Chemical Processing Technologies, Muğla Sıtkı Koçman University, Muğla, Turkey

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_9

cancer has the most incidence in males among other types. It causes more than one and a half million deaths of males in the world. Considering the causes of all cancer types, more than 5 million humans have died till now (World Health Organization (WHO) 2008). As for the cure, most of the cancer treatments have failed because most of the drugs used in therapy damage even healthy cells.

Currently, the researchers have got interested in mushrooms due to their anticancer and immunomodulation activities. Most of these are safe and do not damage healthy cells. There are more than 11.000 mushrooms found in the wild and nearly 2.000 are nontoxic to humans, but only 300 have pharmaceutical characteristics (Sheena et al. 2005; Ozturk et al. 2008, 2016). Among these, the *Ganoderma* genus is well known as it has been used by the local people since ancient times. As per the inscriptions from ancient Egyptian records, only kings and their family were allowed to drink *Ganoderma* infusion. If public found *Ganoderma* anywhere, the finder must bring it to the royal palace. Currently, the mushrooms are used in pharmacy and medicine, besides their consumption as a vegetable. They are mainly utilized as immunomodulators and antitumor agents (Zhang et al. 2007) because they include triterpenes and polysaccharides having the potential to strengthen the immune system and/or to prevent cancer. Because of these features, mushrooms have become a vital source of drugs in present-day medicine (Mizuno 1999).

One of the widely consumed species from this genus is *Ganoderma lucidum*, mostly used as a therapeutic agent today. It is currently produced at an industrial scale in some countries for marketing purposes. The extracts of *G. lucidum* are added to coffee and tea products for easy consumption. Even healthy people use Ganoderma extracts as dietary supplements. Recent findings on *G. lucidum* indicate that other *Ganoderma* species also have the potential to treat diseases, including cancers since they show wide range of therapeutic activities. The genus *Ganoderma* as a whole is attracted attention by the researchers to investigate and isolate the biologically active compounds. Mostly, as small molecules, lanostane-type terpenoids, sterols, phenolics, and alkaloids, indicating various biological activities, were isolated from the *Ganoderma* species (Moradali et al. 2007; Huang et al. 2007; Rout and Banerjee 2007; Regina et al. 2008; Tong et al. 2009).

Several types of *Ganoderma* species, with different colors such as white, yellow, light black, purple, red, and black, are naturally growing in various regions in the world. More than 463 compounds have been isolated from various *Ganoderma* species. Many of these have been tested for different biological activities. The isolated small molecules of *Ganoderma* species were also studied for their anticancer activity during the last 20 years. The *Ganoderma* species interested in this chapter are *Ganoderma lucidum*, *G. tsugae*, *G. orbiforme*, *G. amboinense*, *G. sinense*, *G. colossum*, *G. concinna*, *G. leucocontextum*, *G. capense*, *G. applanatum*, *G. hainanense*, *G. cochlear*, *G. theaecolum*, *G. boninense*, *G. gibbosum*, *G. calidophilum*, and *G. lingzhi*. From these 17 *Ganoderma* species, 463 compounds, most of them being lanostanoid-type triterpenes, have been evaluated with their bioactivities (Fig. 9.1).

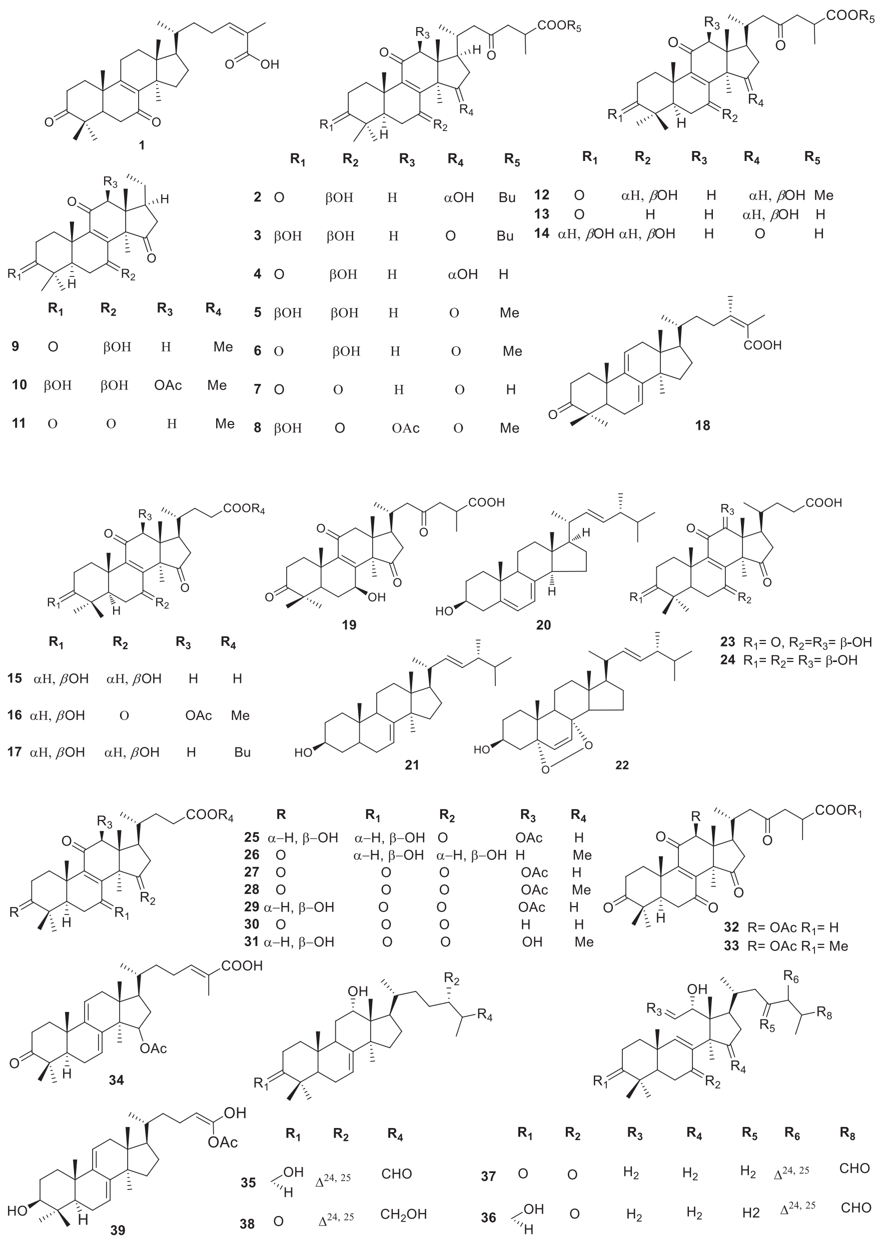


Fig. 9.1 The structures of compounds isolated from 17 *Ganoderma* species. (The ChemDraw Ultra 14.0 version was used to draw the structures of bioactive compounds (**1**–**463**) using the related papers published)

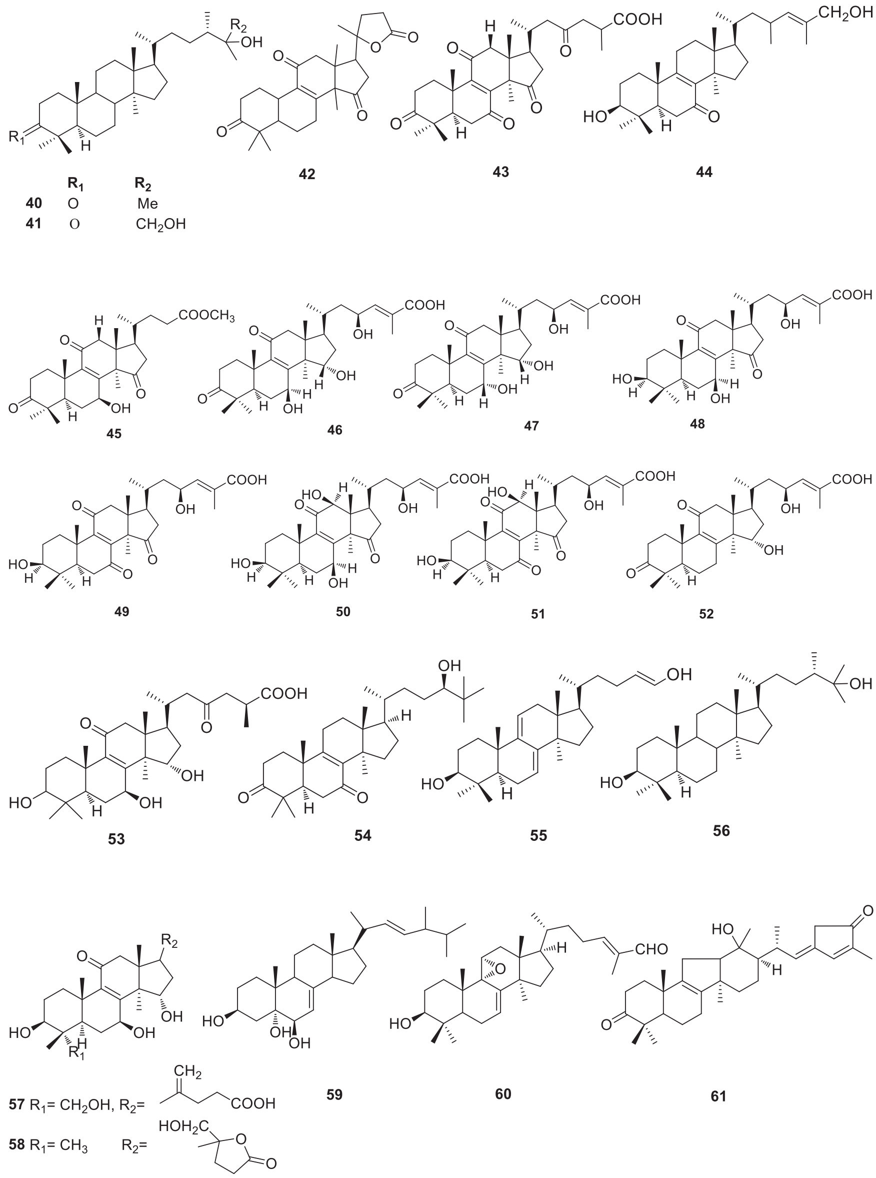


Fig. 9.1 (continued)

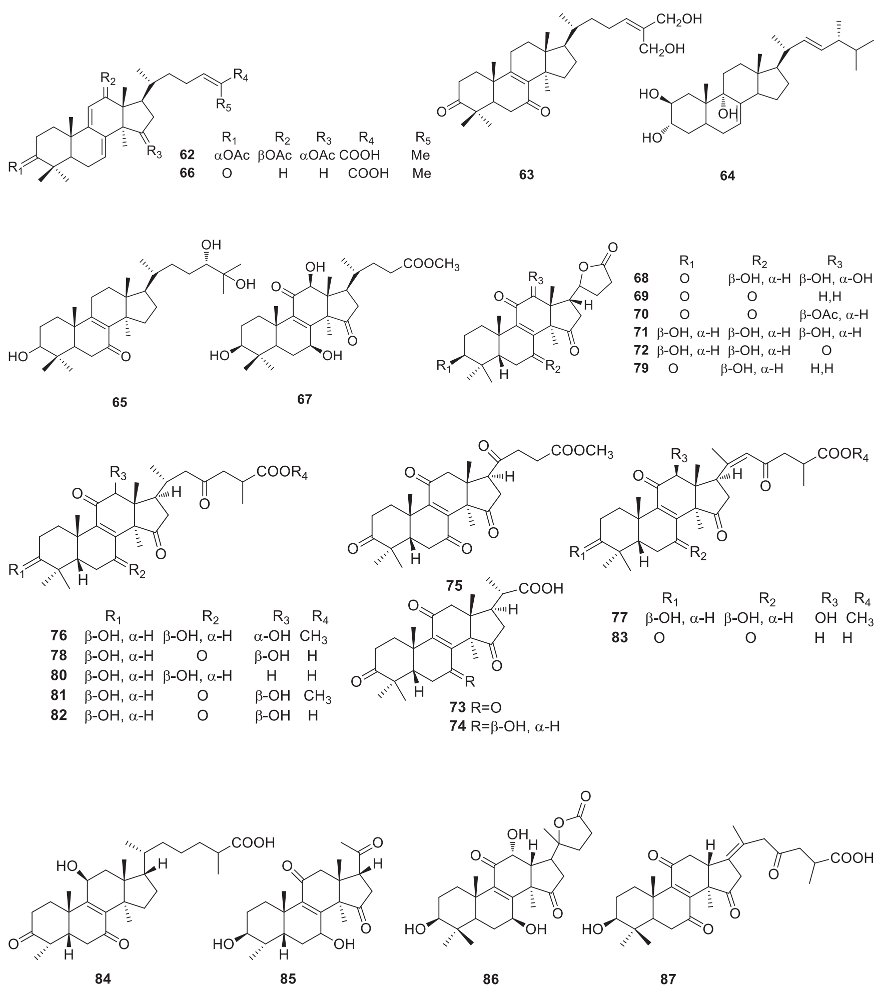


Fig. 9.1 (continued)

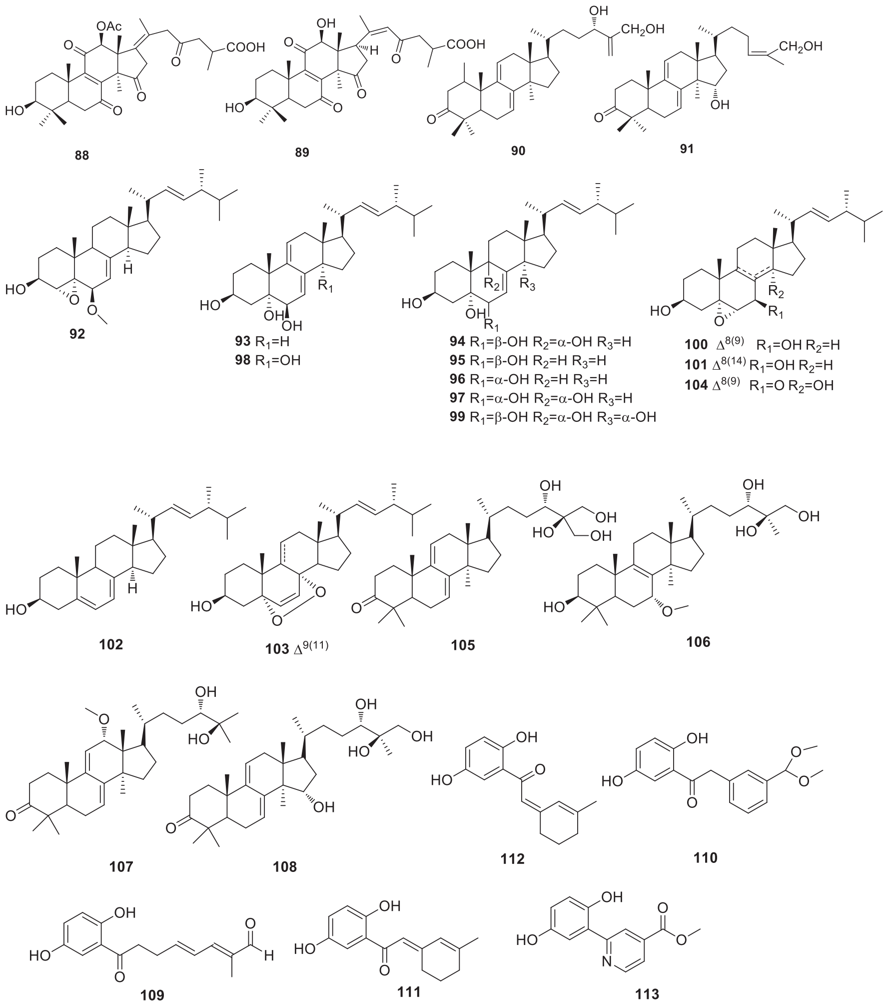


Fig. 9.1 (continued)

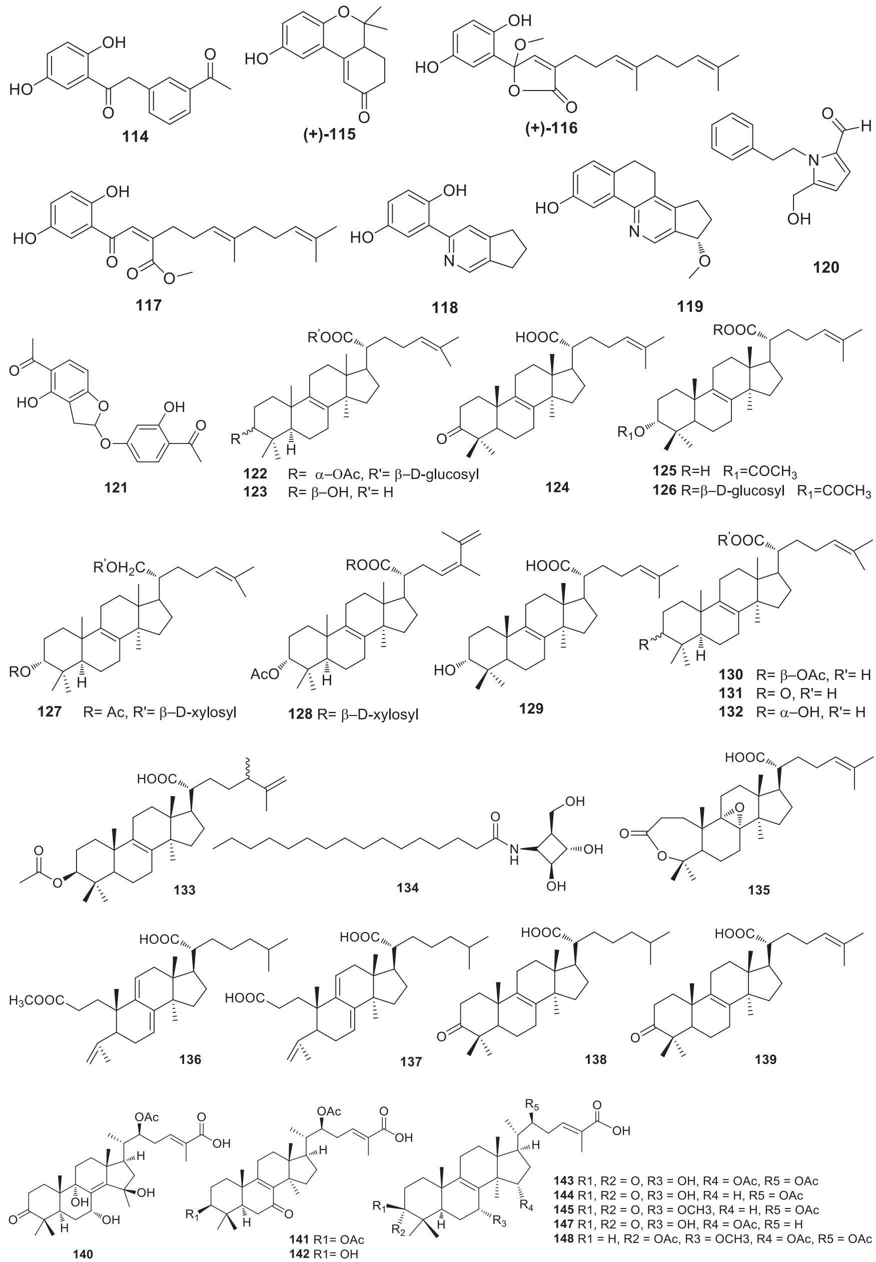
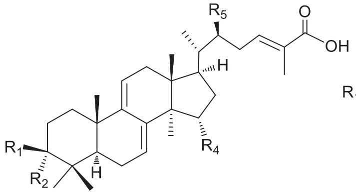
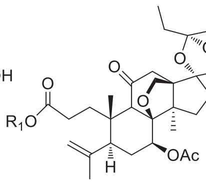


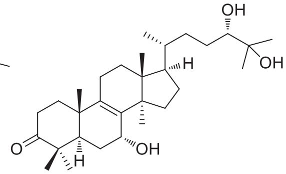
Fig. 9.1 (continued)



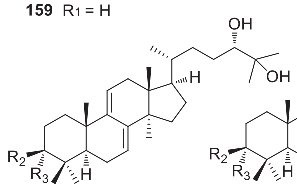
146 R1, R2 = O, R4 = H, R5 = OAc
149 R1, R2 = O, R4 = OAc, R5 = OAc
150 R1, R2 = O, R4 = OAc, R5 = H
151 R1, R2 = O, R4 = OH, R5 = OAc
152 R1 = OAc, R2 = H, R4 = OAc, R5 = OAc
153 R1 = OH, R2 = H, R4 = OAc, R5 = OAc
154 R1 = H, R2 = OAc, R4 = OAc, R5 = OAc
155 R1 = H, R2 = OAc, R4 = H, R5 = OAc
156 R1 = H, R2 = OH, R4 = OAc, R5 = OAc
157 R1 = H, R2 = OH, R4 = OAc, R5 = H
158 R1 = H, R2 = OH, R4 = H, R5 = OAc



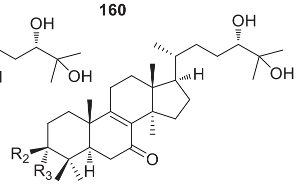
159 R1 = H



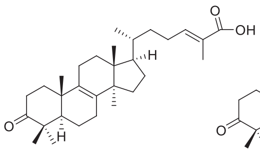
160



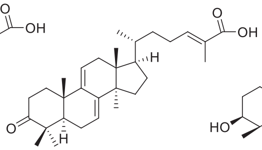
161 R2, R3 = O
162 R2 = OH, R3 = H



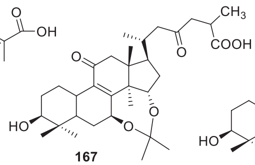
163 R2, R3 = O
164 R2 = OH, R3 = H



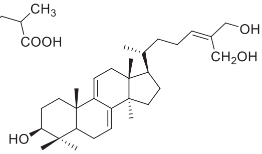
165



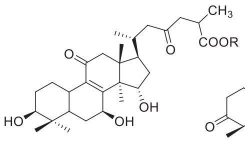
166



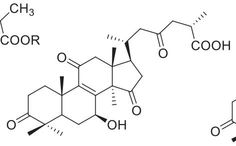
167



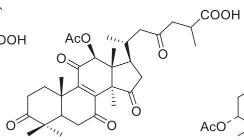
168



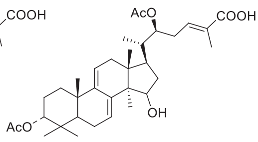
169 R=CH_3
170 R=H



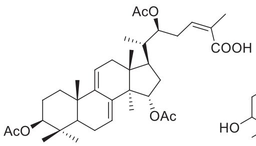
171



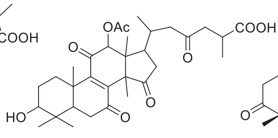
172



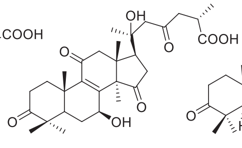
173



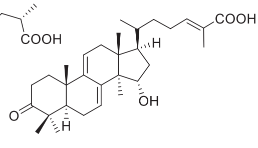
174



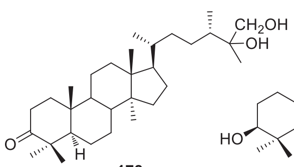
175



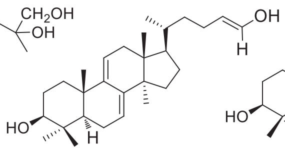
176



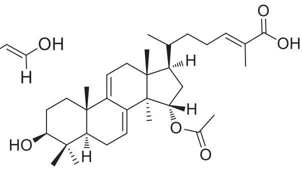
177



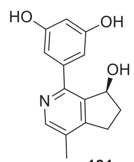
178



179

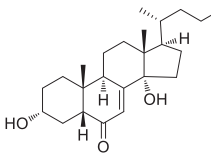


180

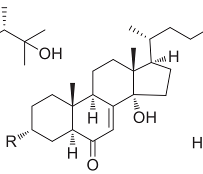


181

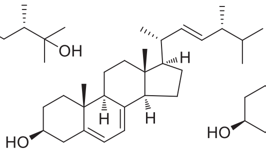
Fig. 9.1 (continued)



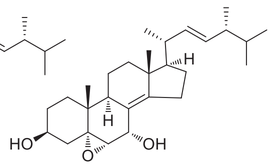
182



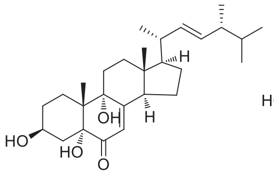
183 R = βOH
184 R = αOH



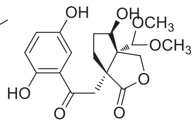
185



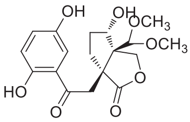
186



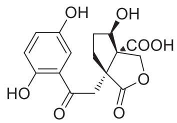
187



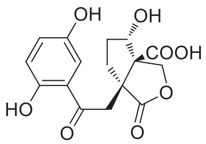
(+)-188



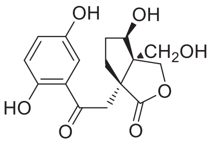
(-)-188



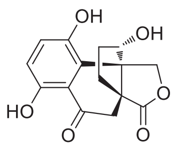
(+)-189



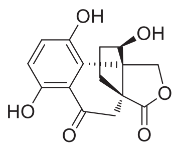
(-)-189



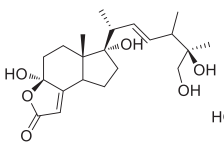
(+)-190



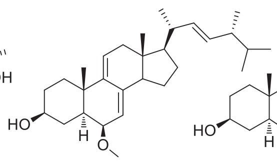
(+)-191



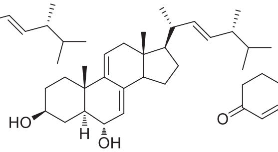
(-)-191



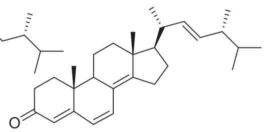
192



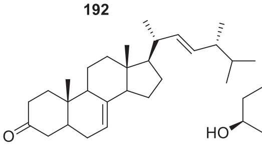
193



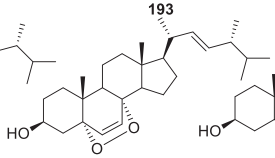
194



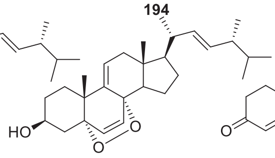
195



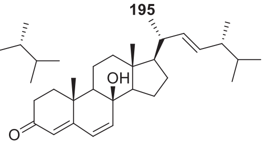
196



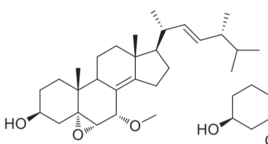
197



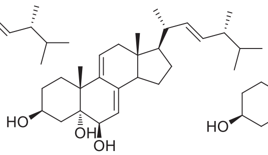
198



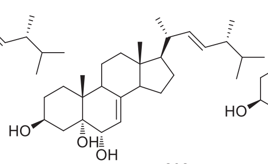
199



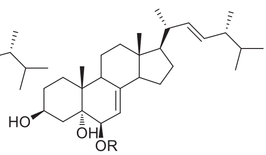
200



201

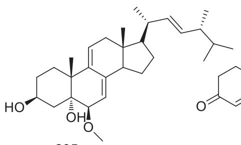


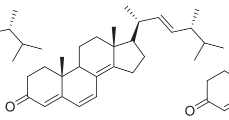
202

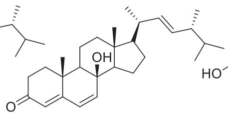


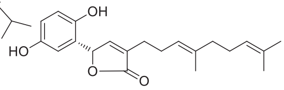
203 R = H
204 R = CH_3

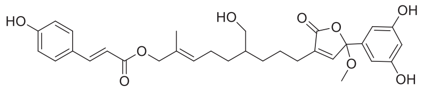
Fig. 9.1 (continued)

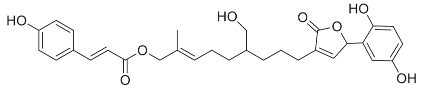

205

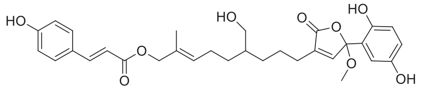

206

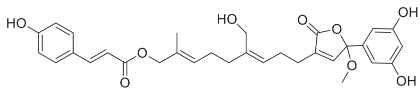

207

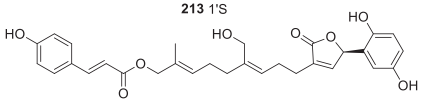

220

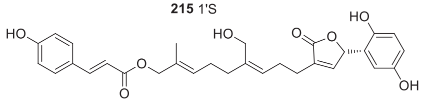

208 1'R
209 1'S

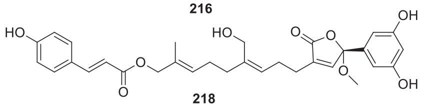

210 1'R
211 1'S

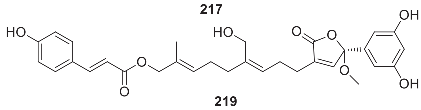

212 1'R
213 1'S

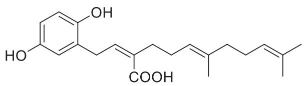

214 1'R
215 1'S

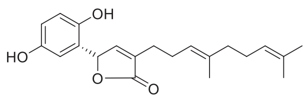

216

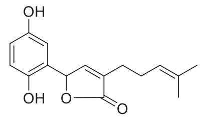

217

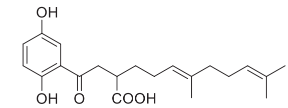

218

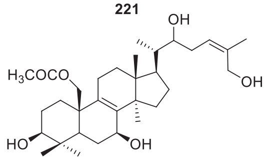

219


220


221


223


222


224

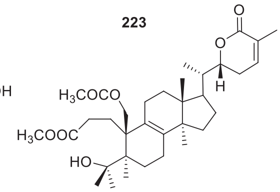

229

Fig. 9.1 (continued)

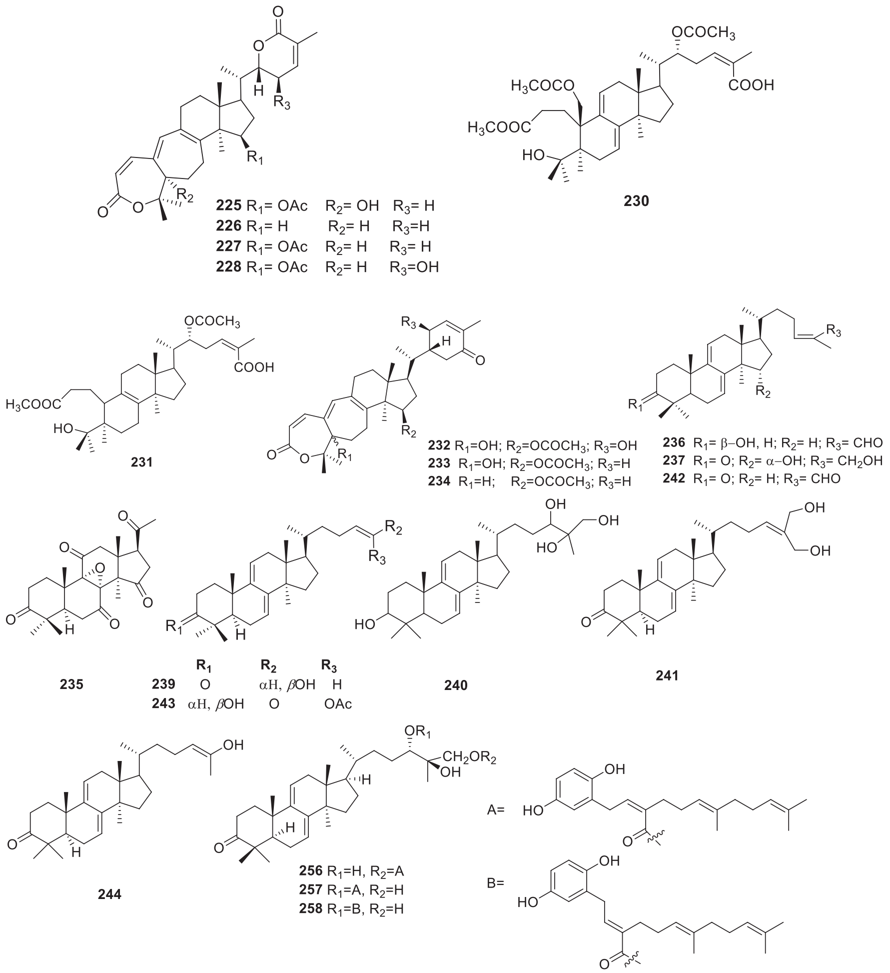
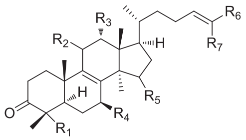
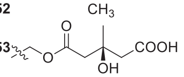
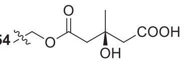
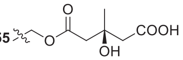
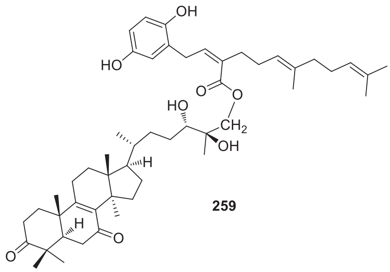


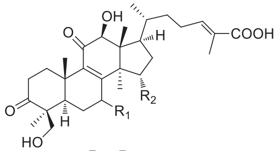
Fig. 9.1 (continued)



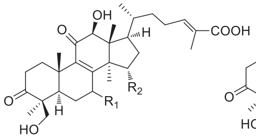
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
244	CH_2OH	O	H	OH	H	COOH	CH_3
245	CH_2OH	O	OH	OH	H	COOH	CH_3
246	CH_2OH	O	OAc	OH	H	COOH	CH_3
247	CH_2OH	O	OAc	OH	O	COOH	CH_3
248	CH_2OH	O	OH	OH	O	COOH	CH_3
249	CH_2OH	O	OAc	O	H	COOH	CH_3
250	CH_3	O	H	OH	H	CH_2OH	CH_2OH
251	CH_3	O	H	O	H	CH_2OH	CH_2OH
252	CH_3	O	H	H	OH	CH_2OH	CH_2OH
253		O	OAc	OH	O	COOH	CH_3
254		O	OH	O	O	COOH	CH_3
255		O	H	O	O	COOH	CH_3
260	CH_3	O	H	O	H	CH_2OH	CH_2OH
261	CH_3	O	H	O	H	CH_2OH	CH_3
262	CH_3	OH	H	O	H	COOH	CH_3
263	CH_3	O	H	O	H	COOH	CH_3



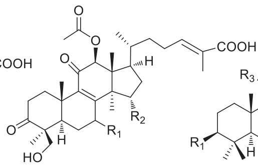
259



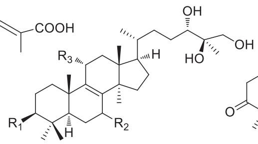
	R_1	R_2
264	β-OH	=O
265	β-OH	OH
266	α-OH	OH
267	=O	OH
271	H	OH



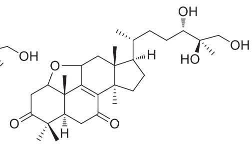
	R_1	R_2
264	β-OH	O
265	β-OH	OH
266	α-OH	OH
267	O	OH
271	H	OH



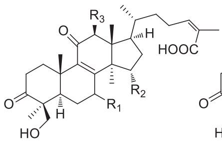
	R_1	R_2
273	β-OH	O
274	α-OH	OH
275	O	OH
276	O	O
277	H	OH



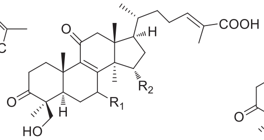
	R_1	R_2	R_3
282	O	O	OH
283	O	β-OH	O
284	OH	O	OH



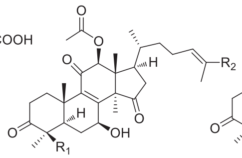
285



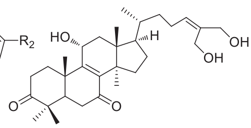
	R_1	R_2	R_3
268	=O	=O	OH
280	α-OH	OH	OAc



	R_1	R_2
269	β-OH	OH
270	=O	=O
272	H	OH



	R_1	R_2
278	CHO	COOH
279	CH_2OH	COOMe



281

Fig. 9.1 (continued)

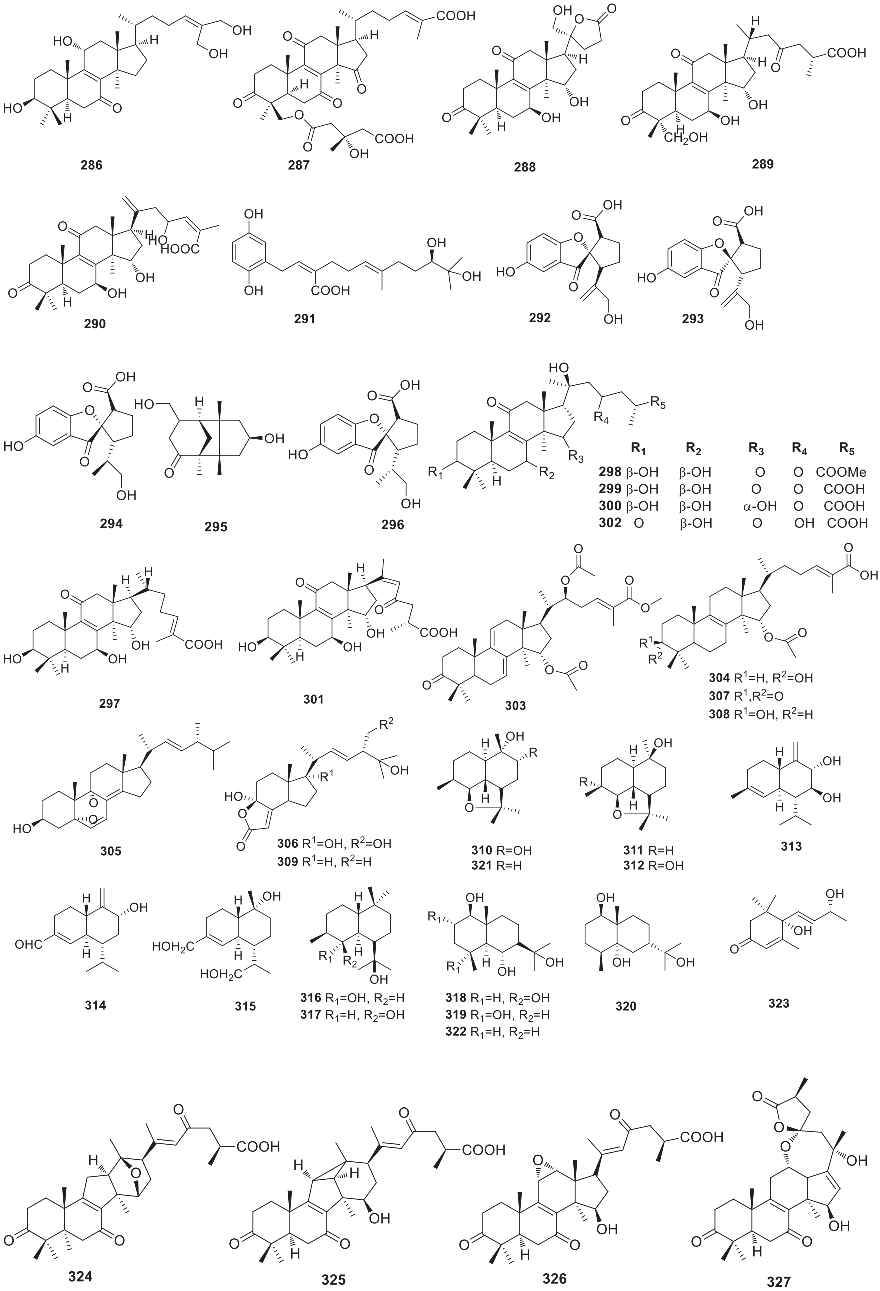
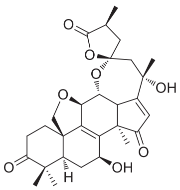
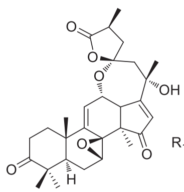


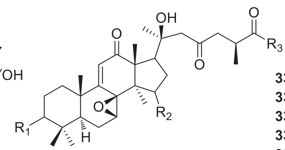
Fig. 9.1 (continued)



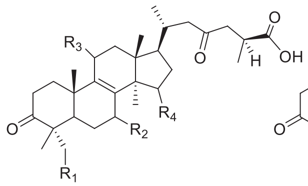
328

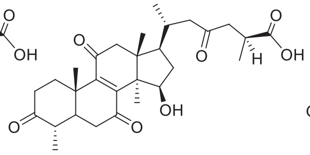


329

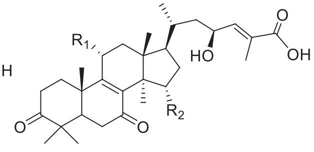


330	R_1=β-OH,	R_2=β-OH,	R_3=OCH3
331	R_1=O,	R_2=α-OH,	R_3=OH
332	R_1=O,	R_2=O,	R_3=OH
333	R_1=O,	R_2=β-OH,	R_3=OCH3
334	R_1=O,	R_2=β-OH,	R_3=OH



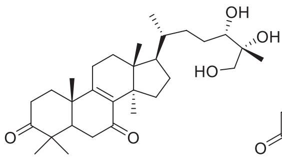


339

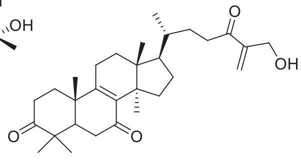


	R_1	R_2
342	H	H
343	O	β-OH

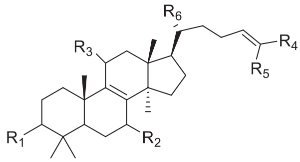
	R_1	R_2	R_3	R_4
335	OH	O	O	β-OH
336	OH	O	H	H
337	H	O	H	β-OH
338	OH	O	H	β-OH
340	OAc	O	O	β-OH
341	OAc	O	H	β-OH

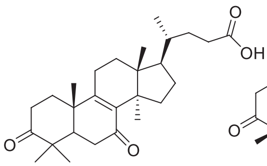


344

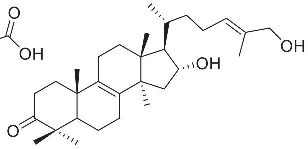


345



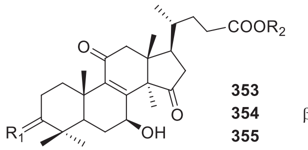


351

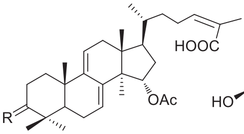


352

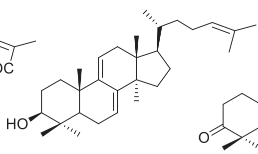
	R_1	R_2	R_3	R_4	R_5	R_6
346	β-OH	O	α-OH	CH_2OH	CH_2OH	CH_3
347	O	O	H	CH_2OH	CH_3	CH_2OH
348	O	O	α-OH	CHO	CH_3	CH_3
349	O	O	H	CH_2OH	CH_2OH	CH_3
350	β-OH	O	H	CH_2OH	CH_3	CH_3



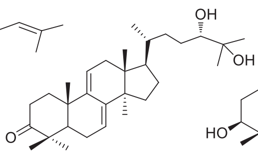
	R_1	R_2
353	β-OH	CH_3
354	β-OH	H
355	O	H



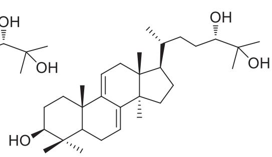
356



357



358



359

Fig. 9.1 (continued)

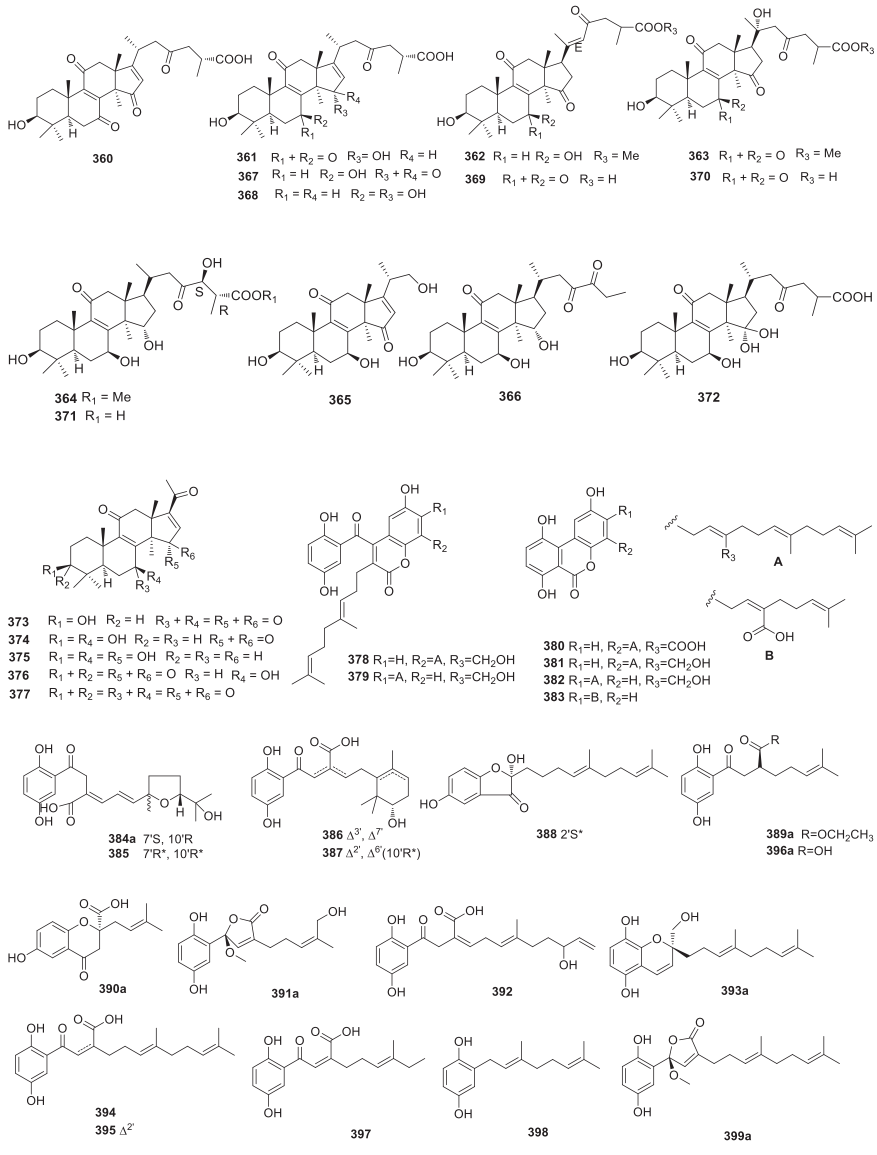
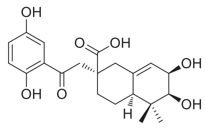
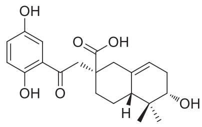


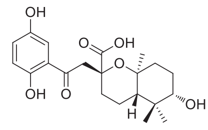
Fig. 9.1 (continued)



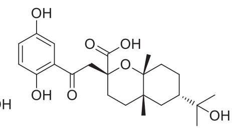
400



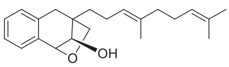
401



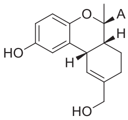
402



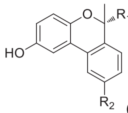
403



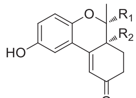
(-)-404

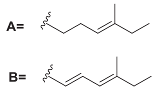


(+)-405

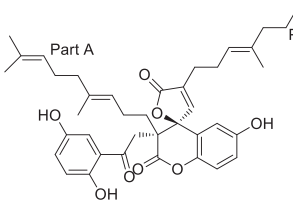


(-)-406 R_1=A, R_2=OH
(-)-407 R_1=B, R_2=CHO
(-)-408 R_1=A, R_2=CHO
409 R_1=CH_3, R_2=$COOCH_3$

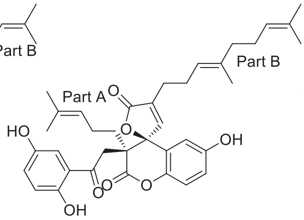




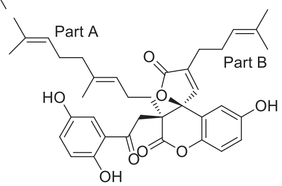
410a R_1=A, R_2=OH
(-)-411 R_1=CH_3, R_2=OH
(-)-412 R_1=CH_3, R_2=H



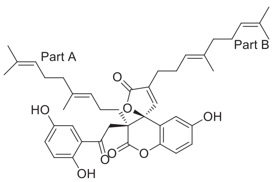
413



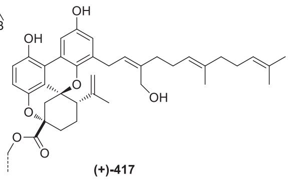
414



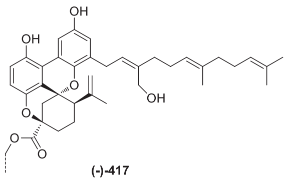
415



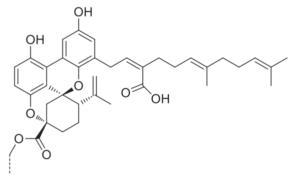
416



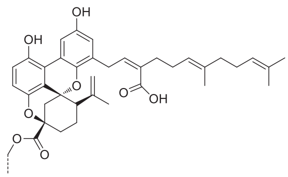
(+)-417



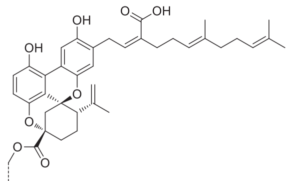
(-)-417



(+)-418



(-)-418



(-)-419

Fig. 9.1 (continued)

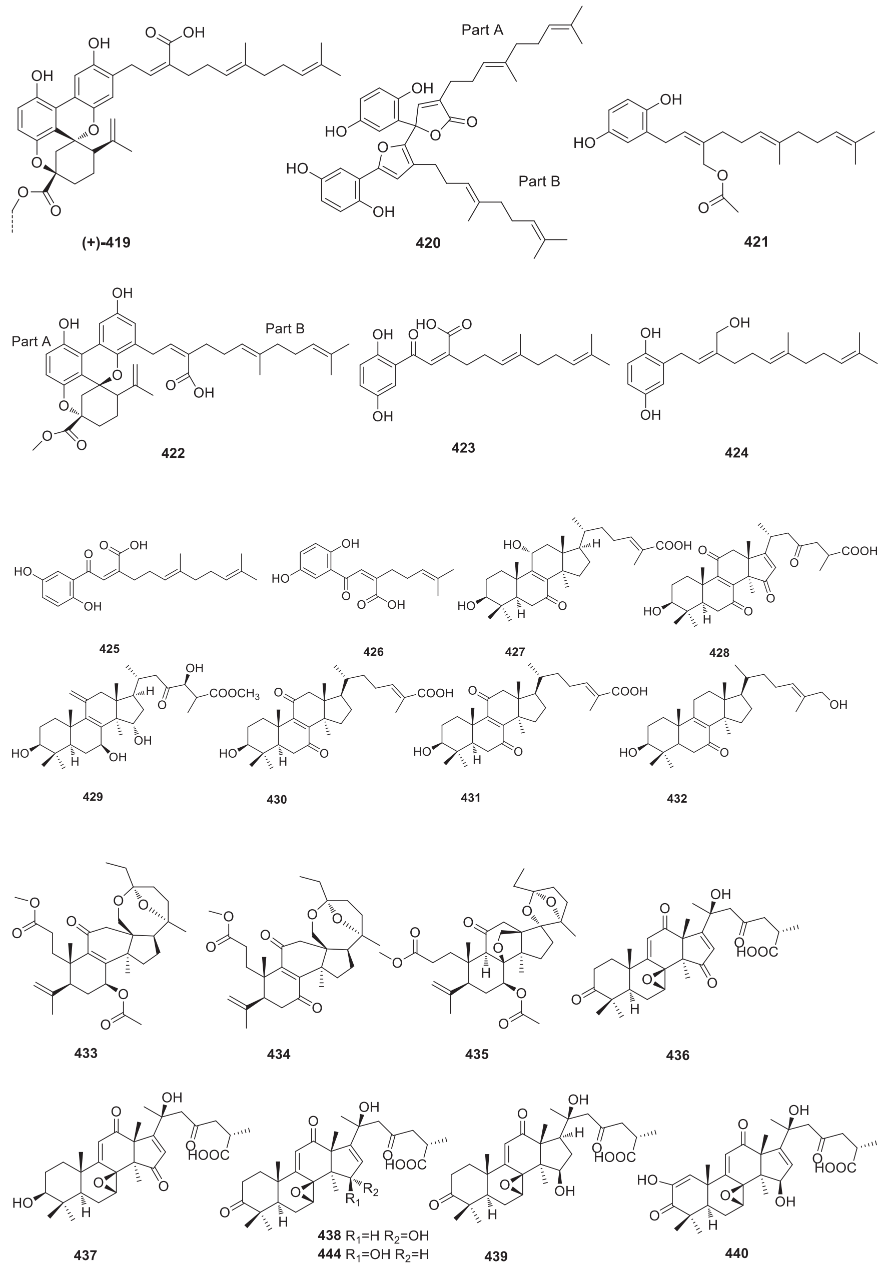
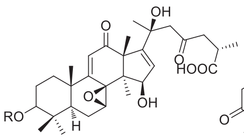
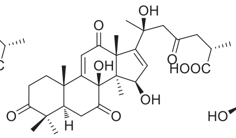


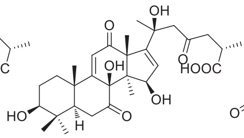
Fig. 9.1 (continued)



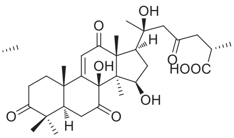
441 R=COH
445 R=H



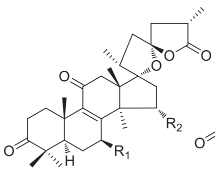
442



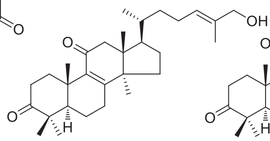
443



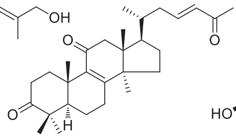
446



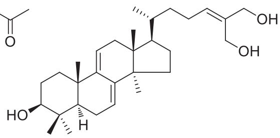
447 R_1=H, R_2=OH
448 R_1=OH, R_2=OH
449 R_1=H, R_2=OAc
450 R_1=OAc, R_2=OH



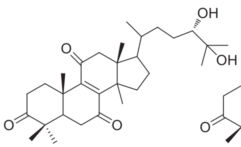
451



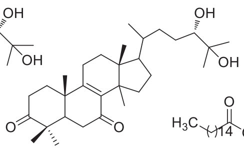
452



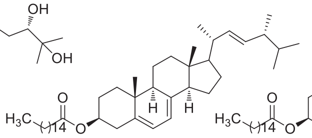
453



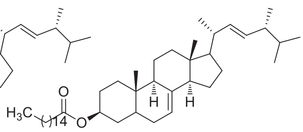
454



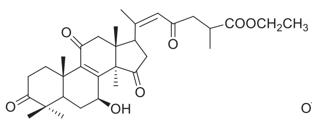
455



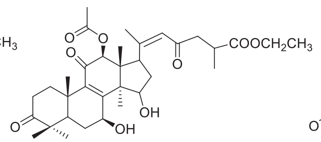
456



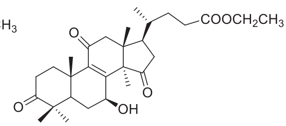
457



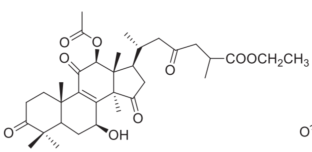
458



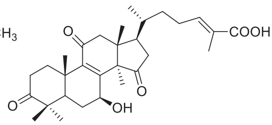
459



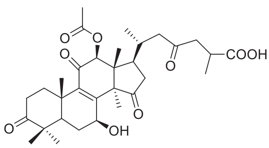
460



461



462



463

Fig. 9.1 (continued)

9.2 Bioactive Compounds Found in *Ganoderma lucidum* (Curtis) P. Karst

G. lucidum triterpenoid ganoderic acid DM (**1**), also available in the market, inhibited the colony formation and proliferation in MCF-7 (breast) cancerous cell lines. The activity increases with increasing concentration time-dependently. The protein level of cycle D1, c-Myc, CDK6, p-Rb, and CDK2 in MCF-7 cell lines too significantly decreased with the treatment of **1** (Wu et al. 2012a).

In mycochemical studies, butylganoderate A (**2**), butylganoderate B (**3**), ganoderic acid A (**4**), methylganoderate B (**5**), methylganoderate D (**6**), methylganoderate E (**7**), methylganoderate H (**8**), methyllucidenate A (**9**), methyllucidenate P (**10**), and methyllucidenate F (**11**) were obtained from *G. lucidum*. The inhibitory effects on adipocyte differentiation in 3T3-L1 cells of isolated compounds (**2–11**) along with methyllucidenate A (**12**), methylganoderate F (**13**), ganoderic acid F (**14**), ganoderic acid T-Q (**15**), **16** and n-butyllucidenate N (**17**) were investigated (Lee et al. 2010). Most of the tested compounds showed activity at 40 μg/mL, and inhibitory activity ranged from 22 to 56%. These results indicate the differentiation of 3 T3-L1. *n*-Butyllucidenate N (**17**) shows the best lipid droplet formation inhibitory activity (56%) among the others via accumulating lipid droplets in cell lines. *n*-Butyl lucidenate N (**17**) also suppressed GPDH (glycerol-3-phosphate dehydrogenase) activity to lipid accumulation effectively (Lee et al. 2010). Ganoderic acid Sz (**18**), ganoderic acid C1 (**19**), ergosterol (**20**), stella sterol (**21**), and ergosterol peroxide (**22**) were also reported from this mushroom (Seo et al. 2009). All these triterpenoids were examined for their anti-complement potential, and only compounds **18**, **20**, and **22** exhibited anti-complement activity against the classical pathway of complement media (IC_{50}: 44.6 μM, 52.0 μM, and 126.8 μM, respectively). The isolated compound **40** was studied for its affects against miR-378 U87 cell lines having drug-resistance aggressive cancer cell features. It was reported that if further clinical development of **22** is achieved, it may serve as a potent drug with ability to sort out the drug resistance in cancer cells (Wu et al. 2012b).

The strains of *G. lucidum* also contain lucidenic acids B-C (**23–24**). The anti-invasive activity of **15**, **23–24** using HepG2 (human hepatoma carcinoma) cell lines were investigated, 200 nM phorbol 12-myristate 13-acetate (PMA) and 50 μM of each lucidenic acids were mixed and incubated for 24 h. The mixture significantly inhibited HepG2 cancer cell line growth and inhibited MMP-9 (matrix metalloproteinase-9) stimulated with PMA. Lucidenic acids (**15**, **23–24**) can be considered as the anti-invasive against hepatoma cell lines (Weng et al. 2007).

Lucidenic acid P (**25**), a triterpene acid methyl ester, methyllucidenate Q (**26**), lucidenic acid D2 (**27**), methyllucidenate D2 (**28**), lucidenic acid E2 (**29**), lucidenic acid F (**30**), methyllucidenate F (**11**), methyllucidenate L (**12**), methylganoderate F (**13**), ganoderic acid F (**14**), and T-Q (**15**) together with **4**, **9**, **10**, **16**, and **24** were isolated from *G. lucidum* (Iwatsuki et al. 2003). All triterpenoid carboxylic acids from this mushroom (**4**, **24**, **25**, **27**, **29**, **32**, and **34**) and eight methyl esters (**9**, **10**, **11**, **16**, **26**, **28**, **31,** and **33**), except **30**, were evaluated for their potential to inhibit antitumor promoters using the initiation of early antigen of EBV-EA (Epstein-Barr virus) in Raji cells by TPA (phorbol myristate acetate). The compounds studied displayed higher activity (96–100% at 1×10^3 mol ratio/TPA) on EBV-EA induction (Iwatsuki et al. 2003), and were more effective than *β*-carotene. Therefore, it was suggested that triterpenoids are potential cancer chemopreventive agents (Iwatsuki et al. 2003). This mushroom provided 3 new lucialdehydes, lucialdehyde A (**35**), lucialdehyde C (**36**), and lucialdehyde B (**37**), and a ganodermanonol (**38**), together with **4**, **14**, **19**, **39**, **40**, and **41**. Cytotoxicity of lanostane triterpenoids was evaluated against LLC (Lewis lung), Meth-A (murine sarcoma), T-47D (breast), and Sarcoma-180 (diarthrosis tissue tumor) cancerous cell lines. Only triterpenoids **36–38, 40** showed cytotoxic activity on all cells. Triterpenoid **37** was the most potent cytotoxic against tumor cell lines indicating ED_{50} values in the range of 3 and 10 μg/mL, respectively. As for triterpenoid **38**, it had moderate cytotoxic activity against Meth-A cells (Gao et al. 2002). Lucidenolactone (**42**) along with **11, 24**, and **43–45** isolated from *G. lucidum* showed cytotoxic activity against P-388, Hep G2.2.15, and Hep G2 tumor cell lines. Although **43–45** displayed unusual cytotoxic activity against P-388, Hep G2.2.15, and Hep G2 cancerous cell lines, none demonstrated activity against KB and CCM2 tumor cell lines (Wu et al. 2001).

The spores of *G. lucidum* contain ganoderic acid γ (**46**), ganoderic acid δ (**47**), ganoderic acid ε (**48**), ganoderic acid ζ (**49**), ganoderic acid η (**50**), ganoderic acid θ (**51**), ganolucidic acid D (**52**), ganoderic acid C2 (**53**) along with lucidumol A (**54**), and **40, 41, 55,** and **56**. Meth-A and LLC tumor cells were used to evaluate the cytotoxic activity of **46–54** in vitro. Lucidumol A (**54**) and **40, 41, 55,** and **56** had cytotoxicity on both cancer cell lines. Among ganoderic alcohols, lucidumol A (**54**) (ED_{50}: 2.3 μg/mL) had the highest cytotoxicity to LLC cancer cell lines while **41** (ED_{50}: 3.4 μg/ml) inhibited Meth-A cancerous cell lines. On the contrary, ganoderic acids γ-θ (**46–51**) showed no activity against both tumor cells (Min et al. 2000).

Lucidenic acid O (**57**), lucidenic lactone (**58**), and cerevisterol (**59**) were selectively obtained from *G. lucidum* (Mizushina et al. 1999). The terpenoids **57** and **58** inhibited rat DNA polymerase B, and calf DNA polymerase A, successfully. The lanostanoids (**57–59**) isolated by these workers showed antiviral activity against the human immunodeficiency virus type 1 reverse transcriptase. However, only **59** inhibited the DNA polymerase A (Mizushina et al. 1999).

Zhao et al. (2015a) were two triterpenoids in lanostane (**60**) and abeo-lanostane skeletons (**61**) from *G. lucidum*. The lanostanoids **60** and **61** were used to test antifungal and cytotoxic activities; none of these exhibited antibacterial activity against *Candida albicans* or cytotoxic activity against HL-60 (human myeloid leukemia), A-549 (lung cancer), MCF-7 (breast cancer), SMMC-7721 (hepatocellular carcinoma), and SW480 (human colon cancer) human cancer cell lines.

3α,12β,15α-triacetoxy-5α-lanosta-7,9(11),24-trien-26-oic acid (**62**) and 5α-lanosta-8,24-diene-26,27-dihydroxy-3,7-dione (**63**), and triterpenoids **1**, **4**, **9**, **24**, **26**, **31**, **32**, **40, 41, 44**, **45**, **55, 64–67** were isolated from the *G. lucidum* specimens collected from Vietnam. Their cytotoxic activity was experimented against A549 (nonsmall lung), MCF-7 (breast), and PC-3 (prostat) cancerous cell lines and out of these triterpenoid (**62**) exhibited noteworthy activity against PC-3 cell lines (IC_{50}:11.5 μM). As for anti-angiogenesis activity of **1**, **4**, **9**, **24**, **26**, **32**, **40, 41, 44**,

45, **55, 64–67**, only ganoderic acid F (**31**) potentially inhibited the generation of human umbilical vein endothelial cells (Nguyen et al. 2015).

G. lucidum also contains highly oxygenated lanostane triterpenoids. Recently, 12 new norlanostanoids containing 27, 25 carbons were isolated and elucidated. The new rare nortriterpenoids (**68–72** and **75**) comprise of a 17*β*-pentatomic lactone ring, **99** had 27 carbons, while **73** and **74** had 25 carbons. The triterpenoids **68–79** were elucidated for the first time. The new and known lanostanoids **11, 30, 68–79, 80–85** were studied for their P-glycoprotein (P-gp) inhibitory activity using human MCF-7 (breast adenocarcinoma) cell lines resistant to doxorubicin. Among the lanostanoids **11, 68**, **72**, and **84** highly accumulated doxorubicin in MCF-7/doxorubicin cell lines when compared with the negative control. This means that **11, 68**, **72**, and **84** exhibit P-glycoprotein inhibitory activity significantly. The docking study suggested the P-gp distinguishing mechanisms for **11, 68**, **72**, and **84**, very close to each other when matched with verapamil's data, latter was used as a positive control (Zhao et al. 2015b). The chloroform extract of the *G. lucidum* gave 4 new lanostanoids; 12-epi-ganoderlactone D (**86**), 3*β*-hydroxy-12-deacetoxyganodernoid D (**87**), 3*β*-hydroxyganodernoid D (**88**), and 12*β*-hydroxyganoderenic F (**89**). These were also tested for their inhibitory effects on p-glycoprotein following the method mentioned above, but no activity was observed for all compounds (Zhao et al. 2016a).

Li et al. (2016a, b) isolated a new lanostanoid, 24(*S*),26-dihydroxy-5*α*-lanosta-7,9,25-trien-3-one (**90**), and 5α-lanosta-7,9(11),24-triene-15α,26-dihydroxy-3-one (**91**), and ganoderic acid DM (**1**), which were tested for their cytotoxicity against HCT-116 (colon cancer), KB (cervix carcinoma derivatives), and OE-19 (caucasian esophageal) cancerous cell lines. Among these, only **91** was slightly cytotoxic to all malignant cell lines (Li et al. 2016a, b).

Chen et al. (2017a) isolated 14 ergosterol type lanostane steroids (**92–104, 22**) from the lipid extract of *G. lucidum*. The new lanostane steroids were named as (22*E*)-4α, 5α-epoxy-6*β*-methoxy-7,22-diene-3*β*-ergosterol (**92**). The cytotoxicity of new steroid (**92**) and others (**93–103, 22**) was investigated against MDA-MB-231 and HepG2 cell lines, and NIH/3 T3 (mouse fibroblasts) healthy cell lines, and HUVEC (human umbilical vein endothelial) cell lines. The steroids **94–103** significantly inhibited the MDA-MB-231 and HepG2 cancer cell lines. Moreover, **93** exhibited cytotoxic activity against HepG2 and MDA-MB-231 tumor cell lines as well, and **95** against HUVECs cell lines. In the same study, ergosterol amount of the different extracts of *G. lucidum* was investigated to make way for the production of pharmaceuticals or food supplements to be used as antitumor or anti-angiogenesis chemotherapy agents (Chen et al. 2017a).

Five new ganoderols, namely ganodermanontetrol (**105**), 3*β*, 24*S*, 25*R*, 26-tetradroxy-7*α*-methoxy-8-ene-lanost-ol (**106**), 12*α*-methoxy-ganodermanondiol (**107**), lucidumol A (**54**), and 15α-hydroxy-ganodermanontriol (**108**), were isolated from *G. lucidum*. Chen et al. (2017b) studied the cytotoxic activity of 5 of these ganoderols (**54**, **105–108**) against MDA-MB-231 (breast) and HepG2 (hepatocellular) cancer cell lines. The results obtained for these isolated compounds were analyzed by computer using 3D-QSAR models to contribute to designing novel therapeutics in anticancer studies (Chen et al. 2017b).

Recently new aromatic compounds were obtained from *G. lucidum*. The names of these new lucidumins were elucidated as lucidumins A (**109**), B (**110**), C (**111**), D (**112**), and E (**113**), while known compounds were lingzhine C, ganocochlearin B, fornicin B, cochlearin I, ganocochlearine A, lucidimine A, and ganodine (**114–120**). Among them, **110–112** and **115–118,** which provided significant neuroprotective activity in damaged PC12 cells induced with corticosterone. The vitality of cells lied between 70 and 126% inhibitions. Some of the compounds were also tested for their anti-inflammatory activities in RAW264.7 macrophages. **109–113** and **118** well inhibited the production of NO (nitric oxide) (IC_{50} ranged from 4.68 to 15.49 μM (Lu et al. 2019). The compound **118** proved as potent neuroprotective and anti-inflammatory agent with 2.49 μM EC_{50}, and a 4.68 μM IC_{50}, respectively (Lu et al. 2019).

9.3 Bioactive Compounds Isolated from *Ganoderma tsugae* Murr

Benzofuran structured compound separated from *G. tsugae*; namely, ganodone (**121**) was tested for the cytotoxicity against HCT-116 cell lines (La Clair et al. 2011). In earlier study, it had afforded tsugarioside A (**122**), 3*β*-hydroxy-5*α*-lanosta-8, 24-dien-21-oic acid (**123**), and 3-oxo-5*α*-lanosta-8, 24-dien-21-oic acid (**124**) along with **125** and **126** (Lin et al. 1988; Gan et al. 1998). Tsugarioside B (**127**) and tsugarioside C (**128**), together with **129** (Su et al. 2000), were purified. The CaSKi (cervix derived from metastatic site), HT-3 (cervical carcinoma from metastatic site), PLC/PRF/5 (human hepatoma), SiHa (grade II, squamous), T-24 (urinary bladder transitional cell), and 212 (neuroblastoma) cancer cell lines were used to determine cytotoxic activity of these compounds (**123–126,** 1**28, 130–132**) isolated during two investigations. Compound **124** significantly inhibited the growth of T-24 (transitional cell) cancer cell line. Compounds **124–125** and **130** displayed remarkable cytotoxicity against CaSKi, T-24, and HT-3 cancer cell lines (Su et al. 2000).

Five new compounds isolated from *G. tsugae* included one lanostanoid (**133**), one novel palmitamide (**134**), and three seco-lanostanoids (**135**–**137**). The new lanostanoid was tsugaric acid F (**133**). The lanostanoid, 3-oxo-5α, lanosta-8-en-21-oic acid **(138)** was derived over 3-oxo-5α-lanosta-8,24-dien-21-oic acid (1**39**). The new lanostanoid (**133)** and derived compound (**138)** inhibited xanthine oxidase (XO) significantly (IC50: 313.3 and 43.9 μM, respectively). The superoxide in rat neutrophils was generated with formyl-Met-Leu-Phe and then cytochalasin B, and the inhibitory activity of superoxide radical in neutrophils was tested in vivo. The seco-lanostanoid, **137** inhibited superoxide generation, effectively in vivo (IC_{50}: 1.3 μM). Moreover, the **135**–**138** displayed cytotoxicity against PC3 (human prostate adenocarcinoma) cell lines. The compounds **137** and **138** are worthy natural compounds to be used in chemotherapy (Lin et al. 2016).

9.4 Bioactive Compounds Isolated from *Ganoderma orbiforme* (Fr.) Ryvarden

G. orbiforme is another tree mushroom resembling *G. lucidum* in shape. It contains the *Ganoderma* lanostanoids, including a novel, rearranged compound ganorbiformin A (**140**). In all, 19 lanostane type triterpenoids (**140–158**) were extracted, which seven are ganorbiformins A-G (**140–146**). The cytotoxic activity of the isolated compounds (**140**, **143–146**, **151–152**, **154**, **156**, and **158**) was tested against KB, MCF-7, and NCIH187 cancerous cell lines and Vero cell lines (nonmalignant) (Isaka et al. 2013). The compounds **140**, **143–146**, **151**, **156**, and **158** proven inactive in all assays. However, the C-3 epimer of **156** (**154**) and ganoderic acid T (**156**) exhibited all activities. The C-3 epimer compound (**154**) might serve as a potent pharmaceutical agent due to its weak cytotoxic activity to Vero cell lines (IC_{50} 16 μM), (Isaka et al. 2013). During the latest study on the cultivated *G. orbiforme,* ganoboninketal D (**159**), and (24S)-3-oxo-7α,24,25-trihydroxylanosta-8-ene (**160**), together with 6 known lanostanes (**161–166**) were isolated. Their cytotoxic activity was studied and only **164** (IC_{50}: 49 μg/mL), **165** (IC_{50}: 40 μg/mL), and **166** (IC_{50}: 20 μg/mL) exhibited cytotoxicity. Other compounds were noncytotoxic at 50 μg/ml (Isaka et al. 2017).

9.5 Bioactive Compounds Isolated from *Ganoderma amboinense* (Lam.) Pat

Sixteen lanostanoids were isolated from *G. amboinense*. These are: ganodermacetal (**167**), ganodermatriol (**168**), methylganoderate C (**169**), ganoderic acid C-D (**170**, **171**), ganoderic acid F (**172**), ganoderic acid P (**173**), lanosta-15*α*-deacetoxyganoderic acid P (**174**), ganoderic acid H (**175**), and ganoderic acid N (**176**), 15-hydroxy ganoderic acid S (**177**), ganodermanontriol (**178**), ganoderiol F (**179**) along with **1**, **5**, **7** (Yang et al. 2012). The in vitro toxicity of compounds **167**, **169**, **172**, **174**, **178**, and **179** was investigated using *Artemia salina* larvae. Four compounds **167, 169, 178**, and **179** indicated significant toxicity in the growth of larvae in the range of 70% and 91.5 as compared to chaetomugilin A (Yang et al. 2012). Ganoderic acid X (**180**), a lanostanoid inhibiting the growth of several cancerous cell lines, was also isolated from *G. amboinense* together with other cytotoxic lanostanoids. The lanostanoids isolated have proved inhibitory in topoisomerase I and topoisomerase II*α* enzymes in vitro (Li et al. 2005).

The lanostane triterpenoid ganoderic acid X (**180**) exhibited DNA synthesis inhibitory activity in HuH-7 (human hepatoma) cell lines. It also triggered apoptosis in HuH-7 cell lines, c-Jun *N*-terminal/stress-activated protein kinase (JNK), and the extracellular signal-regulated kinase (ERK) activities were increased by ganoderic acid X (**180**) (Li et al. 2005). It inhibited JNK–ERK, topoisomerases I–II*α*, and HuH-7 cancer cell lines. This points out that ganoderic acid X (**180**) can be promoted for cancer therapy.

9.6 Bioactive Compounds Isolated from *Ganoderma sinense*

The alkaloid sinensine (**181**) isolated from *G. sinense* protects HUVEC (umbilical vein endothelial) healthy cell lines, injured by H_2O_2-oxidation induction. The effective percentage concentration was calculated as 6.23 mmol/L (Liu et al. 2010).

In a recent mycochemical study on *G. sinense*, 3 new ergosterols (**182–184**) and known ergosterols (**59, 185–187**) exhibiting inhibitory activity against NO production were isolated. The ergosterols were named as ganocalidophins A-C (**182–184**) and ergosta-5,7,22-trien-3β-ol (**185**), 5α,6α-epoxyergosta-8(14),22-dien-3β,7α-diol (**186**), 3β,5α,9α-trihydroxyergosta-7,22-dien-6-one (**187**), and cerevisterol (**59**). The ranging of IC_{50} values 17.7 to 32.4 μM indicated that ergosterols **182–184** and **187** have potent inhibitory activity against NO production (Mei et al. 2019).

G. sinense contains 4 meroterpenoids; applanatumols F (**188**), I (**189**), H (**190**), and lingzhiol (**191**). Out of these **188**, **189**, and **191** are racemic mixtures of each other. However, **190** is the single enantiomer. Following the separation of enantiomers, probable activity of **188–191** on hydrogen peroxide (H_2O_2)-induced cell deaths was determined. In addition, underlying molecular mechanisms in human healthy liver LO2 cells of compounds **188–191** were also established. Out of the isolated compounds and their enantiomers, **189a** was the active one, its specific rotation was positive, effectively protecting LO2 (healthy human liver) cell lines from the cell damage by H_2O_2, by inducing apoptosis. The reactive oxygen species (ROS) increases following the cell exposures to H_2O_2. Due to the inhibitory activity of H_2O_2, ROS was indirectly inhibited following treatment with **189a**. This compound had also abilities to arrest the potential decrease of mitochondrial membrane, caspase-3 activation, nuclear fragments, and PARP (polymerase) cleavage. In **189a**-treated cells, upregulation of antioxidant enzymes phosphorylation Akt, Nrf2, and the HO-1 levels increases. The increment of these antioxidant enzymes means that it exhibited antioxidant activity against oxidative damage, which may protect LO2 cells against oxidative damage via PI3K/Akt-mediated activation of the Nrf2/HO-1 pathway (Gao et al. 2018).

HK2 (Hexokinase 2) is a rate-limiting enzyme in the first step of the glycolysis pathway. Normally, it is available in all cells; however, its amount is high in cancer cells. HK2 has a key role in the carcinogenic and metastatic processes, as such, it offers alternative objectives for cancer therapy. Theoretical calculations following virtual ligand screening program indicated that 3*β*-ol steroid (**193**) having *α* hydroxyl at C-5, *β* methoxy at C-6 position and double bonds at C-7 and C-9(11), and C-22 positions; isolated from *G. sinense*; could bind to HK2 because it has significant binding free energy to exhibit binding affinity with HK2. In vitro microscale thermophoresis (MST), enzyme inhibition, and cell-based assays related to the HK2 target were carried out for steroid **193**, and other 12 steroid analogues; tetraoxycitricolic acid (**192**), (22*E*,24*R*)-ergosta-7,9(*11*),22-triene-3*β*,5*α*,6*α*-triol (**194**), ergosta-4,6,8(*14*),22-tetraen-3-one (**195**), ergosta-7,22-dien-3-one (**196**), (22*E*,24*S*)-5*α*,8*α*-epidioxy-24-methyl-cholesta-6,22-dien-3*β*-ol (**197**), (22*E*,24*S*)-5*α*,8*α*-epidioxy-24-methyl-cholesta-6,9(*11*),22-trien-3β-ol (**198**), cyathisterol (**199**), 22*E*-7*α*-methoxy-5*α*,6*α*-epoxyergosta-8(*14*),22-dien-3*β*-ol (**200**), (22*E*,24*R*)-ergosta-7,9(*11*),22-triene-3*β*,5*α*,6*β*-triol (**201**), stigmasta-7,22-

diene-3*β*,5*α*,6*α*-triol (**202**), (22*E*,24*R*)-ergosta-7,22-diene-3*β*,5*α*,6*β*-triol (**203**), and 22*E*-6*β*-methoxyergosta-7,22-diene-3*β*,5*α*-triol (**204**) isolated from *G. sinense*. The compound **193** was exhibited inhibitory activity and was recommended as a potent HK2 inhibitor. Computational and laboratory analysis made steroid **193** as a natural HK2 inhibitor. Therefore, it could be used in cancer therapy by targeting at HK2 inhibitor (Bao et al. 2018).

IDH (isocitrate dehydrogenase) plays an essential role in the tricarboxylic acid cycle. Mutation of IDH enzyme results in cancers, such as sarcoma, glioblastoma, and acute myeloid leukemia. *G. sinense* contains 3 natural steroids **205–207** exhibiting inhibitory activity on IDH enzyme. Steroid **207** has the highest binding affinity to IDH1 with substantial binding free energy. The kinetic studies revealed that **207** inhibits the enzyme noncompetitively. In HT1080 (fibrosarcoma) cell lines, the EC_{50} of **207**; for reducing the concentration of D-2HG; was found to be 35.97 μM. After treating with **207**, the methylation levels of histone H3K9me3 (an epigenetic modification to the DNA packaging protein histone H3) in HT1080 cells were reduced. The anti-proliferative sensitivity of **207** decreased in HT1080 cells by the knockdown of mutant IDH1. The compound **207** could be considered as an effective potential agent in tumor therapies as proposed by Zheng et al. (2018).

New ganosinensols E-J (**208–213**), together with two known farnesyl phenolic compounds (**214–215**), were isolated from the ethanol extract of *G. sinense*. By using virtual ligand screening in a computer, the isolated farnesyl phenolic compounds, rather uncommon in natural products, are predicted to have high binding affinity to MTH1 (the mut-T homolog-1). MTH1 is a gene that is a medicine target to treat various cancers, but there are conflicting results. The cancerous cell lines are more addictive to said gene than healthy cells. MTH1 plays a significant role in maintaining the survival of cancer cells, but it is not necessary for healthy cells. Inhibitory effects of compounds (**208–215**) on MTH1 were also confirmed with in vitro cell-based experiments. The results of cellular thermal shift and siRNA knockdown assays indicated that these compounds bind with the MTH1 enzyme in intact cell lines, expressly. As these compounds (**208–215**) exhibit very low cytotoxicity on healthy human cell lines, with excellent selectivity and specificity to MTH1, it has placed them among the potential anticancer lead compounds (Gao et al. 2017). *G. sinense* has also 4 new compounds; ganosinensols A-D (**216–219**). These compounds with farnesyl phenolic skeleton exhibit productive inhibitory activity against nitric oxide production induced with LPS in RAW 264.7 macrophages. The IC_{50} ranges from 1.0 to 2.5 μM (Wang et al. 2016a).

9.7 Bioactive Compounds Isolated from *Ganoderma colossum*

G. colossum is another medicinally valuable mushroom species of the *Ganoderma* genus. Five farnesyl hydroquinones, namely fornicin B (**116**), ganomycin B (**220**), ganomycin I (**221**), and fornicin C (**222**), and fornicin A (**223**), were isolated from *G. colossum*. Two compounds, ganomycin B (**220**) (IC_{50}: 7.5 μg/mL) and ganomycin I (**221**) (IC_{50}: 1.0 μg/mL), significantly inhibit HIV-1 protease (El-Dine et al. 2009). The cytotoxicities of fornicin B (**116**), fornicin C (**222**), and fornicin A (**223**) were tested using Hep-2 (human larynx carcinoma) cell lines. All compounds exhibited more or less cytotoxic activity in the range of 15 and 23 μg/mL IC_{50} values (Niu et al. 2006; Salah et al. 2008).

Eight new lanostane type triterpenes, colossolactone A (**224**), colossolactone G (**225**), schisanlactone A (**226**), colossolactone E (**227**), colossolactone VIII (**228**), colossolactone VII (**229**), colossolactone VI (**230**), and colossolactone V (**231**) were purified from *G. colossum*. Among the tested triterpenoids, only **226**, **227**, **229**, and **231** inhibited HIV-1 protease exhibiting IC_{50} ranges between 5.0 and 13.8 μg/mL (El-Dine et al. 2008).

Three cytotoxic triterpene dilactones (**232**–**234**) were isolated from *G. colossum*. Among these, colossolactone H (**232**) shows the most potent cytotoxic activity. Its anticancer mechanism and the potential use in cancer therapy were evaluated. The lung cancer was treated with **232**, and the gene expression profiling analysis was performed. The results have revealed that 252 genes are upregulated, while 398 is downregulated by compound **232**. On the basis of analysis of enrichment of gene ontology in cell cycle progression, downregulated genes got enriched significantly, whereas in the metabolic process, upregulated genes were enriched for cellular response to the stimulus and oxidation-reduction.

As a result, **232** seems to be responsible for stopping the growth of cells, causing DNA damage. It was possible to induce apoptosis through high reactive oxygen species in cells, and also increase the tumor suppressor p53 protein. The last three events enable more cytotoxicity of the mixture of **232** and gefitinib (EGFR inhibitory drug used in mutated cancers) against gefitinib-resistant lung cancer (H1650). The mixture was used in athymic mice having no T cells, and the mixture of gefitinib and **232** inhibited the growth of lung cancer tumors, effectively (Chen et al. 2016).

9.8 Bioactive Compounds Isolated from *Ganoderma concinna* Ryvarden

Studies on *G. concinna* yielded 12 triterpenoids, these are 8*α*,9*α*-epoxy-4,4,14α-trimethyl-3,7,11,15,20-pentaoxo-5*α*-pregrane (**235**), 5*α*-lanosta-7,9(11),24-triene-3*β*-hydroxy-26-al(**236**),5*α*-lanosta-7,9(11),24-triene-15*α*-26-dihydroxy-3-one (**237**), ganoderic acid Y (**239**), ganoderiol A (**240**), ganoderiol B (**241**), ganoderiol F (**179**), ganoderal A^3 (**242**), ganodermadiol (**243**), ganodermenonol (**243A**), ganodermatriol (**168**), and ganodermanontriol (**178**). The results of cytotoxic activity of the tested triterpenoids indicated that **235**, **236**, and **237** induce apoptosis in promyelocytic leukemia HL-60 cell lines (Gonzalez et al. 2002).

9.9 Bioactive Compounds Isolated from *Ganoderma leucocontextum*

The *G. leucocontextum* has 26 lanostanoids, with 16 completely new. The new lanostanoids have been listed as ganoleucoins A-P (**244–259**). The names of remaining 10 known triterpenes (**1**, **18**, **178**, **179**, **239**, **241**, **260–263**) were ganoderiol J (**260**), ganoderic acid DM (**1**), ganoderone A (**261**), 11-hydroxy-3,7-dioxo-5-lanosta-8,24(E)-dien-26-oic acid (**262**), 3,7-dioxo-8,24(Z)-tirucalladien-26-oic acid (**263**), ganoderic acid Sz (**18**), ganodermanontriol (**178**), ganoderiol F (**179**), ganoderiol B (**241**), and ganoderic acid Y (**239**). Lanostanoids **1**, **18**, **178**, **239**, **244**, **246**, **249**, **253–257**, and **260** inhibited HMG-CoA reductase. Lanostanoids **256** (IC_{50}:13.6 μM), **257** (IC_{50}: 2.5 μM), and **259** showed remarkable inhibitory activity against α-glucosidase. The cytotoxic activity of **1, 18, 178, 179, 239, 241, 244–263** was performed against K562 (human bone marrow) and PC-3 (human prostate) cancerous cell lines in vitro. Lanostanoids **1**, **239**, **244**, **245**, **249**, **250**, **253**, **255**, and **259** exhibited good cytotoxic activity against K562 cells. The IC_{50} ranged between 10 and 20 μM (Wang et al. 2015).

Twenty-four new lanostanoids, such as leucocontextins A-R (**264–281**) and leucocontextins S-X (**282–287**), were isolated from *G. leucocontextum*. The cytotoxicity evaluation revealed that only leucocontextins R (**281**) exhibited weak cytotoxic activity against K562 (IC_{50}: 20 μM) and MCF-7 (IC_{50}: 30 μM) cell lines (Zhao et al. 2016b, c).

The mycochemical studies revealed 16 compounds including new lanostanoids like ganoleucoins Q-S (**288–290**), and 13 known lanostanoids such as ganoderic acid C2 (**53**), ganomycin J (**291**), spiroapplanatumine M (**292**), spiroapplanatumine D (**293**), spirolingzhine A (**294**), ganosinensine (**295**), spirolingzhine B (**296**), ganoderic GS-2 (**297**), methylganoderate L (**298**), ganoderic acid I (**299**), ganoderic acid L (**300**), ganoderenic acid C (**301**), and 7β,20,23ξ-trihydroxy-3,11,15-trioxolanosta-8-en-26-oic acid (**302**). All compounds obtained were tested for their neuroprotective activity in PC12 cell lines. Compounds **288** and **289** displayed a protective effect against the damage of H_2O_2 at 200 μM. The vitality rate of **288** was 83.19 ± 0.92%, while the rate of **2** was 73.37 ± 1.25% at the same concentration. The neurite outgrowth at 50–200 μM was induced by the compounds **288** and **289**. The results point out that *G. leucocontextum* and its compounds are a potential medicine to prevent neurodegenerative diseases (Chen et al. 2018).

9.10 Bioactive Compounds Isolated from *Ganoderma capense* (Lloyd) Teng

Seven compounds including 2 new lanostanoid (**303** and **304**), 2 new ergostane-type steroids (**305** and **306**), and 3 known lanostanoids (**307** and **308**) and steroid (**309**) were isolated from *G. capense*. Among the compounds, **303** indicates cytotoxic activity against NCI-H1650 (human lung cancer, derived from the metastatic site) cell lines. The IC_{50} of **303** was 22.3 μM. Steroid **309** also exhibited cytotoxic activity against 5 cancerous cell lines, including HCT116 (colon cancer, colorectal), BGC823 (gastric), Daoy (brain/cerebellum, desmoplastic cerebellar medulloblastoma), HepG2 (liver, hepatocellular), and NCI-H460 (lung) cancer cell lines. The IC_{50} values of **309** were reported as 17.4, 21.4, 21.9, 28.1, and 42.1 μM, respectively (Tan et al. 2018).

G. capense also has cadinane and eudesmane-type sesquiterpenoids. New sesquiterpenoids were named as ganodermanol A-H (**310–317**), ganodermanol I-K (**318–320**), and rel-(+)-(2aR,5R,5aR,8S,8aS,8bR)-decahydro-2,2,5,8-tetramethyl-2Hnaphtho[1,8-*bc*] furan-5-ol (**321**), eudesm-1β, 6α, 11-triol (**322**), bluemenol A (**323**). Among the isolated compounds, ganodermanol C (**312**), ganodermanol D (**313**), and ganodermanol I (**318**) have moderate activity against HCT116 (colorectal) carcinoma cells. The IC_{50} of **312–313** and **318** is 24.5, 16.6, and 12.2 μM, respectively. Ganodermanol D (**313**) also exhibits cytotoxic activity against BGC823, Daoy, and HepG2 (IC_{50}: 49.9, 31.1, and 27.9 μM, respectively). Ganodermanol F (**315**), however, has weak cytotoxicity against both NCI-H1650 and Daoy cancerous cell lines (IC_{50}: 28.9 and 35.5 μM, respectively) (Tan et al. 2017).

The two studies have revealed that *G. capense* is a good source of lanostane steroids, lanostane triterpenoids, and sesquiterpenes; however, it seems that the isolated pure compounds cannot be used in therapy alone.

9.11 Bioactive Compounds Isolated from *Ganoderma applanatum* (Pers.) Pat

G. applanatum possesses ganoapplanic acid A (**324**) and ganoapplanic acid B (**325**), both novel rearranged triterpenoids, and ganoapplanilactones A-C (**327**–**329**) which are new spiro-lanostane triterpenoids, and ganoapplanic acids C and F (**326** and **332**), and methyl ganoapplaniates D and E (**330** and **331**), together with two known triterpenoids (**333** and **334**) were isolated. The triterpenoids **324**, **326**, **330**, **332**, and **334** successfully inhibit proliferation of HSCs (hepatic stellate) cells, induced by TGF-b1 (transforming growth factor-b1), in vitro (Li et al. 2018).

9.12 Bioactive Compounds Isolated from *Ganoderma hainanense*

Mycochemical investigations of *G. hainanense* revealed 14 new lanostanoids and 5 known compounds. According to the structure elucidation, the compounds were named as ganohainanic acids A-E (**335–339**), and acetyl ganohainanic acids A (**340**) and C (**341**), and hainanic acids A-B (**342–343**), and 24*S*,25*R*-dihydroxy-3,7-dioxo-8-en-5α-lanosta-26-ol (**344**), 3,7,24-trioxo-8,25-dien-5α-lanosta-26-ol (**345**), 3β,7β-dihydroxy-11-oxo-8,24*E*-dien-5α-lanosta-26-ol (**346**), 21-hydroxy-3,7-

dioxo-8,24*E*-dien-5*α*-lanosta-26-ol (**347**), hainanaldehyde A (**348**), ganoderol J (**349**), ganoderone A (**261**), lucidadiol (**350**), ganodermanontriol (**178**), and 4,4,14α-trimethyl-3,7-dioxo-5α-chol-8-en-24-oic acid (**351**). The cytotoxic activity using MTT method of isolated new and known lanostanoids **178**, **261**, **335**, **336–342**, **344–346**, **350–351** was studied against SMMC-7721, MCF-7, A-549, HL-60, and SW480 cancerous cell lines. Lanostanoids **344**, **348**, and **350** having IC_{50} values in 15–40 μM range selectively inhibit the growth of MCF-7, A549, SMMC-7721, and HL60 malignant cells. In contrast, none of the lanostanoids exhibit activity against SW480 (colorectal adenocarcinoma) cell lines (Peng et al. 2015).

In another study with *G. hainanense*, 12 compounds (**9**, **18**, **179**, **239**, **352–359**) in lanostane triterpenoid structure, including a new lanostanoid; 16*α*, 26-dihydroxy lanosta-8,24-dien-3-one (**352**) were reported. Compounds **2–12** were elucidated as methyllucidenate A (**9**), ganoderic acid Sz (**18**), ganoderiol F (**179**), ganoderic acid Y (**239**), methyl lucidenate N (**353**), lucidenic acid N (**354**), lucidenate A (**355**), ganodermic acid TQ (**356**), agnosterone (**357**), ganodermanondiol (**358**), and lucidumol B (**359**). The cytotoxicity evaluation of all compounds against K-562, SMMC-7721, and SGC-7901 was carried out. Lanostanoids **239**, **352**, **353**, **355**, and **357** exhibited specific cytotoxic activity against K-562 cell lines. Some of the lanostanoids like **239**, **353**, **355**, and **357** also indicated cytotoxicity against SMMC-7721 and SGC-7901 cell lines (Ma et al. 2013).

The fruiting body of *G. hainanense* possessed 20 pure lanostanoids (**53**, **299**, **360–377**). The new lanostanoids are named as ganoderenses A-E (**360–364**), and ganoderenses F and G (**365** and **366**). Out of these latter 2 were nor-triterpenoids. Among the lanostanoids, **360** and **371** were the crystals. Isolated and elucidated 20 compounds were screened for their thioredoxin reductase (TrxR) inhibitory activity, which is a potential target for cancer chemotherapy. Unfortunately, all lanostanoids are inactive (Li et al. 2016a, b).

9.13 Bioactive Compounds Isolated from *Ganoderma cochlear* (Nees) Merr

G. cochlear too is medicinally valuable. Studies on its protective effects against kidney disorders and cochlearoids F-K (**378–383**) revealed that novel meroterpenoids were isolated from its fruiting body. Meroterpenoids **378–381** and **383** significantly inhibit the overproduction of fibronectin in HKC-8 cells induced by TGF-b1 (Wang et al. 2016b).

The mycochemical studies on *G. cochlear* revealed new meroterpenoids, cochlearols E-M (**384–392**), and known meroterpenoids **393–399**. These were purified and elucidated. The racemic mixtures of **384**, **389–391**, **393**, and **396** were further purified using chiral HPLC. The renoprotective activity of the meroterpenoids was performed using healthy rat and diseased renal interstitial fibroblast cells (NRKe49F cell lines). It was noted that the compounds with enantiomers of **390a**, **390b**, and **393a** have potent proliferation inhibitory effect in TGF-β1-induced NRK-49F cells (Wang et al. 2019a). In addition, 12 new meroterpenoids;,cochlearols N-Y

(**400–411**) and their 2 known analogs, ganocochlearins B (**115**) and C (**412**), were purified. Renoprotective activity of **115**, **400–412** was also carried out using TGF-β1-induced NRK-49F cell lines. On the basis of activity results, ganocochlearins S (**405**), U (**407**), X (**410**), and Y (**411**) exhibited renoprotective activity against fibronectin overproduction in TGF-β1-induced NRK-49F cells (Wang et al. 2019b).

Qin et al. (2018) purified new spiro meroterpenoidal dimeric enantiomers from *G. cochlear*. The spiro meroterpenoidal were mostly racemic mixtures, and the isolated enantiomers were named as (+)- and (−)-spirocochlealactones A-C (**413–415**), and ganodilactone (**416**). Cytotoxic activity of **413–416** against A549 (lung), K562 (bone marrow, chronic myelogenous leukemia), and Huh-7 (liver) human cancer cell lines was also performed. The compounds exhibited some cytotoxic activity. Notably, (+)-spirocochlealactone A (**413**) and (+)-ganodilactone (**416**) indicated moderately cytotoxic activity against A549 cell lines (IC_{50}: 7.14 and 9.47 μM, respectively) (Qin et al. 2018).

These authors continued to isolate cytotoxic compounds from *G. cochlear*, and meroterpenoids, like (±) cochlearoids N-P (**417–419**), were obtained. The inhibitory activity of meroterpenodis **417–419** was carried out against human cancer cells over BRD4 (a member of the bromodomain and extraterminal protein family). The results show that the enantiomers of (±)-**417** were the BRD4 inhibitors, while only enantiomers (−)-**417** (IC_{50}: 7.68 μM) and (+)-**419** (IC_{50}: 6.68 μM) were found to be cytotoxic to K562 (bone marrow) cancerous cells (Qin et al. 2019).

G. cochlear also afforded 7 meroterpenoids, 3 of these are new namely; (+)- and (−)-gancochlearol C (**420**), (+)- and (−)-cochlearoid Q (**422**), and gancochlearol D (**421**). The meroterpenoids (**420–426**) were subjected to cytotoxic activity studies against H1975 (lung cancer), PC9 (lung cancer), A549 (lung cancer) cell lines, and inhibitory activity of *N*-acetyltransferase enzyme. The *N*-acetyltransferase enzyme was significantly inhibited by (+)-gancochlearol C (**420**) with an IC_{50} value of 5.29 μM. Among the isolated compounds, only ganomycin F (**424**) exhibited moderate activity against H1975 cancerous cell lines, indicating 19.47 μM IC_{50} value (Cheng et al. 2018). It seems that *G. cochlear* is a source of meroterpenoids, which could play a potential role to inhibit the growth of tumors in vitro.

9.14 Bioactive Compounds Isolated from *Ganoderma theaecolum* J.D. Zhao (1984)

The study on the isolation and structural elucidation of cytotoxic compounds from *G. theaecolum* was reported by Liu et al. (2017). In all, 7 lanostane triterpenoids were isolated, out of these 3 were elucidated for the first time. These triterpenes were named as ganoderic acid XL_3 (**427**), ganoderic acid XL_4 (**428**), ganoderic acid XL_5 (**429**), ganoderic acid Y (**239**), 7-oxo-ganoderic acid Z (**430**), 7-oxo-ganoderic acid Z_2 (**431**), and ganoderon B (**432**). The cytotoxic activity of isolated triterpenoids (**239**, **427–432**) was tested against BGC823 (gastric cancer), HepG2 (hepatocellular liver carcinoma), HCT116 (human colon colorectal carcinoma), MDA-MB-231 (human breast adenocarcinoma), and H460 (human lung carcinoma) cell lines, in vitro. Out of these, **239** and **431** displayed cytotoxicity against H460 cell lines exhibiting 22.4 and 43.1 μM IC_{50} values, respectively. The compounds **239** and **430** also demonstrated moderate cytotoxic activity against MDA-MB-231 cancer cell lines, their IC_{50} values were 49.1 and 75.8 μM, respectively (Liu et al. 2017).

9.15 Bioactive Compounds Isolated from *Ganoderma boninense* Pat

The only mycochemical study on the isolation and structural elucidation of cytotoxic compounds from *G. boninense* was published by Ma et al. (2014). In this study, new nortriterpenes such as ganoboninketals A-C (**433–435**), with rearranged 3,4-seco-27-norlanostane skeletons, were isolated from *G. boninense*. The compounds (**433–435**) were tested for their cytotoxic activity against a series of cancerous cell lines. Except compound **434**, all showed cytotoxicity against A549 cell line displaying 47.6 and 35.8 μM IC_{50} values, respectively. Moreover, **434** had weak cytotoxicity against HeLa cell lines (IC_{50}: 65.5 μM). What's more, the ganoboninketals A-C (**433–435**) inhibited NO in the LPS-induced macrophages by demonstrating 98.30, 24.30, and 60.90 μM IC_{50}, respectively (Ma et al. 2014).

9.16 Bioactive Compounds Isolated from *Ganoderma gibbosum* (Blume & T. Nees) Pat

The cytotoxic compounds isolated from *G. gibbosum* were published by Pu et al. (2017). This study revealed 8 new and 3 known highly oxygenated gibbosic acids A-H (**436–443**) and elfvingic acid B (**444**), C (**445**), G (**446**). The immunoregulatory activity of the elucidated gibbosic acids (**436–446**) was tested using different approaches. Only, gibbosic acid B (**437**) displayed good immunostimulatory activity in lymphocyte proliferation assay without any induction and ConA-induced mitogenic activity of T-lymphocyte. The lymphocyte proliferation proportion was 20.01% and 21.40%, respectively, at the concentration of 0.1 μM (Pu et al. 2017).

9.17 Bioactive Compounds Isolated from *Ganoderma calidophilum*

Only cytotoxic compounds isolated from *G. calidophilum* were reported by Huang et al. (2017). The mycochemical studies have resulted in the separation of spiroganocalitones A-D (**447–450**), ganodecalones A and B (**451–452**) and known lanostane triterpenes ganoderiol F (**179**) ganoderone A (**261**), ganodermanondiol (**358**), and ganoderol B (**453**). The cytotoxic activity of all isolates was carried out against BEL7402, SGC790, and K562 cancer cell lines. The lanostanoid ganoderone A (**261**) showed more or less cytotoxicity against below cancerous cell lines, indicating 7.62, 6.28, and 3.55 mM IC_{50} values, respectively (Huang et al. 2017).

9.18 Bioactive Compounds Isolated from *Ganoderma lingzhi*

G. lingzhi, a member of the Reishi family, is used as medicine in Asian countries. The only study on the isolation of cytotoxic compounds from this species was published by Amen et al. (2016a). The mycochemical study of an apolar extract of *G. lingzhi* revealed that it contains lucidumol C (**454**) and 6 known mycochemicals (**4**, **20**, **22**, **455**–**457**). The cytotoxicity of the isolated compounds was tested against several cancerous cell lines, including colorectal (Caco-2 and HCT-116), cervical (HeLa), breast (MCF-7) and liver (HepG2) carcinoma and human fibroblast (HF19 and TIG-1) cell lines. Lucidumol C (**454**) can be used in the treatment of colon cancer as a potential candidate as it exhibits selective cytotoxic activity against HCT-116 cancerous cell lines (IC_{50}: 7.86 ± 4.56 μM). Moreover, **454** also exhibits noteworthy cytotoxicity to HeLa, HepG2, and Caco-2 cancerous cell lines (Amen et al. 2016a). Moreover, 8 triterpenes isolated here, and 2 have been elucidated for the first time as ethyl esters of triterpene acid from *G. lingzhi*. The compounds have been named as methyl ganoderenate D (**458**), 12β-acetoxy-7β-hydroxy-3,11,15,23-tetraoxo-5α-lanosta-8,20-dien-26-oic acid (**459**), methyl lucidenate A (**9**), ethyl lucidenate A (**460**), 12β-acetoxy-3,7,11,15,23-pentaoxo-5α-lanosta-8-en-26-oi acid ethyl ester (**461**), ganoderic acid GS-1 (**462**), 12β-acetoxy-7β-hydroxy-3,11,15,23-tetraoxo-5α-lanosta-8,20-dien-26-oic acid (**463**), and ganoderic acid F (**14**). The cytotoxicity potential of isolated compounds was assayed using the above cancerous and fibroblast cell lines. However, only compound **458** exhibited selective moderate cytotoxicity to MCF-7 and weak activity to HeLa cell lines (Amen et al. 2016b).

9.19 Conclusions

Since ancient times, the medicinal plants and mushrooms have played a vital role in drug research due to their stereochemistry power. Aspirin, taxol, artemisinin, and huperzine A and tacrine, along with penicillin and antibiotics, are typical examples. Millions of novel and new chemicals have been isolated as natural products possessing chiral centers. Natural products mostly contain chiral centers, which bring an advantage for a compound to be a drug. The compounds from natural origin mostly take place as a single enantiomer. One enantiomer of the pure compound can be used medicinally. As against this, another enantiomer of the drug may be toxic or ineffective. These newly discovered compounds as natural products can prove advantageous in some diseases. During the past century more than 200,000 natural compounds have been isolated from nature, but only some were developed as medicines. The statistical data reveal that almost 50% of the drugs approved between 1993 and 2007 were natural products. In 2008, 225 new drugs from natural origin were developed, and 38% of these were used as anticancer drugs but were toxic. The anticancer drugs used currently have many side effects. The searches for new biologically active nontoxic therapeutics are continuing. The researchers have considered mushrooms as a rich sources of cytotoxic compounds. Therefore, mushrooms have been investigated, particularly since the last two decades in detail, in order to find a cure for cancer. The reason being that lately this disease is almost the most seen in the whole world, and its treatment has become a challenge.

The *Ganoderma* genus has been studied in detail during the last twenty years, to discover biologically effective active compounds. Till now hundreds of medicinally valuable compounds have been isolated from the genus. Lanostane-type compounds were mostly isolated by researchers to check their cytotoxicity against many cancer cell lines.

The data published show that important new cytotoxic compounds that may be potent for cancer treatment have been isolated from *Ganoderma* genus. However, we have to keep in mind that *Ganoderma* species can be used homeopathically, and they should not be considered as nostrums. Many scientific achievements have been made in 2020. These studies stress that compounds to be used in cancer must be tested in vivo after successful in vitro testing. New bioactive compounds isolated or to be isolated from *Ganoderma* species should be nontoxic to healthy cells but exterminate cancerous cells by apoptosis, and this must be tested in patients by doctors.

The temperature, habitat, altitude, humidity, and host tree influence the ingredients of the natural products. Therefore, an optimization of the chemical compounds of *Ganoderma* species with medicinal uses is necessary. Moreover, there is little information about the pharmacology of bioactive chemicals of *Ganoderma* species. The dose of the bioactive extracts, fractions, and the pure bioactive compounds are still not known to be used to treat cancer-related diseases. *Ganoderma* species due to their afforded compounds or standardized extracts or standardized fractions promise to be potent anticancer agents for the future.

Acknowledgments The authors would like to thank TUBITAK (Scientific and Technological Research Council of Turkey) for supporting this study under the project number TUBITAK-TBAG-114Z635.

References

Amen YM, Zhu Q, Tran H-B et al (2016a) A new cytotoxic lanostanoid triterpene from *Ganoderma lingzhi* against human cancer cells. J Nat Med 70:661–666

Amen YM, Zhu Q, Afifi MS et al (2016b) New cytotoxic lanostanoid triterpenes from *Ganoderma lingzhi*. Phytochem Lett 17:64–70

Bao F, Yang K, Wu C et al (2018) New natural inhibitors of hexokinase 2 (HK2): steroids from *Ganoderma sinense*. Fitoterapia 125:123–129

Chen S-Y, Chang C-L, Chen T-H et al (2016) A new *Ganoderma* triterpenoid exhibits cytotoxicity and potentiates drug efficacy of gefitinib in lung cancer. Fitoterapia 114:81–91

Chen S, Li X, Yong T et al (2017a) Cytotoxic lanostane-type triterpenoids from the fruiting bodies of *Ganoderma lucidum* and their structure-activity relationships. Oncotarget 8(6):10071–10084

Chen S, Yong T, Zhang Y et al (2017b) Anti-tumor and anti-angiogenic ergosterols from *Ganoderma lucidum*. Front Chem 5:Article 85

Chen H, Zhang J, Ren J et al (2018) Triterpenes and meroterpenes with neuroprotective effects from *Ganoderma leucocontextum*. Chem Biodivers 15:e1700567

Cheng L-Z, Qin F-Y, Ma X-C et al (2018) Cytotoxic and N-acetyltransferase inhibitory meroterpenoids from *Ganoderma cochlear*. Molecules 23:1797

El-Dine RS, El Halawany AM, Ma CM et al (2008) Anti-HIV-1 protease activity of lanostane triterpenes from the Vietnamese mushroom *Ganoderma colossum*. J Nat Prod 71:1022–1026

El-Dine RS, El Halawany AM, Ma CM et al (2009) Inhibition of the dimerization and active site of HIV-1 protease by secondary metabolites from the Vietnamese mushroom *Ganoderma colossum*. J Nat Prod 72:2019–2023

Gan KH, Fann YF, Hsu SH et al (1998) Mediation of the cytotoxicity of Lanostanoids and steroids of *Ganoderma tsugae* through apoptosis and cell cycle. J Nat Prod 61:485–487

Gao JJ, Min BS, Ahn EM et al (2002) New triterpene aldehydes, lucialdehydes A-C, from *Ganoderma lucidum* and their cytotoxicity against murine and human tumor cells Chem. Pharm Bull 50:837–840

Gao Y, Zhu L, Guo J et al (2017) Farnesyl phenolic enantiomers as natural MTH1 inhibitors from *Ganoderma sinense*. Oncotarget 8(56):95865–95879

Gao S, Zhang P, Zhang C et al (2018) Meroterpenoids from *Ganoderma sinense* protect hepatocytes and cardiomyocytes from oxidative stress-induced injuries. Fitoterapia 131:73–79

Globocan (2012) Estimated cancer incidence, mortality and prevalence worldwide in 2012. International Agency for Research on Cancer. http://globocan.iarc.fr/Default.aspx. Accessed on 15 May 2017

Gonzalez AG, Leon F, Rivera A et al (2002) New Lanostanoids from the fungus *Ganoderma concinna*. J Nat Prod 65:417–421

Huang QL, Jin Y, Zhang LN et al (2007) Structure, molecular size and antitumor activities of polysaccharides from *Poria cocos* mycelia produced in fermenter. Carbohyd Polym 70:324–333

Huang S-Z, Ma Q-Y, Kong F-D et al (2017) Lanostane-type triterpenoids from the fruiting body of *Ganoderma calidophilum*. Phytochemistry 143:104–110

Isaka M, Chinthanom P, Kongthong S et al (2013) Lanostane triterpenes from cultures of the basidiomycete *Ganoderma orbiforme* BCC 22324. Phytochemistry 87:133–139

Isaka M, Chinthanom P, Mayteeworakoon S et al (2017) Lanostane triterpenoids from cultivated fruiting bodies of the basidiomycete *Ganoderma orbiforme*. Phytochem Lett 21:251–255

Iwatsuki K, Akihisa T, Tokuda H et al (2003) Lucidenic acids P and Q, methyl lucidenate P, and other triterpenoids from the fungus *Ganoderma lucidum* and their inhibitory effects on epstein-barr virus activation. J Nat Prod 66:1582–1585

La Clair JJ, Rheingold AL, Burkart MD (2011) Ganodone, a bioactive benzofuran from the fruiting bodies of *Ganoderma tsugae*. J Nat Prod 74:2045–2051

Lee IS, Seo JJ, Kim JP et al (2010) Lanostane triterpenes from the fruiting bodies of *Ganoderma lucidum* and their inhibitory effects on adipocyte differentiation in 3T3-L1 cells. J Nat Prod 73:172–176

Li CH, Chen PY, Chang UM et al (2005) Ganoderic acid X, a lanostanoid triterpene, inhibits topoisomerases and induces apoptosis of cancer cells. Life Sci 77:252–265

Li P, Shen C-E, Nan T-T, Xu J-H (2016a) A new Lanostanoid from *Ganoderma lucidum*. Chem Nat Compd 52(1):71–73

Li W, Lou L-L, Zhu J-Y et al (2016b) New lanostane-type triterpenoids from the fruiting body of *Ganoderma hainanense*. Fitoterapia 115:24–30

Li L, Peng X-R, Dong J-R et al (2018) Rearranged lanostane-type triterpenoids with antihepatic fibrosis activities from *Ganoderma applanatum*. RSC Adv 8:31287–31295

Lin LJ, Shiao MS, Yeh SF (1988) Triterpenes from *Ganoderma lucidum*. Phytochemistry 27:2269–2271

Lin K-W, Maitraie D, Huang A-M et al (2016) Triterpenoids and an alkamide from *Ganoderma tsugae*. Fitoterapia 108:73–80

Liu C, Zhao F, Chen RY (2010) A novel alkaloid from the fruiting bodies of *Ganoderma sinense* Zhao, Xu et Zhang. Chinese Chem Lett 21:197–199

Liu L-Y, Yan Z, Kang J et al (2017) Three new triterpenoids from *Ganoderma theaecolum*. J Asian Nat Prod Res 19(9):847–853

Lu S-Y, Peng X-R, Dong J-R et al (2019) Aromatic constituents from *Ganoderma lucidum* and their neuroprotective and anti-inflammatory activities. Fitoterapia 134:58–64

Ma Q-Y, Luo Y, Huang S-Z et al (2013) Lanostane triterpenoids with cytotoxic activities from the fruiting bodies of *Ganoderma hainanense*. J Asian Nat Prod Res 15(11):1214–1219

Ma K, Ren J, Han J et al (2014) Ganoboninketals A-C, antiplasmodial 3,4-seco-27-norlanostane triterpenes from *Ganoderma boninense* pat. J Nat Prod 77:1847–1852

Masoodi KZ, Amin I, Mansoor S et al (2020) Botanicals from the Himalayas with anticancer potential – an emphasis on Kashmir Himalayas. In: Munir Ozturk M, Egamberdieva D, Pešić M (eds) Biodiversity and biomedicine – our future. Chapter 11. Academic Press, New York, pp 189–234

Mei RQ, Zuo FJ, Duan XY et al (2019) Ergosterols from *Ganoderma sinense* and their anti-inflammatory activities by inhibiting NO production. Phytochem Lett 32:177–180

Min BS, Gao JJ, Nakamura N, Hattori M (2000) Triterpenes from the spores of *Ganoderma lucidum* and their cytotoxicity against Meth-A and LLC tumor cells. Chem Pharm Bull 48:1026–1033

Mizuno T (1999) The extraction and development of antitumor active polysaccharides from medicinal mushrooms in Japan. Int J Med Mushroom 1:9–30

Mizushina Y, Takahashi N, Hanashima L et al (1999) Lucidenic acid O lactone, new terpene inhibitors of eukaryotic DNA polymerases from basidiomycete, *Ganoderma lucidum*. Bioorgan Med Chem 7:2047–2052

Moradali MF, Mostafavi H, Ghods S, Hedjaroude GA (2007) Immunomodulating and anticancer agents in the realm of macromycetes fungi (macrofungi). Int Immunopharmacol 7:701–724

Nguyen VT, Nguyen TT, Cuong TD et al (2015) Cytotoxic and anti-angiogenic effects of lanostane triterpenoids from *Ganoderma lucidum*. Phytochem Lett 12:69–74

Niu XM, Li SH, Sun HD, Che CT (2006) Prenylated phenolics from *Ganoderma fornicatum*. J Nat Prod 69:1364–1365

Ozturk M, Akcicek E, Guvensen A (2008) Mushrooms and their medicinal value. In: International symposium on food, nutrition and cancer, 17–19 April, Ataturk Culture Centre, Izmir, Turkey, 1–12 p

Ozturk M, Akçiçek E, Güvensen A, Altay V (2016) Mantarların Tıbbi Değeri. In: Ötleş S, Akçiçek E (eds) Kanserden Korunmada Gıdalar ve Beslenme. Sidas Medya Ltd. şti, İzmir, pp 213–220

Peng XR, Liu JQ, Xia JJ et al (2015) Lanostane triterpenoids from *Ganoderma hainanense* J.D. Zhao. Phytochemistry 114:137–145

Pu D-B, Zheng X, Gao J-B et al (2017) Highly oxygenated lanostane-type triterpenoids and their bioactivity from the fruiting body of *Ganoderma gibbosum*. Fitoterapia 119:1–7

Qin F-Y, Yan Y-M, Tu Z-C, Cheng Y-X (2018) Meroterpenoid dimers from *Ganoderma* cochlear and their cytotoxic and COX-2 inhibitory activities. Fitoterapia 129:167–172

Qin F-Y, Yan Y-M, Tu Z-C, Cheng Y-X (2019) (±) Cochlearoids N-P: three pairs of phenolic meroterpenoids from the fungus *Ganoderma cochlear* and their bioactivities. J Asian Nat Prod Res 21(6):542–550

Regina MMG, Elisabeth W, Jamile RR et al (2008) Alternative medium for production of *P. ostreatus* biomass and potential antitumor polysaccharides. Bioresour Technol 99:76–82

Rout S, Banerjee R (2007) Alternative medium for production of *P. ostreatus* biomass and potential antitumor polysaccharides. Bioresour Technol 98:3159–3163

Salah R, El Halawany A, Nakamura N et al (2008) New lanostane triterpene lactones from the Vietnamese mushroom *Ganoderma colossum* (Fr.) C.F. Baker. Chem Pharm Bull 56:642–646

Seo HW, Hung TM, Na MK et al (2009) Steroids and triterpenes from the fruit bodies of *Ganoderma lucidum* and their anti-complement activity. Arch Pharm Res 32:1573–1579

Sheena V, Hertz R, Berman I et al (2005) Transcriptional suppression of human microsomal triglyceride transfer protein by hypolipidemic insulin sensitizers. Biochem Pharmacol 70:1548–1559

Siegel R, Mille K, Jemal A (2017) Cancer statistics. Cancer J 67(1):7–30
Su HJ, Fann YF, Chung MI et al (2000) New lanthostanoids of *Ganoderma tsugae*. J Nat Prod 63:514–516
Tan Z, Zhao J, Liu J et al (2017) Sesquiterpenoids from the cultured mycelia of *Ganoderma capense*. Fitoterapia 118:73–79
Tan Z, Zhao J-L, Liu J-M et al (2018) Lanostane triterpenoids and ergostane-type steroids from the cultured mycelia of *Ganoderma capens*e. J Asian Nat Prod Res 20(9):844–851
Tong H, Xia N, Feng K et al (2009) Structural characterization and in vitro antitumor activity of a novel polysaccharide isolated from the fruiting bodies of *Pleurotus ostreatus*. Bioresour Technol 100:1682–1686
Wang K, Bao L, Xiong W et al (2015) Lanostane triterpenes from the tibetan medicinal mushroom *Ganoderma leucocontextum* and their inhibitory effects on HMG-CoA reductase and α-glucosidase. J Nat Prod 78:1977–1989
Wang M, Wang F, Xu F et al (2016a) Two pairs of farnesyl phenolic enantiomers as natural nitric oxide inhibitors from *Ganoderma sinense*. Bioorg Med Chem Lett 26:3342–3345
Wang X-L, Zhou F-J, Dou M et al (2016b) Cochlearoids F-K: phenolic meroterpenoids from the fungus *Ganoderma cochlear* and their renoprotective activity. Bioorg Med Chem Lett 26:5507–5512
Wang X-L, Wu Z-H, Di L et al (2019a) Renoprotective meroterpenoids from the fungus *Ganoderma cochlear*. Fitoterapia 132:88–93
Wang X-L, Wu Z-H, Di L et al (2019b) Renoprotective phenolic meroterpenoids from the mushroom *Ganoderma cochlear*. Phytochemistry 162:199–206
Weng CJ, Chau CF, Chen KD et al (2007) The anti-invasive effect of lucidenic acids isolated from a new *Ganoderma lucidum* strain. Mol Nutr Food Res 51:1472–1477
World Cancer Report (2014). http://www.videnza.org/wp-content/uploads/World-Cancer-Report-2014.pdf. Accessed on 20 May 2018
World Health Organization (WHO) (2008) Cancer mortality and morbidity, Situation and trends, Data and analysis on cancer mortality and morbidity. http://www.who.int/gho/ncd/mortality_morbidity/cancer/en/index.html. Accessed 20 May 2018
World Health Organization (WHO) (2013) Latest world cancer statistics Global cancer burden rises to 14.1 million new cases in 2012: marked increase in breast cancers must be addressed
Wu TS, Shi LS, Kuo SC (2001) Cytotoxicity of *Ganoderma lucidum* triterpenes. Nat Prod 64:1121–1122
Wu GS, Lu JJ, Guo JJ et al (2012a) Ganoderic acid DM, a natural triterpenoid, induces DNA damage, G1 cell cycle arrest and apoptosis in human breast cancer cells. Fitoterapia 83:408–414
Wu QP, Xie YZ, Deng Z et al (2012b) Ergosterol peroxide isolated from *Ganoderma lucidum* abolishes MicroRNA miR-378-mediated tumor cells on chemoresistance. PLoS One 7:1–14
Yang SX, Yu ZC, Lu QQ et al (2012) Toxic lanostane triterpenes from the basidiomycete *Ganoderma amboinense*. Phytochem Lett 5:576–580
Zhang M, Cui SW, Chueng PC, Wang KQ (2007) Antitumor polysaccharides from mushrooms: a review on their isolation process, structural characteristics and antitumor activity. Trends Food Sci Technol 18:4–19
Zhao Z-Z, Yin R-H, Chen H-P et al (2015a) Two new triterpenoids from fruiting bodies of fungus *Ganoderma lucidum*. J Asian Nat Prod Res 17(7):750–755
Zhao X-R, Huo X-K, Dong P-P et al (2015b) Inhibitory effects of highly oxygenated lanostane derivatives from the fungus *Ganoderma lucidum* on P-glycoprotein and α-glucosidase. J Nat Prod 78:1868–1876
Zhao X-R, Zhang B-J, Deng S et al (2016a) Isolation and identification of oxygenated lanostane-type triterpenoids from the fungus *Ganoderma lucidum*. Phytochem Lett 16:87–91
Zhao Z-Z, Chen H-P, Li Z-H et al (2016b) Leucocontextins A-R, lanostane-type triterpenoids from *Ganoderma leucocontextum*. Fitoterapia 109:91–98
Zhao Z-Z, Chen H-P, Huang Y et al (2016c) Lanostane triterpenoids from fruiting bodies of *Ganoderma leucocontextum*. Nat Prod Bioprospect 6:103–109
Zheng M, Tang R, Deng Y et al (2018) Steroids from *Ganoderma sinense* as new natural inhibitors of cancer associated mutant IDH1. Bioorg Chem 79:89–97

Chapter 10
The Vertebrate Biodiversity of Turkey

Ahmet Karataş, Halit Filiz, Kiraz Erciyas-Yavuz, Saniye Cevher Özeren, and Cemal Varol Tok

10.1 Introduction

It is estimated that about 8.7 million eukaryotic species exist on Earth; however, only 1.2 million species have been taxonomically classified and cataloged to date. The researchers predict that around 86% of all existing terrestrial species and 91% of all marine species are not described yet (Mora et al. 2011). To know the species diversity on Earth is a fundamental question scientists have to face. We are still uncertain about how many species exist, with the exception of a few comprehensively studied taxa, and there is an important gap in our basic knowledge. Climate change, habitat degradation and loss, draining of wetlands, irrigation, pollution, introduction of alien species, and overhunting cause tremendous loss of biodiversity, and species are getting extinct before they are identified and classified. Therefore, it is important to know the biodiversity on global and regional levels and to identify conservation priorities and measures (Ozturk et al. 2010; Imanberdieva et al. 2018; Ozturk 2018).

A. Karataş (✉)
Department of Biology, Faculty of Science and Arts, Niğde Ö. H. University, Niğde, Turkey

H. Filiz
Marine and Inland Waters Sciences and Technology Department, Faculty of Fisheries, Muğla Sıtkı Koçman University, Muğla, Turkey

K. Erciyas-Yavuz
Ornithological Research Center, Ondokuz Mayıs University, Samsun, Turkey

S. C. Özeren
Department of Biology, Faculty of Science, Ankara University, Ankara, Turkey

C. V. Tok
Department of Biology, Faculty of Science and Arts, Çanakkale Onsekiz Mart University, Çanakkale, Turkey

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_10

The Turkish vertebrate fauna is documented here as it is an important part of the country's biodiversity, which consists of 37,175 species of all taxa. Turkey (Türkiye) lies at the conjunction of Europe, the Middle East, Central Asia, and Africa, and acts as a bridge between these regions and their flora and fauna. Being encircled by three seas, surrounded by mountains, and critically located within different climatic and vegetational zones has resulted in high terrestrial, freshwater, and marine biodiversity. It hosts three out of 36 biodiversity hotspots in the world: the Caucasus, the Irano-Anatolian, and the Mediterranean (Şekercioğlu et al. 2011). The vast biodiversity reflects the character of a small continent and is known as "Anatolia". The country was a refugium for most of the species during the last glacial period. Changing environmental conditions have led to shifts in species, and species entered Anatolia from different regions, and many animals settled down here. Adaptation of species to changing climatic features after ice ages affected their geographical distribution, which contributed to this high diversity in Turkey. A unique combination of geological, topographical, and climatic differences, high altitudinal diversity, and different ecosystems (e.g., mountains, steppes, forests, seas, lakes, and rivers) have provided a high level of biodiversity (Ozturk et al. 2010, 2012, 2017a, b; Altay 2019).

The disposition of mountains and the occurrence of high mountains and plateaus have resulted in different climatic conditions; while the continental climate exists in central Anatolia; maritime climate exists in coastal regions. In the Mediterranean countries, the climate is hot with arid summers and mild and rainy winters. These climatic and topographical differences form different ecosystems (Ozturk et al. 2017a). The steppes of Anatolia have diverse plant species and grassland communities. Mountain ecosystems change in altitude dramatically within a small scale and host important biological components. The forests cover some parts of Turkey from south to north and from east to west and differ in structure and composition. Rivers and lakes cover an area of around 10.000 km^2, and seas with different features host many different species from different taxa.

The country is located at the easternmost section of the Mediterranean Sea and has a long coastline (8.333 km) surrounded by three seas: the Black Sea, the Aegean Sea, and the Mediterranean (Levantine) Sea (Alpar et al. 2000). In addition, the Marmara Sea is an inland sea connecting the Black Sea to the Aegean Sea through two narrow straits: the Strait of Istanbul (Bosphorus) and the Strait of Çanakkale (Dardanelle) (Alpar et al. 2000). With different evolutionary histories and geological and hydrological characteristics, these seas make the countries marine ichthyofauna relatively rich. Similarly, terrestrial vertebrate fauna has a rich diversity. Of 11 classes of the vertebrates, with the exception of Myxini, Cladistii, and Sarcopterygii (recently Dipneusti and Coelacanthi), 8 have representatives in the country. In this chapter, Turkish vertebrate fauna is reviewed, and updated checklists of all classes are provided.

10.2 Data Analysis

A total of 1732 vertebrate species are presented in six checklists, including all current valid scientific names for each species, listed in taxonomical order (class, order, family, and species). The threat categories of all vertebrate species are given according to the IUCN Red List (2020), Annexes of Bern Convention (2002), and CITES (2017). Endemic and alien/invasive species are shown too (Appendices 10.1, 10.2, 10.3, 10.4, 10.5, and 10.6). Abbreviations used in the appendices and tables are IUCN (**EX**, extinct; **RE**, regionally extinct; **CR**, critically endangered; **EN**, endangered; **VU**, vulnerable; **NT**, near threatened; **LC**, least concern; **DD**, data deficient; **NE**, not evaluated; **NA**, not applicable), Bern (Annex II indicates "Strictly protected fauna species", Annex III indicates "protected fauna species"), and CITES (Appendix 10.1 indicates "species that are the most endangered among CITES", Appendix 10.2 indicates "species that are not necessarily threatened currently with extinction but that may become so unless trade is closely controlled").

Fish species are divided into two groups: marine and inland fishes. Most of inland fish species spend all their life span in the freshwaters. Some others visit brackish water and marine habitats in a period of their life span in terms of feeding, breeding, and wintering. Similarly, some marine fishes enter brackish and freshwater habitats for similar purposes. Therefore, 38 fish species live in both marine and freshwater habitats. These are shown in one list and marked with a symbol, depending primarily on their marine or inland water availability.

The previous checklist published by Bilecenoğlu et al. (2014) was taken as a baseline for marine fishes. The inland fishes presented in the list are compiled from the previous checklists published by Kuru (2004) and Çiçek et al. (2015, 2016, 2018). However, the current taxonomic status of all fish species has been updated in accordance with the online version of Eschmeyer et al.'s (2020) Catalog of Fishes, synonymized taxa were reassessed in the light of recently published studies, and scientific names were checked against Froese and Pauly (2019). Some fish species which were misidentified and synonymized are excluded from the list even if some of them are erroneously forgotten in the previous checklists, and newly identified ones are added to the list. Alien/invasive fish species entering the Turkish seas and inland waters in different pathways (Lessepsian migrants, aquaculture, biological control, pet trade, researches in universities) are also presented in the list, even if some of them do not form stable populations. Additionally, the zoogeographical origin of each marine species is provided: Atlanto-Mediterranean (***A-M***), cosmopolitan (***C***), Mediterranean endemic (***M-E***), and Indo-Pacific (***I-P***). Zoogeographical distributions are indicated: the Levantine Sea (***LS***), Aegean Sea (***AS***), Marmara Sea (***SM***), and Black Sea (***BS***) (Table 10.1).

The herpetofauna is separated into the classes amphibians and reptiles. Their lists are evaluated in the light of publications up to November 2019. Baran's (1986) work has been used for all publications about the Turkish herpetofauna until 1986. We also used some actual websites such as www.amphibia-web.com, www.reptile-database.com, www.lacerta.de, and www.vipersgarden.at to check and control the new scientific names and distribution of the species.

Table 10.1 The IUCN status for the vertebrates of Turkey

	EX	EW	RE	CR	EN	VU	NT	LC	DD	NE	Species
Petromyzonti	–	–	(1)	–	1	–	1[a]	2	–	–	4
Elasmobranchii	–	–	–	5	4	19	12	10	15	–	65
Holocephali	–	–	–	–	–	–	1	–	–	–	1
Actinopterii	4	1	(3)	28[a]	46	37	21[a]	463[a]	46	178	824
Amphibia	–	–	–	2	5	4	5	11	–	9	36
Reptilia	–	–	–	6	9	5	6	77	5	32	140
Aves	(1?)	–	(2)	3[a]	5	17	25	435[a]	–	–	485
Mammalia	–	–	(2)	–	6[a,b]	14	11	124	12	7	173
Total	4 + (1?)	1	(8)	44[a]	75[b]	96	82[a]	1122[a]	78	226	**1728**

[a]Due to extinction according to the following information; categories, given in the present IUCN Red List as CR, NT, and LC, that its species number should be reduced. In case of change, the number of species to be added to the relevant category is given in parentheses. Four fish species extinct in Turkey, which are listed as CR (*Acipenser persicus* and *A. sturio*), NT (*Caspiomyzon wagneri*), LC (*Alosa caspia*) by the IUCN, should be given as regionally extinct (RE). Similarly, two bird (*Lyrurus tetrix* and *Anhinga rufa*), given as LC in the Red List and two mammal species (*Panthera tigris* and *Dama (dama) mesopotamica*), listed as EN, should be considered as RE. Of these, the population of *D. mesopotamica* in Turkey and Caspian tiger (*P. tigris virgata*) living in Turkey and Iran before 1970s were completely extinct (EX). *Numenius tenuirostris* is listed as CR by the IUCN, but it is probably (?) extinct (EX)

[b]*Dama (dama) mesopotamica* is sometimes treated as subspecies and is given as EN and included in the IUCN threat category list, whereas it isn't included in the species list

Several different taxonomic lists are available for the birds of the world. The list provided here is based on the taxonomical classification of the IOC World Bird List (Gill and Donsker 2020), which has been prepared according to recent taxonomic revisions.

As for mammals, main reference is the checklist given by Kryštufek and Vohralík (2009). Taxonomic changes after this publication are given with respect to new references such as Wilson et al. (2017) and Wilson and Mittermeier (2018).

10.3 Marine Fishes

The Turkish marine ichthyofauna (*TrMI*) has experienced different natural and anthropogenic phenomena, causing intraspecific or community changes over time. With the Mediterranean Sea, Turkish seas also went through dramatic changes in its ichthyofauna in the last six million years and more quickly in recent times. The changes in marine environmental conditions have been followed by changes in ichthyofauna composition. We can monitor these changes in *TrMI* mainly through the checklists and sometimes in fish museum collections. Observations on fishes along the coast of the Anatolian Peninsula are available since the prehistoric times (Bilecenoğlu et al. 2014), but information on *TrMI* has been studied and compiled over the last 65 years (Bilecenoğlu et al. 2014).

The *TrMI* consists of a total of 530 species of fishes belonging to 154 families, 44 orders, and 4 classes. The majority of the taxa belong to the classes of Actinopteri (sometimes as Actinopterygii) (463 spp.), followed by Elasmobranchii (65 spp.) and one species each of Petromyzonti and Holocephali. Turkish Mediterranean (Levantine coast) has 453 spp. and the Aegean Sea 453 spp., with the highest diversity, followed by Sea of Marmara (257 spp.) and Black Sea (151 spp.). *TrMI* is dominated by Atlanto-Mediterranean fishes (303 spp.), followed by Indo-Pacific fishes (79 spp.), cosmopolitan (79 spp.), and Mediterranean endemic (69 spp.) (Appendix 10.1). A total of 90 (16.9% of total) species are non-native (35 alien, 29 established, and 26 invasive), originating from Indo-Pacific (79 spp.), Atlantic (7 spp.), and cosmopolitan (4 spp.).

The following taxonomic changes/revisions have been considered in our current list: we used *Pempheris rhomboidea* (Kossmann & Räuber, 1877) (formerly misidentified as *Pempheris vanicolensis* Cuvier, 1831 (sensu Azzurro et al. 2015)), *Oxyurichthys petersii* (Klunzinger, 1871) (formerly as *Oxyurichthys papuensis* (Valenciennes, 1837) (sensu Bilecenoğlu et al. 2014)), *Lagocephalus guentheri* (Miranda Ribeiro, 1915) (formerly misidentified as *Lagocephalus spadiceus* (Richardson, 1845) (sensu Matsuura et al. 2011)), *Bregmaceros nectabanus* Whitley, 1941 (formerly misidentified as *Bregmaceros atlanticus* (Goode & Bean, 1886) (sensu Harold and Golani, 2016)), *Atherinomorus forskalii* (Rüppell, 1838) (formerly as *Atherinomorus lacunosus* (Forster, 1801) (sensu Eschmeyer et al. 2020)), and *Equulites popei* (Whitley, 1932) (formerly misidentified as *E. elongatus* (Günther, 1874) (sensu Mavruk et al. 2019)). Also, the family Centracanthidae is no longer recognized as valid. It is considered as a synonym of Sparidae (Betancur-R et al. 2017).

10.4 Inland Fishes

Kuru (2004) has listed a total of 236 species and subspecies belonging to 26 families. Following this checklist, Frickle et al. (2007) reported 248 freshwater and 279 marine fish species in transitional waters. In a recent publication by Çiçek et al. (2015), a total of 368 fish species (including 10 questionable species) belonging to 31 families, 16 orders, and two classes has been given. A total of 153 endemic and 28 non-native species are also reported from the Turkish inland waters in this publication. The number of fish species is increasing day by day with the identification of new species.

Currently, a total of 402 inland fish species belonging to 38 families of 20 orders are listed in the Turkish inland waters (Appendix 10.2). Among the inland fish species, 278 (69.15%) are inhabiting freshwaters, 76 (14.43%) inhabit both fresh and brackish waters, 45 (11.19%) of these are inhabiting freshwaters, brackish, and marine habitats. In addition, 3 fish species (0.75%) prefer to inhabit brackish and salty waters. In the list, 189 out of 402 species (47.01%) are endemic to Turkey, including 188 out of 398 species (47.24%) of the class Actinopteri and 1 out of 3 species (33.33%) of the class Petromyzonti.

Cypriniformes is the largest order with 270 species (67.16% in total). Leuciscidae (minnows) is the largest family (include 123 species) with a rate of 30.60% in the ichthyofauna. Cyprinidae (carps) is the second family (including 57 species) with a rate of 14.18% and Nemacheilidae (Stone Loaches) the third with 40 species and a rate of 9.95%. According to the Red List (IUCN 2020), totally, five species including four endemics are extinct (EX) globally. Additionally, four species are extinct (RE) in Turkey.

According to the Bern Convention, one species (*Acipenser sturio*) is included in Annex II, one species (*Huso huso*) is included both in Annex II and Annex III, and 13 species (*Petromyzon marinus, Acipenser ruthenus, A. stellatus, Alosa fallax, Sabanejewia aurata, Alburnoides bipunctatus, Alburnus chalcoides, Leucaspius delinatus, Rutilus frisii, Rhodeus sericeus, Silurus glanis, Syngnathus abaster, Neogobius fluviatilis*) are included in Appendix III. As for CITES (2017), one species (*Acipenser sturio*) is listed in Appendix I, and five species (*Acipenser nudiventris, A. ruthenus, A. stellatus, Huso huso*, and *Anguilla anguilla*) are listed in Appendix II.

The species which are excluded from the list as being synonymous are based on taxonomic and molecular studies given below according to the priority rule. Following species are synonyms of valid name with priority, given in paranthesis: *Cobitis kurui* (*C. fahirae*), *C. fusunae* (*C. joergbohleni*) (sensu Freyhof et al.), *Oxynoemacheilus erdali* (*O. bergianus*) (sensu Freyhof et al. 2019), *O. freyhofi* (*O. euphraticus*) (sensu Freyhof and Özuluğ, 2017), *O. phoxinoides* (*O. angorae*) (sensu Çiçek et al. 2019), *Barbus bergi* (*B. tauricus*) (sensu Turan et al.), *C. baliki* and *C. banarescui* (*C. tinca*) (sensu Özdemir 2015), *Garra caudomaculata* (*G. culiciphaga*) (sensu Yoğurtçuoğlu et al. 2018), *Garra menderesensis* (*G. klatti*) and *Pseudophoxinus kervillei* (*P. libani*) (sensu Eschmeyer et al. 2020), *Alburnus selcuklui* and *A. mossulensis* (*A. sellal*) (sensu Freyhof et al. 2018b), *Alburnoides recepi* (*Alburnus caereleus*) (sensu Birecikligil et al. 2017), and *Knipowitschia ephesi* (*K. ricasolii*) (sensu Çiçek et al.).

The names of some genera and species have been changed due to recent taxonomic and molecular studies as discussed below. Behrens-Chapuis et al. (2015) included labeonine species belonging to *Crossocheilus*, *Hemigrammocapoeta*, *Tylognathus*, and *Typhlogarra* in the genus *Garra* based on mt COI. So, the species belonging to *Crossocheilus klatti, Hemigrammocapoeta culiciphaga*, and *H. kemali* are included in the genus *Garra* in the given list. *Petroleuciscus borysthenicus* is named as *Squalius borysthenicus* in the last annotated checklist (Çiçek et al. 2015), but this species is placed in *Petroleuciscus* genus. *Schistura chrysicristane*, belonging to the family Nemacheilidae is included in the genus *Paraschistura* and corrected as *Paraschistura chrysicristane. Luciobarbus lorteti* is named as *Barbus lorteti* in the last checklist (Çiçek et al. 2015), but this species is placed in the genus *Luciobarbus*, whereas *Luciobarbus escherichii* is placed in *Barbus* genus, and corrected as *Barbus escherichii* in the present list. Freyhof et al. (2018a) reviewed the generic position of *Petroleuciscus kurui*, placing it in *Alburnus*. Bogutskaya (2002) reviewed the generic status of *Leuciscus borysthenicus*, placing it in *Petroleuciscus,* but this species is written erroneously as *Squalius borysthenicus* in the last checklist (Çiçek et al. 2015).

Some freshwater fish species listed in the previous checklists are excluded from the present list as their distribution is geographically not in Turkish waters. These are discussed below based on the last available information. *Ladigesocypris ghigii* (Gianferrari, 1927) is a native species in Greece and restricted to streams on Rhodes Island (Froese and Pauly 2019). Taxonomic and molecular studies of the Cobitidae family conducted by Perdices et al. (2018) and Freyhof et al. (2018c) have shown that *Cobitis vardarensis* and *Misgurnus fossilis* are not inhabiting Turkish inland waters. *Cobitis vardarensis* is a native species in Albania, Greece, North Macedonia, and Serbia, and *M. fossilis* is inhabiting Europe and western Asia (Kottelat and Freyhof 2007). *Cobitis taenia* distributes in Atlantic drainages from the Seine northward, Baltic basin south of 61°N, upper Volga drainages, northern Black Sea basin, except Danube (IUCN 2020). Taxonomic research of the loach genus *Oxynoemacheilus* studied by Freyhof et al. (2018c), *Oxynoemacheilus bureschi, O. insignis*, and *O. panthera* are not inhabiting Turkish waters. *O. bureschi* is restricted to the Strymon, Varda, and Nestos river basins in northern Greece and Bulgaria. *O. insignis* is restricted to few streams in the Damascus basin in Syria and to several streams in the Jordan-Dead Sea basin in Israel, Jordan, and Syria. *O. panthera* is an endemic species in the Damascus basin in Syria. Also, there is no record of the distribution of *Barbatula barbatula* in Turkey. This species ranges in Northern and Eastern Europe and West Asia (Kottelat and Freyhof 2007). Records of *Oxynoemacheilus chomanicus* and *O. kurdistanicus* which distribute Tigris River basin in the Middle East and Asia Minor in Turkey require confirmation.

There are 368 species (91.54%) native (indigenous) and 34 species (8.46%) non-native in Turkish inland waters (Yalçın-Özdilek 2007; Ekmekçi et al. 2013; Tarkan et al. 2015; Emiroğlu et al. 2016; Yoğurtçuoğlu and Ekmekçi 2018; İnnal and Sungur 2019). Among the native species, 17 have been translocated to different water bodies mainly for sustainable fisheries and aquaculture. The non-native species were introduced to the water bodies for the development of aquaculture and fisheries, biological control, research purpose and ornamental fish trade and naturally. Within the non-native species, *Acipenser baerii* and *Ictalurus punctatus* were never released to the natural environment; therefore, these species are not included in the present list. Also, the species of *Morone* genus are not included in the present list, because the hybrids of *M. chrysops* and *M. saxatilis* are inhabiting just one location, Kemer Dam Lake. Among the non-native species, *Salvelinus fontinalis, S. alpinus, Coregonus macrophthalmus,* and *C. lavaretus* are extinct in the natural habitat which have been translocated. Most of the non-native species (*Salmo salar, Hypophthalmichthys molitrix*, *Coregonus laveratus, Ctenopharyngodon idella, Pygocentrus nattereri, Pterygoplichthys disjunctivus, P. pardalis, Pangasius sanitwongsei, Heteropneustes fosillis, Coptodon zilli, C. rendalli, Hemichromis letourneuxi, Oreochromis aureus, O. mossambicus, O. niloticus, Sarotherodon galilaeus*) are dispersed in the wild, but do not form stable populations.

Among the native species, *Cyprinus carpio, Atherina boyeri, Tinca tinca, Esox lucius, Sander lucioperca, Silurus glanis,* and *Perca fluviatilis*, and within the non-native species *Carassius gibelio, Pseudorasbora parva, Gambusia holbrooki*, and *Lepomis gibbosus* are widespread introduced species (Tarkan et al. 2015).

Furthermore, *C. carpio, A. boyeri, G. holbrooki, C. gibelio*, and *P. parva* have formed a widespread population and have become dominant species in the ichthyofauna where they were introduced. So, these species are considered as invasive species in Turkish inland waters, which have affected native fish species populations negatively (Tarkan et al. 2015).

10.5 Amphibia (Amphibians)

Turkey is rich in herpetofauna with the species number of 36 amphibians (20 Caudata (Urodela) and 16 Anura) and 140 reptiles, which is almost equal to whole Europe. This diverse and rich herpetofauna is the result of wide surface, variable zoogeographical formations, and very high habitat diversity in the country. Moreover, due to these variable geographical formations, there are many isolated populations and endemics such as mountain frogs, salamanders, and vipers.

Currently, herpetofaunal studies of a specific region or an area have increased. In addition to the classical taxonomical studies, there are several molecular taxonomical studies on reptile species. As a result of these studies, some species have been recently included in the Turkish herpetofauna, whereas some have been excluded. For example, in a recent molecular study, *Bufotes sitibundus* is newly included in the Turkish herpetofauna instead of *Bufotes variabilis* (Pallas, 1769) and *B. viridis* (Laurenti, 1768). Since *B. variabilis* is invalid species and *B. viridis* and *Lissotriton vulgaris* (Linnaeus, 1758) are not found in Turkey, these three have not been added to the list (Wielstra et al. 2015; Dufresnes et al. 2019).

According to recent studies, there are 20 different salamander species in Turkey, from the family Salamandridae of the order Caudata (Urodela). Out of these, 10 species (27.78%) are endemic to the country. Additionally, there are 16 frog/toad species belonging to six families of the order Anura. Of these, three species of the family Ranidae are endemics (Appendix 10.3).

10.6 Reptilia (Reptiles)

A total number of 140 species (11 Testudinata, 71 Lacertilia, and 58 Ophidia-Sauria) of reptiles are distributed in Turkey, belonging to 24 families. Twenty species (14.29%) are endemic to the country (Appendix 10.4). Endemic species are included in five families (eight from family Lacertidae, one from family Phyllodactylidae; one from family Blanidae), with nine species from the suborder Lacertilia of the order Squamata. The endemic snakes include seven species from the family Viperidae, two species from the family Colubridae, and one species from the family Typhlopidae. These are included in the suborder Ophidia of the order Squamata. Of these, one turtle and one lizard are invasive; *Trachemys scripta* (Schoepff, 1792) and *Podarcis siculus* (Rafinesque-Schmaltz, 1810). According to recent studies, *Mediodactylus kotschyi* (Steindachner, 1870), *Lacerta trilineata* (Bedriaga, 1886), and *Mesalina brevirostris* (Blanford, 1874) are not distributed in Turkey. Thus, these three species have been deleted from the list (Smíd et al. 2017; Kotsakiozi et al. 2018; Kornilios et al. 2019).

10.7 Birds (Aves)

Birds are a vital part of biodiversity and have a major role in ecosystem services (Rajpar et al. 2017, 2020). The main factors that limit and determine the presence of birds in any area are climate, altitude, and vegetation. As a result of various biogeographical and climatic conditions, surrounded by three seas, sharp changes in altitude from sea level to around 5000 m, and location on a crossroad between continents, Turkey hosts a rich avian fauna. Bosphorus, Çoruh valley, and Hatay Belen are important bottlenecks for soaring migratory species, whereas many active flying passerines and waterbirds can be seen during breeding, migration, and wintering seasons across the country. While around 11,500 bird species are reported from all over the world, 485 bird species have been recorded in Turkey. There are several different lists where the species numbers are given up to 500 species and more for Turkey. But some of the records could not be proven and not included in the recent list. Furthermore, some taxonomically split species are still considered as different species; those lists too are excluded from this list.

A total number of 396 species are observed regularly, while 313 species are breeding. A total of 485 species belonging to 25 orders and 76 families have been reported from Turkey (Appendix 10.5). The most numerous orders are the Passeriformes (passerines—213 species) and Charadriiformes (waders—87 species), while the most numerous families are Anatidae (36 species), Scolopacidae (33 species), Muscicapidae (31 species), and Accipitridae (30 species). Two parrot species (Psittaculidae), one myna species (Sturnidae), and one bulbul species (Pycnonotidae) are invasive. There are new sightings for some species like black swan (*Cygnus atratus*), plum-headed parakeet (*Psittacula cyanocephala*), African gray parrot (*Psittacus erithacus*), bank myna (*Acridotheres ginginianus*), indigo bunting (*Passerina cyanea*), and zebra finch (*Taeniopygia guttata*), which are not considered for inclusion to the countries list, as these are considered as pets or escapees from zoos or private collections in farms.

Turkey lies at the far most south distribution of 13 species (e.g., *Grus grus*, *Melanitta fusca*), far most east distribution for 8 species (e.g., *Regulus ignicapilla, Emberiza cirlus*), far most west distribution for 23 species (e.g., *Halcyon smyrnensis, Francolinus francolinus*), and far most north distribution for 7 species (e.g., *Passer moabiticus, Pycnonotus xanthopygos*) breeding area. There are no endemic bird species in Turkey, but some of the species (*Sitta krueperi, Larus armenicus, Hippolais olivetorum, Sylvia ruppeli, Emberiza cineracea*) have breeding area almost entirely restricted to Turkey. There are 11 endemic subspecies, which are completely restricted to Turkey, for example, *Dendrocoptes medius anatoliae*, *Dendrocopos major paphlagoniae*, *Calandrella brachydactyla woltersi, Alauda rufescens aharonii, Eremophila alpestris kumerloevei, Prunella modularis euxina, Panurus biarmicus kosswigi, Montifringilla nivalis leucura, Pyrrhula pyrrhula rossikowi, Phylloscopus collybita brevirostris,* and *Prinia gracilis akyildizi.* The distribution and the population of most of the species are not well known and need detailed studies.

Based on IUCN's threat category, 3 species are critically endangered (**CR**), 5 species are endangered (**EN**), 17 species are vulnerable **(VU**), 25 species are near threatened (**NT**), and 435 species are the least concern (**LC**). According to the Bern Convention, 330 species are included in Annex II, 144 species are included in Annex III, and 11 species are not listed. For CITES (2017), 9 species in Annex I, 59 species in Annex II, and 417 species are not subject to CITES.

10.8 Mammals (Mammalia)

Turkey is home to 173 species (158 terrestrial and 15 marine mammals) belonging to 36 families of nine mammal orders (Appendix 10.6). The most dominant families are Cricetidae (30 spp.) and Vespertilionidae (29 spp.). The endemism rate of mammals is 2.87%, with five endemic species, a shrew (*Crocidura arispa*) and four rodents (*Spermophilus taurensis*, *Dryomys laniger*, *Microtus anatolicus*, and *Acomys cilicicus*).

Terrestrial mammals are mostly species of the Palearctic region, including several species from Ethiopian and Oriental regions. At least, five species are alien/invasive. *Oryctolagus cuniculus* (Linnaeus, 1758) has got established in some islands. *Rattus rattus* (Linnaeus, 1758) and *R. norvegicus* (Berkenhout, 1769) are widely distributed, originating from Mongolia and India, respectively. A Neotropical rodent, *Myocastor coypus* (Molina, 1782) is found in Turkish Thrace and Iğdır. A Lessepsian migrant *Sousa plumbea* (G. Cuvier, 1829), an Indian Ocean species, has been added to the list recently (Doganyılmaz and Ozbilgin 2018). Lastly, *Nyctereutes procyonoides* (Gray, 1834) was observed by a camera trap photo (Çağan Şekercioğlu, pers. comm.). It is still not known either established or escaped from fur farms.

Studies based on molecular markers have confirmed the taxonomic status of *M. dogramacii* Kefelioğlu & Kryštufek, 1999) and identified *M. qazvinensis* Golenishchov, 2002 from NW Iran, considered here as a subspecies. Also *Mus domesticus* Schwarz & Schwarz, 1943) was included in *Mus musculus* Linnaeus, 1758 as a subspecies (Wilson et al. 2017). Similarly, Kryštufek and Vohralík (2009) suggested *Acomys cilicicus* Spitzenberger, 1978 as a subspecies of *A. cahirinus*. They listed *Calomyscus bailwardi* Thomas, 1905 in Turkish fauna. But Wilson et al. (2017) reported that Gaziantep and Hakkari are possible ranges of *C. bailwardi* and *C. urartensis* Vorontsov, Kartavtseva & Potapova, 1979.

Gazella dorcas (Linnaeus, 1758) was included by Kryštufek and Vohralík (2009), who mentioned its presence in Turkey is under question. This species is omitted here, since its historical records were possibly confused with ones of

G. gazella (Pallas, 1766), added to the list in last 15 years. *Gazella subgutturosa* (Güldenstaedt, 1780) was divided into two species, and *subgutturosa* s.str. was deleted, and *G. marica* Thomas, 1897 was added (sensu Wacher et al. 2010, who regarded *marica* as a separate species).

Castor fiber Linnaeus, 1758 (Rodentia: Castoridae), *Sicista caucasica* Vinogradov, 1925 (Rodentia: Sminthidae), *Lynx pardinus* (Temminck, 1827) and *Mustela erminea* Linnaeus, 1758 (Carnivora: Mustelidae) have been listed by various authors. But there is no record based on museum material. On the otherhand, *Myotis aurascens* Kuzyakin, 1935 and *M. nipalensis* (Dobson, 1871) are synonyms of *M. davidii* (Peters, 1869); *Dryomys pictus* (Blanford, 1875) are a synonym of *D. nitedula* and both *Apodemus fulvipectus* (Ognev, 1924) and *A. hermonensis* Filippucci, Simson & Nevo, 1989 are synonyms of *A. witherbyi* (Thomas, 1902) and also *Camelus dromedarius* Linnaeus, 1758 (Cetartiodactyla: Camelidae) is known only from domestic stocks. *Microtus schidlovskii* Argyropulo, 1933 is regarded as a subspecies of *M. irani* Thomas, 1921. Therefore, these are removed from the present checklist.

10.9 Conclusions

A total of 215 species, out of 1728 vertebrate species, have been listed here. These are globally endangered (vulnerable or higher classification). Four of the listed species are extinct (**EX**), one is extinct in the wild (**EW**), one is probably extinct, 43 are critically endangered (**CR**), 77 are endangered (**EN**), 92 are vulnerable (**VU**), 83 are near threatened (**NT**), 1123 are the least concern (**LC**), 74 are data deficient according to the IUCN (2020)'s Red List Categories (Table 10.1). A total of 211 species have not been evaluated (**NE**) yet. Additionally, nine of these (eight species and one subspecies) are extinct in Turkey, and these should be regarded as regionally extinct (**RE**).

Ongoing studies prevail new insight into the fauna of Turkey. Still there are taxonomical differences and discussions and uncertain taxonomical status, and day by day, new species are added to the fauna of Turkey. To understand countries' biodiversity, we need to follow changes, detect threats, and consider it as one of the highest priorities to save the existing species. The utmost need is to perceive the existing taxa. Therefore, the given vertebrate fauna checklists summarize the recent taxonomic status of species in Turkey and show the importance of the vertebrate biodiversity in the country. **ANNOTATION: ADDENDUM AND CORRIGENDUM** To the Marine fishes (TrMI) section, a non-native species, *Hazeus ingressus* Engin, Larson & Irmak, 2018 (Gobiiformes: Gobiidae) described recently by Engin et al. (2018) should be added. This Indo-Pacific originated species is not evaluated (NE) by IUCN. Previously *Spicara flexuosa* Rafinesque, 1810 (Perciformes: Sparidae) has long been accepted a synonym of *Spicara maena* (Linnaeus, 1758) (Froese and Pauly 2019), but now it is considered as valid (Bektaş et al. 2018). Atlanto-Mediterranean originated *S. flexuosa* is known from all Turkish seas and is listed as

LC on IUCN Red List. With the addition of these two species the species in TrMI has increased from 530 to 532 species. Since the submission of the chapter for publication, some new species' for Turkey's inland waters have been identified and revisions and distribution studies (Cicek et al. 2020; Freyhof and Yogurtcuoglu 2020; Kaya et al. 2020) published. **Cypriniformes: Cobitidae** *Cobitis saniae* Eagderi, Jouladeh-Roudbar, Jalili, Sayyadzadeh & Esmaeili, 2017 - **Spined Loach [E/NE]: Chorock River Basin.** Nemacheilidae *Oxynoemacheilus arsaniasus* Freyhof, Kaya, Turan & Geiger, 2019 - Erzurum Loach [E/NE]: Murat River, and Upper Karasu River (Muş Province). *Oxynoemacheilus cyri* (Berg, 1910) - **Banded Kura Loach [E/LC]: The species is endemic to the upper Kura drainage in Caspian** Sea Basin, Turkey. **Oxynoemacheilus hamwii >(Krupp & Schneider, 1991)** - Orontes Sportive Loach [E/NE]: The species was known from the headwaters in the Asi drainage in Turkey, extirpated from northern Syria. **Oxynoemacheilus muefiti Freyhof, Kaya, Turan & Geiger, 2019** - Erzurum Loach [E/NE]: Upper Murat River and tributaries of Atatürk Reservoir. **Seminemacheilus dursunavsari Çiçek, 2020** - Avşar Crested Loach [E/NE]: Göksu River Drainage. **Cyprinidae Alburnoides coskuncelebii Turan, Kaya, Aksu, Bayçelebi & Bektaş, 2019** - Spirlin [E/NE]: Büyük Melen River-Southern Black Sea Basin. **Alburnoides turani Kaya, 2020** - Filyos Spirlin [E/NE]: Filyos River Basin, Black Sea Drainage. **Alburnus magnificus Freyhof & Turan, 2019** - Shemaya [E/NE]: Northern Orontes River Basin. **Barbus xanthos Güçlü, Kalayci, Küçük & Turan, 2020** - Barbel [E/NE]: Southeastern Eagean Drainage. **Gobio fahrettini Turan, Kaya, Baycelebi, Aksu & Bektas, 2018** [E/NE]: Ilgın Gudgeon-Lake Ilgın Basin, Konya. **Phoxinus colchicus Berg 1910** [N/LC]: Caucasian Black Sea Basin of Russia, Georgia and eastern Turkey near Hopa. **Salmoniformes: Salmonidae** *Salmo fahrettini* Turan, Kalayci, Bektas, Kaya & Baycelebi, 2020 [E/NE]: **Euphrates** trout-Northeastern Drainage of Euphrates River. Cyprinodontiformes: Aphaniidae *Paraphanius alexandri* (Akşıray, 1948) [E/NE]: Mediterranean coastal region of Ceyhan River Basin (Turkey). *Paraphanius mentoides* (Akşıray, 1948) - Kırkgöz Killifish [E/NE]: Kırkgöz Spring - Antalya Province. *Paraphanius orontis* (Akşıray, 1948) - Killifish [E/NE]: Orontes River Basin and Titreyengöl, Hatay and Antalya provinces (Turkey). *Paraphanius similis* (Akşıray, 1948) - Killifish [E/NE]: Mediterranean tributaries, Konya, Adana and Niğde provinces (south-central Turkey). **Of the family Cyprinidae,** *Barbus ercisianus* and *Luciobarbus kosswigi* are accepted as synonyms of *B. lacerta* (Eschmeyer et al. (2020) on 06 January 2020, but latter *B. ercisianus* [E/NE] is accepted as valid species by same database on 02 November 2020. Similarly, *Capoeta angorae* and *C. kosswigi* are junior synonyms of *C. damascina* (sensu Levin et al. 2012; Eschmeyer et al. (2020) on 02 November version. Thus, two more species shoul be added to the list at Table 2. On the contrary six species can be excluded from the list. *Petromyzon marinus* inhabits in the northeast Atlantic extends from Norway, Iceland, and the Barents Sea south to northern Africa, including the western Mediterranean Sea. The distribution of *Eudontomyzon mariae* (Berg, 1931) which inhabits Ukrainian brooks, requires confirmation in Turkey. *Alosa caspia* extants in Azerbaijan; the Islamic Republic of Iran; Kazakhstan; Russian Federation; Turkmenistan. The species *Barbus tauricus* belongs to Cyprinidae family and is restricted to seven streams of the Crimea (IUCN 2020; Eschmeyer et al. 2020). Another Cyprinid species *Alburnus hohenackeri* inhabits in western and southeastern Caspian Basin (IUCN 2020; Eschmeyer et al. 2020). *Phoxinus phoxinus* belongs to the family Leuciscidae is not found in Turkey (IUCN 2020; Eschmeyer et al. 2020). Three non-native species, *Salmo salar*, *Stenodus leucichthys* and *Oreochromis mossambicus*, can be excluded from the list because of the distribution range, not introduced and established a stable population in the wild. After these changes the number of native (indigenous) Turkish inland fish species has increased from 368 to 381, the percentage increases from 91.54% to 92.48%, while non-native species decreases from 34 species (8.46%) to 31 species (7.58%). The Actinopteri has increased from 824 species to 838 species after excluding the 7 species, including 3 non-native, and adding the 2 marine and 19 inland fishes to the list, while the Petromyzonti has decreased from 4 marine fishes to 2. The endemic Actinopteri species number has increased from 188 to 206 species. In Amphibia section; *Pelobates fuscus* (Laurenti, 1768) (Anura: Pelobatidae) [IUCN^{G}, ^{M}, ^{EU}: LC] from Thrace and in Reptilia section *Daboia palaestinae* (Werner, 1938) (Ophidia: Viperidae) [IUCN^{G}: LC, Hatay] has been erroneously not added to the list. With these additions Anura species number changes from 16 to 17, Amphibia from 36 to 37; Ophidia (Sauria) from 58 to 59, Reptilia from 140 to 141 species. With the latest corrections the Turkish vertebrates consists of 1.745 species belonging to 324 families of 89 orders of 8 classes. The total endemic vertebrates are 245 species (14.04% of all species).

Appendices

Appendix 10.1: Recent Checklist of Turkish Marine Ichthyofauna ([a]Sources 1–36)

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Petromyzonti						
Petromyzontiformes						
Petromyzontidae	*Petromyzon marinus* Linnaeus, 1758[1]	A-M	A[26]	3	LC	LS, AS
Elasmobranchii						
Hexanchiformes						
Hexanchidae	*Heptranchias perlo* (Bonnaterre, 1788)[1]	C		1	NT	LS, AS
	Hexanchus griseus (Bonnaterre, 1788)[1]	C		1	NT	LS, AS, SM, BS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Lamniformes						
Odontaspididae	*Carcharias taurus* Rafinesque, 1810[1]	C		1	VU	LS, AS
	Odontaspis ferox (Risso, 1810)[1]	C		1	VU	LS, AS
Lamnidae	*Carcharodon carcharias* (Linnaeus, 1758)[1]	C		1	VU	LS, AS, SM
	Isurus oxyrinchus Rafinesque, 1810[1]	C		1	VU	LS, AS
	Lamna nasus (Bonnaterre, 1788)[1]	C		1	VU	LS, AS, SM
Cetorhinidae	*Cetorhinus maximus* (Gunnerus, 1765)[1]	C		1	VU	LS, AS
Alopiidae	*Alopias superciliosus* Lowe, 1841[1]	C	A[27]	1	VU	LS, AS, SM
	Alopias vulpinus (Bonnaterre, 1788)[1]	C		1	VU	LS, AS, SM, BS
Carcharhiniformes						
Scyliorhinidae	*Galeus melastomus* Rafinesque, 1810[1]	A-M		1	LC	LS, AS, SM
	Scyliorhinus canicula (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Scyliorhinus stellaris (Linnaeus, 1758)[1]	A-M		1	NT	LS, AS, SM
Triakidae	*Mustelus asterias* Cloquet, 1821[1]	A-M		1	LC	LS, AS, SM, BS
	Mustelus mustelus (Linnaeus, 1758)[1]	A-M		1	VU	LS, AS, SM
	Mustelus punctulatus Risso, 1827[1]	A-M		1	DD	LS, AS
	Galeorhinus galeus (Linnaeus, 1758)[1]	C		1	VU	LS, AS, SM
Carcharhinidae	*Carcharhinus altimus* (Springer, 1950)[1]	C	A/E[28]	1	DD	LS
	Carcharhinus brevipinna (Müller & Henle, 1839)[1]	C		1	NT	LS, AS
	Carcharhinus limbatus (Müller & Henle, 1839)[1]	C		1	NT	LS
	Carcharhinus plumbeus (Nardo, 1827)[1]	C		1	VU	LS, AS
	Prionace glauca (Linnaeus, 1758)[1]	C		1	NT	LS, AS, SM

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Sphyrnidae	*Sphyrna zygaena* (Linnaeus, 1758)[1]	C		1	VU	LS, AS
Squaliformes						
Dalatiidae	*Dalatias licha* (Bonnaterre, 1788)[1]	C		1	NT	LS, AS, SM
Etmopteridae	*Etmopterus spinax* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS
Oxynotidae	*Oxynotus centrina* (Linnaeus, 1758)[1]	A-M		1	VU	LS, AS, SM
Centrophoridae	*Centrophorus granulosus* (Bloch & Schneider, 1801)[1]	A-M		1	VU	LS, AS, SM
	Centrophorus uyato (Rafinesque, 1810)[1]	C		1	DD	AS
Squalidae	*Squalus acanthias* Linnaeus, 1758[1]	C		1	VU	LS, AS, SM, BS
	Squalus blainville (Risso, 1827)[1]	A-M		1	DD	LS, AS, SM, BS
Echinorhiniformes						
Echinorhinidae	*Echinorhinus brucus* (Bonnaterre, 1788)[1]	C		1	DD	LS, AS, SM
Squatiniformes						
Squatinidae	*Squatina aculeata* Cuvier, 1829[1]	A-M		1	CR	LS, AS
	Squatina oculata Bonaparte, 1840[1]	A-M		1	CR	LS, AS, SM
	Squatina squatina (Linnaeus, 1758)[1]	A-M		1	CR	LS, AS, SM, BS
Torpediniformes						
Torpedinidae	*Torpedo nobiliana* Bonaparte, 1835[1]	A-M		1	DD	LS, AS, SM
	Torpedo marmorata Risso, 1810[1]	A-M		1	DD	LS, AS, SM
	Torpedo torpedo (Linnaeus, 1758)[1]	A-M		1	DD	LS, AS, SM
Rhinopristiformes						
Rhinobatidae	*Rhinobatos rhinobatos* (Linnaeus, 1758)[1]	A-M		1	EN	LS, AS
Glaucostegidae	*Glaucostegus cemiculus* (Geoffroy St. Hilaire, 1817)	A-M		1	CR	LS, AS
Rajiformes						
Rajidae	*Dipturus batis* (Linnaeus, 1758)[1]	A-M		1	CR	LS, AS, SM
	Dipturus oxyrinchus (Linnaeus, 1758)[1]	A-M		1	NT	LS, AS, SM
	Leucoraja circularis (Couch, 1838)[1]	A-M		1	VU	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Leucoraja fullonica (Linnaeus, 1758)[1]	A-M		1	NT	LS, AS
	Leucoraja naevus (Müller & Henle, 1841)[1]	A-M		1	LC	LS, AS, SM
	Raja asterias Delaroche, 1809[1]	M-E		1	LC	LS, AS, SM
	Raja clavata Linnaeus, 1758[1]	A-M		1	NT	LS, AS, SM, BS
	Raja miraletus Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM
	Raja montagui Fowler, 1910[1]	A-M		1	LC	LS, AS, SM
	Raja polystigma Regan, 1923[1]	M-E		1	NT	AS
	Raja radula Delaroche, 1809[1]	M-E		1	DD	LS, AS, SM
	Raja undulata Lacépède, 1802[1]	A-M		1	EN	LS, AS
	Rostroraja alba (Lacépède, 1803)[1]	A-M		1	EN	LS, AS
Myliobatiformes						
Dasyatidae	*Dasyatis centroura* (Mitchill, 1815)[1]	A-M		1	LC	LS, AS
	Dasyatis marmorata (Steindachner, 1892)[1]	A-M		1	DD	LS
	Dasyatis pastinaca (Linnaeus, 1758)[1]	A-M		1	DD	LS, AS, SM, BS
	Dasyatis tortonesei Capapé, 1975[1]	M-E		1	DD	LS, AS
	Himantura uarnak (Forsskål, 1775)[1]	I-P	A/E[28]	1	VU	LS
	Himantura leoparda (Manjaji-Matsumoto & Last, 2008)[2]	I-P	A[26]	1	VU	LS
	Pteroplatytrygon violacea (Bonaparte, 1832)[1]	C		1	LC	LS, AS
	Taeniura grabata (Geoffoy St. Hilaire, 1817)[1]	A-M		1	DD	LS
Gymnuridae	*Gymnura altavela* (Linnaeus, 1758)[1]	A-M		1	VU	LS, AS, SM, BS
Myliobatidae	*Myliobatis aquila* (Linnaeus, 1758)[1]	A-M		1	DD	LS, AS, SM
	Aetomylaeus bovinus (Geoffoy St. Hilaire, 1817)[1]	A-M		1	DD	LS, AS
Rhinopteridae	*Rhinoptera marginata* (Geoffoy St. Hilaire, 1817)[1]	A-M		1	NT	LS, AS
Mobulidae	*Mobula mobular* (Bonnaterre, 1788)[1]	A-M		1	EN	LS, AS
Holocephali						
Chimaeriformes						

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Chimaeridae	*Chimaera monstrosa* Linnaeus, 1758[1]	A-M		1	NT	LS, AS, SM
Actinopteri						
Acipenseriformes						
Acipenseridae	*Acipenser gueldenstaedtii* Brandt & Ratzeburg, 1833[1]	M-E		3	CR	AS, SM, BS
	Acipenser nudiventris Lovetsky, 1828[1]	M-E		3	CR	SM, BS
	Acipenser stellatus Pallas, 1770[1]	M-E		3	CR	AS, SM, BS
	Acipenser sturio Linnaeus, 1758[1]	A-M		3	CR	AS, SM, BS
	Huso huso (Linnaeus, 1758)[1]	M-E		3	CR	AS, SM, BS
Notacanthiformes						
Notacanthidae	*Notacanthus bonaparte* Risso, 1840[1]	A-M		1	NE	LS, AS
Anguilliformes						
Synaphobranchidae	*Dysomma brevirostre* (Facciolà, 1887)[1]	A-M		1	LC	LS, AS
Heterenchelyidae	*Panturichthys fowleri* (Ben-Tuvia, 1953)[1]	M-E		1	DD	LS
Muraenidae	*Enchelycore anatina* (Lowe, 1838)[1]	A-M	A[28]	1	LC	LS, AS
	Gymnothorax unicolor (Delaroche, 1809)[1]	A-M		1	LC	LS, AS
	Muraena helena Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM
Chlopsidae	*Chlopsis bicolor* Rafinesque, 1810[1]	A-M		1	LC	LS
Ophichthidae	*Apterichtus caecus* (Linnaeus, 1758)[1]	A-M		1	LC	LS
	Dalophis imberbis (Delaroche, 1809)[1]	A-M		1	NE	LS, AS
	Echelus myrus (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS
	Ophichthus rufus (Rafinesque, 1810)[1]	M-E		1	LC	LS, AS
	Ophisurus serpens (Linnaeus, 1758)[1]	C		1	LC	LS, AS
	Pisodonophis semicinctus (Richardson, 1848)[1]	A-M	A/E[28]	1	LC	AS
Nettastomatidae	*Nettastoma melanurum* Rafinesque, 1810[1]	A-M		1	LC	LS, AS
	Facciolella oxyrhyncha (Bellotti, 1883)[1]	A-M		1	NE	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Congridae	*Ariosoma balearicum* (Delaroche, 1809)[1]	A-M		1	LC	LS, AS
	Conger conger (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Gnathophis mystax (Delaroche, 1809)[1]	A-M		1	LC	LS, AS
Nemichthyidae	*Nemichthys scolopaceus* Richardson, 1848[1]	C		1	LC	LS, AS
Anguillidae	*Anguilla anguilla* (Linnaeus, 1758)[1]	A-M		3	CR	LS, AS, SM, BS
Clupeiformes						
Clupeidae	*Alosa fallax* (Lacépède, 1803)[1]	A-M		3	LC	LS, AS, SM, BS
	Alosa caspia (Eichwald, 1838)[1]	M-E		3	LC[RE]	SM, BS
	Alosa immaculata Bennett, 1835[1]	M-E		3	VU	BS
	Alosa maeotica (Grimm, 1901)[1]	M-E		3	LC	SM, BS
	Alosa tanaica (Grimm, 1901)[1]	M-E		3	LC	SM, BS
	Clupeonella cultriventris (Nordmann, 1840)[1]	M-E		3	LC	SM, BS
	Etrumeus golanii DiBattista, Randall & Bowen, 2012[1]	I-P	A/E[28]	1	DD	LS, AS
	Herklotsichthys punctatus (Rüppell, 1837)[1]	I-P	A/E[28]	1	LC	LS
	Sardina pilchardus (Walbaum, 1792)[1]	A-M		3	LC	LS, AS, SM, BS
	Sardinella aurita Valenciennes, 1847[1]	A-M		3	NE	LS, AS, SM, BS
	Sardinella maderensis (Lowe, 1838)[1]	A-M		1	VU	LS, AS
	Sprattus sprattus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
Dussumieriidae	*Dussumieria elopsoides* Bleeker, 1849[1]	I-P	A/E[28]	1	LC	LS
Engraulidae	*Engraulis encrasicolus* (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Encrasicholina punctifer (Fowler, 1938)[3]	I-P	A[26]	1	LC	LS
	Stolephorus insularis Hardenberg, 1933[4]	I-P	A/E[28]	1	LC	LS
Gonorynchiformes						
Chanidae	*Chanos chanos* (Forsskål, 1775)[1]	I-P	A[29]	3	NE	LS
Siluriformes						

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Plotosidae	*Plotosus lineatus* (Thunberg, 1787)[5]	I-P	I[27]	3	NE	LS
Argentiniformes						
Argentinidae	*Argentina sphyraena* Linnaeus, 1758[1]	A-M		1	NE	LS, AS, SM
	Glossanodon leioglossus (Valenciennes, 1848)[1]	A-M		1	LC	AS
Microstomatidae	*Microstoma microstoma* (Risso, 1810)[1]	C		1	LC	AS
	Nansenia oblita (Facciolà, 1887)[1]	A-M		1	NE	AS
Stomiiformes						
Gonostomatidae	*Cyclothone braueri* Jespersen & Tåning, 1926[1]	C		1	LC	LS, AS
	Cyclothone pygmaea Jespersen & Tåning, 1926[1]	M-E		1	LC	LS
	Gonostoma denudatum Rafinesque, 1810[1]	A-M		1	LC	LS
Sternoptychidae	*Maurolicus muelleri* (Gmelin, 1789)[1]	A-M		1	LC	AS, SM
	Argyropelecus hemigymnus Cocco, 1829[1]	C		1	LC	LS, AS, SM
Phosichthyidae	*Vinciguerria attenuata* (Cocco, 1838)[1]	C		1	LC	LS, AS
	Vinciguerria poweriae (Cocco, 1838)[1]	C		1	LC	AS
Stomiidae	*Bathophilus nigerrimus* Giglioli, 1882[1]	C		1	LC	AS
	Chauliodus sloani Bloch & Schneider, 1801[1]	C		1	LC	LS, AS
	Stomias boa (Risso, 1810)[1]	C		1	LC	LS, AS, SM
Aulopiformes						
Aulopidae	*Aulopus flamentosus* (Bloch, 1792)[1]	A-M		1	LC	LS, AS
Chlorophthalmidae	*Chlorophthalmus agassizi* Bonaparte, 1840[1]	A-M		1	LC	LS, AS
Ipnopidae	*Bathypterois dubius* Vaillant, 1888[1]	M-E		1	LC	AS
Synodontidae	*Saurida lessepsianus* Russell, Golani & Tikochinski, 2015[1]	I-P	I[30]	1	LC	LS, AS
	Synodus saurus (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS
Paralepididae	*Arctozenus risso* (Bonaparte, 1840)[1]	C		1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Lestidiops jayakari (Boulenger, 1889)[1]	C		1	LC	LS, AS
	Lestidiops sphyrenoides (Risso, 1820)[1]	A-M		1	LC	AS
	Sudis hyalina Rafinesque, 1810[1]	A-M		1	DD	LS, AS
Evermannellidae	*Evermannella balbo* (Risso, 1820)[1]	C		1	LC	LS
Myctophiformes						
Myctophidae	*Benthosema glaciale* (Reinhardt, 1837)[1]	A-M		1	LC	LS, AS, SM
	Ceratoscopelus maderensis (Lowe, 1839)[1]	A-M		1	LC	LS, AS
	Diaphus holti Tåning, 1918[1]	A-M		1	LC	LS, AS
	Diaphus metopoclampus (Cocco, 1829)[1]	C		1	LC	LS, AS
	Diaphus rafinesquii (Cocco, 1838)[1]	A-M		1	LC	AS
	Electrona risso (Cocco, 1829)[1]	C		1	LC	LS
	Gonichthys cocco (Cocco, 1829)[1]	A-M		1	LC	LS
	Hygophum benoiti (Cocco, 1838)[1]	A-M		1	LC	LS, AS, SM
	Lampanyctus crocodilus (Risso, 1810)[1]	A-M		1	LC	LS, AS, SM
	Lampanyctus pusillus (Johnson, 1890)[1]	C		1	LC	LS
	Lobianchia dofleini (Zugmayer, 1911)[1]	C		1	LC	LS, AS
	Lobianchia gemellarii (Cocco, 1838)[1]	C		1	LC	AS
	Myctophum punctatum Rafinesque, 1810[1]	A-M		1	LC	LS, AS, SM
	Notoscopelus bolini Nafpaktitis, 1975[1]	C		1	LC	LS
	Notoscopelus elongatus (Costa, 1844)[1]	M-E		1	LC	AS, SM
	Notoscopelus kroyeri (Malm, 1861)[1]	A-M		1	LC	AS
	Symbolophorus veranyi (Moreau, 1888)[1]	A-M		1	LC	LS
Lampriformes						
Lampridae	*Lampris guttatus* (Brünnich, 1788)[1]	C		1	LC	AS
Lophotidae	*Lophotus lacepede* Giorna, 1809[1]	A-M		1	LC	AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Trachipteridae	*Trachipterus trachypterus* (Gmelin, 1789)[1]	C		1	LC	LS, AS, SM
	Zu cristatus (Bonelli, 1819)[1]	C		1	LC	LS, AS
Regalecidae	*Regalecus glesne* Ascanius, 1772[1]	C		1	LC	LS, AS
Zeiformes						
Zeidae	*Zeus faber* Linnaeus, 1758[1]	C		3	DD	LS, AS, SM, BS
Gadiformes						
Bregmacerotidae	*Bregmaceros nectabanus* Whitley, 1941[1]	I-P	A/E[28]	1	LC	LS, AS
Macrouridae	*Caelorinchus caelorhincus* (Risso, 1810)[1]	A-M		1	NE	LS, AS
	Hymenocephalus italicus Giglioli, 1884[1]	A-M		1	LC	LS, AS
	Nezumia aequalis (Günther, 1878)[1]	A-M		1	LC	LS, AS, SM
	Nezumia sclerorhynchus Valenciennes, 1838[1]	A-M		1	LC	LS, AS, SM
	Trachyrincus scabrus (Rafinesque, 1810)[1]	A-M		1	LC	LS, AS
Moridae	*Gadella maraldi* (Risso, 1810)[1]	A-M		1	LC	LS, AS
	Lepidion lepidion Risso, 1810[1]	M-E		1	LC	AS
	Mora moro (Risso, 1810)[1]	C		1	LC	LS
Gadidae	*Gadiculus argenteus* Guichenot, 1850[1]	A-M		1	NE	LS, AS, SM
	Merlangius merlangus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM
	Micromesistius poutassou (Risso, 1827)[1]	A-M		1	NE	LS, AS, SM
	Trisopterus minutus (Linnaeus, 1758)[1]	A-M		1	NE	LS, AS, SM
Lotidae	*Gaidropsarus biscayensis* (Collett, 1890)[1]	A-M		1	NE	AS, SM
	Gaidropsarus mediterraneus (Linnaeus, 1758)[1]	A-M		3	NE	LS, AS, SM, BS
	Gaidropsarus vulgaris (Cloquet,1824)[1]	A-M		1	LC	AS, SM
	Molva macrophthalma (Rafinesque, 1810)[1]	A-M		1	LC	LS, AS
Phycidae	*Phycis blennoides* (Brünnich, 1768)[1]	A-M		1	NE	LS, AS
	Phycis phycis (Linnaeus, 1766)[1]	A-M		3	LC	LS, AS
Merlucciidae	*Merluccius merluccius* (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Trachichthyiformes						
Trachichthyidae	*Hoplostethus mediterraneus* Cuvier, 1829[1]	A-M		1	LC	LS, AS
Holocentriformes						
Holocentridae	*Sargocentron rubrum* (Forsskål, 1775)[1]	I-P	I[30]	1	LC	LS, AS
Ophidiiformes						
Ophidiidae	*Benthocometes robustus* (Goode & Bean, 1886)[1]	M-E		1	LC	LS, AS
	Ophidion barbatum Linnaeus, 1758[1]	A-M		3	NE	LS, AS, SM, BS
	Ophidion rochei Müller, 1845[1]	M-E		3	DD	AS, SM, BS
	Parophidion vassali (Risso, 1810)[1]	M-E		1	DD	AS, SM
Carapidae	*Carapus acus* (Brünnich, 1768)[1]	M-E		1	LC	LS, AS, SM
	Echiodon dentatus (Cuvier, 1829)[1]	A-M			LC	AS
Bythitidae	*Bellottia apoda* Giglioli, 1883[1]	A-M		1	LC	LS, AS
Scombriformes						
Nomeidae	*Cubiceps gracilis* (Lowe, 1843)[1]	A-M		1	LC	LS, AS
Centrolophidae	*Centrolophus niger* (Gmelin, 1789)[1]	C		1	LC	LS, AS
	Schedophilus ovalis (Cuvier, 1833)[1]	A-M		1	NE	LS, AS
Stromateidae	*Stromateus fiatola* Linnaeus, 1758[1]	A-M		1	LC	LS, AS
Pomatomidae	*Pomatomus saltatrix* (Linnaeus, 1766)[1]	C		1	VU	LS, AS, SM, BS
Scombridae	*Auxis rochei* (Risso, 1810)[1]	C		3	LC	LS, AS, SM, BS
	Euthynnus alletteratus (Rafinesque, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Katsuwonus pelamis (Linnaeus, 1758)[1]	C		1	LC	LS, AS, SM
	Orcynopsis unicolor (Geoffoy St. Hilaire, 1817)[1]	A-M		1	LC	LS, AS
	Sarda sarda (Bloch, 1793)[1]	A-M		3	LC	LS, AS, SM, BS
	Scomber colias Gmelin, 1789[1]	A-M		3	LC	LS, AS, SM, BS
	Scomber scombrus Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Scomberomorus commerson (Lacépède, 1800)[1]	I-P	I[27]	1	NT	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Thunnus alalunga (Bonnaterre, 1788)[1]	C		3	NT	LS, AS, SM, BS
	Thunnus thynnus (Linnaeus, 1758)[1]	A-M		3	EN	LS, AS, SM, BS
Bramidae	*Brama brama* (Bonnaterre, 1788)[1]	C		1	LC	LS, AS
Gempylidae	*Ruvettus pretiosus* Cocco, 1833[1]	C		1	LC	LS, AS
Trichiuridae	*Lepidopus caudatus* (Euphrasen, 1788)[1]	C		1	DD	LS, AS
	Trichiurus lepturus Linnaeus, 1758[1]	C		1	LC	LS, AS
Syngnathiformes						
Fistulariidae	*Fistularia commersonii* Rüppell, 1838[1]	I-P	I[30]	1	LC	LS, AS
	Fistularia petimba Lacépède, 1803[6]	I-P	A[28]	1	LC	LS
Centriscidae	*Macroramphosus scolopax* (Linnaeus, 1758)[1]	C		1	LC	LS, AS
Syngnathidae	*Hippocampus fuscus* Rüppell, 1838[1]	I-P	A/E[28]	1	NE	LS
	Hippocampus guttulatus Cuvier, 1829[1]	A-M		3	DD	LS, AS, SM, BS
	Hippocampus hippocampus (Linnaeus, 1758)[1]	A-M		3	DD	LS, AS, SM, BS
	Nerophis maculatus Rafinesque, 1810[1]	A-M		3	NE	SM
	Nerophis ophidion (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Syngnathus abaster Risso, 1827[1]	A-M		3	LC	LS, AS, SM, BS
	Syngnathus acus Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Syngnathus phlegon Risso, 1827[1]	A-M		1	DD	LS, AS, SM
	Syngnathus schmidti Popov, 1927[1]	M-E		3	DD	SM, BS
	Syngnathus tenuirostris Rathke, 1837[1]	M-E		3	NT	LS, AS, SM, BS
	Syngnathus typhle Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Syngnathus variegatus Pallas, 1814[1]	M-E		3	DD	BS
Dactylopteridae	*Dactylopterus volitans* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Gobiiformes						
Gobiidae	*Aphia minuta* (Risso, 1810)[1]	A-M		3	NE	LS, AS, SM, BS
	Chromogobius quadrivittatus (Steindachner, 1863)[1]	M-E		1	LC	LS, AS, SM
	Chromogobius zebratus (Kolombatović, 1891)[1]	M-E		1	LC	LS, AS
	Corcyrogobius liechtensteini (Kolombatović, 1891)[7]	M-E		1	DD	AS
	Crystallogobius linearis (Düben, 1845)[1]	A-M		3	LC	AS
	Deltentosteus collonianus (Risso, 1820)[1]	A-M		1	NE	LS
	Deltentosteus quadrimaculatus (Valenciennes, 1837)[1]	A-M		3	NE	LS, AS, SM
	Didogobius splechtnai Ahnelt & Patzner, 1995[1]	M-E		1	DD	AS
	Gobius auratus Risso, 1810[1]	A-M		1	LC	LS, AS, SM
	Gobius bucchichi Steindachner, 1870[1]	A-M		3	LC	LS, AS, SM, BS
	Gobius cobitis Pallas, 1814[1]	A-M		3	NE	LS, AS, SM, BS
	Gobius couchi Miller & El-Tawil, 1974[1]	A-M		3	LC	AS
	Gobius cruentatus Gmelin, 1789[1]	A-M		1	LC	LS, AS, SM, BS
	Gobius fallax Sarato, 1889[1]	A-M		1	LC	LS, AS
	Gobius geniporus Valenciennes, 1837[1]	M-E		1	LC	LS, AS, SM
	Gobius kolombatovici Kovačić & Miller, 2000[1]	M-E		1	DD	AS
	Gobius niger Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Gobius paganellus Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Gobius roulei de Buen, 1928[1]	A-M		1	LC	LS, AS
	Gobius xanthocephalus Heymer & Zander, 1992[1]	A-M		1	NE	AS
	Gobius vittatus Vinciguerra, 1883[1]	M-E		1	LC	LS, AS
	Knipowitschia caucasica (Berg, 1916)[1]	M-E		3	LC	LS, AS, SM
	Lesueurigobius friesii (Malm, 1874)[1]	A-M		3	LC	LS, AS, SM

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Lesueurigobius suerii Risso, 1810[1]	A-M		1	LC	LS, AS
	Mesogobius batrachocephalus (Pallas, 1814)[1]	M-E		3	LC	SM, BS
	Millerigobius macrocephalus (Kolombatović, 1891)[1]	M-E		1	DD	AS
	Neogobius melanostomus (Pallas, 1814)[1]	M-E		3	LC	AS, SM, BS
	Odondebuenia balearica (Pellegrin & Fage, 1907)[1]	M-E		1	LC	SM
	Oxyurichthys petersi (Klunzinger, 1871)[1]	I-P	A/E[28]	3	LC	LS, AS
	Pomatoschistus adriaticus Miller, 1973[1]	M-E		3	NE	AS, SM
	Pomatoschistus bathi Miller, 1982[1]	M-E		3	DD	AS, SM
	Pomatoschistus marmoratus (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Pomatoschistus minutus (Pallas, 1770)[1]	A-M		3	LC	AS, SM, BS
	Pomatoschistus quagga (Heckel, 1839)[1]	M-E		1	LC	AS
	Ponticola eurycephalus (Kessler, 1874)[1]	M-E		3	LC	BS
	Ponticola platyrostris (Pallas, 1814)[1]	M-E		3	LC	BS
	Ponticola ratan (Nordmann, 1840)[1]	M-E		3	NE	BS
	Ponticola syrman (Nordmann, 1840)[1]	M-E		3	LC	SM, BS
	Thorogobius ephippiatus (Lowe, 1839)[1]	A-M		1	LC	LS, AS
	Thorogobius macrolepis (Kolombatović, 1891)[1]	M-E		1	LC	LS, AS
	Trypauchen vagina (Bloch & Schneider, 1801)[1]	I-P	A[28]	3	NE	LS
	Zebrus zebrus (Risso, 1827)[1]	M-E		1	LC	LS, AS, BS
	Vanderhorstia mertensi Klausewitz, 1974)[1]	I-P	A/E[27]	1	NE	LS, AS
	Zosterisessor ophiocephalus (Pallas, 1814)[1]	M-E		3	LC	LS, AS, SM, BS
Istiophoriformes						
Xiphiidae	*Xiphias gladius* Linnaeus, 1758[1]	C		3	LC	LS, AS, SM, BS
Istiophoridae	*Tetrapturus belone* Rafinesque, 1810[1]	M-E		1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Pleuronectiformes						
Citharidae	*Citharus linguatula* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM
Scophthalmidae	*Lepidorhombus boscii* (Risso, 1810)[1]	A-M		1	NE	LS, AS, SM
	Lepidorhombus whifagonis (Walbaum, 1792)[1]	A-M		1	NE	LS, AS, SM
	Scophthalmus maximus (Linnaeus 1758)[1]	A-M		3	NE	AS, SM, BS
	Scophthalmus rhombus (Linnaeus, 1758)[1]	A-M		3	NE	LS, AS, SM
	Zeugopterus regius (Bonnaterre, 1788)[1]	A-M		1	NE	LS, AS, SM
Bothidae	*Arnoglossus imperialis* (Rafinesque, 1810)[1]	A-M		1	LC	LS, AS, SM
	Arnoglossus kessleri Schmidt, 1915[1]	M-E		3	DD	LS, AS, SM, BS
	Arnoglossus laterna (Walbaum, 1792)[1]	A-M		3	LC	LS, AS, SM, BS
	Arnoglossus rueppelii (Cocco, 1844)[1]	A-M		1	LC	LS, AS
	Arnoglossus thori Kyle, 1913[1]	A-M		3	DD	LS, AS, SM, BS
	Bothus podas (Delaroche, 1809)[1]	A-M		3	LC	LS, AS
Pleuronectidae	[a]*Platichthys flesus* (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
Soleidae	*Buglossidium luteum* (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Dicologlossa cuneata (Moreau, 1881)[1]	A-M		1	LC	AS, SM
	Microchirus ocellatus (Linnaeus, 1758)[1]	A-M		1	DD	LS, AS, SM
	Microchirus variegatus (Donovan, 1808)[1]	A-M		3	LC	LS, AS, SM, BS
	Monochirus hispidus Rafinesque, 1814[1]	A-M		1	NE	LS, AS, SM
	Pegusa impar (Bennett, 1831)[1]	A-M		1	LC	LS, AS, SM, BS
	Pegusa nasuta (Pallas, 1814)[1]	M-E		3	LC	AS, SM, BS
	Pegusa. lascaris (Risso, 1810)[1]	A-M		3	LC	AS, SM, BS
	Solea aegyptiaca Chabanaud, 1927[1]	M-E		3	LC	LS
	Solea solea (Linnaeus, 1758)[1]	A-M		3	DD	LS, AS, SM, BS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Synapturichthys kleinii (Risso, 1827)[1]	C		1	DD	LS, AS, SM
Cynoglossidae	*Cynoglossus sinusarabici* (Chabanaud, 1931)[1]	I-P	A/E[28]	1	NE	LS, AS
	Symphurus nigrescens Rafinesque, 1810[1]	A-M		1	LC	LS, AS
Atheriniformes						
Atherinidae	*Atherina boyeri* Risso, 1810[1]	A-M		3	LC	LS, AS, SM, BS
	Atherina hepsetus Linnaeus, 1758[1]	A-M		3	NE	LS, AS, SM, BS
	Atherinomorus forskalii (Rüppell, 1838)[1]	I-P	I[30]	1	NE	LS, AS
Beloniformes						
Scomberesocidae	*Scomberesox saurus* (Walbaum, 1792)[1]	A-M		1	LC	LS, AS, SM
Belonidae	*Belone belone* (Linnaeus, 1761)[1]	A-M		1	LC	LS, AS, SM, BS
	Belone svetovidovi Collette & Parin, 1970[1]	A-M		1	NE	LS, AS
	Tylosurus acus (Lacépède, 1803)[1]	A-M		1	LC	LS, AS
Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)[1]	I-P	A/E[28]	1	NE	LS, AS
	Hyporhamphus picarti (Valenciennes, 1847)[1]	A-M		3	LC	LS
Exocoetidae	*Cheilopogon heterurus* (Rafinesque, 1810)[1]	A-M		1	LC	LS
	Hirundichthys rondeletii (Valenciennes, 1847)[1]	C		1	LC	LS, AS, SM
	Parexocoetus mento (Valenciennes, 1847)[1]	I-P	I[27]	1	NE	LS, AS
Mugiliformes						
Mugilidae	*Chelon auratus* (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Chelon labrosus (Risso, 1827)[1]	A-M		3	LC	LS, AS, SM, BS
	Chelon ramada (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Chelon saliens (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Chelon carinatus (Valenciennes, 1836)[1]	I-P	A/E[28]	3	NE	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Mugil cephalus Linnaeus, 1758[1]	C		3	LC	LS, AS, SM, BS
	Oedalechilus labeo (Cuvier, 1829)[1]	A-M		3	NE	LS, AS, SM
	Planiliza haematocheila (Temminck & Schlegel, 1845)[1]	I-P	A/E[28]	3	NE	AS, SM, BS
Gobiesociformes						
Gobiesocidae	*Apletodon dentatus* (Facciolà, 1887)[1]	A-M		1	LC	LS, AS, SM, BS
	Apletodon incognitus Hofrichter & Patzner, 1997[1]	A-M		1	LC	LS, AS
	Diplecogaster bimaculata (Bonnaterre, 1788)[1]	A-M		3	LC	LS, AS, SM, BS
	Gouania willdenowi (Risso, 1810)[1]	M-E		1	DD	LS, AS
	Lepadogaster candolii Risso, 1810[1]	A-M		3	NE	LS, AS, SM, BS
	Lepadogaster lepadogaster (Bonnaterre, 1788)[1]	A-M		3	LC	LS, AS, SM, BS
	Diplecogaster umutturali Bilecenoğlu, Yokeş & Kovačić, 2017[8]	M-E		1	NE	LS
	Opeatogenys gracilis (Canestrini, 1864)[1]	M-E		1	VU	LS, AS
Blenniiformes						
Tripterygiidae	*Tripterygion delaisi* Cadenat & Blache, 1970[1]	A-M		1	LC	LS, AS
	Tripterygion melanurus Guichenot, 1850[1]	M-E		3	LC	LS
	Tripterygion minor Kolombatović, 1904[1]	M-E		3	NE	AS
	Tripterygion tripteronotus (Risso, 1810)[1]	M-E		3	LC	LS, AS, SM, BS
Clinidae	*Clinitrachus argentatus* (Risso, 1810)[1]	A-M		1	LC	LS, AS, SM
Blenniidae	*Aidablennius sphynx* (Valenciennes, 1836)[1]	A-M		3	LC	LS, AS, SM, BS
	Blennius ocellaris Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Coryphoblennius galerita (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Microlipophrys adriaticus (Steindachner & Kolombatović, 1883)[1]	M-E		3	DD	AS, SM, BS
	Microlipophrys canevae (Vinciguerra, 1880)[1]	A-M		1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Microlipophrys dalmatinus (Steindachner & Kolombatović, 1883)[1]	M-E		1	DD	LS, AS
	Microlipophrys nigriceps (Vinciguerra, 1883)[1]	M-E		3	LC	AS
	Omobranchus punctatus (Valenciennes, 1836)[1]	I-P	A[27]	3	LC	LS
	Parablennius gattorugine (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Parablennius incognitus (Bath, 1968)[1]	A-M		3	LC	LS, AS, SM, BS
	Parablennius rouxi (Cocco, 1833)[1]	A-M		1	LC	LS, AS
	Parablennius sanguinolentus (Pallas, 1814)[1]	A-M		3	LC	LS, AS, SM, BS
	Parablennius. tentacularis (Brünnich, 1768)[1]	A-M		3	LC	LS, AS, SM, BS
	Parablennius thysanius (Jordan & Seale, 1907)[1]	I-P	A[28]	1	LC	LS
	Parablennius zvonimiri (Kolombatović, 1892)[1]	M-E		3	DD	LS, AS, SM, BS
	Lipophrys trigloides (Valenciennes, 1836)[1]	A-M		3	LC	LS, AS, SM
	Petroscirtes ancylodon Rüppell, 1835[1]	I-P	A/E[27]	1	LC	LS, AS
	Salaria basilisca (Valenciennes, 1836)[1]	M-E		1	LC	LS, AS
	Salaria pavo (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Scartella cristata (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS
Acanthuriformes						
Lobotidae	*Lobotes surinamensis* (Bloch, 1790)[1]	C		1	LC	LS, AS
Chaetodontidae	*Heniochus intermedius* Steindachner, 1893[1]	I-P	A[27]	1	LC	LS
Ephippidae	*Platax teira* (Forsskål, 1775)[1]	I-P	A[27,28]	1	LC	AS
Leiognathidae	*Equulites klunzingeri* (Steindachner, 1898)[1]	I-P	A/E[27,28]	1	NE	LS, AS
	Equulites popei (Whitley, 1932)[21]	I-P	A[27]	1	NE	LS
Siganidae	*Siganus luridus* (Rüppell, 1829)[1]	I-P	I[30]	1	LC	LS, AS
	Siganus rivulatus Forsskål, 1775[1]	I-P	I[30]	1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Caproidae	*Capros aper* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM
Luvaridae	*Luvarus imperialis* Rafinesque, 1810[1]	C		1	NE	LS, AS
Lophiiformes						
Lophiidae	*Lophius budegassa* Spinola, 1807[1]	A-M		1	LC	LS, AS, SM, BS
	Lophius piscatorius Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM, BS
Tetraodontiformes						
Molidae	*Mola mola* (Linnaeus, 1758)[1]	C		1	VU	LS, AS, SM
	Ranzania laevis (Pennant, 1776)[1]	C		1	LC	LS, AS
Diodontidae	*Cyclichthys spilostylus* (Leis & Randall, 1982)[1]	I-P	AI[28]	1	NE	LS
Tetraodontidae	*Lagocephalus lagocephalus* (Linnaeus, 1758)[1]	C		1	LC	LS, AS
	Lagocephalus guentheri Miranda Ribeiro, 1915[9]	I-P	I[30]	1	LC	LS, AS, SM
	Lagocephalus sceleratus (Gmelin, 1789)[1]	I-P	I[30]	1	LC	LS, AS, SM
	Lagocephalus suezensis Clark & Gohar, 1953[1]	I-P	I[30]	1	LC	LS, AS
	Sphoeroides pachygaster (Müller & Troschel, 1848)[1]	C	A/E[28]	1	LC	LS, AS
	Torquigener flavimaculosus Hardy & Randall, 1983[1]	I-P	I[30]	1	LC	LS, AS
	Tylerius spinosissimus (Regan, 1908)[1]	I-P	A[26]	1	LC	LS
Ostraciidae	*Ostracion cubicus* Linnaeus, 1758[10]	I-P	A[27]	1	NE	LS
Monacanthidae	*Stephanolepis diaspros* Fraser-Brunner, 1940[1]	I-P	I[30]	1	LC	LS, AS, SM
Balistidae	*Balistes capriscus* Gmelin, 1789[1]	A-M		1	NE	LS, AS, SM, BS
Centrarchiformes						
Terapontidae	*Pelates quadrilineatus* (Bloch, 1790)[1]	I-P	A/E[29]	3	NE	LS
Acropomatiformes						
Champsodontidae	*Champsodon capensis* Regan, 1908[1]	I-P	A[26]	1	LC	LS
	Champsodon nudivittis (Ogilby, 1895)[1]	I-P	A[26]	1	NE	LS, AS
	Champsodon vorax Günther, 1867[1]	I-P	A[26]	1	NE	LS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Pempheridae	*Pempheris rhomboidea* (Kossmann & Räuber, 1877)[13]	I-P	I[27]	1	NE	AS
Polyprionidae	*Polyprion americanus* (Bloch & Schneider, 1801)[1]	C		1	DD	LS, AS, SM
Epigonidae	*Epigonus constanciae* (Giglioli, 1880)[1]	A-M		1	NE	AS
	Epigonus denticulatus Dieuzeide, 1950[1]	C		1	NE	AS
	Epigonus telescopus (Risso, 1810)[1]	C		1	NE	AS
	Microichthys coccoi Rüppell, 1852[1]	M-E		1	LC	AS
Perciformes						
Moronidae	*Dicentrarchus labrax* (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Dicentrarchus punctatus Bloch, 1792[1]	A-M		3	LC	LS, A1
Serranidae	*Anthias anthias* (Linnaeus, 1758)[1]	A-M		1	NE	LS, AS, SM, BS
	Cephalopholis taeniops (Valenciennes, 1828)[14]	A-M	A[27]	1	LC	AS
	Epinephelus aeneus (Geoffoy St. Hilaire, 1817)[1]	A-M		3	NT	LS, AS
	Epinephelus coioides (Hamilton, 1822)[15]	I-P	A/E[27]	3	LC	LS
	Epinephelus caninus (Valenciennes, 1843)[1]	A-M		1	DD	LS, AS
	Epinephelus costae (Steindachner, 1878)[1]	A-M		1	DD	LS, AS
	Epinephelus haifensis Ben-Tuvia, 1953[1]	A-M		1	DD	LS, AS
	Epinephelus marginatus (Lowe, 1834)[1]	A-M		1	EN	LS, AS, SM
	Mycteroperca rubra (Bloch, 1793)[1]	A-M		1	LC	LS, AS
	Serranus cabrilla (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Serranus hepatus (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Serranus scriba (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
Callanthiidae	*Callanthias ruber* (Rafinesque, 1810)[1]	A-M		1	LC	LS, AS
Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)[16]	I-P	A[26]	1	NE	LS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Priacanthus prolixus Starnes, 1988[17]	I-P	A[26]	1	NE	LS
	Priacanthus sagittarius Starnes, 1988[18]	I-P	A[26]	1	NE	LS
Apogonidae	*Apogon imberbis* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM
	Apogonichthyoides pharaonis (Bellotti 1874)[1]	I-P	I[30]	1	NE	LS, AS
	Cheilodipterus novemstriatus (Rüppell, 1838)[19]	I-P	A/E[28]	1	NE	LS
	Jaydia smithi Kotthaus, 1970[1]	I-P	A/E[28]	1	NE	LS
	Jaydia queketti (Gilchrist, 1903)[1]	I-P	A/E[28]	1	NE	LS, AS
	Ostorhinchus fasciatus (White, 1790)[1]	I-P	A/E[28,29]	1	NE	LS, AS
Sillaginidae	*Sillago suezensis* Golani, Fricke & Tikochinski, 2013[1]	I-P	I[27]	2	NE	LS, AS
Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)[1]	C	A[27,28]	1	LC	AS
Echeneidae	*Echeneis naucrates* Linnaeus, 1758[1]	C		1	DD	LS, AS, SM
	Remora australis (Bennett, 1840)[1]	C		1	LC	LS, AS
	Remora remora (Linnaeus, 1758)[1]	C		3	LC	LS, AS, SM
	Remora osteochir (Cuvier, 1829)[1]	C		1	LC	LS, AS
Carangidae	*Alectis alexandrinus* (Geoffoy St. Hilaire, 1817)[1]	A-M		1	LC	LS, AS
	Alepes djedaba (Forsskål, 1775)[1]	I-P	I[30]	1	LC	LS, AS
	Campogramma glaycos (Lacépède, 1801)[1]	A-M		1	LC	LS, AS
	Caranx crysos (Mitchill, 1815)[1]	A-M		1	LC	LS, AS
	Caranx rhonchus Geoffoy St. Hilaire, 1817[1]	A-M		1	LC	LS, AS
	Decapterus russelli (Rüppell, 1830)[1]	I-P	A/E[29]	1	LC	LS
	Lichia amia (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Naucrates ductor (Linnaeus, 1758)[1]	C		3	LC	LS, AS, SM, BS
	Pseudocaranx dentex (Bloch & Schneider, 1801)[1]	C		1	LC	LS, AS
	Seriola dumerili (Risso, 1810)[1]	C		1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Seriola fasciata (Bloch, 1793)[1]	A-M	A/E[28]	1	LC	LS
	Trachinotus ovatus (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS
	Trachurus declivis (Jenyns, 1841)[20]	I-P	A[26]	3	LC	LS
	Trachurus indicus Nekrasov, 1966[1]	I-P	A[27,28]	1	VU	LS
	Trachurus mediterraneus (Steindachner, 1868)[1]	A-M		1	LC	LS, AS, SM, BS
	Trachurus picturatus (Bowdich, 1825)[1]	A-M		1	LC	LS, AS
	Trachurus trachurus (Linnaeus, 1758)[1]	A-M		3	VU	LS, AS, SM, BS
Coryphaenidae	*Coryphaena hippurus* Linnaeus, 1758[1]	C		1	LC	LS, AS
Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)[22]	I-P	A[27,28]	3	LC	AS
Haemulidae	*Pomadasys incisus* (Bowdich, 1825)[1]	A-M		1	LC	LS, AS
	Pomadasys stridens (Forsskål, 1775)[1]	I-P	I[30]	1	LC	LS
Sparidae	*Argyrops filamentosus* (Valenciennes, 1830)[23]	I-P	A[26]	1	LC	LS
	Boops boops (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Dentex dentex (Linnaeus, 1758)[1]	A-M		3	VU	LS, AS, SM, BS
	Dentex gibbosus (Rafinesque, 1810)[1]	A-M		3	LC	LS, AS, SM
	Dentex macrophthalmus (Bloch, 1791)[1]	A-M		1	LC	LS, AS
	Dentex maroccanus Valenciennes, 1830[1]	A-M		1	LC	LS, AS
	Diplodus annularis (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Diplodus cervinus (Lowe, 1838)[1]	A-M		1	LC	LS, AS
	Diplodus puntazzo (Cetti, 1777)[1]	A-M		3	LC	LS, AS, SM, BS
	Diplodus sargus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Diplodus vulgaris (Geoffoy St. Hilaire, 1817)[1]	A-M		3	LC	LS, AS, SM, BS
	Lithognathus mormyrus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Oblada melanura (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Pagellus acarne (Risso, 1827)[1]	A-M		3	LC	LS, AS, SM
	Pagellus bogaraveo (Brünnich, 1768)[1]	A-M		3	NT	LS, AS, SM
	Pagellus erythrinus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Pagrus auriga Valenciennes, 1843[1]	A-M		1	LC	LS, AS
	Pagrus caeruleostictus (Valenciennes, 1830)[1]	A-M		1	LC	LS, AS
	Pagrus pagrus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM
	Sarpa salpa (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Sparus aurata Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Spondyliosoma cantharus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Centracanthus cirrus Rafinesque, 1810[1]	A-M		1	LC	LS, AS
	Spicara maena (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Spicara smaris (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
Lethrinidae	*Monotaxis grandoculis* (Forsskål, 1775)[1]	I-P	A[27]	1	LC	LS
Nemipteridae	*Nemipterus randalli* Russell, 1986[1]	I-P	I[30]	1	LC	LS, AS
Sciaenidae	*Argyrosomus regius* (Asso, 1801)[1]	A-M		3	LC	LS, AS, SM, BS
	Sciaena umbra Linnaeus, 1758[1]	A-M		3	NT	LS, AS, SM, BS
	Umbrina cirrosa (Linnaeus, 1758)[1]	A-M		3	NE	LS, AS, SM, BS
Mullidae	*Mullus barbatus* Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Mullus surmuletus Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Parupeneus forsskali (Fourmanoir & Guézé, 1976)[1]	I-P	A/E[28]	1	NE	LS, AS
	Upeneus moluccensis (Bleeker, 1855)[1]	I-P	I[30]	1	NE	LS, AS
	Upeneus pori Ben-Tuvia & Golani, 1989[1]	I-P	I[30]	1	NE	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Cepolidae	*Cepola macrophthalma* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)[24]	A-M	A[29]	1	LC	AS
	Chromis chromis (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
Labridae	*Acantholabrus palloni* (Risso, 1810)[1]	A-M		1	LC	LS, AS
	Bodianus speciosus (Bowdich, 1825)[36]	A-M	A[36]	1	DD	AS
	Coris julis (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Ctenolabrus rupestris (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Labrus bergylta Ascanius, 1767[1]	A-M		1	LC	AS, SM
	Labrus merula Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM
	Labrus mixtus Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM
	Labrus viridis Linnaeus, 1758[1]	A-M		1	VU	LS, AS, SM, BS
	Lappanella fasciata (Cocco, 1833)[1]	A-M		1	LC	AS
	Pteragogus trispilus Randall, 2013[1]	I-P	A/E[28]	1	NE	LS, AS
	Symphodus cinereus (Bonnaterre, 1788)[1]	A-M		3	LC	LS, AS, SM, BS
	Symphodus doderleini Jordan, 1890[1]	M-E		3	LC	LS, AS, SM
	Symphodus mediterraneus (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM
	Symphodus melanocercus (Risso, 1810)[1]	M-E		3	LC	LS, AS, SM
	Symphodus melops (Linnaeus, 1758)[1]	A-M		1	LC	AS
	Symphodus ocellatus (Forsskål, 1775)[1]	M-E		3	LC	LS, AS, SM, BS
	Symphodus roissali (Risso, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
	Symphodus rostratus (Bloch, 1791)[1]	M-E		3	LC	LS, AS, SM, BS
	Symphodus tinca (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Talassoma pavo (Linnaeuus, 1758)[1]	A-M		3	LC	LS, AS, SM
	Xyrichtys novacula (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
Scaridae	*Scarus ghobban* Forsskål, 1775[1]	I-P	A/E[27]	3	LC	LS
	Sparisoma cretense (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS
Ammodytidae	*Gymnammodytes cicerelus* (Rafinesque, 1810)[1]	A-M		3	LC	LS, AS, SM, BS
Trachinidae	*Echiichthys vipera* (Cuvier, 1829)[1]	A-M		3	NE	LS, AS, SM
	Trachinus araneus Cuvier, 1829[1]	A-M		3	LC	LS, AS, SM
	Trachinus draco Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Trachinus radiatus Cuvier, 1829[1]	A-M		3	LC	LS, AS, SM
Uranoscopidae	*Uranoscopus scaber* Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
Callionymidae	*Callionymus fasciatus* Valenciennes, 1837[1]	M-E		3	LC	LS, AS, SM
	Callionymus filamentosus Valenciennes, 1837[1]	I-P	I[30]	1	NE	LS, AS
	Callionymus lyra Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM, BS
	Callionymus maculatus Rafinesque, 1810	A-M		1	LC	LS, AS, SM
	Callionymus pusillus Delaroche, 1809[1]	A-M		3	NE	LS, AS, SM, BS
	Callionymus risso LeSueur, 1814[1]	A-M		3	NE	LS, AS, SM, BS
	Diplogrammus randalli Fricke, 1983[25]	I-P	A[26]	1	NE	AS
	Synchiropus phaeton (Günther, 1861)[1]	A-M		1	LC	LS, AS
	Synchiropus sechellensis Regan, 1908[1]	I-P	A[28]	1	NE	LS
Sphyraenidae	*Sphyraena chrysotaenia* Klunzinger, 1884[1]	I-P	I[30]	1	NE	LS, AS
	Sphyraena flavicauda Rüppell, 1838[1]	I-P	I[27]	1	NE	LS
	Sphyraena sphyraena (Linnaeus, 1758)[1]	A-M		3	LC	LS, AS, SM, BS
	Sphyraena viridensis Cuvier, 1829[1]	A-M		1	LC	LS, AS
Sebastidae	*Helicolenus dactylopterus* (Delaroche, 1809)[1]	A-M		1	LC	LS, AS, SM
Scorpaenidae	*Scorpaena elongata* Cadenat, 1943[1]	A-M		1	LC	LS, AS

Class **Order** Family	Scientific name	ZO	A/I/E	H	IUCN	Turkey distribution
	Scorpaena loppei Cadenat, 1943[1]	A-M		1	LC	LS, AS
	Scorpaena maderensis Valenciennes, 1833[1]	A-M		1	LC	LS, AS
	Scorpaena notata Rafinesque, 1810[1]	A-M		1	LC	LS, AS, SM, BS
	Scorpaena porcus Linnaeus, 1758[1]	A-M		1	LC	LS, AS, SM, BS
	Scorpaena scrofa Linnaeus, 1758[1]	A-M		3	LC	LS, AS, SM
	Pterois miles (Bennett, 1828)[11]	I-P	I[30]	1	LC	LS, AS
	Pterois volitans (Linnaeus, 1758)[12]	I-P	A[26]	1	LC	LS
Synanceiidae	*Synanceia verrucosa* Bloch & Schneider, 1801[1]	I-P	A[28]	1	NE	LS
Triglidae	*Chelidonichthys cuculus* (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Eutriglia gurnardus (Linnaeus, 1758)[1]	A-M		3	NE	LS, AS, SM, BS
	Chelidonichthys lastoviza (Bonnaterre, 1788)[1]	A-M		1	NE	LS, AS, SM
	Chelidonichthys lucerna (Linnaeus, 1758)[1]	A-M		1	LC	LS, AS, SM, BS
	Chelidonichthys obscurus (Walbaum, 1792)[1]	A-M		1	NE	LS, AS
	Lepidotrigla cavillone (Lacépède, 1801)[1]	A-M		1	NE	LS, AS, SM
	Lepidotrigla dieuzeidei Blanc & Hureau, 1973[1]	A-M		1	NE	LS, AS, SM
	Trigla lyra Linnaeus, 1758[1]	A-M		1	NE	LS, AS, SM
Peristediidae	*Peristedion cataphractum* (Linnaeus, 1758)[1]	A-M		1	NE	LS, AS, SM

[a]**Sources:** **[1]**Bilecenoğlu et al. (2014), **[2]**Yücel et al. (2017), **[3]**Çiftçi et al. (2017), **[4]**Dalyan et al. (2014), **[5]**Doğdu et al. (2016), **[6]**Ünlüoğlu et al. (2018), **[7]**Gökoğlu et al. (2014), **[8]**Bilecenoğlu et al. (2017), **[9]**Akyol and Aydın (2016), **[10]**Gerovasileiou et al. (2017), **[11]**Turan et al. (2014), **[12]**Gürlek et al. (2016c), **[13]**Akyol et al. (2017), **[14]**Engin et al. (2016), **[15]**Gökoğlu and Özvarol (2015), **[16]**Ergüden et al. (2018), **[17]**Gürlek et al. (2017), **[18]**Gökoğlu and Teker (2018), **[19]**Turan et al. (2015), **[20]**Gürlek et al. (2016b), **[21]**Irmak et al. (2015), **[22]**Akyol (2019), **[23]**Gürlek et al. (2016a), **[24]**Bilecenoğlu (2016), **[25]**Seyhan et al. (2017), **[26]**Turan et al. (2018a, b, c), **[27]**MAMIAS (2019), **[28]**Golani et al. (2019), **[29]**Zenetos et al. (2017), **[30]**Bilge et al. (2019), **[31]**Fricke et al. (2007), **[32]**Froese and Pauly (2019), **[33]**Abdul Malak et al. (2011), **[34]**IUCN (2016), **[35]**IUCN (2020), **[36]**Filiz et al. (2019)

ZO zoogeographical origin, *A/I/E* alien/invasive/established, *H* habitat types—**1**, oseanodromous; **2**, potamodromous; **3**, diadromous

Appendix 10.2: Recent Checklist of Turkish Inland Ichthyofauna ([a]Sources 1–53)

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
Petromyzonti **Petromyzontiformes** Petromyzontidae	*Caspiomyzon wagneri* (Kessler, 1870)	N	NT[RE]	fw, bw; m	24
	Eudontomyzon mariae (Berg, 1931) **	N	LC	fw, bw	22
	Lampetra lanceolata Kux & Steiner, 1872	E	EN	fw	12; 22
	[b]*Petromyzon marinus* Linnaeus, 1758 **	AI	LC	fw, bw; m	all coast & bw
Actinopteri **Acipenseriformes** Acipenseridae	*Acipenser colchicus* Marti, 1940	N	NE	fw	22
	[b]*Acipenser gueldenstaedtii* Brandt & Rotzeburg, 1833	N	CR	fw, bw; m	all coast BS; extinct W & C BS
	[b]*Acipenser nudiventris* Lovetzsky, 1828	N	CR	fw, bw; m	all coast BS watershed
	Acipenser persicus Borodin, 1897	N	CR[RE]	fw, bw; m	24
	Acipenser ruthenus Linnaeus, 1758	N	VU	fw, bw	13; 22
	[b]*Acipenser stellatus* Pallas, 1771	N	CR	fw, bw; m	MS, AS, Mar, BS watershed
	[b]*Acipenser sturio* Linnaeus, 1758	N	CR[RE]	fw, bw; m	AS, Mar, BS watershed
	[b]*Huso huso* (Linnaeus, 1758)	N	CR	fw, bw; m	AS, Mar, BS watershed
Anguilliformes Anguillidae	[b]*Anguilla anguilla* (Linnaeus, 1758)	N	CR	fw, bw; m	1, 2; 4–8; 12; 13; 15; 17; 18; 20
Clupeiformes Clupeidae	[b]*Alosa caspia* (Eichwald, 1838) **	N	LC[RE]	fw, bw; m	24
	[b]*Alosa fallax* (Lacépède, 1823)	N	LC	fw, bw; m	all coasts
	[b]*Alosa immaculata* Bennett, 1835	N	VU	fw, bw; m	all coast BS
	[b]*Alosa maeotica* (Grimm, 1901)	N	LC	fw, bw; m	all coast BS
	[b]*Alosa tanaica* (Grimm, 1901)	N	LC	fw, bw; m	all coast BS & Mar
	[b]*Clupeonella cultriventris* (Nordman, 1840)	N	LC	fw, bw; m	all coast BS & Mar
	Clupeonella muhlisi Neu, 1934	E	EN	fw	3a

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	[b]*Sprattus sprattus* (Linnaeus, 1758)	N	LC	fw, bw; m	all coasts
Cypriniformes Cobitidae	*Cobitis afifeae* Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	6; 7
	Cobitis aliyeae Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	18; 20
	Cobitis anabelae Freyhof, Bayçelebi & Geiger, 2018	N	NE	fw	19a
	Cobitis battalgilae Băcescu, 1962	E	EN	fw	8c; 16
	Cobitis bilseli Battalgil, 1942	E	EN	fw	16a
	Cobitis damlae Erk'akan & Özdemir, 2014	E	NE	fw	8c
	Cobitis dorademiri Özdemir, Erk'akan & Özeren, 2017	E	NE	fw	8b
	Cobitis emrei Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	12c
	Cobitis elazigensis Coad & Sarieyyüpoglu, 1988	N	LC	fw	21a
	Cobitis erkakanae Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	21c
	Cobitis evreni Erk'akan, Özeren & Nalbant, 2008	E	EN	fw	20b
	Cobitis fahireae Erk'akan, Atalay-Ekmekçi & Nalbant, 1998	E	LC	fw	2–7
	Cobitis kellei Erk'akan, Atalay-Ekmekçi & Nalbant, 1998	E	CR	fw	26a
	Cobitis joergbohleni Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	18c
	Cobitis levantina Krupp & Moubayed, 1992	N	EN	fw	19
	Cobitis phrygica Battalgazi, 1944	E	EN	fw	10a; 10b; 10c, 10d
	Cobitis pirii Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	9b; 9c
	Cobitis pontica Vasil'eva & Vasil'ev, 2006	N	LC	fw	3b; 12
	Cobitis puncticulata Erk'akan, Atalay-Ekmekçi & Nalbant, 1998	N	EN	fw	3
	Cobitis satunini Gladkov 1935	N	LC	fw	22

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Cobitis simplicispina Hankó, 1925	E	LC	fw	12; 11a; 11b; 15
	Cobitis sipahilerae Özdemir, Erk'akan & Özeren, 2017	E	NE	fw	9
	Cobitis splendens Erk'akan, Atalay-Ekmekçi & Nalbant, 1998	E	CR	fw	13
	Cobitis strumicae Karaman, 1955	N	LC	fw	1
	Cobitis troasensis Freyhof, Bayçelebi & Geiger, 2018	E	NE	fw	4a
	Cobitis turcica Hankó, 1925	E	EN	fw	16a
	Sabanejewia aurata (De Filippi, 1863)	N	LC	fw	24
	Sabanejewia balcanica (Karaman, 1922)	N	LC	fw	1
	Sabanejewia caspia (Eichwald, 1838)	N	NE	fw	24
Nemachelidae	*Oxynoemacheilus anatolicus* Erk'akan, Özeren & Nalbant, 2008	E	EN	fw	10a
	Oxynoemacheilus angorae (Steindachner, 1897)	E	LC	fw	11; 12; 15
	Oxynoemacheilus araxensis (Bănărescu & Nalbant, 1978)	E	DD	fw	21a
	Oxynoemacheilus argyrogramma (Heckel, 1847)	N	LC	fw	21
	Oxynoemacheilus atili Erk'akan, 2012	E	NT	fw	9e; 16a
	Oxynoemacheilus banarescui (Delmastro, 1982)	E	NT	fw	13
	Oxynoemacheilus bergianus (Derjavin, 1934)	N	LC	fw	21; 24b; 26
	Oxynoemacheilus brandtii (Kessler, 1877)	N	LC	fw	24
	Oxynoemacheilus cemali Turan, Kaya, Kalaycı, Bayçelebi & Aksu, 2019	E	NE	fw	22; 23
	Oxynoemacheilus ceyhanensis (Erk'akan, Nalbant & Özeren, 2007)	E	DD	fw	29

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Oxynoemacheilus ciceki Sungur, Eagderi & Jalili, 2017	E	NE	fw	18c
	Oxynoemacheilus cinicus (Erk'akan, Nalbant & Özeren, 2007)	E	DD	fw	7
	Oxynoemacheilus ercisianus (Erk'akan & Kuru, 1986)	E	EN	fw	25
	Oxynoemacheilus eregliensis (Bănărescu & Nalbant, 1978)	E	VU	fw	16
	Oxynoemacheilus euphraticus (Bănărescu & Nalbant, 1964)	N	NE	fw	21; 26
	Oxynoemacheilus evreni (Erk'akan, Nalbant & Özeren, 2007)	E	LC	fw	20
	Oxynoemacheilus frenatus (Heckel, 1843)	N	LC	fw	26a
	Oxynoemacheilus germencicus (Erk'akan, Nalbant & Özeren, 2007)	E	VU	fw	5; 7
	Oxynoemacheilus hazarensis Freyhof & Özuluğ, 2017	E	NE	fw	26a
	Oxynoemacheilus kaynaki Erk'akan, Özeren & Nalbant, 2008	E	LC	fw	21a
	Oxynoemacheilus kentritensis Freyhof, Kaya & Turan 2017	N	NE	fw	26a
	Oxynoemacheilus kosswigi (Erk'akan & Kuru, 1986)	E	LC	fw	14; 15
	Oxynoemacheilus mediterraneus (Erk'akan, Nalbant & Özeren, 2007)	E	LC	fw	9b; 9c
	Oxynoemacheilus mesudae Erk'akan, 2012	E	EN	fw	7; 7a
	Oxynoemacheilus namiri (Krupp & Schneider 1991)	N	LC	fw	19
	Oxynoemacheilus paucilepis (Erk'akan, Nalbant & Özeren, 2007)	E	EN	fw	21a
	Oxynoemacheilus samanticus (Bănărescu & Nalbant, 1978)	E	LC	fw	15; 18; 21

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Oxynoemacheilus seyhanensis (Bănărescu, 1968)	E	CR	fw	18b
	Oxynoemacheilus seyhanicola (Erk'akan, Nalbant & Özeren, 2007)	E	EN	fw	18a
	Oxynoemacheilus simavica (Balık & Bănărescu, 1978)	E	CR	fw	5
	Oxynoemacheilus theophilii Stoumboudi, Kottelat & Barbieri, 2006	N	LC	fw	5; 6; 7
	Oxynoemacheilus tigris (Heckel, 1843)	N	CR	fw	21a
	Oxynoemacheilus veyselorum Çiçek, Eagderi & Sungur, 2018	E	NE	fw	24
	Paracobitis zabgawraensis Freyhof, Esmaeili, Sayyadzadeh & Geiger, 2014	N	NE	fw	26b
	Paraschistura chrysicristinae (Nalbant, 1998)	E	CR	fw	26
	Seminemacheilus ahmeti Sungur, Jalili, Eagderi & Çiçek, 2018	E	NE	fw	18c
	Seminemacheilus ispartensis Erk'akan, Nalbant & Özeren, 2007	E	VU	fw	9b; 11a; 11b
	Seminemacheilus lendlii (Hankó, 1925)	E	VU	fw	16a; 16b
	Turcinoemacheilus kosswigi Bănărescu & Nalbant, 1964	N	LC	fw	26
	Turcinoemacheilus minimus Esmaeili, Sayyadzadeh, Özulug, Geiger & Freyhof, 2014	E	NE	fw	21c
Cyprinidae s.str.	*Arabibarbus grypus* (Heckel, 1843)	N	VU	fw	21; 26
	Barbus anatolicus Turan, Kaya, Geiger & Freyhof, 2018	E	NE	fw	15
	Barbus cyclolepis Heckel, 1839	N	LC	fw	5; 6; 7
	Barbus cyri De Filippi, 1865	N	NE	fw	24
	Barbus escherichii (Steindachner, 1897)	E	LC	fw	12

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Barbus lacerta Heckel, 1843	N	LC	fw	21; 26
	Barbus niluferensis Turan, Kottelat & Ekmekçi, 2009	E	NT	fw	3
	Barbus oligolepis Battalgil, 1941	E	LC	fw	2; 12b
	Barbus pergamonensis Karaman, 1971	N	LC	fw	5; 6; 7
	Barbus rionicus Kamensky 1899	N	NE	fw	23
	Barbus tauricus Kessler, 1877 **	N	VU	fw	2
	Capoeta antalyensis (Battalgil, 1944)	E	VU	fw	9c
	Capoeta aydinensis Turan, Küçük, Kaya, Güçlü & Bektaş, 2017	E	NE	fw	7
	Capoeta barroisi Lortet, 1894	N	EN	fw	19
	Capoeta bergamae Karaman, 1969	E	NT	fw	4–8
	Capoeta caelestis Schöter, Özuluğ & Freyhof, 2009	E	LC	fw	17a
	Capoeta capoeta (Güldenstädt, 1773)	N	LC	fw	24
	Capoeta damascina (Valenciennes, 1842)	N	LC	fw	18; 19; 20
	Capoeta ekmekciae Turan, Kottelat, Kirankaya, Engin, 2006	N	NT	fw	23
	Capoeta erhani Turan, Kottelat & Ekmekçi, 2008	E	LC	fw	20
	Capoeta mauricii Küçük, Turan, Şahin & Gülle, 2009	E	EN	fw	16a; 16b
	Capoeta oguzelii Elp, Osmanoğlu, Kadak & Turan, 2018	E	NE	fw	13
	Capoeta pestai (Pietschmann, 1933)	E	CR	fw	9b
	Capoeta sieboldii (Steindachner, 1864)	N	LC	fw	12
	Capoeta tinca (Heckel, 1843)	E	LC	fw	12
	Capoeta trutta (Heckel, 1843)	N	LC	fw	21; 26
	Capoeta turani Özuluğ & Freyhof, 2008	E	NT	fw	18a

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Capoeta umbla (Heckel, 1843)	N	LC	fw	21; 26
	Carasobarbus chantrei (Sauvage, 1882)	N	NT	fw	19
	Carasobarbus kosswigi (Ladiges, 1960)	N	VU	fw	21; 26
	Carasobarbus luteus (Heckel, 1843)	N	LC	fw	21; 26
	Carassius auratus (Linnaeus, 1758)	AI	LC	fw	27
	Carassius carassius (Linnaeus, 1758)	AI	LC	fw	27
	Carassius gibelio (Bloch, 1782)	AI	NE	fw	27
	Cyprinion kais Heckel, 1843	N	LC	fw	21; 26
	Cyprinion macrostomum Heckel, 1843	N	LC	fw	21; 26
	Cyprinus carpio Linnaeus, 1758	N/T	NE	fw	27
	Garra culiciphaga (Pellegrin, 1927)	E	LC	fw	18a; 20
	Garra kemali (Hankó, 1925)	E	EN	fw	16a; 16b
	Garra klatti (Kosswig, 1950)	E	EN	fw	7
	Garra rufa (Heckel, 1843)	N/T	LC	fw	18–21; 26
	Garra turcica (Karaman, 1971)	N	NE	fw	21; 26
	Garra variabilis (Heckel, 1843)	N	LC	fw	21; 26
	Luciobarbus barbulus Heckel, 1847	N	NE	fw	21; 26
	Luciobarbus caspius (Berg, 1914)	N	NE	fw	24
	Luciobarbus capito (Güldenstädt, 1773)	N	VU	fw, bw	25
	Luciobarbus esocinus Heckel, 1843	N	VU	fw	21; 26
	Luciobarbus kersin (Heckel, 1843)	N	DD	fw	21; 26
	Luciobarbus kottelati Turan, Ekmekçi, İlhan & Engin, 2008	E	VU	fw	7
	Luciobarbus lorteti (Sauvage, 1882)	N	DD	fw	19

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Luciobarbus lydianus (Boulenger, 1896)	E	LC	fw	4; 5; 6
	Luciobarbus mursa (Güldenstädt, 1773)	N	LC	fw	24
	Luciobarbus mystaceus (Pallas, 1814)	N	NE	fw	21; 26
	Luciobarbus pectoralis (Heckel, 1843)	N	LC	fw	18; 19; 20
	Luciobarbus subquincunciatus (Günther, 1868)	N	CR	fw	21; 26
	Luciobarbus xanthopterus Heckel, 1843	N	VU	fw	21; 26
	Schizothorax prophylax Pietschmann, 1933	E	NE	fw	9b
Danionidae	*Barilius mesopotamicus* Berg, 1932	N	LC	fw	21; 26
Leuciscidae	*Abramis brama* (Linnaeus, 1758)	N/T	LC	fw, bw	2; 4; 13; 22; 24
	Acanthobrama centisquama Heckel, 1843	N	CR	fw, bw	19
	Acanthobrama marmid Heckel, 1843	N	LC	fw, bw	18; 19; 21; 26
	Acanthobrama microlepis (De Filippi, 1863)	N	LC	fw	24
	Acanthobrama orontis Berg, 1949	E	NE	fw, bw	19
	Acanthobrama thisbeae Freyhof & Özuluğ, 2014	E	NE	fw, bw	20
	Alburnoides bipunctatus (Bloch, 1782)	N	LC	fw, bw	1
	Alburnoides diclensis Turan, Bektaş, Kaya & Bayçelebi, 2016	E	NE	fw	26a
	Alburnoides eichwaldii (De Filippi, 1863)	N	LC	fw	24
	Alburnoides emineae Turan, Kaya, Ekmekçi & Doğan, 2014	E	NE	fw	21c
	Alburnoides fasciatus (Nordmann, 1840)	N	LC	fw	22
	Alburnoides freyhofi Turan, Kaya, Bayçelebi, Bektaş & Ekmekçi, 2017	E	NE	fw	15
	Alburnoides kosswigi Turan, Kaya, Bayçelebi, Bektaş & Ekmekçi, 2017	E	NE	fw	12; 12a; 13

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Alburnoides kurui Turan, Kaya, Bayçelebi, Bektaş & Ekmekçi, 2017	E	NE	fw	14
	Alburnoides manyasensis Turan, Ekmekçi, Kaya & Güçlü, 2013	E	LC	fw	2; 3
	Alburnoides smyrnae Pellegrin 1927	E	NE	fw, bw	7
	Alburnoides velioglui Turan, Kaya, Ekmekçi & Doğan, 2014	E	NE	fw	21a
	Alburnus adanensis Battalgil, 1944	E	NE	fw	18
	Alburnus akili Battalgil, 1942	E	EX	fw	16a
	Alburnus alburnus (Linnaeus, 1758)	N/T	LC	fw	2
	Alburnus attalus Özuluğ & Freyhof, 2007	E	EN	fw	4b
	Alburnus baliki Bogutskaya, Küçük & Ünlü, 2000	E	EN	fw	9a; 18
	Alburnus battalgilae Özuluğ & Freyhof, 2007	E	VU	fw	5
	Alburnus caeruleus Heckel, 1843	N	LC	fw	21; 26
	Alburnus carianorum Freyhof, Kaya, Bayçelebi, Geiger & Turan 2019	E	NE	fw	7; 8c
	Alburnus carinatus Battalgil, 1941	E	EN	fw	3
	Alburnus chalcoides (Güldenstadt, 1772)	N/T	LC	fw, bw	13; 22; 27
	Alburnus demiri Özuluğ & Freyhof, 2008	E	VU	fw	7; 8a
	Alburnus derjugini Berg, 1923	N	LC	fw	22; 23
	Alburnus escherichii Steindachner, 1897	E/T	LC	fw, bw	9d; 12; 15; 16a
	Alburnus filippii Kessler, 1877	N	LC	fw	24
	Alburnus goekhani Özuluğ, Geiger & Freyhof, 2018	E	NE	fw	14; 15
	Alburnus heckeli Battalgil, 1944	E	LC	fw	26a
	Alburnus hohenackeri Kessler, 1877 **	N	LC	fw, bw	24
	Alburnus istanbulensis Battalgil, 1941	E	LC	fw	1; 2; 13

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Alburnus kotschyi Steindachner, 1863	E	LC	fw, bw	18–20
	Alburnus kurui (Bogutskaya, 1995)	E	DD	fw	26b
	Alburnus nasreddini Battalgil, 1944	E	CR	fw	11a; 11b; 12a
	Alburnus nicaeensis Battalgil, 1941	E	EX	fw	12b
	Alburnus orontis Sauvage, 1882	N	VU	fw, bw	19
	Alburnus schischkovi (Drensky, 1943)	N	EN	fw	1
	Alburnus sellal Heckel, 1843	N	LC	fw	21; 26
	Alburnus tarichi (Güldenstädt, 1824)	E/T	NT	fw, bw	25
	Alburnus timarensis Kuru, 1980	E	CR	fw	25
	Blicca bjoerkna (Linnaeus, 1758)	N	LC	fw, bw	2; 13
	Chondrostoma angorense Elvira, 1987	E	LC	fw	12; 15
	Chondrostoma beysehirense Bogutskaya, 1997	E	EN	fw	16a
	Chondrostoma ceyhanense Küçük, Turan, Güçlü, Mutlu & Çiftçi, 2017	E	NE	fw	18; 20
	Chondrostoma colchicum Derjugin, 1899	N	LC	fw	23
	Chondrostoma cyri Kessler, 1877	N	LC	fw	24
	Chondrostoma fahirae (Ladiges, 1960)	E	EN	fw	8; 10
	Chondrostoma holmwoodii (Boulenger, 1896)	E	VU	fw	4b, 5; 6
	Chondrostoma kinzelbachi Krupp, 1985	N	EN	fw	19
	Chondrostoma meandrense Elvira, 1987	E	VU	fw	7
	Chondrostoma nasus (Linnaeus, 1758)	N	LC	fw	4
	Chondrostoma regium (Heckel, 1843)	N	LC	fw	21; 26
	Chondrostoma toros Küçük, Turan, Güçlü, Mutlu & Çiftçi, 2017	E	NE	fw	17a

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Chondrostoma turnai Güçlü, Çiftçi, Küçük, Turan & Mutlu, 2018	E	NE	fw	7
	Chondrostoma vardarense Karaman, 1928	N	NT	fw	1
	Ladigesocypris mermere (Ladiges, 1960)	E	DD	fw	4–8
	Leucalburnus satunini (Berg, 1910)	E	LC	fw	24b
	Leucaspius delineatus (Heckel, 1843)	N	LC	fw	1; 2
	Leuciscus aspius (Linnaeus, 1758)	N	LC	fw, bw	1; 2; 12; 24
	Leuciscus idus (Linnaeus, 1758)	N	LC	fw, bw	1
	Leuciscus vorax (Heckel, 1843)	N	LC	fw, bw	19; 21; 26
	Petroleuciscus borysthenicus (Kessler, 1859)	N	LC	fw, bw	1; 2; 13; 22
	Petroleuciscus smyrnaeus (Boulenger, 1896)	N	LC	fw	4b; 5; 6; 7
	Petroleuciscus ninae Turan, Kalaycı, Kaya, Bektaş & Küçük, 2018	E	NE	fw	7
	Phoxinus phoxinus (Linnaeus, 1758) **	N	LC	fw	1; 2
	Phoxinus strandjae Drensky, 1926	N	EN	fw	1
	Pseudophoxinus alii Küçük, 2007	E	EN	fw	9c
	Pseudophoxinus anatolicus (Hankó, 1925)	E	EN	fw	16a; 16d
	Pseudophoxinus antalyae Bogutskaya, 1992	E	VU	fw	9a
	Pseudophoxinus battalgili Bogutskaya, 1997	E	LC	fw	9e; 12a; 16a; 16b;16d
	Pseudophoxinus burduricus Küçük, Gülle, Güçlü, Çiftçi & Erdoğan, 2013	E	EN	fw	10a; 10b
	Pseudophoxinus caralis (Battalgil, 1942)	E	NE	fw	16a
	Pseudophoxinus cilicicus Saç, Özuluğ, Geiger & Freyhof, 2019	E	NE	fw	18; 19; 20
	Pseudophoxinus crassus (Ladiges, 1960)	E	EN	fw	16b; 16c

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Pseudophoxinus egridiri (Karaman, 1972)	E	EN	fw	9b
	Pseudophoxinus elizavetae Bogutskaya, Küçük & Atalay, 2006	E	CR	fw	18c
	Pseudophoxinus evliyae Freyhof & Özuluğ, 2010	E	EN	fw	9d
	Pseudophoxinus fahrettini Freyhof & Özuluğ, 2010	E	EN	fw	9c
	Pseudophoxinus firati Bogutskaya, Küçük & Atalay, 2006	E	EN	fw	21a; 21c
	Pseudophoxinus handlirschi (Pietschmann, 1933)	E	EX	fw	9b
	Pseudophoxinus hittitorum Freyhof & Özuluğ, 2010	E	EN	fw	16a
	Pseudophoxinus iconii Küçük, Gülle & Güçlü, 2016	E	NE	fw	16c
	Pseudophoxinus libani (Lortet, 1883)	N	LC	fw	19
	Pseudophoxinus maeandri (Ladiges, 1960)	E	EN	fw, bw	7a; 7b
	Pseudophoxinus maeandricus (Ladiges, 1960)	E	CR	fw	11
	Pseudophoxinus mehmeti Ekmekçi, Atalay, Yoğurtçuoğlu, Turan & Küçük, 2015	E	NE	fw	10e
	Pseudophoxinus ninae Freyhof & Özulug, 2006	E	CR	fw	9c
	Pseudophoxinus turani Küçük & Güçlü, 2014	E	NE	fw	19
	Pseudophoxinus zekayi Bogutskaya, Küçük & Atalay, 2006	E	VU	fw	20
	Pseudophoxinus zeregi (Heckel, 1843)	N	LC	fw, bw	19
	Rutilus frisii (Nordmann, 1840)	N	LC	fw, bw	2; 12b;13; 22
	Rutilus rutilus (Linnaeus, 1758)	N	LC	fw, bw	1
	Scardinius elmaliensis Bogutskaya, 1997	E	EN	fw	9d

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Scardinius erythrophthalmus (Linnaeus, 1758)	N	LC	fw	1
	Squalius adanaensis Turan, Kottelat & Doğan, 2013	E	NT	fw	18a
	Squalius anatolicus (Bogutskaya, 1997)	E	LC	fw	9e; 16a; 16b
	Squalius aristotelis Özuluğ & Freyhof, 2011	E	LC	fw	4a
	Squalius berak Heckel, 1843	N	LC	fw	21; 26
	Squalius cappadocicus Özuluğ & Freyhof, 2011	E	CR	fw	16b
	Squalius carinus Özuluğ & Freyhof, 2011	E	EN	fw	7a
	Squalius cephaloides (Battalgil, 1942)	E	VU	fw	2
	Squalius cephalus (Linnaeus, 1758)	N	LC	fw, bw	22
	Squalius cii (Richardson, 1857)	E	LC	fw	3b; 12b
	Squalius fellowesii (Günther, 1868)	E	LC	fw	4–8
	Squalius irideus (Ladiges, 1960)	E	NT	fw	8a; 8b
	Squalius kosswigi (Karaman, 1972)	E	EN	fw	6a
	Squalius kottelati Turan, Yilmaz & Kaya, 2009	N	NT	fw	19; 20
	Squalius lepidus Heckel, 1843	N	LC	fw	21; 26
	Squalius orientalis (Nordmann 1840)	E	NE	fw	24a
	Squalius orpheus Kottelat & Economidis, 2006	N	LC	fw	1
	Squalius pursakensis (Hankó, 1925)	E	LC	fw	12
	Squalius recurvirostris Özuluğ & Freyhof, 2011	E	VU	fw	11a; 11b; 12a
	Squalius semae Turan, Kottelat & Bayçelebi, 2017	E	NE	fw	21a
	Squalius seyhanensis Turan, Kottelat & Doğan, 2013	E	DD	fw	18b
	Squalius spurius Heckel, 1843	N	DD	fw, bw	19

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Squalius turcicus De Filippi, 1865	N	LC	fw	24
	Vimba melanops (Heckel, 1839)	N	DD	fw, bw	1
	Vimba mirabilis (Ladiges, 1960)	E	LC	fw, bw	5; 6; 7
	Vimba vimba (Linnaeus, 1758)	N	LC	fw, bw	1–13; 15; 22; 23
Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes, 1844)	AI	NE	fw, bw	27
	Hypophthalmichthys molitrix (Valenciennes, 1844)	AI	NT	fw	27
Tincidae	*Tinca tinca* (Linnaeus, 1758)	N/T	LC	fw, bw	27
Acheilognathidae	*Rhodeus amarus* (Bloch, 1782)	N	LC	fw, bw	1–7
	Rhodeus sericeus (Pallas, 1776)	N	LC	fw, bw	13; 22
Gobionidae	*Gobio artvinicus* Turan, Japoshvili, Aksu & Bektaş, 2016	E	NE	fw	22; 23
	Gobio baliki Turan, Kaya, Bayçelebi & Bektaş, 2017	E	NE	fw	13
	Gobio battalgilae Naseka, Erk’akan & Küçük, 2006	E	DD	fw	16a
	Gobio bulgaricus Drensky, 1926	N	LC	fw	1
	Gobio gymnostethus Ladiges, 1960	E	CR	fw	16b
	Gobio hettitorum Ladiges, 1960	E	CR	fw	16b
	Gobio insuyanus Ladiges, 1960	E	CR	fw	16c
	Gobio intermedius Battalgil, 1944	E	EN	fw	11a; 11b
	Gobio kizilirmakensis Turan, Japoshvili, Aksu & Bektaş, 2016	E	NE	fw	15
	Gobio kovatschevi Chichkoff, 1937	N	VU	fw	1
	Gobio maeandricus Naseka, Erk’akan & Küçük, 2006	E	EN	fw	7a; 7b
	Gobio microlepidotus Battalgil, 1942	E	VU	fw	16a

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Gobio sakaryaensis Turan, Ekmekçi, Luskova & Mendel, 2012	E	LC	fw	12
	Pseudorasbora parva (Temminck & Schlegel, 1846)	AI	LC	fw	27
	Romanogobio macropterus (Kamensky, 1901)	N	LC	fw	24
Characiformes Serrasalmidae	*Pygocentrus nattereri* Kner, 1858	AI	NE	fw	12c
Siluriformes Loricariidae	*Pterygoplichthys disjunctivus* (Weber, 1991)	AI	NE	fw	12; 19
	Pterygoplichthys pardalis (Castelnau, 1855)	AI	NE	fw	12
Bagridae	*Mystus pelusius* (Solander, 1794)	N	LC	fw	19; 21; 26
Sisoridae	*Glyptothorax armeniacus* (Berg, 1918)	N	NE	fw	21; 26
	Glyptothorax cous (Linnaeus, 1766)	N	NE	fw	21; 26
	Glyptothorax kurdistanicus (Berg, 1931)	N	DD	fw	21; 26
	Glyptothorax steindachneri (Pietschmann, 1913)	N	NE	fw	21; 26
Pangasiidae	*Pangasius sanitwongsei* Smith 1931	AI	NE	fw	12
Siluridae	*Silurus glanis* Linnaeus, 1758	N/T	LC	fw	1; 2; 12–15; 22; 23; 27
	Silurus triostegus Heckel, 1843	N/T	LC	fw, bw	21; 26
Clariidae	*Clarias gariepinus* Burchell, 1822	N/T	LC	fw	17
Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	AI	LC	fw	26
Esociformes Esocidae	*Esox lucius* Linnaeus, 1758	N/T	LC	fw, bw	1; 2; 12; 13; 15
Salmoniformes Salmonidae	*Coregonus albula* (Linnaeus, 1758)	AI	LC	Fw, bw	24b
	Coregonus macrophthalmus Nüsslin, 1882	AI^{ex}	LC	fw	12b
	Coregonus lavaretus (Linnaeus, 1758)	AI^{ex}	VU	fw	12b
	Oncorhynchus mykiss (Walbaum, 1792)	AI	NE	fw, bw	27
	Salmo abanticus Tortonese, 1954	E	VU	fw, bw	13a; 13b

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Salmo caspius Kessler, 1877	N	NE	fw, bw	24
	Salmo chilo Turan, Kottelat & Engin, 2012	E	NE	fw	20a
	Salmo coruhensis Turan, Kottelat & Engin, 2010	N	NT	fw, bw; m	22; 23
	Salmo euphrataeus Turan, Kottelat & Engin, 2014	E	NE	fw	21c
	Salmo kottelati Turan, Doğan, Kaya & Kanyılmaz, 2014	E	NE	fw	9a
	Salmo labecula Turan, Kottelat & Engin, 2012	E	EN	fw	9c;18a
	Salmo labrax Pallas, 1814	N	LC	fw, bw; m	22
	Salmo munzuricus Turan, Kottelat & Kaya, 2017	E	NE	fw	21a
	Salmo okumusi Turan, Kottelat & Engin, 2014	E	NE	fw	21c
	Salmo opimus Turan, Kottelat & Engin, 2012	E	NE	fw	9a; 20b
	Salmo platycephalus Behnke, 1968	E	EN	fw, bw	18b
	Salmo rizeensis Turan, Kottelat & Engin, 2010	N	LC	fw	22; 23
	Salmo salar Linnaeus, 1758	AI	LC	fw, bw; m	22
	Salmo tigridis Turan, Kottelat & Bektaş, 2011	E	DD	fw	26a
	Salmo trutta Linnaeus, 1758	AI	LC	fw, bw; m	1
	Salvelinus alpinus (Linnaeus, 1758)	AI[ex]	LC	fw, bw; m	22
	Salvelinus fontinalis (Mitchill, 1814)	AI[ex]	NE	fw, bw; m	22
	Stenodus leucichthys (Güldenstädt, 1772)	N	EW	fw, bw; m	24
Syngnathiformes Syngnathidae	[b]*Nerophis ophidion* (Linnaeus, 1758)	N	LC	bw, m	all coasts
	[b]*Syngnathus abaster* Risso, 1827	N	LC	fw, bw; m	all coasts
	Syngnathus schmidti Popov 1928	N	DD	fw, bw; m	BS, Mar
Gobiiformes Gobiidae	*Babka gymnotrachelus* (Kessler, 1857)	N	LC	fw, bw	2; 13
	Benthophilus nudus Berg, 1898	N	LC	fw, bw	13; 22

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	[b]*Knipowitschia caucasica* (Berg, 1916)	N/T	LC	fw, bw; m	m, fw & estuarine in BS; Mar & AS
	Knipowitschia byblisia Ahnelt, 2011	E	LC	fw	8b
	Knipowitschia caunosi Ahnelt, 2011	E	LC	fw	8b
	Knipowitschia longecaudata (Kessler, 1877)	N	LC	fw, bw	13; 22
	Knipowitschia mermere Ahnelt, 1995	E	VU	fw, bw	5
	Knipowitschia ricasolii (Di Caporiacco, 1935)	E	CR	fw, bw	6
	[b]*Mesogobius batrachocephalus* (Pallas, 1814)	N	LC	fw, bw	2; 13; 22
	Neogobius fluviatilis (Pallas, 1814)	N	LC	fw, bw; m	12; 13; 22
	[b]*Neogobius melanostomus* (Pallas, 1814)	N	LC	fw, bw; m	13; 22
	Pomatoschistus anatoliae Engin & Innal, 2017	E	NE	fw, bw	17a
	Ponticola constructor (Nordmann, 1840)	N	LC	fw	22
	Ponticola cyrius (Kessler, 1874)	N	LC	fw, bw	24
	[b]*Ponticola eurycephalus* (Kessler, 1874)	N	LC	fw, bw	13; 22
	[b]*Ponticola platyrostris* (Pallas, 1814)	N	LC	fw, bw	22
	[b]*Ponticola ratan* (Nordmann, 1840)	N	NE	fw, bw	13; 22
	Ponticola rizensis (Kovacic & Engin, 2008)	E	EN	fw	22
	[b]*Ponticola syrman* (Nordmann, 1840)	N	LC	fw, bw	2; 13; 22
	Ponticola turani (Kovacic & Engin, 2008)	E	VU	fw	22
	Proterorhinus semilunaris (Heckel, 1839)	N	LC	fw, bw	1; 2
Synbranchiformes Mastacembelidae	*Mastacembelus mastacembelus* (Banks & Solander in Russell, 1794)	N	LC	fw, bw	21; 26
Pleuronectiformes Scophthalmidae	[b]*Scophthalmus maximus* (Linnaeus, 1758)	N	NE	bw, m	BS coasts

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
Pleuronectidae	[b]*Platichthys flesus* (Linnaeus, 1758)	N	LC	fw, bw; m	all coasts
Cichliformes Cichlidae	*Coptodon rendalli* (Boulenger, 1897)	AI	LC	fw, bw	18a; 20a
	Coptodon zillii (Gervais, 1848)	AI	LC	fw, bw	18a; 20a
	Hemichromis letourneuxi Sauvage, 1880	AI	LC	fw, bw	10
	Oreochromis aureus (Steindachner, 1864)	AI	LC	fw, bw	18a; 20a
	Oreochromis mossambicus (Peters, 1852)	AI	NE	fw, bw	18a; 20a
	Oreochromis niloticus (Linnaeus, 1758)	AI	LC	fw, bw	18a; 20a
	Sarotherodon galilaeus (Linnaeus, 1758)	AI	NE	fw, bw	18a; 20a
Atheriniformes Atherinidae	[b]*Atherina boyeri* Risso, 1810	N/T	LC	fw, bw; m	all coastal bw; L İznik; introduced dam lakes in C Anatolia
	[b]*Atherina hepsetus* Linnaeus, 1758	AI	NE	fw, bw; m	all coastal bw; marginally entering fw habitats
Cyprinodontiformes Poecilidae	*Gambusia holbrooki* Girard, 1859	AI	LC	fw, bw	27
	Poecilia reticulata Peters, 1859	AI	NE	fw, bw	6
Aphaniidae	*Aphanius anatoliae* (Leidenfrost, 1912)	AI	NT	fw, bw	16
	Aphanius asquamatus (Sözer, 1942)	E	LC	fw	26a
	Aphanius danfordii (Boulenger, 1890)	E	CR	fw, bw	18c
	Aphanius fasciatus (Valenciennes, 1821)	N	LC	fw, bw; m	1; 2; 4–9; 17–20
	Aphanius fontinalis Akşiray, 1948	E	NE	fw, bw	10a
	Aphanius iconii Akşiray, 1948	E	NE	fw, bw	9b; 16a
	Aphanius irregularis Yoğurtçuoğlu & Freyhof, 2018	E	NE	fw	7c
	Aphanius maeandricus Akşiray, 1948	E	NE	fw, bw	7

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
	Aphanius marassantensis Pfleiderer, Geiger & Herder, 2014	E	NE	fw	15a; 15b
	Aphanius mento (Heckel, 1843)	N/T	LC	fw	9; 18–20
	Aphanius meridionalis Akşiray, 1948	E	NE	fw	10c
	Aphanius saldae Akşiray, 1955	E	NE	fw	10b
	Aphanius splendens (Kosswig & Sözer, 1945)	E	EX	fw, bw	9f
	Aphanius sureyanus (Neu, 1937)	E	EN	fw, bw	10a
	Aphanius transgrediens (Ermin, 1946)	E	CR	fw	10d
	Aphanius villwocki Hrbek & Wildekamp, 2003	E	LC	fw	12
Mugiliformes Mugilidae	[b]*Chelon auratus* (Risso, 1810)	N	LC	fw, bw; m	all coasts
	[b]*Chelon labrosus* (Risso, 1827)	N	LC	fw, bw; m	all coasts
	[b]*Chelon ramada* (Risso, 1827)	N	LC	fw, bw; m	all coasts
	[b]*Chelon saliens* (Risso, 1810)	N	LC	fw, bw; m	all coasts
	[b]*Chelon carinatus* (Valenciennes, 1836)	N	NE	bw, m	coasts of MS & bw
	[b]*Mugil cephalus* Linnaeus, 1758	N	LC	fw, bw; m	2; 4–8; 13–15; 17–20
	[b]*Oedalechilus labeo* (Cuvier, 1829)	N	NE	fw, bw; m	eustaries of Mar, AS & MS
	Planiliza abu (Heckel, 1843)	N	LC	fw, bw; m	19; 21; 26
	[b]*Planiliza haematocheilus* (Temminck & Schlegel, 1845)	AI	NE	fw, bw; m	BS, Mar, northern AS
Blenniiformes Blenniidae	*Salaria fluviatilis* Assoy del Rio, 1801	N	LC	fw, bw; m	1; 2–8; 9a; 9c; 9e;12; 13; 17–20
	[b]*Salaria pavo* (Risso, 1810)	N	LC	fw, bw; m	MS, Mar, BS coasts
Centrarchiformes Centrarchidae	*Lepomis gibbosus* Linnaeus, 1758	AI	LC	fw	27
Perciformes Moronidae	[b]*Dicentrarchus labrax* (Linnaeus, 1758)	N	LC	fw, bw; m	all coasts & bw
	[b]*Dicentrarchus punctatus* (Bloch, 1792)	N	LC	fw, bw; m	AS, MS coasts

CLASS **Order** Family	Species name	Status	IUCN	Habitat	Turkey distribution
Percidae	Gymnocephalus cernua (Linnaeus, 1758)	AI	LC	fw, bw	1
	Perca fluviatilis Linnaeus, 1758	N/T	LC	fw, bw	1; 2
	Sander lucioperca (Linnaeus, 1758)	N/T	LC	fw, bw	1; 2; 12; 15; 16
	Sander volgensis (Gmelin, 1789)	AI	LC	fw, bw	27
Gasterosteidae	*Gasterosteus aculeatus* Linnaeus, 1758	N	LC	fw, bw; m	2; 12b; 13
	Pungitius platygaster (Kessler, 1859)	N	LC	fw, bw	1

a**References**: **1**. Bayçelebi et al. (2015); **2**. Bayçelebi et al. (2018); **3**. Bilecenoğlu et al. (2014); **4**. Birecikligil et al. (2017); **5**. Bogutskaya (2002); **6**. Çiçek et al. (2015); **7**. Çiçek et al. 2016; **8**. Çiçek et al.(2018); **9**. Çiçek et al. (2019a); **10**. Çiçek et al. (2019b); **11**. Ekmekçi et al. (2013); **12**. Erkakan and Özdemir (2014); **13**. Erkakan et al. (2017); **14**. Emiroğlu et al. (2016); **15.** Eschmeyer et al. (2020); **16**. Freyhof et al. (2011); **17**. Freyhof et al. (2017); **18**. Freyhof et al. (2018a); **19**. Freyhof et al. (2018b); **20**. Freyhof et al. (2018c); **21**. Frickle et al. (2007); **22**. Froese and Pauly (2019); **23**. Güçlü et al. (2018); **24**. IUCN (2020); **25**. Khaefi et al. (2017); **26.** Kuru (2004); **27**. Küçük et al. (2015); **28**. Levin et al. (2012); **29**. Nalbant and Bianco (1998); **30**. Ninua et al. (2018); **31**. Özdemir (2015); **32.** Özdemir (2018); **33**. Saç and Özulug (2015); **34**. Saç et al. (2019); **35**. Tarkan et al. (2015); **36**. Turan et al. (2018b); **37**. Turan et al. (2018c); **38**. Turan et al. (2019); **39**. Türkmen (2019); **40**. Vidal et al. (2010); **41**. Yalçın Özdilek (2007); **42**. Yoğurtçuoğlu and Ekmekçi (2018); **43**. Yoğurtçuoğlu et al. (2018); **44.** Yoğurtçuoğlu and Freyhof (2018); **45**. Engin and Innal (2017); **46**. Emiroğlu et al. (2016); **47**. İnnal and Sungur (2019); **48**. Freyhof et al. (2019); **49**. Kottelat and Freyhof (2007); **50**. Perdices et al. (2018); **52**. Bern Convention (2002); **53**. CITES (2017)

River basin: **1**, Meriç; **2**, Marmara (a, Nortwest; b, Armutlu); **3**, Susurluk (a, Lake Apolyont; b, Simav River Drainage); **4**, Aegean Sea Water (a, Tuzla River Drainage; b, North Aegean Basin-Bakırçay); **5**, Gediz (a, Lake Marmara); **6**, Küçük Menderes (a, Tahtalı River Drainage); **7**, Büyük Menderes (a, Lake Işıklı; b, Dinar; c, Kaklık); **8**, West Mediterranean (a, Eşen; b, Köyceğiz; c, Dalaman); **9**, Central Mediterranean (a, Antalya; b, Lake Eğirdir; c, Aksu & Köprü River Drainage; d, Lake Avlan; e, Manavgat River Basin; f, Lake Gölcük); **10**, Burdur (a, Lake Burdur; b, Lake Salda; c, Lake Söğüt; d, Lake Acı; e, Alanköy Reservoir); **11**, Akarçay (a, Lake Akşehir; b, Lake Eber); **12**, Sakarya (a, Lake Ilgın; b, Lake İznik; c, Lake Sapanca); **13**, Western Black Sea (a, Lake Abant; b, Lake Yedigöller); **14**, Yeşilırmak; **15**, Kızılırmak (a, Hirfanlı Dam Lake; b, Lake Balık); **16**, Central Anatolia (a, Lake Beyşehir; b, Lake Tuz Gölü; c, Cihanbeyli; d, Lake Suğla); **17**, East Mediterranean (a, Göksu River Basin); **18,** Seyhan (a, Lower region; b, Zamantı River Drainage; c, Sultan Marsh); **19**, Asi; **20**, Ceyhan (a, Akdere River; b, Upper region; c, Lower region); **21**, Fırat-Euphrates (a, Upper region; b, Central region; c, Lower region); **22,** Eastern Black Sea; **23**, Çoruh; **24**, Kura-Aras (a, Aras River Drainage; b, Kura River Drainage); **25**, Lake Van; **26**, Dicle-Tigris (a, Upper region-Lake Hazar; b, Lower region); **27**, Translocated /Introduced many ponds); **28**, Cultivation in ponds in Black Sea

Origin: *N* native, *E* Endemic, *T* translocated, *AI* Alien/Invasive; [ex] unsuccessful introduction, [RE] Extinct regionally/in Turkey; [b]**common species for both of marine and inland fishes**; *fw* freshwater, *bw* brackishwater, *m* marine, *BS* Black Sea, *Mar* Marmara Sea, *AS* Aegean Sea, *MS* Mediterranean Sea. ** unclear status in Turkish fauna and require confirmation.

Appendix 10.3: The Checklist of Amphibians in Turkey

Order Family	Latin name	IUCN[G]	IUCN [EU]	IUCN [M]	Bern	CITES	Turkey distribution
Caudata							
Salamandridae	*Lissotriton kosswigi* (Freytag, 1955) (**E**)	–	–	–	–	–	Mar, B
Salamandridae	*Lissotriton lantzi* (Wolterstorff, 1914)	NE	–	NE	–	–	B
Salamandridae	*Lissotriton schmidtleri* (Raxworthy, 1988)[a]	–	–	–	–	–	–
Salamandridae	*Lyciasalamandra antalyana* (Başoğlu & Baran, 1976) (**E**)	EN	–	EN	I	–	M
Salamandridae	*Lyciasalamandra atifi* (Başoğlu, 1967) (**E**)	EN	–	EN	II	–	M
Salamandridae	*Lyciasalamandra billae* (Franzen & Klewen, 1987) (**E**)	CR	–	CR	–	–	M
Salamandridae	*Lyciasalamandra fazilae* (Başoğlu & Atatür, 1974) (**E**)	EN	–	EN	II	–	A
Salamandridae	*Lyciasalamandra flavimembris* (Mutz & Steinfartz, 1995) (**E**)	EN	–	EN	II	–	A
Salamandridae	*Lyciasalamandra luschani* (Steindachner, 1891)	VU	NA	EN	II	–	A, M
Salamandridae	*Mertensiella caucasica* (Waga, 1876)	VU	–	NE	II	–	B
Salamandridae	*Neurergus barani* Öz, 1994 (**E**)[a]	–	–	–	–	–	E
Salamandridae	*Neurergus crocatus* Cope, 1862	VU	–	NE	II	–	E
Salamandridae	*Neurergus strauchii* (Steindachner, 1887) (**E**)	VU	–	VU	II	–	E
Salamandridae	*Ommatotriton nesterovi* Litvinchuk, Zuiderwijk, Borkin & Rosanov, 2005 (**E**)	NE	–	NE	–	–	B
Salamandridae	*Ommatotriton ophryticus* (Berthold, 1846)	NT	–	NE	III	–	B
Salamandridae	*Ommatotriton vittatus* (Gray, 1835)	LC	–	NE	III	–	M
Salamandridae	*Salamandra infraimmaculata* Martens, 1885	NT	–	NT	III	–	E,C,M

Order Family	Latin name	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Salamandridae	*Triturus ivanbureschi* Arntzen & Wielstra, 2013	NE	NE	–	–	–	B, A, Mar
Salamandridae	*Triturus anatolicus* Wielstra & Arntzen, 2016 (**E**)	NE	–	–	–	–	B
Salamandridae	*Triturus karelinii* (Strauch, 1870)	LC	LC	NE	II	–	B
Anura							
Bombinatoridae	*Bombina variegata* (Linnaeus, 1758)	LC	LC	LC	III	–	TT
Bombinatoridae	*Bombina bombina* (Linnaeus, 1761)	LC	LC	LC	II	–	Mar
Pelobatidae	*Pelobates syriacus* Boettger, 1889	LC	LC	LC	II	–	AR
Pelodytidae	*Pelodytes caucasicus* Boulenger, 1896	NT	NA	NE	II	–	B
Hylidae	*Hyla orientalis* Bedriaga, 1890	NE	–	–	–	–	B, M,C, A, Mar
Hylidae	*Hyla savigyni* Audouin, 1827	LC	LC	LC	–	–	M, E
Bufonidae	*Bufo bufo* (Linnaeus, 1758)	LC	LC	LC	III	–	B, M,C, A, Mar
Bufonidae	*Bufo verrucosissimus* (Pallas, 1814)	NT	–	–	III	–	B
Bufonidae	*Bufotes sitibundus* (Pallas, 1771)[a]	–	–	–	–	–	AR
Ranidae	*Pelophylax bedriagae* (Camerano, 1882)	LC	–	LC	–	–	M, Mar, A
Ranidae	*Pelophylax caralitanus* (Arıkan, 1988) (**E**)	NT	–	NE	–	–	M, C
Ranidae	*Pelophylax ridibundus* (Pallas, 1771)	LC	LC	NE	III	–	E, SE, C, Ma, B
Ranidae	*Rana dalmatina* Fitzinger, 1838	LC	–	LC	III	–	Mar, B
Ranidae	*Rana holtzi* Werner, 1898 (**E**)[a]	CR	–	NE	II	–	M
Ranidae	*Rana macrocnemis* Boulenger, 1885	LC	–	LC	III	–	AR
Ranidae	*Rana tavasensis* Baran & Atatür, 1986 (**E**)	EN	–	LC	III	–	A, M

[a]Newly described, name-changed, or controversial species; *E* endemic, *IUCN[G]* global redlist, *IUCN[EU]* regional redlist for Europe, *IUCN[M]* regional redlist for Mediterranean, *B* Black Sea region, *M* Mediterranean region, *A* Aegean region, *C* central Anatolia region, *Mar* Marmara region, *E* eastern Anatolia region, *SE* southeastern Anatolia region, *TT* Turkish Thrace, *AR* all regions

Appendix 10.4: The Checklist of Reptiles in Turkey

Order Family	Latin names	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Testudinata							
Cheloniidae	*Caretta caretta* (Linnaeus, 1758)	VU	–	LC	II	I	M
Cheloniidae	*Chelonia mydas* (Linnaeus, 1758)	EN	–	NE	II	I	M
Dermochelyidae	*Dermochelys coriacea* (Vandelli, 1761)	VU	–	NE	II	I	M
Emydidae	*Emys orbicularis* (Linnaeus, 1758)	NT	NT	NT	II	–	Mar, C, A, M, B, SE
Emydidae	*Trachemys scripta* (Schoepff, 1792) **(I)**	LC	–	–	II	–	–
Geoemydidae	*Mauremys caspica* (Gmelin, 1774)	NE	–	LC	II	–	C, SE, E
Geoemydidae	*Mauremys rivulata* (Valenciennes, 1833)	LC	LC	LC	III	–	Mar, B, A, SE, M
Trionychidae	*Trionyx triunguis* (Forskål, 1775)	VU	NA	CR	II	II	A, M
Trionychidae	*Rafetus euphraticus* (Daudin, 1801)	EN	–	EN	–	II	SE
Testudinidae	*Testudo graeca* (Linnaeus, 1758)	VU	VU	LC	II	II	AR (except E BS)
Testudinidae	*Testudo hermanni* Gmelin, 1789	NT	NT	NT	II	II	TT
Squamata							
Blanidae	*Blanus alexandri* Sindaco, Kornilios, Sacchi & Lymberakis, 2014)	NE	–	NE	–	–	SE, M
Blanidae	*Blanus aporus* Werner, 1898 (**E**)	NE	–	NE	–	–	M
Blanidae	*Blanus strauchi* (Bedriaga, 1884)	LC	NA	LC	III	–	A, M
Agamidae	*Paralaudakia caucasica* (Eichwald, 1831)	LC	–	NE	III	–	E
Agamidae	*Stellagama stellio* (Linnaeus, 1758)	LC	LC	LC	II	–	AR
Agamidae	*Phrynocephalus horvathi* Mehely, 1894	CR	–	–	III	–	E
Agamidae	*Trapelus ruderatus* (Olivier, 1804)	LC	–	LC	III	–	SE, E, M, C

Order Family	Latin names	IUCN[G]	IUCN[EU]	IUCN[M]	Bern	CITES	Turkey distribution
Chamaeleonidae	*Chamaeleo chamaeleon* (Linnaeus, 1758)	LC	NA	LC	II	II	SE, M, A
Phyllodactylidae	*Asaccus barani* Torki, Ahmadzadeh, Ilgaz, Avcı & Kumlutaş, 2011 (**E**)	NE	–	LC	III	–	SE
Gekkonidae	*Mediodactylus heterocercus* (Blanford, 1874) [a]	LC	–	LC	III	–	SE
Gekkonidae	*Mediodactylus orientalis* (Stepanek, 1937)	NE	–	–	III	–	M, C
Gekkonidae	*Mediodactylus danilewskii* (Strauch, 1887)	NE	–	–	–	–	M, Mar
Gekkonidae	*Cyrtopodion scabrum* (Heyden, 1827)	LC	–	LC	III	–	SE
Gekkonidae	*Hemidactylus turcicus* (Linnaeus, 1758)	LC	LC	LC	III	–	SE, E, M, C, Mar
Gekkonidae	*Stenodactylus grandiceps* Haas, 1952	LC	–	NE	III	–	SE
Eublepharidae	*Eublepharus agramainyu* Anderson & Leviton, 1966	DD	–	LC	III	–	SE
Lacertidae	*Acanthodactylus boskianus* (Daudin, 1802)	NE	–	LC	III	–	SE
Lacertidae	*Acanthodactylus harranensis* Baran, Kumlutaş, Lanza, Sindaco, Ilgaz, Avcı & Crucitti, 2005 (**E**)	CR	–	–	III	–	SE
Lacertidae	*Acanthodactylus schreiberi* Boulenger, 1878	EN	EN	EN	III	–	M
Lacertidae	*Anatololacerta anatolica* (Werner, 1900)	LC	NA	NE	III	–	A, Mar, C
Lacertidae	*Anatololacerta budaki* (Eiselt & Schmidtler, 1987) [a]	LC	–	–	III	–	A, M
Lacertidae	*Anatololacerta danfordi* (Günther, 1876) (**E**)	LC	–	LC	III	–	M, C

Order Family	Latin names	IUCN[G]	IUCN [EU]	IUCN [M]	Bern	CITES	Turkey distribution
Lacertidae	*Anatololacerta pelasgiana* (Mertens, 1959)	LC	LC	LC	III	–	A, C
Lacertidae	*Apathya cappadocica* (Werner, 1902)	LC	–	LC	III	–	M, SE, E, C
Lacertidae	*Darevskia adjarica* (Darewsky & Eiselt, 1980)	NE	–	–	III	–	B
Lacertidae	*Darevskia armeniaca* (Méhely, 1909)	LC	–	NE	III	–	B, E
Lacertidae	*Darevskia bendimahiensis* (Schmidtler, Eiselt & Darevsky, 1994) (**E**)	EN	–	NE	III	–	E
Lacertidae	*Darevskia bithynica* (Méhely, 1909) (**E**)	NE	–	NE	III	–	Mar,B
Lacertidae	*Darevskia clarkorum* (Darevsky & Vedmederja 1977)	EN	–	NE	III	–	B
Lacertidae	*Darevskia derjugini* (Nikolsky, 1898)	NT	–	NE	III	–	B
Lacertidae	*Darevskia rudis* (Bedriaga, 1886)	LC	–	LC	III	–	B, C
Lacertidae	*Darevskia parvula* (Lantz & Cyrén, 1913) (**E**)	LC	–	NE	III	–	B, E
Lacertidae	*Darevskia pontica* (Lantz & Cyrén, 1918) [a]	NE	–	–	III	–	TT
Lacertidae	*Darevskia raddei* (Boettger, 1892)	LC	–	NE	III	–	E
Lacertidae	*Darevskia sapphirina* (Schmidtler, Eiselt & Darevsky, 1994) (**E**)	LC	–	NE	III	–	E
Lacertidae	*Darevskia unisexualis* (Darevsky, 1966)	NT	–	NE	III	–	E
Lacertidae	*Darevskia uzzelli* (Darevsky & Danielyan, 1977) (**E**)	EN	–	NE	III	–	E
Lacertidae	*Darevskia valentini* (Boettger, 1892)	LC	–	LC	III	–	E, C, B
Lacertidae	*Eremias pleskei* Nikolsky, 1905	CR	–	NE	III	–	E
Lacertidae	*Eremias strauchi* Kessler, 1878	LC	–	NE	III	–	E

Order Family	Latin names	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Lacertidae	*Eremias suphani* Başoğlu & Hellmich, 1968	LC	–	NE	III	–	E
Lacertidae	*Iranolacerta brandtii* (de Filippi, 1863)	DD	–	NE	–	–	E
Lacertidae	*Lacerta agilis* (Linnaeus, 1758)	LC	LC	LC	III	–	B, E
Lacertidae	*Lacerta media* Lantz & Cyrén, 1920	LC	–	LC	III	–	M, SE, E, C, B
Lacertidae	*Lacerta pamphylica* Schmidtler, 1975 (**E**)	LC	–	LC	III	–	A, M
Lacertidae	*Lacerta strigata* Eichwald, 1831	LC	LC	NE	III	–	E
Lacertidae	*Lacerta diplochondrodes* Wettstein, 1952	NE	–	–	–	–	A, M, Mar
Lacertidae	*Lacerta viridis* (Laurenti, 1768)	LC	LC	LC	II	–	Mar, B
Lacertidae	*Mesalina microlepis* (Angel, 1936)	NE	–	–	II	–	SE
Lacertidae	*Ophisops elegans* Ménétriés, 1832	LC	LC	LC	II	–	AR
Lacertidae	*Parvilacerta parva* (Boulenger, 1887)	LC	–	LC	II	–	M, C, A, B, E
Lacertidae	*Phoenicolacerta cyanisparsa* (Schmidtler & Bischoff, 1999)	LC	–	LC	–	–	M, SE
Lacertidae	*Phoenicolacerta laevis* (Gray, 1838)	LC	–	LC	III	–	M, SE, A
Lacertidae	*Podarcis muralis* (Laurenti, 1768)	LC	–	NE	II	–	C, A, Mar, B
Lacertidae	*Podarcis siculus* (Rafinesque–Schmaltz, 1810) **(I)**	LC	LC	LC	II	–	Mar, B
Lacertidae	*Podarcis tauricus* (Pallas, 1814)	LC	LC	LC	II	–	Mar, B
Lacertidae	*Timon kurdistanicus* (Suchow, 1936)	LC	–	LC	–	–	SE
Scincidae	*Ablepharus bivittatus* (Ménétriés, 1832)	LC	–	NE	III	–	E
Scincidae	*Ablepharus budaki* Göçmen, Kumlutaş & Tosunoğlu, 1996	LC	LC	LC	III	–	C, A, M, SE

Order Family	Latin names	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Scincidae	*Ablepharus chernovi* Darevsky, 1953	LC	–	LC	III	–	M,SE, E, C
Scincidae	*Ablepharus kitaibelii* (Bibron & Bory de St. Vincent, 1833)	LC	LC	LC	II	–	B, M, C, A, Mar
Scincidae	*Chalcides ocellatus* (Forskål, 1775)	NE	LC	–	II	–	M, SE, A
Scincidae	*Eumeces schneideri* (Daudin, 1802)	NE	LC	LC	III	–	C, A, M, SE
Scincidae	*Ophiomorus kardesi* Kornilios, Kumlutaş, Lymberakis & Ilgaz, 2018	LC	–	LC	II	–	M
Scincidae	*Heremites auratus* (Linnaeus, 1758)	LC	NA	NE	III	–	Mar, A, C, E, SE, M
Scincidae	*Heremites septemtaeniatus* (Reuss, 1834)	NE	–	–	–	–	SE, E
Scincidae	*Heremites vittatus* (Olivier, 1804)	LC	LC	LC	III	–	B, A, C, M, SE, E
Varanidae	*Varanus griseus* (Daudin, 1803)	NE	–	LC	III	I	SE
Anguidae	*Anguis fragilis* (Linnaeus, 1758)[a]	NE	LC	LC	III	–	Mar, B
Anguidae	*Anguis colchica* (Nordmann, 1840)[a]	NE	LC	LC	III	–	Mar, B
Anguidae	*Pseudopus apodus* (Pallas, 1775)	NE	LC	LC	II	–	B, M, C, A, Mar
Leptotyphlopidae	*Myriopholis macrorhyncha* (Jan, 1860)	NE	–	LC	–	–	SE
Typhlopidae	*Xerotyphlops vermicularis* (Merrem, 1820)	NE	LC	LC	III	–	Mar, A, C, E, SE, M
Typhlopidae	*Letheobia episcopus* Franzen & Wallach, 2002 (**E**)	DD	–	DD	III	–	SE
Boidae	*Eryx jaculus* (Linnaeus, 1758)	NE	LC	NE	III	II	AR
Natricidae	*Natrix natrix* (Linnaeus, 1758)	LC	LC	LC	II	–	AR
Natricidae	*Natrix tessellata* (Laurenti, 1768)	LC	LC	LC	II	–	AR
Psammophiidae/ Lamprophiidae[a]	*Malpolon insignitus* (Geoffroy de St. Hilaire, 1827)	LC	LC	LC	III		M, SE, A

Order Family	Latin names	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Colubridae	*Coronella austriaca* Laurenti, 1768	LC	LC	LC	II	–	M, B, E
Colubridae	*Dolichophis caspius* (Gmelin, 1789)	LC	LC	LC	III	–	Mar, A, C, E, SE, M
Colubridae	*Dolichophis jugularis* (Linnaeus, 1758)	LC	LC	LC	II	–	M, C, SE
Colubridae	*Dolichophis schmidti* (Nikolsky, 1909)	LC	–	LC	III	–	C, E
Colubridae	*Eirenis aurolineatus* (Venzmer, 1919) (**E**)	LC	–	LC	III	–	M
Colubridae	*Eirenis barani* Schmidtler, 1988	LC	–	LC	III	–	SE, M
Colubridae	*Eirenis collaris* (Ménétriés, 1832)	LC	–	NE	III	–	E
Colubridae	*Eirenis coronella* (Schlegel, 1837)	LC	–	LC	III	–	SE
Colubridae	*Eirenis decemlineatus* (Duméril, Bibron & Duméril, 1854)	LC	–	LC	III	–	M, E
Colubridae	*Eirenis eiselti* Schmidtler & Schmidtler, 1978)	LC	–	LC	III	–	E
Colubridae	*Eirenis hakkariensis* Schmidtler & Eiselt, 1991	NE	–	DD	III	–	E
Colubridae	*Eirenis levantinus* Schmidtler, 1993	LC	–	LC	III	–	M, SE
Colubridae	*Eirenis lineomaculatus* Schmidt, 1939	LC	–	LC	III	–	SE, E
Colubridae	*Eirenis modestus* Martin, 1838	LC	LC	LC	III	–	AR
Colubridae	*Eirenis occidentalis* Rajabizadeh, Nagy, Adriaens, Avcı, Masroor, Schmidtler, Nazarov, Esmaeili & Christiaens, 2015	NE	–	LC	III	–	SE
Colubridae	*Eirenis punctatolineatus* (Boettger, 1892)	LC	–	LC	III	–	E
Colubridae	*Eirenis rothii* Jan, 1863	LC	–	LC	III	–	SE
Colubridae	*Eirenis thospitis* Schmidtler & Lanza, 1990	DD	–	DD	III	–	E
Colubridae	*Elaphe dione* (Pallas, 1773)	LC	LC	NE	III	–	B

Order Family	Latin names	IUCN[G]	IUCN EU	IUCN M	Bern	CITES	Turkey distribution
Colubridae	*Elaphe sauromates* (Pallas, 1811)	LC	LC	LC	III	–	B, M, C, A, Mar
Colubridae	*Elaphe urartica* Jablonski, Kukushkin, Avcı, Bunyatova, Kumlutaş, Ilgaz, Polyakova, Shiryaev, Tuniyev, Jandzik, 2019[a]	NE	–	–	–	–	E
Colubridae	*Hemorrhois nummifer* (Reuss, 1834)	LC	LC	LC	III	–	S Turkey
Colubridae	*Hemorrhois ravergieri* (Ménétries, 1832)	LC	NA	LC	III	–	M, A, B, E
Colubridae	*Platyceps chesneii* (Martin, 1838)[a]	NE		LC	–	–	SE
Colubridae	*Platyceps collaris* (Müller, 1878)	LC	LC	LC	III	–	M, Mar, A,
Colubridae	*Platyceps najadum* (Eichwald, 1831)	LC	LC	LC	II	–	AR
Colubridae	*Muhtarophis barani* Olgun, Avcı, Ilgaz, Üzüm & Yılmaz, 2007 (**E**)	DD	–	NE	–	–	M, SE
Colubridae	*Rhynchocalamus melanocephalus* (Jan, 1862)	LC	–	NE	–	–	SE
Colubridae	*Rhynchocalamus satunini* (Nikolsky, 1899)	NE	–	NE	–	–	SE
Colubridae	*Spalerosophis diadema* (Schlegel, 1837)	NE	–	LC	III	–	SE
Colubridae	*Telescopus fallax* Fleischmann, 1831	LC	LC	LC	II	–	E, A, SE
Colubridae	*Telescopus nigriceps* (Ahl, 1924)	LC	–	LC	–	–	SE
Colubridae	*Zamenis hohenackeri* (Strauch, 1873)	LC	–	LC	III	–	M, A, B, E
Colubridae	*Zamenis longissimus* (Laurenti, 1768)	LC	LC	LC	II	–	Mar, B
Colubridae	*Zamenis situla* (Linnaeus, 1758)	LC	LC	LC	II	–	M, Mar, A
Viperidae	*Macrovipera lebetina* (Linnaeus, 1758)	NE	LC	LC	II	–	B, E, SE

Order Family	Latin names	IUCN^G	IUCN ^{EU}	IUCN ^{M}	Bern	CITES	Turkey distribution
Viperidae	*Montivipera albizona* (Nilson, Andren & Flärdh, 1990)[a]	EN	–	NE	II	–	C, E
Viperidae	*Montivipera raddei* (Boettger, 1890)	NT	–	NE	III	–	E
Viperidae	*Montivipera wagneri* (Nilson & Andrén, 1984) (**E**)	CR	–	NE	II	II	E
Viperidae	*Montivipera bulgardaghica* (Nilson & Andrén, 1985) (**E**)	LC	–	NE	III	–	M, C
Viperidae	*Montivipera xanthina* (Gray, 1849)	LC	–	LC	II	–	M, Mar, A
Viperidae	*Vipera ammodytes* (Linnaeus, 1758)	LC	LC	LC	II	–	Mar, B, C
Viperidae	*Vipera anatolica* Eiselt & Baran, 1970 (**E**)	CR	–	EN	III	–	M
Viperidae	*Vipera barani* Böhme & Joger, 1983 (**E**)[a]	NT	–	NT	II	–	Mar, B, C
Viperidae	*Vipera darevskii* Vedmederja, Orlov & Tuniyev, 1986	CR	–	NE	III	–	B, E
Viperidae	*Vipera eriwanensis* (Reuss, 1933)[a]	VU	–	NE	III	–	E
Viperidae	*Vipera kaznakovi* Nikolsky, 1909	EN	–	NE	II	–	B, E
Viperidae	*Vipera olguni* Tuniyev, Avcı, Tuniyev, Agasian & Agasian, 2012 (**E**)	NE	–	NE	III	–	B, E
Viperidae	*Vipera pontica* Billing, Nilson & Sattler, 1990 (**E**)[a]	EN	–	–	II	–	B, E
Viperidae	*Vipera sakoi* Tuniyev, Avcı, Tuniyev, Ilgaz, Olgun, Petrova, Bodrov, Geniez & Teynié, 2018 (**E**)[a]	NE	–	–	III	–	E
Elapidae	*Walterinnesia morgani* (Mocquard, 1905)	NE	–	NE	III	–	SE

[a]Newly described, name-changed, or controversial species; *E* endemic, *I* Invasive, *IUCN^G* global redlist, *IUCN^{EU}* regional redlist for Europea, *IUCN^M* regional redlist for Mediterranean, *B* Black Sea region, *M* Mediterranean region, *A* Aegean region, *C* central Anatolia region, *Mar* Marmara region, *E* eastern Anatolia region, *SE* southeastern Anatolia region, *TT* Turkish Thrace, *AR* all regions

Appendix 10.5: The Birds' List of Turkey

Order	Family	Scientific name	Status	IUCN	Bern	CITES
Anseriformes	Anatidae	*Branta bernicla* (Linnaeus, 1758)	v	LC	III	–
	Anatidae	*Branta ruficollis* (Pallas, 1769)	w	**VU**	II	II
	Anatidae	*Branta leucopsis* (Bechstein, 1803)	v	LC	II	–
	Anatidae	*Anser anser* (Linnaeus, 1758)	R, W	LC	III	–
	Anatidae	*Anser fabalis* (Latham, 1787)	v	LC	III	–
	Anatidae	*Anser brachyrhynchus* Baillon, 1834	v	LC	III	–
	Anatidae	*Anser albifrons* (Scopoli, 1769)	p, W	LC	III	–
	Anatidae	*Anser erythropus* (Linnaeus, 1758)	v	**VU**	II	–
	Anatidae	*Cygnus olor* (Gmelin, 1789)	r, W	LC	III	–
	Anatidae	*Cygnus columbianus* (Ord, 1815)	W	LC	II	–
	Anatidae	*Cygnus cygnus* (Linnaeus, 1758)	W	LC	II	–
	Anatidae	*Alopochen aegyptiaca* (Linnaeus, 1766)	v	LC	III	–
	Anatidae	*Tadorna tadorna* (Linnaeus, 1758)	R, W	LC	II	–
	Anatidae	*Tadorna ferruginea* (Pallas, 1764)	R, W	LC	II	–
	Anatidae	*Spatula querquedula* (Linnaeus, 1758)	S, P, w	LC	III	–
	Anatidae	*Spatula clypeata* (Linnaeus, 1758)	r, P, W	LC	III	–
	Anatidae	*Mareca strepera* (Linnaeus, 1758)	R, P, W	LC	III	–
	Anatidae	*Mareca penelope* (Linnaeus, 1758)	W	LC	III	–
	Anatidae	*Anas platyrhynchos* Linnaeus, 1758	R, P, W	LC	III	–
	Anatidae	*Anas acuta* Linnaeus, 1758	r, P, W	LC	III	–
	Anatidae	*Anas crecca* Linnaeus, 1758	R, P, W	LC	III	–
	Anatidae	*Marmaronetta angustirostris* (Menetries, 1832)	S, w	**VU**	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Anatidae	*Netta rufina* (Pallas, 1773)	R, P, W	LC	III	–
	Anatidae	*Aythya ferina* (Linnaeus, 1758)	R, P, W	**VU**	III	–
	Anatidae	*Aythya nyroca* (Güldenstädt, 1770)	R, P, W	**NT**	III	–
	Anatidae	*Aythya fuligula* (Linnaeus, 1758)	R, P, W	LC	III	–
	Anatidae	*Aythya marila* (Linnaeus, 1761)	w	LC	III	–
	Anatidae	*Somateria mollissima* (Linnaeus, 1758)	w	**NT**	III	–
	Anatidae	*Melanitta fusca* (Linnaeus, 1758)	R, w	**VU**	III	–
	Anatidae	*Melanitta nigra* (Linnaeus, 1758)	w	LC	III	–
	Anatidae	*Clangula hyemalis* (Linnaeus, 1758)	v	**VU**	III	–
	Anatidae	*Bucephala clangula* (Linnaeus, 1758)	W	LC	III	–
	Anatidae	*Mergellus albellus* (Linnaeus, 1758)	W	LC	II	–
	Anatidae	*Mergus merganser* Linnaeus, 1758	w	LC	III	–
	Anatidae	*Mergus serrator* Linnaeus, 1758	W	LC	III	–
	Anatidae	*Oxyura leucocephala* (Scopoli, 1769)	R, P, W	**EN**	II	II
Galliformes	Phasianidae	*Lyrurus tetrix* (Linnaeus, 1758)	ex	LC	III	–
	Phasianidae	*Lyrurus mlokosiewiczi* Taczanowski, 1875	R	**NT**	III	–
	Phasianidae	*Tetraogallus caspius* (Gmelin, 1784)	R	LC	III	I
	Phasianidae	*Alectoris chukar* (Gray, 1830)	R	LC	III	–
	Phasianidae	*Ammoperdix griseogularis* Brandt, 1843	R	LC	III	–
	Phasianidae	*Francolinus francolinus* (Linnaeus, 1766)	R	LC	III	–
	Phasianidae	*Perdix perdix* (Linnaeus, 1758)	R	LC	III	–
	Phasianidae	*Coturnix coturnix* (Linnaeus, 1758)	S, P, w	LC	III	–
	Phasianidae	*Phasianus colchicus* Linnaeus, 1758	R	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
Gaviiformes	Gaviidae	*Gavia stellata* (Pontoppidan, 1763)	w	LC	II	–
	Gaviidae	*Gavia arctica* (Linnaeus, 1758)	W	LC	II	–
	Gaviidae	*Gavia immer* (Brunnich, 1764)	v	LC	II	–
Procellariiformes	Hydrobatidae	*Hydrobates pelagicus* (Linnaeus, 1758)	p	LC	II	–
	Procellariidae	*Calonectris diomedea* (Scopoli, 1769)	S, P, w	LC	II	–
	Procellariidae	*Puffinus yelkouan* (Acerbi, 1827)	R, P, W	**VU**	II	–
Podicipediformes	Podicipedidae	*Tachybaptus ruficollis* (Pallas, 1764)	R, P, W	LC	III	–
	Podicipedidae	*Podiceps grisegena* (Boddaert, 1783)	S, p, k	LC	II	–
	Podicipedidae	*Podiceps cristatus* (Linnaeus, 1758)	R, P, W	LC	II	–
	Podicipedidae	*Podiceps auritus* (Linnaeus, 1758)	w	**VU**	II	–
	Podicipedidae	*Podiceps nigricollis* Brehm, 1831	R, P, W	LC	II	–
Phoenicopteriformes	Phoenicopteridae	*Phoenicopterus roseus* Pallas, 1811	R, P, W	LC	III	II
	Phoenicopteridae	*Phoeniconaias minor* Geoffroy Saint–Hilaire, 1798	v	**NT**	III	II
Ciconiiformes	Ciconiidae	*Mycteria ibis* (Linnaeus, 1766)	v	LC	II	–
	Ciconiidae	*Ciconia nigra* (Linnaeus, 1758)	S, P, w	LC	II	II
	Ciconiidae	*Ciconia ciconia* (Linnaeus, 1758)	S, P, w	LC	II	–
Pelecaniformes	Threskiornithidae	*Geronticus eremita* (Linnaeus, 1758)	R	**EN**	II	I
	Threskiornithidae	*Plegadis falcinellus* (Linnaeus, 1766)	S, P, w	LC	II	–
	Threskiornithidae	*Platalea leucorodia* Linnaeus, 1758	S, P, w	LC	II	II
	Ardeidae	*Botaurus stellaris* (Linnaeus, 1758)	R, P, w	LC	II	–
	Ardeidae	*Ixobrychus minutus* (Linnaeus, 1766)	S, P	LC	II	–
	Ardeidae	*Nycticorax nycticorax* (Linnaeus, 1758)	S, P, w	LC	II	–
	Ardeidae	*Ardeola ralloides* (Scopoli, 1769)	S, P	LC	II	–
	Ardeidae	*Bubulcus ibis* (Linnaeus, 1758)	R, P, W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Ardeidae	*Ardea cinerea* Linnaeus, 1758	R, P, W	LC	III	–
	Ardeidae	*Ardea purpurea* (Linnaeus, 1766)	S, P	LC	II	–
	Ardeidae	*Ardea alba* Linnaeus, 1758	s, P, W	LC	II	–
	Ardeidae	*Egretta garzetta* (Linnaeus, 1766)	R, P, W	LC	II	–
	Pelecanidae	*Pelecanus onocrotalus* Linnaeus, 1758	S, P, w	LC	II	–
	Pelecanidae	*Pelecanus rufescens* Gmelin, 1789	v	LC	II	–
	Pelecanidae	*Pelecanus crispus* Bruch, 1832	R, W	**NT**	II	I
Suliformes	Sulidae	*Morus bassanus* (Linnaeus, 1758)	w	LC	III	–
	Phalacrocoracidae	*Microcarbo pygmeus* (Pallas, 1773)	R, P, W	LC	II	–
	Phalacrocoracidae	*Phalacrocorax aristotelis* Linnaeus, 1758	R	LC	II	–
	Phalacrocoracidae	*Phalacrocorax carbo* Linnaeus, 1758	R, P, W	LC	III	–
	Anhingidae	*Anhinga rufa* Pennant, 1769	ex	LC	III	–
Accipitriformes	Pandionidae	*Pandion haliaetus* (Linnaeus, 1758)	P, w	LC	II	II
	Accipitridae	*Elanus caeruleus* (Desfontaines, 1789)	r	LC	II	I
	Accipitridae	*Gypaetus barbatus* (Linnaeus, 1758)	R	**NT**	II	II
	Accipitridae	*Neophron percnopterus* Savigny, 1809	S, P	**EN**	II	II
	Accipitridae	*Pernis apivorus* (Linnaeus, 1758)	S, P	LC	II	II
	Accipitridae	*Pernis ptilorhyncus* Temminck, 1821	v	LC	II	II
	Accipitridae	*Gyps fulvus* (Hablizl, 1783)	R, P, W	LC	II	II
	Accipitridae	*Aegypius monachus* Savigny, 1809	R, p	**NT**	II	II
	Accipitridae	*Circaetus gallicus* (Gmelin, 1788)	S, P	LC	II	II
	Accipitridae	*Terathopius ecaudatus* (Daudin, 1800)	v	LC	II	II
	Accipitridae	*Clanga pomarina* Brehm, 1831	S, P	LC	II	II

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Accipitridae	*Clanga clanga* (Pallas, 1811)	P, W	**VU**	II	II
	Accipitridae	*Hieraaetus pennatus* (Gmelin, 1788)	S, P	LC	II	II
	Accipitridae	*Aquila nipalensis* (Hodgson, 1833)	s, P	**EN**	II	II
	Accipitridae	*Aquila heliaca* Savigny, 1809	R, P, W	**VU**	II	I
	Accipitridae	*Aquila chrysaetos* (Linnaeus, 1758)	R	LC	II	II
	Accipitridae	*Aquila fasciata* (Vieillot, 1822)	R	LC	II	II
	Accipitridae	*Accipiter badius* Gmelin, 1788	v	LC	II	II
	Accipitridae	*Accipiter brevipes* (Severtzov, 1850)	S, P	LC	II	II
	Accipitridae	*Accipiter nisus* (Linnaeus, 1758)	R, P, W	LC	II	II
	Accipitridae	*Accipiter gentilis* (Linnaeus, 1758)	R, P, W	LC	II	II
	Accipitridae	*Circus aeruginosus* (Linnaeus, 1758)	R, P, W	LC	II	II
	Accipitridae	*Circus cyaneus* (Linnaeus, 1766)	P, W	LC	II	II
	Accipitridae	*Circus macrourus* S. G. Gmelin, 1770	s, P, w	**NT**	II	II
	Accipitridae	*Circus pygargus* (Linnaeus, 1758)	S, P	LC	II	II
	Accipitridae	*Milvus milvus* (Linnaeus, 1758)	w, p	**NT**	II	II
	Accipitridae	*Milvus migrans* (Boddaert, 1783)	S, P, W	LC	II	II
	Accipitridae	*Haliaeetus albicilla* (Linnaeus, 1758)	R, P, W	LC	II	II
	Accipitridae	*Buteo lagopus* (Pontoppidan, 1763)	p, w	LC	II	II
	Accipitridae	*Buteo rufinus* (Cretzschmar, 1829)	R	LC	II	II
	Accipitridae	*Buteo buteo* (Linnaeus, 1758)	R, P, W	LC	II	II
Otidiformes	Otididae	*Otis tarda* Linnaeus, 1758	R	**VU**	II	II
	Otididae	*Chlamydotis macqueenii* (J. E. Gray, 1832)	v	**VU**	II	I
	Otididae	*Tetrax tetrax* T. Forster, 1817	r, p, w	**NT**	II	II
Gruiformes	Rallidae	*Rallus aquaticus* Linnaeus, 1758	R, W	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Rallidae	*Crex crex* (Linnaeus, 1758)	s, P	LC	II	–
	Rallidae	*Porzana parva* (Scopoli, 1769)	s, P	LC	II	–
	Rallidae	*Porzana pusilla* (Pallas, 1776)	s, P	LC	II	–
	Rallidae	*Porzana porzana* Linnaeus, 1766	s, P, w	LC	II	–
	Rallidae	*Porphyrio porphyrio* (Linnaeus, 1758)	R	LC	II	–
	Rallidae	*Porphyrio alleni* Thomson, 1842	v	LC	III	–
	Rallidae	*Gallinula chloropus* (Linnaeus, 1758)	R, P, W	LC	III	–
	Rallidae	*Fulica atra* Linnaeus, 1758	R, W	LC	III	–
	Gruidae	*Leucogeranus leucogeranus* Pallas, 1773	v	**CR**	II	I
	Gruidae	*Grus virgo* (Linnaeus, 1758)	s, P	LC	II	II
	Gruidae	*Grus grus* (Linnaeus, 1758)	S, P, W	LC	II	II
Charadriiformes	Burhinidae	*Burhinus oedicnemus* (Linnaeus, 1758)	S, P	LC	II	–
	Haematopodidae	*Haematopus ostralegus* Linnaeus, 1758	R, P, W	**NT**	III	–
	Dromadidae	*Dromas ardeola* Paykull, 1805	v	LC	III	–
	Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)	S, P, w	LC	II	–
	Recurvirostridae	*Recurvirostra avosetta* Linnaeus, 1758	R, W	LC	II	–
	Charadriidae	*Vanellus vanellus* (Linnaeus, 1758)	R, W	**NT**	III	–
	Charadriidae	*Vanellus spinosus* (Linnaeus, 1758)	S, P	LC	III	–
	Charadriidae	*Vanellus cinereus* Brisson, 1760	v	LC	III	–
	Charadriidae	*Vanellus indicus* (Boddaert, 1783)	s	LC	III	–
	Charadriidae	*Vanellus gregarius* (Pallas, 1771)	P	**CR**	III	–
	Charadriidae	*Vanellus leucurus* (Lichtenstein, 1823)	p	LC	III	–
	Charadriidae	*Pluvialis apricaria* (Linnaeus, 1758)	P, W	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Charadriidae	*Pluvialis fulva* (Gmelin, 1789)	v	LC	III	–
	Charadriidae	*Pluvialis dominica* (Müller, 1776)	v	LC	III	–
	Charadriidae	*Pluvialis squatarola* (Linnaeus, 1758)	P, W	LC	III	–
	Charadriidae	*Charadrius hiaticula* Linnaeus, 1758	P, W	LC	II	–
	Charadriidae	*Charadrius dubius* Scopoli, 1786	S, P	LC	II	–
	Charadriidae	*Charadrius alexandrinus* Linnaeus, 1758	R, S, W	LC	II	–
	Charadriidae	*Charadrius leschenaultii* (Lesson, 1826)	S, P	LC	II	–
	Charadriidae	*Charadrius asiaticus* (Pallas, 1773)	v	LC	III	–
	Charadriidae	*Charadrius morinellus* Linnaeus, 1758	P	LC	II	–
	Scolopacidae	*Numenius phaeopus* (Linnaeus, 1758)	P	LC	III	–
	Scolopacidae	*Numenius tenuirostris* Vieillot, 1817	ex	**CR**	II	I
	Scolopacidae	*Numenius arquata* (Linnaeus, 1758)	P, W	**NT**	III	–
	Scolopacidae	*Limosa lapponica* (Linnaeus, 1758)	p, w	**NT**	III	–
	Scolopacidae	*Limosa limosa* (Linnaeus, 1758)	P, W	**NT**	III	–
	Scolopacidae	*Arenaria interpres* (Linnaeus, 1758)	P, w	LC	II	–
	Scolopacidae	*Calidris canutus* (Linnaeus, 1758)	p, w	**NT**	III	–
	Scolopacidae	*Calidris pugnax* (Linnaeus, 1758)	P, W	LC	III	–
	Scolopacidae	*Calidris falcinellus* (Pontoppidan, 1763)	P	LC	II	–
	Scolopacidae	*Calidris ferruginea* (Pontoppidan, 1763)	P, w	**NT**	II	–
	Scolopacidae	*Calidris temminckii* (Leisler, 1812)	P, w	LC	II	–
	Scolopacidae	*Calidris alba* Pallas, 1764	P, W	LC	II	–
	Scolopacidae	*Calidris alpina* (Linnaeus, 1758)	P, W	LC	II	–
	Scolopacidae	*Calidris minuta* (Leisler, 1812)	P, W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Scolopacidae	*Calidris fuscicollis* (Vieillot, 1819)	v	LC	III	–
	Scolopacidae	*Calidris melanotos* Vieillot, 1819	v	LC	III	–
	Scolopacidae	*Scolopax rusticola* Linnaeus, 1758	P, W	LC	III	–
	Scolopacidae	*Lymnocryptes minimus* (Brunnich, 1764)	P, W	LC	III	–
	Scolopacidae	*Gallinago media* (Latham, 1787)	P	**NT**	II	–
	Scolopacidae	*Gallinago gallinago* (Linnaeus, 1758)	P, W	LC	III	–
	Scolopacidae	*Xenus cinereus* (Güldenstädt, 1775)	P	LC	II	–
	Scolopacidae	*Phalaropus tricolor* (Vieillot, 1819)	v	LC	III	–
	Scolopacidae	*Phalaropus lobatus* (Linnaeus, 1758)	P	LC	III	–
	Scolopacidae	*Phalaropus fulicarius* (Linnaeus, 1758)	v	LC	III	–
	Scolopacidae	*Actitis hypoleucos* (Linnaeus, 1758)	S, P, w	LC	III	–
	Scolopacidae	*Actitis macularia* (Linnaeus, 1766)	v	LC	III	–
	Scolopacidae	*Tringa ochropus* Linnaeus, 1758	s, P, W	LC	II	–
	Scolopacidae	*Tringa flavipes* (Gmelin, 1789)	v	LC	III	–
	Scolopacidae	*Tringa totanus* (Linnaeus, 1758)	S, P, W	LC	III	–
	Scolopacidae	*Tringa stagnatilis* (Bechstein, 1803)	P	LC	II	–
	Scolopacidae	*Tringa glareola* (Linnaeus, 1758)	P	LC	II	–
	Scolopacidae	*Tringa erythropus* (Pallas, 1764)	P, W	LC	III	–
	Scolopacidae	*Tringa nebularia* (Gunnerus, 1767)	P, W	LC	III	–
	Glareolidae	*Cursorius cursor* (Latham, 1787)	S	LC	II	–
	Glareolidae	*Glareola pratincola* Linnaeus, 1766	S, P	LC	II	–
	Glareolidae	*Glareola nordmanni* Fischer von Waldheim, 1842	p	**NT**	II	–
	Laridae	*Rissa tridactyla* (Linnaeus, 1758)	w	**VU**	III	–
	Laridae	*Chroicocephalus genei* (Brème, 1839)	S, p, W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Laridae	*Chroicocephalus ridibundus* (Linnaeus, 1766)	R, P, W	LC	III	–
	Laridae	*Hydrocoloeus minutus* (Pallas, 1776)	P, W	LC	II	–
	Laridae	*Ichthyaetus audouinii* (Payraudeau, 1826)	R, W	LC	II	–
	Laridae	*Ichthyaetus melanocephalus* (Temminck, 1820)	S, P, W	LC	II	–
	Laridae	*Ichthyaetus ichthyaetus* (Pallas, 1773)	W	LC	III	–
	Laridae	*Ichthyaetus leucophthalmus* (Temminck, 1825)	v	**LC**	III	–
	Laridae	*Larus canus* Linnaeus, 1758	W	LC	III	–
	Laridae	*Larus marinus* Linnaeus, 1758	w	LC	–	–
	Laridae	*Larus hyperboreus* Gunnerus, 1767	v	LC	III	–
	Laridae	*Larus argentatus* Pontoppidan, 1763	v	LC	–	–
	Laridae	*Larus cachinnans* Pallas, 1811	W	LC	III	–
	Laridae	*Larus michahellis* Naumann, 1840	R, W	LC	III	–
	Laridae	*Larus armenicus* Buturlin, 1934	R, W	**NT**	III	–
	Laridae	*Larus fuscus* Linnaeus, 1758	P, w	LC	–	–
	Laridae	*Gelochelidon nilotica* (Gmelin, 1789)	S, P	LC	II	–
	Laridae	*Hydroprogne caspia* (Pallas, 1770)	R, P, w	LC	II	–
	Laridae	*Thalasseus bengalensis* (Lesson, 1831)	v	LC	III	–
	Laridae	*Thalasseus sandvicensis* (Latham, 1787)	r, P, W	LC	II	–
	Laridae	*Sternula albifrons* Pallas, 1764	S, P	LC	II	–
	Laridae	*Sterna hirundo* Linnaeus, 1758	S, P	LC	II	–
	Laridae	*Sterna paradisaea* Pontoppidan, 1763	v	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Laridae	*Chlidonias hybrida* (Pallas, 1811)	S, P, w	LC	II	–
	Laridae	*Chlidonias leucopterus* (Temminck, 1815)	s, P	LC	II	–
	Laridae	*Chlidonias niger* (Linnaeus, 1758)	s, P	LC	II	–
	Stercorariidae	*Stercorarius skua* Brunnich, 1764	v	LC	III	–
	Stercorariidae	*Stercorarius pomarinus* Temminck, 1815	p	LC	III	–
	Stercorariidae	*Stercorarius parasiticus* (Linnaeus, 1758)	P, w	LC	III	–
	Stercorariidae	*Stercorarius longicaudus* (Vieillot, 1819)	v	LC	III	–
Pterocliformes	Pteroclidae	*Syrrhaptes paradoxus* (Pallas, 1773)	v	LC	II	–
	Pteroclidae	*Pterocles alchata* (Linnaeus, 1766)	S	LC	II	–
	Pteroclidae	*Pterocles senegallus* (Linnaeus, 1771)	v	LC	II	–
	Pteroclidae	*Pterocles orientalis* (Linnaeus, 1758)	R	LC	II	–
Columbiformes	Columbidae	*Columba livia* Gmelin, 1789	R	LC	III	–
	Columbidae	*Columba oenas* Linnaeus, 1758	r, P, W	LC	III	–
	Columbidae	*Columba palumbus* Linnaeus, 1758	R, P, W	LC	–	–
	Columbidae	*Streptopelia turtur* (Linnaeus, 1758)	S, P	**VU**	III	–
	Columbidae	*Streptopelia orientalis* (Latham, 1790)	v	LC	III	–
	Columbidae	*Streptopelia decaocto* (Frivaldszky, 1838)	R	LC	III	–
	Columbidae	*Spilopelia senegalensis* (Linnaeus, 1766)	R	LC	III	–
	Columbidae	*Oena capensis* (Linnaeus, 1766)	v	LC	III	–
Cuculiformes	Cuculidae	*Clamator glandarius* (Linnaeus, 1758)	S, P	LC	II	–
	Cuculidae	*Cuculus canorus* (Linnaeus, 1758)	S, P	LC	III	–
Strigiformes	Tytonidae	*Tyto alba* (Scopoli, 1769)	R	LC	II	II
	Strigidae	*Otus brucei* (Hume, 1873)	s	LC	II	II

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Strigidae	*Otus scops* (Linnaeus, 1758)	S, P, w	LC	II	II
	Strigidae	*Bubo bubo* (Linnaeus, 1758)	R	LC	II	II
	Strigidae	*Ketupa zeylonensis* (Gmelin, 1788)	R	LC	II	II
	Strigidae	*Strix aluco* Linnaeus, 1758	R	LC	II	II
	Strigidae	*Athene noctua* (Scopoli, 1769)	R	LC	II	II
	Strigidae	*Aegolius funereus* (Linnaeus, 1758)	R	LC	II	II
	Strigidae	*Asio otus* (Linnaeus, 1758)	R, P, W	LC	II	II
	Strigidae	*Asio flammeus* (Pontoppidan, 1763)	r, W	LC	II	II
Caprimulgiformes	Caprimulgidae	*Caprimulgus europaeus* Linnaeus, 1758	S, P	LC	II	–
Apodiformes	Apodidae	*Tachymarptis melba* (Linnaeus, 1758)	S, P	LC	II	–
	Apodidae	*Apus apus* (Linnaeus, 1758)	S, P	LC	III	–
	Apodidae	*Apus pallidus* Shelley, 1870	S, P	LC	II	–
	Apodidae	*Apus affinis* (Gray, 1830)	S, P	LC	III	–
Coraciiformes	Coraciidae	*Coracias benghalensis* (Linnaeus, 1758)	v	LC	III	–
	Coraciidae	*Coracias garrulus* Linnaeus, 1758	S, P	LC	II	–
	Alcedinidae	*Halcyon smyrnensis* (Linnaeus, 1758)	R	LC	II	–
	Alcedinidae	*Alcedo atthis* (Linnaeus, 1758)	r, P, W	LC	II	–
	Alcedinidae	*Ceryle rudis* (Linnaeus, 1758)	R	LC	II	–
	Meropidae	*Merops persicus* Pallas, 1773	S, P	LC	III	–
	Meropidae	*Merops apiaster* Linnaeus, 1758	S, P	LC	II	–
Bucerotiformes	Upupidae	*Upupa epops* Linnaeus, 1758	S, P	LC	II	–
Piciformes	Picidae	*Jynx torquilla* (Linnaeus, 1758)	S, P, w	LC	II	–
	Picidae	*Dendrocoptes medius* (Linnaeus, 1758)	R	LC	II	–
	Picidae	*Dryobates minor* (Linnaeus, 1758)	R	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Picidae	*Dendrocopos syriacus* (Ehrenberg, 1833)	R	LC	II	–
	Picidae	*Dendrocopos major* (Linnaeus, 1758)	R	LC	II	–
	Picidae	*Dendrocopos leucotos* (Bechstein, 1802)	R	LC	II	–
	Picidae	*Dryocopus martius* (Linnaeus, 1758)	R	LC	II	–
	Picidae	*Picus viridis* Linnaeus, 1758	R	LC	II	–
	Picidae	*Picus canus* Gmelin, 1788	R	LC	II	–
Falconiformes	Falconidae	*Falco naumanni* Fleischer, 1818	S, P	LC	II	II
	Falconidae	*Falco tinnunculus* Linnaeus, 1758	R, P, W	LC	II	II
	Falconidae	*Falco vespertinus* Linnaeus, 1766	s, P	**NT**	II	II
	Falconidae	*Falco eleonorae* Gene, 1839	S, P	LC	II	II
	Falconidae	*Falco concolor* Temminck, 1825	v	**VU**	II	II
	Falconidae	*Falco columbarius* Linnaeus, 1758	p, W	LC	II	II
	Falconidae	*Falco subbuteo* Linnaeus, 1758	S, P	LC	II	II
	Falconidae	*Falco biarmicus* Temminck, 1825	R	LC	II	II
	Falconidae	*Falco cherrug* Gray, 1834	R, p, w	**EN**	II	II
	Falconidae	*Falco peregrinus* Tunstall, 1771	R, p, W	LC	II	I
Psittaciformes	Psittaculidae	*Psittacula eupatria* (Linnaeus, 1766)	R	**NT**	III	II
	Psittaculidae	*Psittacula krameri* (Scopoli, 1769)	R	LC	III	–
Passeriformes	Laniidae	*Lanius collurio* Linnaeus, 1758	S, P	LC	II	–
	Laniidae	*Lanius isabellinus* Ehrenberg, 1833	v	LC	II	–
	Laniidae	*Lanius phoenicuroides* Schalow, 1875	v	LC	II	–
	Laniidae	*Lanius schach* Linnaeus, 1758	v	LC	II	–
	Laniidae	*Lanius minor* Gmelin, 1788	S, P	LC	II	–
	Laniidae	*Lanius excubitor* Linnaeus, 1758	W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Laniidae	*Lanius senator* Linnaeus, 1758	S, P	LC	II	–
	Laniidae	*Lanius nubicus* Lichtenstein, 1823	S, P	LC	II	–
	Oriolidae	*Oriolus oriolus* (Linnaeus, 1758)	S, P	LC	II	–
	Corvidae	*Garrulus glandarius* (Linnaeus, 1758)	R	LC	–	–
	Corvidae	*Pica pica* (Linnaeus, 1758)	R	LC	–	–
	Corvidae	*Nucifraga caryocatactes* (Linnaeus, 1758)	v	LC	II	–
	Corvidae	*Pyrrhocorax pyrrhocorax* (Linnaeus, 1758)	R	LC	II	–
	Corvidae	*Pyrrhocorax graculus* (Linnaeus, 1766)	R	LC	II	–
	Corvidae	*Coloeus monedula* (Linnaeus, 1758)	R	LC	–	–
	Corvidae	*Corvus frugilegus* Linnaeus, 1758	R, W	LC	–	–
	Corvidae	*Corvus cornix* Linnaeus, 1758	R	LC	–	–
	Corvidae	*Corvus ruficollis* Lesson, 1830	v	LC	III	–
	Corvidae	*Corvus corax* Linnaeus, 1758	R	LC	III	–
	Corvidae	*Corvus rhipidurus* Hartert, 1918	v	LC	III	–
	Bombycillidae	*Bombycilla garrulus* (Linnaeus, 1758)	w	LC	II	–
	Hypocoliidae	*Hypocolius ampelinus* Bonaparte, 1850	v	LC	III	–
	Paridae	*Periparus ater* (Linnaeus, 1758)	R, W	LC	II	–
	Paridae	*Poecile lugubris* Temminck, 1820	R	LC	II	–
	Paridae	*Poecile palustris* (Linnaeus, 1758)	R	LC	II	–
	Paridae	*Cyanistes caeruleus* (Linnaeus, 1758)	R, W	LC	II	–
	Paridae	*Parus major* Linnaeus, 1758	R	LC	II	–
	Remizidae	*Remiz pendulinus* (Linnaeus, 1758)	R, P, W	LC	III	–
	Panuridae	*Panurus biarmicus* (Linnaeus, 1758)	R, P, W	LC	II	–
	Alaudidae	*Alaemon alaudipes* (Desfontaines, 1789)	v	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Alaudidae	*Ammomanes deserti* (Lichtenstein, 1823)	R	LC	III	–
	Alaudidae	*Ammomanes cinctura* (Gould, 1841)	v	LC	III	–
	Alaudidae	*Lullula arborea* (Linnaeus, 1758)	R, W	LC	III	–
	Alaudidae	*Alauda leucoptera* (Pallas, 1811)	v	LC	II	–
	Alaudidae	*Alauda gulgula* Franklin, 1831	v	LC	–	–
	Alaudidae	*Alauda arvensis* Linnaeus, 1758	R, P, W	LC	III	–
	Alaudidae	*Galerida cristata* (Linnaeus, 1758)	R	LC	III	–
	Alaudidae	*Eremophila alpestris* (Linnaeus, 1758)	R, W	LC	II	–
	Alaudidae	*Calandrella brachydactyla* (Leisler, 1814)	S, P	LC	II	–
	Alaudidae	*Melanocorypha bimaculata* (Menetries, 1832)	S, P	LC	II	–
	Alaudidae	*Melanocorypha calandra* (Linnaeus, 1766)	R	LC	II	–
	Alaudidae	*Melanocorypha yeltoniensis* (Forster, 1767)	v	LC	II	–
	Alaudidae	*Alauda rufescens* (Vieillot, 1819)	S, P	LC	II	–
	Pycnonotidae	*Pycnonotus leucotis* (Gould, 1836)	v	LC	II	–
	Pycnonotidae	*Pycnonotus xanthopygos* (Ehrenberg, 1833)	R	LC	II	–
	Hirundinidae	*Riparia riparia* (Linnaeus, 1758)	S, P	LC	II	–
	Hirundinidae	*Hirundo rustica* (Linnaeus, 1758)	S, P	LC	II	–
	Hirundinidae	*Ptyonoprogne rupestris* (Scopoli, 1769)	S, P, w	LC	II	–
	Hirundinidae	*Delichon urbicum* (Linnaeus, 1758)	S, P	LC	II	–
	Hirundinidae	*Cecropis daurica* (Laxmann, 1769)	S, P	LC	II	–
	Cettiidae	*Cettia cetti* (Temminck, 1820)	R, W	LC	II	–
	Aegithalidae	*Aegithalos caudatus* (Linnaeus, 1758)	R, p, W	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Phylloscopidae	*Phylloscopus trochilus* (Linnaeus, 1758)	P	LC	II	–
	Phylloscopidae	*Phylloscopus collybita* (Vieillot, 1817)	R, P, w	LC	II	–
	Phylloscopidae	*Phylloscopus sindianus (*Brooks, 1880)	S, P	LC	II	–
	Phylloscopidae	*Phylloscopus neglectus* Hume, 1870	v	LC	II	–
	Phylloscopidae	*Phylloscopus orientalis* (Brehm, 1855)	S, P	LC	II	–
	Phylloscopidae	*Phylloscopus sibilatrix* (Bechstein, 1793)	s, P	LC	II	–
	Phylloscopidae	*Phylloscopus fuscatus* (Blyth, 1842)	v	LC	II	–
	Phylloscopidae	*Phylloscopus proregulus* (Pallas, 1811)	v	LC	II	–
	Phylloscopidae	*Phylloscopus inornatus* (Blyth, 1842)	p	LC	II	–
	Phylloscopidae	*Phylloscopus humei* (Brooks, 1878)	v	LC	II	–
	Phylloscopidae	*Phylloscopus borealis* (Blasius, 1858)	v	LC	II	–
	Phylloscopidae	*Phylloscopus nitidus* (Blyth, 1843)	S, P	LC	II	–
	Phylloscopidae	*Phylloscopus throchiloides* (Sundevall, 1837)	v	LC	II	–
	Acrocephalidae	*Acrocephalus griseldis* Hartlaub, 1891	v	LC	–	–
	Acrocephalidae	*Acrocephalus arundinaceus* (Linnaeus, 1758)	S, P	LC	II	–
	Acrocephalidae	*Acrocephalus melanopogon* (Temminck, 1823)	R, P, W	LC	II	–
	Acrocephalidae	*Acrocephalus paludicola* (Vieillot, 1817)	v	**VU**	II	–
	Acrocephalidae	*Acrocephalus schoenobaenus* (Linnaeus, 1758)	S, P	LC	II	–
	Acrocephalidae	*Acrocephalus agricola* (Jerdon, 1845)	S	LC	II	–
	Acrocephalidae	*Acrocephalus dumetorum* (Blyth, 1849)	v	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Acrocephalidae	*Acrocephalus scirpaceus* (Hermann, 1804)	S, P	LC	II	–
	Acrocephalidae	*Acrocephalus palustris* (Bechstein, 1798)	s, P	LC	II	–
	Acrocephalidae	*Iduna caligata* (Lichtenstein, 1823)	P	LC	II	–
	Acrocephalidae	*Iduna rama* (Sykes, 1832)	v	LC	II	–
	Acrocephalidae	*Iduna pallida* (Ehrenberg, 1833)	S, P	LC	II	–
	Acrocephalidae	*Iduna opaca* Cabanis, 1850	v	LC	II	–
	Acrocephalidae	*Hippolais languida* (Ehrenberg, 1833)	S	LC	II	–
	Acrocephalidae	*Hippolais olivetorum* Strickland, 1837	S, P	LC	II	–
	Acrocephalidae	*Hippolais polyglotta* (Vieillot, 1817)	v	LC	II	–
	Acrocephalidae	*Hippolais icterina* (Vieillot, 1817)	s, P	LC	II	–
	Locustellidae	*Locustella naevia* (Boddaert, 1783)	P	LC	II	–
	Locustellidae	*Locustella fluviatilis* (Wolf, 1810)	s, P	LC	II	–
	Locustellidae	*Locustella luscinioides* (Savi, 1824)	S, P	LC	II	–
	Cisticolidae	*Cisticola juncidis* (Rafinesque, 1810)	R	LC	II	–
	Cisticolidae	*Prinia gracilis* Lichtenstein, 1823	R	LC	II	–
	Leiothrichidae	*Argya altirostris* (Hartert, 1909)	R	LC	III	–
	Sylviidae	*Sylvia atricapilla* (Linnaeus, 1758)	R, P, w	LC	II	–
	Sylviidae	*Sylvia borin* (Boddaert, 1783)	S, P	LC	II	–
	Sylviidae	*Sylvia nisoria* (Bechstein, 1795)	S, P	LC	II	–
	Sylviidae	*Sylvia curruca* (Linnaeus, 1758)	S, P	LC	II	–
	Sylviidae	*Sylvia crassirostris* Cretzschmar, 1830	S, P	LC	II	–
	Sylviidae	*Sylvia nana* (Ehrenberg, 1833)	v	LC	II	–
	Sylviidae	*Sylvia communis* Latham, 1787	S, P	LC	II	–
	Sylviidae	*Sylvia conspicillata* Temminck, 1820)	S	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Sylviidae	*Sylvia cantillans* (Pallas, 1764)	S, P	LC	II	–
	Sylviidae	*Sylvia melanocephala* (Gmelin, 1789)	R, p, w	LC	II	–
	Sylviidae	*Sylvia mystacea* Ménétries, 1832	S, P	LC	II	–
	Sylviidae	*Sylvia ruppeli* Temminck, 1823	S, P	LC	II	–
	Sylviidae	*Sylvia melanothorax* Tristram, 1872	v	LC	II	–
	Regulidae	*Regulus ignicapilla* (Temminck, 1820)	R, p, W	LC	II	–
	Regulidae	*Regulus regulus* (Linnaeus, 1758)	R, p, W	LC	II	–
	Troglodytidae	*Troglodytes troglodytes* (Linnaeus, 1758)	R, W	LC	II	–
	Sittidae	*Sitta europaea* Linnaeus, 1758	R	LC	II	–
	Sittidae	*Sitta krueperi* Pelzeln, 1863	R	LC	II	–
	Sittidae	*Sitta neumayer*Michahelles, 1830	R	LC	II	–
	Sittidae	*Sitta tephronota* Sharpe, 1872	R	LC	II	–
	Tichodromidae	*Tichodroma muraria* (Linnaeus, 1766)	R, W	LC	III	–
	Certhiidae	*Certhia familiaris* Linnaeus, 1758	R	LC	II	–
	Certhiidae	*Certhia brachydactyla* Brehm, 1820	R	LC	II	–
	Sturnidae	*Acridotheres tristis* (Linnaeus, 1766)	r	LC	III	–
	Sturnidae	*Pastor roseus* (Linnaeus, 1758)	S, P	LC	II	–
	Sturnidae	*Sturnus vulgaris* Linnaeus, 1758	R, P, W	LC	–	–
	Turdidae	*Turdus torquatus* Linnaeus, 1758	S, P, w	LC	II	–
	Turdidae	*Turdus merula* Linnaeus, 1758	R, P, W	LC	III	–
	Turdidae	*Turdus atrogularis* Jarocki, 1819	v	LC	III	–
	Turdidae	*Turdus pilaris* Linnaeus, 1758	P, W	LC	III	–
	Turdidae	*Turdus iliacus* Linnaeus, 1766	P, W	**NT**	III	–
	Turdidae	*Turdus philomelos* Brehm, 1831	R, P, W	LC	III	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Turdidae	*Turdus viscivorus* Linnaeus, 1758	R, P, W	LC	III	–
	Muscicapidae	*Cercotrichas galactotes* (Temminck, 1820)	S, P	LC	II	–
	Muscicapidae	*Muscicapa striata* (Pallas, 1764)	S, P	LC	II	–
	Muscicapidae	*Erithacus rubecula* (Linnaeus, 1758)	R, P, W	LC	II	–
	Muscicapidae	*Luscinia svecica* (Linnaeus, 1758)	s, P, W	LC	II	–
	Muscicapidae	*Luscinia luscinia* (Linnaeus, 1758)	P	LC	II	–
	Muscicapidae	*Luscinia megarhynchos* (Brehm, 1831)	S, P	LC	II	–
	Muscicapidae	*Irania gutturalis* (Guérin–Méneville, 1843)	S, P	LC	II	–
	Muscicapidae	*Tarsiger cyanurus* Pallas, 1773	v	LC	–	–
	Muscicapidae	*Ficedula hypoleuca* (Pallas, 1764)	P	LC	II	–
	Muscicapidae	*Ficedula albicollis* (Temminck, 1815)	P	LC	II	–
	Muscicapidae	*Ficedula semitorquata* (Homeyer, 1885)	S, P	LC	II	–
	Muscicapidae	*Ficedula parva* (Bechstein, 1792)	S, P	LC	II	–
	Muscicapidae	*Phoenicurus ochruros* (Gmelin, 1774)	R, P, W	LC	II	–
	Muscicapidae	*Phoenicurus phoenicurus* (Linnaeus, 1758)	S, P	LC	II	–
	Muscicapidae	*Monticola saxatilis* (Linnaeus, 1766)	S, P	LC	II	–
	Muscicapidae	*Monticola solitarius* (Linnaeus, 1758)	R, W	LC	II	–
	Muscicapidae	*Saxicola rubetra* (Linnaeus, 1758)	S, P	LC	II	–
	Muscicapidae	*Saxicola rubicola* (Linnaeus, 1766)	R, W	LC	II	–
	Muscicapidae	*Saxicola maurus* (Pallas, 1773)	P, w	LC	II	–
	Muscicapidae	*Oenanthe oenanthe* (Linnaeus, 1758)	S, P	LC	II	–
	Muscicapidae	*Oenanthe isabellina* (Temminck, 1829)	S, P	LC	II	–
	Muscicapidae	*Oenanthe monacha* (Temminck, 1825)	v	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Muscicapidae	*Oenanthe deserti* (Temminck, 1829)	s, P	LC	II	–
	Muscicapidae	*Oenanthe hispanica* (Linnaeus, 1758)	S, p	LC	II	–
	Muscicapidae	*Oenanthe cypriaca* (Homeyer, 1884)	P	LC	II	–
	Muscicapidae	*Oenanthe pleschanka* (Lepechin, 1770)	S, P	LC	II	–
	Muscicapidae	*Oenanthe melanura* (Temminck, 1824)	v	LC	II	–
	Muscicapidae	*Oenanthe leucopyga* (Brehm, 1855)	v	LC	II	–
	Muscicapidae	*Oenanthe finschii* (Heuglin, 1869)	R, w	LC	II	–
	Muscicapidae	*Oenanthe lugens* (Lichtenstein, 1823)	v	LC	II	–
	Muscicapidae	*Oenanthe xanthoprymna* (Hemprich & Ehrenberg, 1833)	S, P	LC	II	–
	Cinclidae	*Cinclus cinclus* (Linnaeus, 1758)	R	LC	II	–
	Passeridae	*Passer domesticus* (Linnaeus, 1758)	R	LC	–	–
	Passeridae	*Passer hispaniolensis* (Temminck, 1820)	S, P, w	LC	III	–
	Passeridae	*Passer moabiticus* (Tristram, 1864)	S	LC	III	–
	Passeridae	*Passer montanus* (Linnaeus, 1758)	R	LC	III	–
	Passeridae	*Carpospiza brachydactyla* (Bonaparte, 1850)	S, P	LC	III	–
	Passeridae	*Petronia petronia* (Linnaeus, 1766)	R	LC	II	–
	Passeridae	*Gymnoris xanthocollis* (Burton, 1838)	S, P	LC	III	–
	Passeridae	*Montifringilla nivalis* (Linnaeus, 1766)	R	LC	II	–
	Prunellidae	*Prunella collaris* (Scopoli, 1769)	R, W	LC	II	–
	Prunellidae	*Prunella montanella* (Pallas, 1776)	v	LC	II	–
	Prunellidae	*Prunella ocularis* (Radde, 1884)	R, W	LC	II	–
	Prunellidae	*Prunella atrogularis* (Brandt, 1844)	v	LC	II	–
	Prunellidae	*Prunella modularis* (Linnaeus, 1758)	r, P, W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Motacillidae	*Motacilla flava* Linnaeus, 1758	S, P	LC	II	–
	Motacillidae	*Motacilla citreola* (Pallas, 1776)	S, P, w	LC	II	–
	Motacillidae	*Motacilla cinerea* Tunstall, 1771	R, P, W	LC	II	–
	Motacillidae	*Motacilla alba* Linnaeus, 1758	R, P, W	LC	II	–
	Motacillidae	*Anthus richardi* Vieillot, 1818	p, w	LC	II	–
	Motacillidae	*Anthus godlewskii* (Taczanowski, 1876)	v	LC	II	–
	Motacillidae	*Anthus campestris* (Linnaeus, 1758)	S, P	LC	II	–
	Motacillidae	*Anthus pratensis* (Linnaeus, 1758)	P, W	**NT**	II	–
	Motacillidae	*Anthus trivialis* (Linnaeus, 1758)	S, P	LC	II	–
	Motacillidae	*Anthus hodgsoni* (Richmond, 1907)	v	LC	II	–
	Motacillidae	*Anthus cervinus* (Pallas, 1811)	P, w	LC	II	–
	Motacillidae	*Anthus rubescens* (Tunstall, 1771)	v	LC	II	–
	Motacillidae	*Anthus spinoletta* (Linnaeus, 1758)	R, W	LC	II	–
	Fringillidae	*Fringilla coelebs* Linnaeus, 1758	R, P, W	LC	III	–
	Fringillidae	*Fringilla montifringilla* Linnaeus, 1758	P, W	LC	III	–
	Fringillidae	*Coccothraustes coccothraustes* (Linnaeus, 1758)	R, P, W	LC	II	–
	Fringillidae	*Pyrrhula pyrrhula* (Linnaeus, 1758)	R, W	LC	III	–
	Fringillidae	*Rhodopechys sanguineus* (Gould, 1838)	S, w	LC	III	–
	Fringillidae	*Bucanetes githagineus* (Lichtenstein, 1823)	s	LC	II	–
	Fringillidae	*Bucanetes mongolicus* (Swinhoe, 1870)	s	LC	III	–
	Fringillidae	*Carpodacus erythrinus* (Pallas, 1770)	S, P	LC	II	–
	Fringillidae	*Chloris chloris* (Linnaeus, 1758)	R, P, W	LC	II	–
	Fringillidae	*Rhodospiza obsoleta* (Lichtenstein, 1823)	R	LC	III	–
	Fringillidae	*Linaria flavirostris* (Linnaeus, 1758)	R, W	LC	II	–

Order	Family	Scientific name	Status	IUCN	Bern	CITES
	Fringillidae	*Linaria cannabina* (Linnaeus, 1758)	R, P, W	LC	II	–
	Fringillidae	*Acanthis flammea* (Linnaeus, 1758)	v	LC	II	–
	Fringillidae	*Loxia curvirostra* Linnaeus, 1758	R, P, W	LC	II	–
	Fringillidae	*Carduelis carduelis* (Linnaeus, 1758)	R, P, W	LC	II	–
	Fringillidae	*Serinus pusillus* (Pallas, 1811)	R, W	LC	II	–
	Fringillidae	*Serinus serinus* (Linnaeus, 1766)	R	LC	II	–
	Fringillidae	*Spinus spinus* (Linnaeus, 1758)	r, P, W	LC	II	–
	Emberizidae	*Emberiza calandra* (Linnaeus, 1758)	R, P, W	LC	III	–
	Emberizidae	*Emberiza citrinella* Linnaeus, 1758	r, P, W	LC	II	–
	Emberizidae	*Emberiza leucocephalos* Gmelin, 1771	v	LC	II	–
	Emberizidae	*Emberiza cia* (Linnaeus, 1766)	R	LC	II	–
	Emberizidae	*Emberiza buchanani* Blyth, 1844	S, P	LC	III	–
	Emberizidae	*Emberiza cineracea* Brehm, 1855	S, P	**NT**	II	–
	Emberizidae	*Emberiza hortulana* Linnaeus, 1758	S, P	LC	III	–
	Emberizidae	*Emberiza caesia* Cretzschmar, 1827	S, P	LC	II	–
	Emberizidae	*Emberiza cirlus* Linnaeus, 1766	R	LC	II	–
	Emberizidae	*Emberiza pusilla* Pallas, 1776	v	LC	II	–
	Emberizidae	*Emberiza rustica* Pallas, 1776	v	**VU**	III	–
	Emberizidae	*Emberiza melanocephala* Scopoli, 1769	S, P	LC	II	–
	Emberizidae	*Emberiza bruniceps* Brandt, 1841	v	LC	III	–
	Emberizidae	*Emberiza schoeniclus* (Linnaeus, 1758)	R, P, W	LC	II	–
	Calcariidae	*Calcarius lapponicus* (Linnaeus, 1758)	v	LC	II	–
	Calcariidae	*Plectrophenax nivalis* (Linnaeus, 1758)	v	LC	II	–

Status: *R* resident, *S* summer migrant breeder, *P* passage migrant, *W* wintering, *V* vagrant, *ex* extinct in the wild

Appendix 10.6: The Mammal List of Turkey ([a]Sources 1–18)

Order Family	Species name	IUCN	IUCN[M]	IUCN[EU]	Bern	CITES
Eulipotyphla						
Erinaceidae	*Erinaceus concolor* Martin, 1838	LC	LC	–	–	–
	Erinaceus roumanicus Barrett–Hamilton, 1900	LC	LC	–	–	–
	Hemiechinus auritus (Gmelin, 1770)	LC	LC	–	–	–
Soricidae	*Sorex minutus* Linnaeus, 1766	LC	LC	–	III	–
	Sorex volnuchini Ognev, 1922	LC	LC	–	III	–
	Sorex raddei Satunin, 1895 s.l. (=*S. batis* Thomas, 1913)	LC	LC	–	III	–
	Sorex satunini Ognev, 1921	LC	LC	–	III	–
	Sorex araneus Linnaeus, 1758	LC	LC	–	III	–
	Neomys teres Miller, 1908	LC	LC	–	III	–
	Neomys milleri Mottaz, 1907[1, 2]	NE	NE	–	III	–
	Crocidura leucodon (Hermann, 1780)	LC	LC	–	III	–
	Crocidura suaveolens (Pallas, 1811) s.str.	LC	LC	–	III	–
	Crocidura (suaveolens) gueldenstaedtii (Pallas, 1811) * [3]	NE	NE	–	III	–
	Crocidura arispa Spitzenberger, 1971 (**E**)	LC	LC	–	III	–
	Suncus etruscus (Savi, 1822)	LC	LC	–	III	–
Talpidae	*Talpa europaea* Linnaeus, 1758	LC	LC	–	–	–
	Talpa martinorum Kryštufek, Nedyalkov, Astrin & Hutterer, 2018[4]	NE	NE	–	–	–
	Talpa caeca Savi, 1822[4]	LC	LC	–	–	–
	Talpa levantis Thomas, 1906	LC	LC	–	–	–
	Talpa (caucasica) ognevi Stroganov, 1944 * [5]	NE	NE	–	–	–
	Talpa davidiana (Milne-Edwards, 1884)	DD	DD	–	–	–
Chiroptera						
Pteropodidae	*Rousettus aegyptiacus* (E. Geoffroy, 1810)	LC	NT	NA	II	–
Emballonuridae	*Taphozous nudiventris* Cretzschmar, 1830	LC	LC	–	II	–
Rhinolophidae	*Rhinolophus ferrumequinum* (Schreber, 1774)	LC	NT	NT	II	–
	Rhinolophus hipposideros (Borkhausen, 1797)	LC	NT	NT	II	–
	Rhinolophus euryale Blasius, 1853	NT	VU	VU	II	–
	Rhinolophus mehelyi Matschie, 1901	VU	VU	VU	II	–
	Rhinolophus blasii Peters, 1867	LC	NT	VU	II	–

Order Family	Species name	IUCN	IUCN^{M}	IUCN^{EU}	Bern	CITES
Vespertilionidae	*Vespertilio murinus* (Linnaeus, 1758)	LC	NA	LC	II	–
	Eptesicus serotinus Schreber, 1774	LC	LC	LC	II	–
	Eptesicus anatolicus Felten, 1971	LC	LC	NA	II	–
	Nyctalus leisleri (Kuhl, 1817)	LC	LC	LC	II	–
	Nyctalus noctula (Schreber, 1774)	LC	LC	LC	II	–
	Nyctalus lasiopterus (Schreber, 1780)	VU	NT	DD	II	–
	Pipistrellus pipistrellus (Schreber, 1774)	LC	LC	LC	III	–
	Pipistrellus pygmaeus (Leach, 1825)	LC	LC	LC	II	–
	Pipistrellus nathusii (Keyserling & Blasius, 1839)	LC	LC	LC	II	–
	Pipistrellus kuhlii (Kuhl, 1817)	LC	LC	LC	II	–
	Hypsugo savii (Bonaparte, 1837)	LC	LC	LC	II	–
	Plecotus auritus (Linnaeus, 1758)	LC	LC	LC	II	–
	Plecotus macrobullaris Kuzyakin, 1965	LC	NT	NT	II	–
	Plecotus austriacus (J. Fischer, 1829)	LC	NT	NT	II	–
	Plecotus kolombatovici Đulić, 1980	LC	LC	NT	II	–
	Barbastella barbastellus (Schreber, 1774)	NT	NT	VU	II	–
	Otonycteris hemprichii Peters, 1859	LC	–	–	II	–
	Myotis mystacinus (Kuhl, 1817)	LC	LC	LC	II	–
	Myotis davidii (Peters, 1869)[6]	LC	NA	–	II	–
	Myotis brandtii (Eversmann, 1845)	LC	LC	LC	II	–
	Myotis alcathoe von Helversen & Heller, 2001	DD	DD	DD	II	–
	Myotis emarginatus (E. Geoffroy, 1806)	LC	LC	LC	II	–
	Myotis nattereri (Kuhl, 1817)	LC	LC	LC	II	–
	Myotis schaubi Kormos, 1934 **	DD	DD	–	II	–
	Myotis bechsteinii (Kuhl, 1817)	NT	NT	VU	II	–
	Myotis myotis (Borkhausen, 1897)	LC	LC	LC	II	–
	Myotis blythii (Tomes, 1857)	LC	NT	NT	II	–
	Myotis daubentonii (Kuhl, 1817)	LC	LC	LC	II	–
	Myotis capaccinii (Bonaparte, 1837)	VU	VU	VU	II	–
Miniopteridae	*Miniopterus schreibersii* (Kuhl, 1817)	NT	–	–	II	–
	Miniopterus pallidus Thomas, 1907[7]	NE	NE	NE	–	–
Molossidae	*Tadarida teniotis* (Rafinesque, 1814)	LC	LC	LC	II	–

Order Family	Species name	IUCN	IUCN^M	IUCN^EU	Bern	CITES
Lagomorpha						
Ochotonidae	*Ochotona rufescens* (Gray, 1842)	LC	–	–	–	–
Leporidae	*Lepus europaeus* Pallas, 1778	LC	LC	LC	III	–
	Oryctolagus cuniculus (Linnaeus, 1758) (**A/I**)	NT	NT	NT	–	–
Rodentia						
Sciuridae	*Sciurus vulgaris* Linnaeus, 1758	LC	LC	LC	III	–
	Sciurus anomalus Gmelin, 1778	LC	LC	NA	II	–
	Spermophilus citellus (Linnaeus, 1766)	VU	VU	VU	II	–
	Spermophilus xanthoprymnus (Bennett, 1835)	NT	NT	NT	–	–
	Spermophilus taurensis Gündüz, Jaarola, Tez, Yeniyurt, Polly & Searle, 2007 (**E**)	LC	LC	–	–	–
Gliridae	*Glis glis* (Linnaeus, 1766)	LC	LC	LC	III	–
	Muscardinus avellanarius (Linnaeus, 1758)	LC	LC	LC	III	–
	Dryomys nitedula (Pallas, 1778)	LC	LC	LC	III	–
	Dryomys laniger Felten & Storch, 1968 (**E**)	DD	DD	–	II	–
	Myomimus roachi (Bate, 1937)	VU	VU	EN	II	–
	Myomimus setzeri Rossolimo, 1976	DD	DD	–	III	–
	Eliomys melanurus Wagner, 1840	LC	LC	–	III	–
Dipodidae	*Scarturus elater* (Lichtenstein, 1828)	LC	–	–	–	–
	Scarturus euphratica (Thomas, 1881)	NT	NT	–	–	–
	Scarturus aulacotis (Wagner, 1840)[8, 11]	NE	NE	–		–
	Scarturus williamsi (Thomas, 1897)	LC	NT	–	–	–
Cricetidae	*Ellobius lutescens* Thomas, 1897	LC	LC	–	–	–
	Prometheomys schaposchnikowi Satunin, 1901	LC	VU	–	–	–
	Clethrionomys glareolus (Schreber, 1780)	LC	LC	LC	–	–
	Arvicola amphibius (Linnaeus, 1758) s.str.	LC	LC	LC	–	–
	Arvicola (amphibius) persicus de Filippi, 1865 * [9]	NE	NE	NE	–	–
	Microtus subterraneus (de Sélys Longchamps, 1836)	LC	LC	LC	–	–
	Microtus majori Thomas, 1906	LC	LC	LC	–	–
	Microtus daghestanicus Schidlovsky, 1919	LC	LC	–	–	–

Order Family	Species name	IUCN	IUCN[M]	IUCN[EU]	Bern	CITES
	Microtus (arvalis) obscurus (Eversmann, 1841) * [10, 11]	LC	LC	LC	–	–
	Microtus mystacinus de Filippi, 1865[11, 12]	LC	LC	LC	–	–
	Microtus socialis (Pallas, 1773)	LC	LC	LC	–	–
	Microtus irani Thomas, 1921	VU	–	–	–	–
	Microtus elbeyli Yiğit, Çolak & Sözen, 2016[11]	DD	–	–	–	–
	Microtus anatolicus Kryštufek & Kefelioğlu, 2001 (**E**)	DD	DD	–	–	–
	Microtus guentheri (Danford & Alston, 1880)	LC	LC	LC	–	–
	Microtus hartingi Barret–Hamilton, 1903[11]	LC	LC	LC	–	–
	Microtus dogramacii Kefelioğlu & Kryštufek, 1999[11]	LC	LC	–	–	–
	Chionomys nivalis (Martins, 1842)	LC	LC	LC	III	–
	Chionomys lasistanius Neuhäuser, 1936[11]	LC	LC	–	–	–
	Chionomys roberti (Thomas, 1906)	LC	DD	–	–	–
	Cricetulus migratorius (Pallas, 1773)	LC	LC	LC	–	–
	Mesocricetus auratus (Waterhouse, 1839)	VU	VU	–	–	–
	Mesocricetus brandti (Nehring, 1898)	NT	NT	–	–	–
Muridae	*Micromys minutus* (Pallas, 1771)	LC	LC	LC	–	–
	Apodemus sylvaticus (Linnaeus, 1758)	LC	LC	LC	–	–
	Apodemus flavicollis (Melchior, 1834)	LC	LC	LC	–	–
	Apodemus witherbyi (Thomas, 1902)	LC	LC	NA	–	–
	Apodemus uralensis (Pallas, 1811)	LC	NA	LC	–	–
	Apodemus mystacinus (Danford & Alston, 1877)	LC	LC	LC	–	–
	Apodemus agrarius (Pallas, 1771)	LC	LC	LC	–	–
	Rattus rattus (Linnaeus, 1758) (**A/I**)	LC	–	LC	–	–
	Rattus norvegicus (Berkenhout, 1769) (**A/I**)	LC	–	–	–	–
	Nesokia indica (Gray, 1830)	LC	LC	–	–	–
	Mus musculus domesticus Schwarz & Schwarz, 1943[11]	LC	LC	LC	–	–
	Mus macedonicus Petrov & Ružić, 1983	LC	LC	LC	–	–
	Acomys cilicicus Spitzenberger, 1978 (**E**)	DD	DD	–	–	–

Order Family	Species name	IUCN	IUCN[M]	IUCN[EU]	Bern	CITES
	Tatera indica (Hardwicke, 1807)	LC	NA	–	–	–
	Meriones tristrami Thomas, 1892	LC	LC	NA	–	–
	Meriones vinogradovi Heptner, 1931	LC	LC	–	–	–
	Meriones crassus Sundevall, 1842	LC	LC	–	–	–
	Meriones libycus Lichtenstein, 1823	LC	LC	–	–	–
	Meriones (meridianus) dahli Shidlovsky, 1962 *	EN	EN	–	–	–
	Meriones persicus (Blanford, 1875)	LC	LC	–	–	–
	Gerbillus dasyurus (Wagner, 1842)	LC	LC	–	–	–
Spalacidae	*Nannospalax leucodon* (Nordmann, 1840)	DD	DD	LC	–	–
	Nannospalax xanthodon (Nordmann, 1840)	DD	DD	NA	–	–
	Nannospalax ehrenbergi (Nehring, 1898)	DD	DD	–	–	–
Calomyscidae	*Calomyscus bailwardi* Thomas, 1905 ** [11]	LC	DD	–	–	–
Hystricidae	*Hystrix indica* Kerr, 1792	LC	LC	–	–	–
Echimyidae	*Myocastor coypus* (Molina, 1782) (**A/I**)	LC	–	–	–	–
Carnivora						
Canidae	*Canis lupus* Linnaeus, 1758	LC	LC	LC	II	II
	Canis aureus Linnaeus, 1758	LC	–	LC	–	–
	Vulpes vulpes (Linnaeus, 1758)	LC	LC	LC	–	–
	Nyctereutes procyonoides (Gray, 1834) (**A/I?**)	LC	–	–	–	–
Ursidae	*Ursus arctos* Linnaeus, 1758	LC	VU	LC	II	II
Mustelidae	*Martes martes* (Linnaeus, 1758)	LC	LC	LC	III	–
	Martes foina (Erxleben, 1777)	LC	LC	LC	III	–
	Mustela nivalis Linnaeus, 1766	LC	–	–	III	–
	Mustela putorius Linnaeus, 1758	LC	LC	LC	III	–
	Vormela peregusna (Güldenstaedt, 1770)	VU	VU	VU	II	–
	Meles meles (Linnaeus, 1758)	LC	–	–	III	–
	Lutra lutra (Linnaeus, 1758)	NT	NT	NT	II	I
Herpestidae	*Herpestes ichneumon* (Linnaeus, 1758)	LC	LC	LC	III	–
Hyaenidae	*Hyaena hyaena* (Linnaeus, 1758)	NT	VU	–	–	–
Felidae	*Felis silvestris* Schreber, 1777	LC	LC	LC	II	II
	Felis chaus Schreber, 1777	LC	DD	NA	–	II
	Lynx lynx (Linnaeus, 1758)	LC	EN	LC	III	II
	Caracal caracal (Schreber, 1776)	LC	NT	–	II	I
	Panthera pardus (Linnaeus, 1758)	VU	CR	–	II	I
	Panthera tigris (Linnaeus, 1758)	EN	EX	–	II	I

Order Family	Species name	IUCN	IUCN[M]	IUCN[EU]	Bern	CITES
Phocidae	*Monachus monachus* (Hermann, 1779)	EN	CR	CR	II	I
Cetartiodactyla						
Balaenopteridae	*Balaenoptera acutorostrata* (Lacépède, 1804)[13]	LC	–	LC	II	I
	Balaenoptera physalus (Linnaeus, 1758)	VU	VU	NT	II	I
Physeteridae	*Physeter macrocephalus* Linnaeus, 1758	VU	EN	VU	II	I
Ziphiidae	*Mesoplodon* cf. *europaeus* (Gervais, 1855)[14]	DD	–	DD	–	–
	Ziphius cavirostris Cuvier, 1823	LC	DD	DD	II	II
Delphinidae	*Delphinus delphis* Linnaeus, 1758	LC	EN	DD	II	II
	Globicephala melas (Traill, 1809)	LC	DD	DD	II	II
	Grampus griseus (G. Cuvier, 1812)	LC	DD	DD	II	II
	Pseudorca crassidens (Owen, 1846)	NT	–	NA	II	II
	Sousa plumbea (G. Cuvier, 1829)[15] (**A/I**)	EN	–	–	–	I
	Stenella coeruleoalba (Meyen, 1833)	LC	VU	DD	II	II
	Steno bredanensis G. Cuvier in Lesson, 1828[14]	LC	–	NA	II	–
	Tursiops truncatus (Montagu, 1821)	LC	VU	DD	II	II
Phocaenidae	*Phocoena phocoena* (Linnaeus, 1758)	LC	EN	VU	II	II
Suidae	*Sus scrofa* Linnaeus, 1758	LC	LC	LC	–	–
Cervidae	*Cervus elaphus* Linnaeus, 1758	LC	–	–	III	–
	Dama dama (Linnaeus, 1758) s.str.	LC	LC	LC	III	–
	Dama (dama) mesopotamica (Brooke, 1875)[16, 17]	EN	–	–	–	I
	Capreolus capreolus (Linnaeus, 1758)	LC	LC	LC	III	–
Bovidae	*Rupicapra rupicapra* (Linnaeus, 1758)	LC	LC	LC	III	–
	Capra aegagrus Erxleben, 1777	VU	VU	–	II	–
	Ovis gmelini gmelini Blyth, 1841	VU	EN	–	III	II
	Ovis gmelini anatolica Valenciennes, 1856	VU	EN	–	III	II
	Gazella marica Thomas, 1897[18]	VU	–	–	II	–
	Gazella gazella (Pallas, 1766)	EN	–	–	–	–

[a]**Sources:** [1]Igea et al. (2015), [2]Novakov and Vohralík (2019), [3]Bannikova et al. (2005), [4]Kryštufek et al. (2018), [5]Wilson and Mittermeier (2018), [6]Benda et al. (2016), [7]Bilgin et al. (2012), [8]Bannikova et al. (2019), [9]Mahmoudi et al. (2019), [10]Kryštufek and Vohralík (2009), [11]Wilson et al. (2017), [12]Mahmoudi et al. (2014), [14]Öztürk et al. (2011, 2016), [15]Doganyılmaz Ozbilgin et al. (2018), [16] Feldhamer et al. (1988), Geist (1998), [17] Ferguson et al. (1985), Uerpmann (1987), Randi et al. (2001), Pitra et al. (2004), [18]Wacher et al. (2010). *As in *Meriones (meridianus) dahli*, different

uses for the species name can be seen in the species given in parentheses after the genus name. e.g. *Meriones dahli* or *Meriones meridianus dahli*. ** status in Turkey are unclear.
E endemic, *A/I* alien/invasive, *IUCN* IUCN's global redlist, *IUCN*^{M} Mediterranean redlist, *IUCN*^{EU} European redlist

References

Abdul Malak D, Livingstone SR, Pollard D et al (2011) Overview of the conservation status of the marine fishes of the Mediterranean Sea. IUCN, Gland/Malaga, 61 p

Akyol O (2019) The first record of a mangrove red snapper, *Lutjanus argentimaculatus* (Actinopterygii: Perciformes: Lutjanidae), from the Aegean Sea (Gulf of Izmir, Turkey). Acta Ichthyol Piscat 49(2):209–211

Akyol O, Aydın İ (2016) A new record of *Lagocephalus guentheri* (Tetraodontiformes: Tetraodontidae) from the north-eastern Aegean Sea. Zool Middle East 62(3):271–273

Akyol O, Düzbastılar FO, Ceyhan T (2017) First report of *Pempheris rhomboidea* (Perciformes: Pempheridae) beneath offshore sea-cages in the Aegean Sea. Turkish J Fish Aquat Sci 17(2):449–450

Alpar B, Dogan E, Yuce H, Altıok H (2000) Sea level changes along the Turkish coasts of the Black Sea, the Aegean Sea and the Eastern Mediterranean. Mediterr Mar Sci 1:141–156

Altay V (2019) Ecology of *Pinus sylvestris* L. forests – a case study from Istanbul (Turkey). Pak J Botany 51(5):1711–1718

Bannikova AA, Lavrenchenko LA, Kramerov DA (2005) Phylogenetic relationships between Afrotropical and Palaearctic Crocidura species inferred from Inter-SINE-PCR. Biochem Syst Ecol 33:45–59

Bannikova AA, Lebedev V, Dubrovskaya A et al (2019) Genetic evidence for several cryptic species within the *Scarturus elater* species complex (Rodentia: Dipodoidea): when cryptic species are really cryptic. Biol J Linn Soc Lond 126:16–39

Baran İ (1986) On an island population of *Eirenis modestus* in the Eastern Mediterranean Sea. Zoology in the Middle East 1(1):80–83

Bayçelebi E, Turan D, Japoshvili B (2015) Fish fauna of Çoruh River and two first record for Turkish J Fish Aquat Sci 15:783–794

Bayçelebi E, Kaya C, Turan D et al (2018) Redescription of *Garra turcica* from southern Anatolia (Teleostei: Cyprinidae). Zootaxa 4524(2):227–236

Behrens-Chapuis S, Herder F, Esmaeili HR et al (2015) Adding nuclear rhodopsin data where mitochondrial COI indicates discrepancies-can this marker help to explain conflicts in cyprinids? DNA Barcodes 3(1):187–199

Benda P, Gazaryan S, Vallo P (2016) On the distribution and taxonomy of bats of the *Myotis mystacinus* morphogroup from the Caucasus region (Chiroptera: Vespertilionidae). Turk J Zool 40:1–30

Bern Convention (2002) Appendices of the convention and amendments to the appendices www.coe.int/en/web/bern-convention/appendices. Accessed on 28 Dec 2019

Betancur-R R, Wiley EO, Arratia G et al (2017) Phylogenetic classification of bony fishes. BMC Evol Biol 17:162

Bektas, Y., Aksu, I., Kalayci, G., Irmak, E., Engin, S., & Turan, D. (2018). Genetic differentiation of three *Spicara* (Pisces: Centracanthidae) species, *S. maena*, *S. flexuos*a and *S. smaris*: and intraspecific substructure of S. flexuosa in Turkish coastal waters. Turkish J Fish Aquat Sci 18: 301-311

Bilecenoğlu M (2016) Two marine fish records of Liechtenstein's goby (*Corcyrogobius liechtensteini*) and the Atlantic originated sergeant major (*Abudefduf saxatilis*), new for the Turkish fauna. J Black Sea/Mediterr Environ 22(3):259–265

Bilecenoğlu M, Kaya M, Cihangir B, Çiçek E (2014) An updated checklist of the marine fishes of Turkey. Turk J Zool 38:901–929

Bilecenoğlu M, Yokeş MB, Kovačić M (2017) A new species of *Diplecogaster* (Actinopterygii: Gobiesocidae) from the Mediterranean Sea. Zool Middle East 63(3):210–218

Bilge G, Filiz H, Yapıcı S et al (2019) A risk screening study on the potential invasiveness of Lessepsian fishes in the South-western coasts of Anatolia. Acta Ichthyol Piscat 49(1):23–31

Bilgin R, Gürün K, Maraci Ö et al (2012) Syntopic occurrence in Turkey supports separate species status for *Miniopterus schreibersii schreibersii* and *M. schreibersii pallidus* (Mammalia: Chiroptera). Acta Chiropt 14(2):279–289

Birecikligil S, Eagderi S, Jouladeh-Roudbar A, Çiçek E (2017) *Alburnoides recepi*, a junior synonym of *Alburnus caeruleus* (Teleostei: Cyprinidae). Zootaxa 427(1):129–136

Bogutskaya NG (2002) *Petroleuciscus,* a new genus for the *Leuciscus borysthenicus* species group (Teleostei: Cyprinidae). Zoosyst Rossica 11:235–237

Çiçek E, Sungur-Birecikligil S, Fricke R (2015) Freshwater fishes of Turkey: a revised and updated annotated checklist. Biharean Biol 9(2):141–157

Çiçek E, Sungur-Birecikligil S, Fricke R (2016) Addenda and errata of: freshwater fishes of Turkey: a revised and updated annotated checklist. FishTaxa 1(2):116–117

Çiçek E, Fricke R, Sungur S, Eagderi S (2018) Endemic freshwater fishes of Turkey. FishTaxa 3(4):1–39

Çiçek E, Eagderi S, Sungur S (2019a) *Oxynoemacheilus phoxinoides* (Erk'akan, Nalbant & Özeren, 2007): a junior synonym of *Oxynoemacheilus angorae* (Steindachner, 1897). FishTaxa 4(1):13–17

Çiçek E, Fricke R, Eagderi S et al (2019b) *Knipowitschia ephesi* Ahnelt, 1995, a junior synonym of *Gobius ricasolii* Di Caporiacco, 1935 (Teleostei: Gobiidae). Zool Middle East doi. https://doi.org/10.1080/09397140.2019.1648402

Çiftçi O, Karahan A, Ak Orek Y, Kideys AE (2017) First record of the buccaneer anchovy *Encrasicholina punctifer* (Fowler, 1938) (Clupeiformes; Engraulidae) in the Mediterranean Sea, confirmed through DNA barcoding. J Appl Ichthyol 33(3):520–523

Çiçek E, Sungur S, Fricke R (2020) Freshwater lampreys and fishes of Turkey; a revised and updated annotated checklist 2020. Zootaxa 4809 (2): 241–270

CITES (2017) Convention on International Trade in Endangered Species of Wild Fauna and Flora, Appendices I, II and III. https://cites.org/sites/default/files/eng/app/2017/E--Appendices-2017-10-04.pdf. Accessed on 28 Dec 2019

Dalyan C, Yemisken E, Erguden D et al (2014) First record of the Indian Ocean anchovy *Stolephorus insularis* Hardenberg, 1933 from the northeastern Mediterranean coast of Turkey. J Appl Ichthyol 30(5):1039–1040

Doganyılmaz Ozbilgin Y, Kalecik E, Gücü AC (2018) First record of Humpback dolphins in Mersin Bay, the Eastern Mediterranean. Turkey, Turkish J Fish Aquat Sci 18:187–190

Doğdu SA, Uyan A, Uygur N et al (2016) First record of the Indo-Pacific striped eel catfish, *Plotosus lineatus* (Thunberg, 1787) from Turkish marine waters. NESciences 1(2):25–32

Dufresnes C, Mazepa G, Jablonski D et al (2019) Fifteen shades of green: the evolution of *Bufotes* toads revisited. Mol Phylogenet Evol 141:1–25

Ekmekçi FG, Kırankaya ŞG, Gençoğlu L, Yoğurtçuoğlu B (2013) Present status of invasive fishes in inland waters of Turkey and assessment of the effects of invasion. Istanbul University J Fish Aquat Sci 28:105–140

Emiroğlu Ö, Ekmekçi FG, Aksu S et al (2016) Introduction and establishment of tropical ornamental fish, *Pterygoplichthys* spp. (Actinopterygii: Siluriformes: Loricariidae) in hot springs: Aquarium trade as a potential risk for biodiversity in Turkey. Acta Ichthyol Piscat 46(4):351–356

Engin S, Innal D (2017) A new species of *Pomatoschistus* (Teleostei: Gobiidae) from Southern Anatolia. Zool Middle East 63(4):316–324

Engin S, Irmak E, Seyhan D (2016) New record of the thermophilic *Cephalopholis taeniops* (Osteichthyes: Serranidae) in the Aegean Sea. Zool Middle East 62(2):184–186

Engin S, Larson H, Irmak E (2018) *Hazeus ingressus* sp. nov. a new goby species (Perciformes: Gobiidae) and a new invasion in the Mediterranean Sea. Mediterr Mar Sci 19 (2): 316-325. https://doi.org/10.12681/mms.14336

Ergüden D, Gürlek M, Turan C (2018) Confirmed occurrence of moontail bullseye *Priacanthus hamrur* (Forsskål, 1775) in the Mediterranean Sea with first record off the coast of Turkey. Acta Ichthyol Piscat 48(4):387–391

Erkakan F, Özdemir F (2014) The first new cave fish species, *Cobitis damlae* (Teleostei: Cobitidae) from Turkey. Hacettepe J Biol Chem 42:275–279

Erkakan F, Özdemir F, Özeren SC (2017) Two new species of the genus *Cobitis* Linnaeus (Teleostei: Cobitidae) from Turkey. FishTaxa 2(2):82–89

Eschmeyer WN, van der Laan R, Fricke R (2020) Catalog of Fishes: Genera, Species, References. Electronic version (www.calacademy.org/scientists/projects/eschmeyers-catalog-of-fishes). Accessed on 03 Jan 2020 & on 02 Nov 2020

Feldhamer GA, Farris-Renner KC, Barker CM (1988) *Dama dama*. Mammal Species 317:1–8

Ferguson WW, Porath Y, Paley S (1985) Late Bronze period yields first osteological evidence of *Dama dama* (Artiodactyla; Cervidae) from Israel and Arabia. Mammalia 49:209–214

Filiz H, Sevingel N, Cerim H, Bilge G (2019) First record of the blackbar hogfsh, *Bodianus speciosus* (Actinopterygii: Perciformes: Labridae), in the Mediterranean Sea. Acta Ichthyol Piscat 49(4):399–402

Freyhof J, Erk'akan F, Özeren SC, Perdices A (2011) An overview of the western Palaearctic loach genus *Oxynoemacheilus* (Teleosei: Nemacheilidae). Ichthyol Explore Fres 22:301–312

Freyhof F, Özuluğ M, Saç G (2017) Neotype designation of *Aphanius iconii*, first reviser action to stabilise the usage of *A. fontinalis* and *A. meridionalis* and comments on the family group names of fishes placed in Cyprinodontidae (Teleostei: Cyprinodontiformes). Zootaxa 4294(5):573–585

Freyhof J, Kaya C, Bayçelebi E et al (2018a) Generic assignment of *Leuciscus kurui* Bogutskaya from the upper Tigris drainage, and a replacement name for *Alburnus kurui* Mangit & Yerli (Teleostei: Leuciscidae). Zootaxa 4410(1):113–135

Freyhof J, Özuluğ M, Kaya C et al (2018b) Redescription of *Alburnus kotschyi* Steindachner, 1863, with comments on *Alburnus sellal adanensis* Battalgazi, 1944 (Teleostei: Leuciscidae). Zootaxa 4382(3):573–582

Freyhof J, Bayçelebi E, Geiger M (2018c) Review of the genus *Cobitis* in the Middle East, with the description of eight new species (Teleostei: Cobitidae). Zootaxa 4535(1):1–75

Freyhof J, Kaya C, Turan D, Geiger MF (2019) Review of the *Oxynoemacheilus tigris* group with the description of two new species from the Euphrates drainage (Teleostei: Nemacheilidae). Zootaxa 4612(1):29–57

Freyhof J, Yoğurtçuoğlu B (2020) A proposal for a new generic structure of the killifish family Aphaniidae, with the description of *Aphaniops teimorii* (Teleostei: Cyprinodontiformes). Zootaxa 4810 (3): 421-451

Frickle R, Bilecenoğlu M, Sarı HM (2007) Annotated checklist of fish and lamprey species (Gnathostomata and Petromyzontomorphi) of Turkey, including a Red List of threatened and declining species. Stuttg Beitr Naturk Ser A (Biol) Stuttgart 706:1–169

Froese R, Pauly D (eds) (2019) FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2019). Accessed on 10 Nov 2019

Geist V (1998) Deer of the world: their evolution, behaviour, and ecology. Stackpole Books, Mechanicsburg

Gerovasileiou V, Akel EHKH, Akyol O et al (2017) New Mediterranean biodiversity records (July 2017). Mediterr Mar Sci 18(2):355–384

Gill F, Donsker D (eds) (2020) IOC World Bird List (v 9.2). http://www.worldbirdnames.org/ https://doi.org/10.14344/IOC.ML.109.21. Accessed on 10 Nov 2020

Gökoğlu M, Özvarol Y (2015) *Epinephelus coioides* (Actinopterygii: Perciformes: Serranidae) – a new lessepsian migrant in the Mediterranean Coast of Turkey. Acta Ichthyol Piscat 45(3):307–309

Gökoğlu M, Teker S (2018) Spread of the arrow bulleye *Priacanthus sagittarius* Starnes, 1988 in the Mediterranean Sea. Acta Aquatica: Aquatic Sci J 5(1):1–3

Gökoğlu M, Özvarol Y, Fricke R (2014) *Synchiropus sechellensis* Regan, 1908 (Teleostei: Callionymidae), a new Lessepsian migrant in the Mediterranean Sea. Mediterr Mar Sci 15(2):440–442

Golani D, Orsi-Relini L, Massutí E, Quignard J-P (2019) CIESM Atlas of Exotic Fishes List. WWW Document. http://www.ciesm.org/atlas/appendix1.html. Accessed 10 Nov 2019

Güçlü SS, Çiftçi Y, Küçük F et al (2018) A new *Chondrostoma* species from the B Menderes River Basin, Turkey (Teleostei: Cyprinidae). Zool Middle East 64:315–321

Gürlek M, Ergüden D, Doğdu S, Turan C (2016a) First record of the Indo-Pacific Soldier Bream *Argyrops filamentosus* (Valenciennes, 1830) from the Mediterranean Sea. J Appl Ichthyol 32:1224–1225

Gürlek M, Ergüden D, Doğdu SA, Turan C (2016b) First record of Greenback Horse Mackerel, *Trachurus declivis* (Jenyns, 1841) in the Mediterranean Sea. J Appl Ichthyol 32(5):976–977

Gürlek M, Ergüden D, Uyan A et al (2016c) First record red lionfish *Pterois volitans* (Linnaeus, 1785) in the Mediterranean Sea. NESciences 1(3):27–32

Gürlek M, Ergüden D, Turan C (2017) First record of elongate bulleye *Priacanthus prolixus* in the Mediterranean Sea. NESciences 2(1):44–47

Igea J, Aymerich P, Bannikova AA et al (2015) Multilocus species trees and species delimitation in a temporal context: application to the water shrews of the genus *Neomys*. BMC Evol Biol 15(1):209

Imanberdieva N, Imankul B, Severoğlu Z et al (2018) Potential impacts of climate change on plant diversity of Sary-Chelek biosphere reserve in Kyrgyzstan. In: Egamberdieva D, Ozturk M (eds) Vegetation of Central Asia and environs. Springer Nature, Cham, pp 349–364

İnnal D, Sungur S (2019) First record of non-indigenous fish *Hemichromis letourneuxi* (Cichlidae) from Pınarbaşı Creek (Burdur, Turkey). MAKÜ Fen Bil Enst Derg 10(1):90–94

Irmak E, Engin S, Seyhan D, Özden U (2015) First record of the Slender Pony Fish, *Equulites elongatus* (Günther, 1874) (Osteichthyes: Leiognathidae), from the Turkish coast of the Levantine Sea. Zool Middle East 61(4):386–388

IUCN (2016) The conservation status of sharks, rays and chimaeras in the Mediterranean Sea. IUCN Centre for Mediterranean Cooperation, Campanillas (Malaga), 14 p

IUCN (2020) The IUCN red list of threatened species. Version 2019–3. www.iucnredlist.org. Accessed 01 Jan 2020

Kaya C, Bayçelebi E, Turan D (2020) Taxonomic assessment and distribution of fishes in upper Kura and Aras river drainages. Zoosyst Evol 96 (2): 325-344

Khaefi R, Esmaeili HR, Geiger MF, Eagderi S (2017) Taxonomic review of the cryptic *Barbus lacerta* species group with description of a new species (Teleostei: Cyprinidae). FishTaxa 2(2):90–115

Kornilios P, Thanou E, Lymberakis P et al (2019) A phylogenomic resolution for the taxonomy of Aegean green lizards. Zool Scr 49(1):14–27

Kotsakiozi P, Jablonski D, Ilgaz Ç et al (2018) Multilocus phylogeny and coalescent species delimitation in Kotschy's gecko, *Mediodactylus kotschyi*: hidden diversity and cryptic species. Mol Phylogenet Evol 125:177–187

Kottelat M, Freyhof J (2007) Handbook of European freshwater fishes. Publications Kottelat, Cornol. xiii + 646 p

Kryštufek B, Vohralík V (2009) Mammals of Turkey and Cyprus. Rodentia II: Cricetinae, Muridae, Spalacidae, Calomyscidae, Capromyidae, Hystricidae, Castoridae. Annales Majora, Koper. 371 p

Kryštufek B, Nedyalkov N, Astrin JJ, Hutterer R (2018) News from the Balkan refugium: Thrace has an endemic mole species (Mammalia: Talpidae). Bonn Zool Bull 67:41–57

Küçük F, Bayçelebi E, Güçlü SS, Gülle I (2015) Description of a new species of *Hemigrammocapoeta* (Teleostei: Cyprinidae) from Lake Işıklı. Zootaxa 4052(3):359–365

Kuru M (2004) Recent systematic status of inland water fishes of Turkey. Gazi Üniv Eğitim Fak Derg 24:1–21

Lacerta.de (2019) Lacerta.de, http://www.lacerta.de. Accessed on 09 Jan 2019

Levin BA, Freyhof J, Lajbner Z et al (2012) Phylogenetic relationships of the algae scraping cyprinid genus *Capoeta* (Teleostei: Cyprinidae). Mol Phylogenet Evol 62:542–549

Mahmoudi A, Darvish J, Aliabadian M et al (2014) Chromosomal diversity in the genus *Microtus* at its southern distributional margin in Iran. Folia Zoologica 63(4):290–295

Mahmoudi A, Maul L, Khoshyar M et al (2019) Evolutionary history of water voles revisited: confronting a new phylogenetic model from molecular data with the fossil record. Mammalia https://doi.org/10.1515/mammalia-2018-0178

MAMIAS (2019) Marine Mediterranean invasive alien species. http://mamias.org/search/species. Accessed 10 Nov 2019

Mora C, Tittensor DP, Adl S et al (2011) How many species are there on Earth and in the Ocean? PLoS Biol 9(8):e1001127

Nalbant TT, Bianco PG (1998) The loaches of Iran and adjacent regions with description of six new species (Cobitoidea). Ital J Zool 65:109–125

Ninua L, Tarkhnishvili D, Gvazava E (2018) Phylogeography and taxonomic status of trout and salmon from the Ponto-Caspian drainages, with inferences on European brown trout evolution and taxonomy. Ecol Evol 8:2645–2658

Novakov L, Vohralík V (2019) Discrimination of the sympatric species of water shrews *Neomys fodiens* and *N. milleri* (Soricomorpha, Soricidae). Zool Anz 283:27–32

Özdemir F (2015) Principle components analysis of two pairs of barbels species of the genus *Capoeta* (Teleostei: Cyprinidae) in Turkey. Pak J Zool 47(3):753–762

Özdemir F (2018) *Cobitis fusunae*, a new spined loach species (Teleostei: Cobitidae) from the Sultan Marsh, (Kayseri, Turkey). Hacettepe J Biol Chem 46(4):593–599

Ozturk M (2018) Biodiversity and climate change: our home is on fire. In: 2nd Intern Science Conf on “Natural Sciences, Climate & Biodiversity”, p 68, September 15–17, Muzaffarabad

Ozturk M, Aksoy A, Gucel S, Altundag E (2010) Biodiversity & conservation – a case study from Europe & Turkey. In: Bhatti R, Soomro SA (eds) Proc. of 2nd Intern. Conf. “Biodiversity is our Life” (IC Biour-Life), Center for Biod & Cons. Shah Abdul Latif Univ, Khairpur, pp 1–12

Öztürk AA, Tonay AM, Dede A (2011) Stranding of the beaked whales, Risso’s dolphins, and a minke whale on the Turkish coast of the Eastern Mediterranean Sea. J Black Sea/Mediterr Environ 17:269–274

Ozturk M, Altay V, Gucel S, Aksoy A (2012) Aegean grasslands as endangered ecosystems in Turkey. Pak J Botany 44:7–18

Öztürk AA, Dede A, Tonay AM (2016) Cetaceans in the Turkish waters of the Mediterranean Sea. In: Turan et al (eds) The Turkish part of the Mediterranean Sea; marine biodiversity, fisheries, conservation and governance. Turkish Marine Research Foundation (TUDAV), Publication No: 43, İstanbul, pp 566–571

Ozturk M, Altay V, Gonenç TM (2017a) Herbal from high mountains in the East Mediterranean. In: Bhojraj S et al (eds) Drug discovery from herbs – approaches and applications. DAYA Publishing House, New Delhi, pp 327–367

Ozturk M, Altay V, Gucel S, Altundag E (2017b) Plant diversity of the drylands in Southeast Anatolia-Turkey: role in human health and food security. In: Ansari AA, Gill SS (eds) Plant biodiversity: monitoring, assessment and conservation. CABI, Wallingford, pp 83–124

Perdices A, Özeren SC, Erk’akan F, Freyhof J (2018) Diversity of spined loaches from Asia Minor in a phylogenetic context (Teleostei: Cobitidae). PLoS One 13(10):e0205678

Pitra C, Fickel J, Meijaard E, Groves CP (2004) Evolution and phylogeny of old world deer. Mol Phylogenet Evol 33:880–895

Rajpar MN, Zakaria M, Ozdemir I et al (2017) Avian assemblages at Paya Indah, Natural Wetland Reserve, Malaysia. Expert Opin Environ Biol 6(3):1–10

Rajpar MN, Ozturk M, Altay V et al (2020) Species composition of dry-temperate forest as an important habitat for wildlife fauna species. J Environ Biol 41(SI):328–336

Randi E, Mucci N, Claro-Hergueta F et al (2001) A mitochondrial DNA control region phylogeny of Cervinae: speciation in *Cervus* and implications for conservation. Anim Conserv 4:1–12

Saç G, Özulug M (2015) New data on the distribution and conservation status of *Phoxinus strandjae* (Teleostei: Cyprinidae). Ichthyol Explore Fres 25:381–383

Saç G, Özulug M, Geiger MF, Freyhof J (2019) *Pseudophoxinus cilicicus,* a new spring minnow from southern Anatolia (Teleostei: Leuciscidae). Zootaxa 4671(1):105–118

Şekercioğlu CH, Anderson S, Akçay E et al (2011) Turkey’s globally important biodiversity in crisis. Biol Conserv 144:2752–2769

Seyhan D, Irmak E, Fricke R (2017) *Diplogrammus randalli* (Pisces: Callionymidae), a new Lessepsian migrant recorded from the Mediterranean Sea. Mediterr Mar Sci 18(1):1–3

Smíd J, Moravec J, Gvoždík V et al (2017) Cutting the Gordian Knot: Phylogenetic and ecological diversification of the *Mesalina brevirostris* species complex (Squamata, Lacertidae). Zool Scr 46(6):649–664

Tarkan AS, Marr SM, Ekmekçi FG (2015) Non-native and translocated freshwater fish species in Turkey. FISHMED Fishe Mediterr Environ 2015(003):28

Turan C, Ergüden D, Gürlek M et al (2014) First record of the Indo-Pacific lionfish *Pterois miles* (Bennett, 1828) (Osteichthyes: Scorpaenidae) for the Turkish marine waters. J Black Sea/Mediterr Environ 20(2):158–163

Turan C, Ergüden D, Uygur N et al (2015) First record of the Indian Ocean twospot cardinalfish, *Cheilodipterus novemstriatus* (Actinopterygii: Perciformes: Apogonidae) from Turkish Mediterranean waters. Acta Ichthyol Piscat 45(3):319–322

Turan C, Gürlek M, Başusta N et al (2018a) A checklist of the non-indigenous fishes in Turkish marine waters. NESciences 3(3):333–358

Turan D, Kalaycı G, Kaya C et al (2018b) A new species of *Petroleuciscus* (Teleostei: Cyprinidae) from the B Menderes River, southwestern Anatolia, Turkey. J Fish Biol 92(4):875–887

Turan D, Kaya C, Geiger MF, Freyhof J (2018c) *Barbus anatolicus*, a new barbel from the Kızılırmak and Yeşilırmak River drainages in northern Anatolia (Teleostei: Cyprinidae). Zootaxa 4461(4):539–557

Turan D, Kaya C, Kalaycı G et al (2019) *Oxynoemacheilus cemali*, a new species of stone loach (Teleostei: Nemacheilidae) from the Çoruh River drainage, Turkey. J Fish Biol 94(3):458–468

Türkmen G (2019) Lepistes (*Poecilia reticulata* Peters, 1859)'in Türkiye içsularından ilk kaydı. Ege JFAS 36(4):397–400

Uerpmann H-P (1987) The ancient distribution of ungulate mammals in the Middle East. Dr. Ludwig Reichert Verlag, Wiesbaden

Ünlüoğlu A, Akalın S, Dal İ et al (2018) First record of red cornetfish *Fistularia petimba* (Syngnathiformes: Fistulariidae) from Antalya and İskenderun Bays along Turkish coasts of the Mediterranean Sea. J Appl Ichthyol 34(4):977–980

Vidal O, García-Berthou E, Tedesco PA, García-Marin JL (2010) Origin and genetic diversity of mosquitofish (*Gambusia holbrooki*) introduced to Europe. Biol Invasions 12:841–851

Wacher T, Wronski T, Hammond RL et al (2010) Phylogenetic analysis of mitochondrial DNA sequences reveals polyphyly in the goitred gazelle (*Gazella subgutturosa*). Conserv Genet 12(3):827–831. https://doi.org/10.1007/s10592-010-0169-6

Wielstra B, Bozkurt E, Olgun K (2015) The distribution and taxonomy of *Lissotriton* newts in Turkey (Amphibia, Salamandridae). ZooKeys 484:11–23

Wilson DE, Lacher TE, Mittermeier RA (eds) (2017) Handbook of the mammals of the world, vol 7. Rodents II, Lynx Edicions, Barcelona, 1008 p

Wilson DE, Mittermeier RA (eds.) (2018) Handbook of the Mammals of the World, vol. 8: Insectivores, Sloths and Colugos, Lynx Edicions, Barcelona, 710 pp.

www.amphibia-web.com. Accessed 09 Jan 2019

www.reptile-database.org. Accessed 09 Jan 2019

www.vipersgard.en.at. Accessed 09 Jan 2019

Yalçın Özdilek Ş (2007) Possible threat for Middle East inland water: an exotic and invasive species, *Pterygoplichthys disjunctivus* (Weber, 1991) in Asi River, Turkey (Pisces: Loricariidae). J Fish Aquat Sci 24:303-306

Yoğurtçuoğlu B, Ekmekçi FG (2018) First record of the giant pangasius, *Pangasius sanitwongsei* (Actinopterygi: Siluriformes: Pangaiidae), from Central Anatolia, Turkey. Acta Ichthyol Piscat 48(3):241–244

Yoğurtçuoğlu B, Freyhof J (2018) *Aphanius irregularis*, a new killifish from south-western Anatolia (Cyprinodontiformes: Aphaniidae). Zootaxa 4410(2):319–330

Yoğurtçuoğlu B, Ekmekçi FG, Bektaş Y, Aksu İ et al (2018) First record of *Garra kemali* (Teleostei, Cyprinidae) from Black Sea Basin with a re-description of the species. Ichthyol Explore Fres 1083:1–8

Yücel N, Sakalli A, Karahan A (2017) First record of the honeycomb stingray *Himantura leoparda* (Manjaji- Matsumoto & Last, 2008) (Myliobatoidei: Dasyatidae) in the Mediterranean Sea, confirmed by DNA barcoding. J Appl Ichthyol 33(3):530–532

Zenetos A, Çinar ME, Crocetta F et al (2017) Uncertainties and validation of alien species catalogues: the Mediterranean as an example. Estuar Coast Shelf Sci 191:171–187

Chapter 11
Medicinal Plants of Northeast Anatolia

Salih Terzioğlu and Kamil Coşkunçelebi

11.1 Introduction

Medicinal plants are accepted as a local heritage with global importance. They play an important role in the lives of rural people, particularly in remote parts of the countries with few modern health facilities (Prajapati et al. 2003). The variety and a sheer number of plants with therapeutic properties are quite astonishing. It is estimated that around 70,000 plant species from lichens to flowering plants have been used at one time or another for medicinal purposes as a cornerstone of healthcare since recorded time (Prajapati et al. 2003; Ozturk et al. 2016, 2017a, b, 2018a, b, c, d). In the early years of the twenty-first century, an urgency to explore these traditional remedies to meet patient needs all over the world has come to the forefront. In addition to this an increasing interest in the wild edible plants, even in modern societies, has led to large numbers of ethnobotanical studies.

Turkey is rich in natural plant resources and plant diversity. The latest data indicates that there are 9966 species (3035 of which were endemic to Turkey) of vascular plants distributed in the country (Güner et al. 2012). Due to cultural diversity and the richness of the flora, there is a great accumulation of knowledge of traditional medicine in Anatolia; however, this knowledge is rapidly getting lost with the modernization of society, especially with the development of road communication together with the migration of people from villages to cities (Sezik et al. 1991). One of the first written sources in this country regarding the use of medicinal plants is by Dioscorides who wrote the monumental book of *De Materia Medica* (Altundağ and Ozturk 2011). It states that he used over 600 herbal drugs. Thus, this monumental

S. Terzioğlu (✉)
Faculty of Forestry, Department of Forest Botany, Karadeniz Technical University, Trabzon, Turkey
e-mail: sterzi@ktu.edu.tr

K. Coşkunçelebi
Faculty of Science, Department of Biology, Karadeniz Technical University, Trabzon, Turkey

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_11

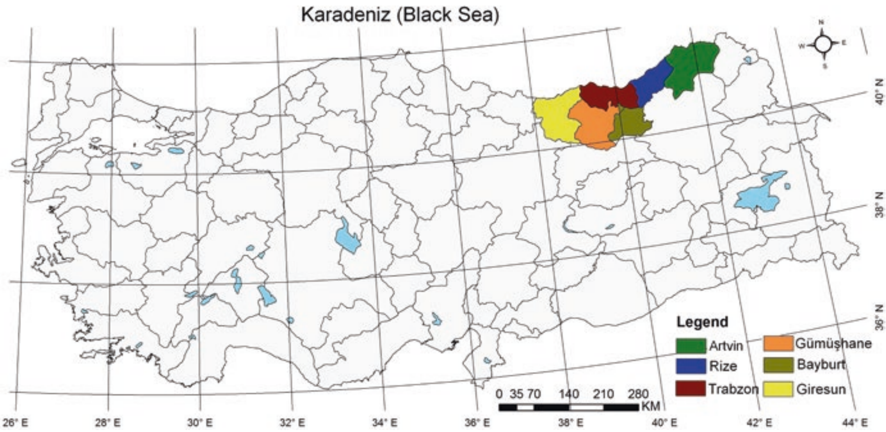


Fig. 11.1 Map of Turkey with Northeast Anatolian area highlighted. (Adapted from Avcı 2014)

book may be assumed to be the oldest comprehensive document on folk medicine of Turkey. A more recent comprehensive document on Anatolian folk medicine has been published by Baytop (1999). Following these many researchers have examined the use of medicinal plants, for example for culinary purposes (Ertuğ 2003; Altay and Çelik 2011; Kaval et al. 2015; Doğan et al. 2016; Altay and Karahan 2017), for the treatment of different diseases (Gürbüz et al. 2003; Sezik et al. 1997; Uğurlu 2011; Erbay et al. 2016) and for variety of applications in general (Kandemir and Beyazoğlu 2002; Altay and Karahan 2012; Altay et al. 2015). There are also a lot of ethnographic studies related to different applications of plants in the everyday life in Turkey (Ertuğ 2014). However, most of the ethnobotanical studies (66.3%) performed in the country are related to using local plants as medicine and culinary purposes. These are restricted to particular localities. In view of this, there is no comprehensive comparative study in Turkey (Ertuğ 2014). There are about 134 research papers, and 20 of theses in terms of ethnobotany cover North Anatolia (Ertuğ 2014); however, only 12 are restricted to NE Anatolia. Trabzon is among the most investigated provinces in terms of ethnobotany (Ertuğ 2014). However, no comprehensive study on medicinal plants of Northeast Anatolia has been published which constitutes the provinces of Artvin, Rize, Trabzon, Gümüşhane, Bayburt and Giresun from east to west (Fig. 11.1).

The objective of this chapter is to summarise the scientific information and scientific and/or local usages of medicinal vascular plant taxa distributed in Northeast Anatolia available till now. It includes medicinal native plants together with the cultivated and naturalized ones whose origin lies in other parts of the world, especially Asia and America. Such reviews will serve as the core reference work for both interests of healthcare people. It will also enlighten the public insights into traditional medicinal uses of plants and provide information for the growing natural drug discovery studies. This review will also present an illustrative overview of some selected plants used as folk medicine in our study area (Figs. 11.2, 11.3 and 11.4).

Fig. 11.2 Medicinal plant taxa: **1** *Satureja spicigera*, **2** *Stachys macrantha*, **3** *Mentha aquatica*, **4** *Thymus praecox*, **5** *Anemone narcissiflora*, **6** *Caltha palustris*

Fig. 11.3 Medicinal plant taxa: **7** *Galanthus woronowii*, **8** *Allium scorodoprassum*, **9** *Ruscus colchicus*, **10** *Colchicum speciosum*, **11** *Alcea hohenackeri*, **12** *Iris pseudacorus*

Fig. 11.4 Medicinal plant taxa: **13** *Papaver lateritium* (endemic to Turkey), **14** *Laurocerasus officinalis*, **15** *Vaccinium arctostaphylos*, **16** *Rhododendron caucasicum*, **17** *Cyclamen coum*, **18** *Primula algida*

11.2 Northeast Anatolia (Turkey)

11.2.1 Topography

The national territory of Turkey covers an area of 814.578 km^2 (Avcı 2014), but the northeast Anatolia covers an area of 43,301 km^2 (Şengül and Kaya 2017). According to Eyüboğlu et al. (2006), the eastern Black Sea mountain belt, which has a length of about 600 km and width of 200 km, can be divided, from north to south, into the northern, southern and axial subzones based on different rock associations, facies changes and tectonic characteristics. It generally has very rugged topography, and we see great changes in altitude within short distances. Elevations differ between the mountains and river valleys and tectonic basins are great. Mountain ranges line steeply along the coast of Black Sea throughout most of the northeast Anatolian section. Ranges are rising at many points over 3000 m. The highest peaks are Kaçkar Mountain (3932 m), Verçenik Mountain (3709 m), Demirkapı Mountain (3376 m), Soğanlı Mountain (3050 m) and Zigana Mountain (2300 m) (Avcı and Avcı 2014). Most of the rocks are basic igneous, but many of the jagged highest peaks are granite. The rivers cleave their way through deep gorges to the sea. The main mother rocks of the inner part of the region are again basic igneous rocks, but some limestone areas also occur.

11.2.2 Climate

The oceanic climate prevails in the north Anatolian region bordering the Black Sea, which receives the greatest amount of rainfall (Akman and Ketenoğlu 1986). Geological and topographic structures are among the main factors affecting the diversity of species in northeast Anatolia. While the mountain ranges running parallel to the Black Sea region of Turkey create a barrier for rain clouds moving inland, they cause abundant rainfall on the mountain slopes facing the coast of this region. The most outstanding feature here is its ample rainfall, which lasts all year round. It receives the greatest amount of rainfall in Turkey. Mainly the eastern part receives 2200 millimetres rain annually and is the only region of Turkey that receives rainfall throughout the year (Şensoy and Demircan 2016). The climatic conditions vary greatly from the north to the south and the southeastern sections of this region. Humid-perhumid climatic conditions prevail in the Eastern Black Sea, whereas continental cold and semiarid-subhumid climates dominate in the south and southeastern parts of the region.

11.2.3 Flora and Vegetation

Northeast Anatolia is rich in different ecosystems and habitats, with unique vascular plant diversity. The region also is called as Colchis sector of Euxine Province, which bounds Euro-Siberian floristic area in Turkey (Davis 1965; Ozturk et al. 1997, 1998). The mountainous region starts just from the sea coast in the north, ascending to the summit of northeastern Black Sea Mountains in the south, up to 3932 m. Lower belt of the region is mainly dominated by both agricultural and sporadic human settlements for which broad-leaved forests, coastal dunes and pseudo-maquis vegetation types have been destroyed. In patches, coastal dune vegetation extends all along the Black Sea coast. This vegetation is extremely destroyed by road construction and is poor in medicinal plant taxa. Pseudo-maquis vegetation covers the lower altitudinal patches along the Black Sea, starting from sea level to 300 (–400) m. This vegetation is mainly dominated by shrubby taxa both of Euro-Siberian and Mediterranean elements. Towards higher altitudes, broad-leaved deciduous forests, mixed deciduous-conifer forests and pure conifer forests, respectively, reach up to treeline (nearly 2000 m or more). These humid-cold forests on the north faces of the Black Sea Mountains are mainly composed of *Castanea sativa*, *Carpinus betulus*, *Fagus orientalis*, *Picea orientalis*, *Abies nordmanniana* and *Pinus sylvestris*. The most common understory of the forest vegetation is *Rhododendron ponticum, Rhododendron luteum, Vaccinium arctostaphylos, Rubus* spp. and *Corylus avellana.* Along the streams, *Alnus glutinosa* and *Salix alba* are the main tree species together with some shrubby taxa such as *Staphylea pinnata* and naturalized *Buddleja davidii*. The upper parts of the north-facing slopes of the mountainous areas are very rich in terms of plant taxa and are included among the Alpine vegetation. Herbaceous plants such as *Agrostis* spp., *Festuca* spp., *Sibbaldia parviflora*, *Alchemilla* spp., *Polygonum bistorta* subsp. *carneum* and *Stachys macrantha* are dominant together with low shrubs such as *Rhododendron caucasicum*, *Vaccinium myrtillus* and *Juniperus communis*, which are dense in patches. At lower altitudes, the vegetation above the treeline is remarkable with sub-alpine species such as *Anemone narcissiflora* and *Aconitum nasutum* mixed with shrubby species.

Dwellings and agricultural fields mainly occupy the lower altitudes of the region which form a narrow line restricted to the Black Sea in the North. In this belt *Camellia sinensis*, *Corylus maxima*, *Citrus reticulata* and *Actinida chinensis* plantations are dominant, and these lands are poor in terms of native medicinal plants. However, there are many native taxa used for medicinal (*Ruscus colchicus*, *Viburnum orientale*, *Hedera colchica*) as well as food purposes (*Trachystemon orientalis*, *Urtica dioica*, *Mespilus germanica*) in these areas. During the last few decades, agricultural activities have decreased to a minimum level due to the migration from villages to the urbanised areas. However, the construction of buildings for housing purposes has continued, and all these have occupied the habitats of medicinal plants.

Towards upper sites, mixed deciduous and/or conifer forests and pure conifer forests are commonly distributed up to subalpine zones of this part of Northeast Anatolia. In this zone, there are several plant species which have been used traditionally for medicinal purposes (*Valeriana alliarifolia*, *Cyclamen coum*), as aromatics (*Satureja spicigera*), as food (*Urtica dioica*, *Vaccinium arctostaphylos*, *Laurocerasus officinalis*), and for ornamental purposes (*Paeonia mascula*, *Rhododendron ponticum*). Above the treeline, subalpine habitats are noteworthy and dominated by *Anemone narcissiflora*, *Veratrum album*, *Aconitum nasutum* and shrubby *Betula litwinowii* which are used for different purposes by villagers. Alpine zone is the richest zone in terms of plant diversity of northeast Anatolia. In this zone, the herbaceous plants (*Polygonum bistorta*, *Alchemilla pseudocartalinica*, *Thymus praecox*, *Cota tinctoria*, *Solidago virgaurea*) are dominant, and groups of low shrubs (*Rhododendron caucasicum*, *Juniperus communis*, *Vaccinium myrtillus*, *Daphne oleoides*) are in patches. This vegetation is also the richest zone of the region in terms of medicinal plants. Together with other functions in these ecosystems, these plants supply different benefits to local people such as medicine and food. Many of the taxa are listed as ethnobotanical plants by the researchers, but none were studied scientifically.

11.3 Medicinal Plants

Medicinal plants have curative properties due to the presence of various complex chemical substances of different composition, which are found as secondary plant metabolites in one or more parts of these plants (Prajapati et al. 2003; Ozturk and Hakeem 2018, 2019a, b). Discovery of new leading molecules to be used for the health of mankind has been a crucial issue in both the past and present and will be in the future too. During the past five decades the pharmaceutical industries are making huge investments on pharmacological, clinical and chemical researches globally (Prajapati et al. 2003). In order to evaluate such molecules, it is logical to give priority to the folk remedies in which the local plants are and have been used in traditional medicine. Nearly 80% of the world population uses mainly medicinal plants to cure illnesses and ailments (UICN et al. 1993). The role of medicinal plants in the maintenance of human health and treatment of diseases as therapeutic alternatives throughout the world is progressing at a fast speed (WHO 2002). Nowadays plants are an important source of current drugs, and about 25% of the drugs prescribed worldwide come from medicinal plants (Rates 2001). Almost 17,810 plant species are used as medicine, 5538 plant species as human food, and 2503 plant species are regarded as poisonous (RBG Kew 2017). More than 120 compounds from 90 plant species are available as prescription drugs (Calixto 2005) at present.

There have been quite a large number of traditional remedies used to treat various diseases and disorders in Anatolia for thousands of years. However, due to the globalization trend, traditional knowledge, including the use of medicinal plants, has vanished for some time. These have been replaced by the use of synthetic and artificial products, which are on the rise. At the same time indigenous plant species are replaced with introduced ones which push the local plants used traditionally.

The number of scientific studies on Turkish traditional medicine is very poor. According to Baytop (1999), the number of plant species used in Turkey as folk remedies is around 1500; however, the estimated number is far more than that presented in the monumental book (Ozturk et al. 2012a, b).

During the past decade, a dramatic increase in export of medicinal plants attests to worldwide interest in these products. A total of 36 million hectares of medicinal and aromatic plants are cultivated worldwide, and the income from aromatic plant trade has been about 50 billion dollars in the year of 2000 and 180 billion dollars in 2016 (Temel et al. 2018). Turkey has considerable export potential for medical and aromatic herbs; however, the exact number and amount of exported herbs are not clear.

According to Koyuncu (1990) and Güneş and Özhatay (2011), there are 500 medicinal herbs in Turkey, whereas Başer (2000) reports that 1000 herbs are used for medical purposes. Başer (2000) has also reported that nearly 70–100 medicinal and aromatic herbs are in the list of exported plant sources of Turkey. The foreign trade of medicinal and aromatic plants in Turkey during 2015 has been shown with an export value of 280 million dollars and import of 254 million dollars (Temel et al. 2018). Özhatay et al. (1997) have reported that 350 medicinal plants are sold in the herbal list of Turkey. Contrary to this Özgüven et al. (2005) have reported that 347 medicinal and aromatic herbs are in the list of domestic trade and foreign trade. This corresponds to approximately 2.9% of the flora of Turkey, which is low, relative to the global average of 17.1% (Akbulut and Bayramoğlu 2013). These contradictions result from the lack of regular records for the trade of medicinal and aromatic herbs in Turkey.

The strategic position of the northeast Anatolia has aided in the development of a rich amount of knowledge concerning medicinal and edible plant species (Şekercioğlu et al. 2006). Wild edible plant species appear in the early and late spring and are consumed as vegetable sources in the region under question (Saraç et al. 2013; Özbucak et al. 2007). Northeast Anatolia is poor in folk medicine in spite of its rich flora, partly because of economically important tea and hazelnut cultivation (Sezik et al. 1991). However, the region also hosts a remarkable amount of vascular plants used for several purposes such as medicinal, food and aromatic (Terzioğlu et al. 2015). According to Bayramaoğlu et al. (2009), 284 medicinal plants are sold in the herbal list located in the northeast Black Sea area of Turkey.

North Anatolia known as Black Sea region is divided into three sections based on climatic and topographic conditions such as the west, middle and northeast. Out of these the northeast includes the cities of Artvin, Rize, Trabzon, Bayburt, Gümüşhane and Giresun. This part of Turkey is also named as Euro-Siberian region which represents the Euxine province from the phytogeographical point of view. Furthermore, NE Anatolian part of the province is named as Colchis sector (Davis 1971). It shows different characteristics of topography, socio-economic welfare and ethnicity when compared to the other two parts of the Black Sea region. According to Anşin (1981) 25% of plant species distributed in Turkey are recorded from northeast Anatolia. Terzioğlu et al. (2015) has reported that northeast Anatolia hosts more than 3200 vascular plant taxa of which 465 are endemic to Turkey. Literature survey shows

Table 11.1 Some important data of provinces compiled from the literature

	Artvin	Rize	Trabzon	Gümüşhane	Bayburt	Giresun
Population	174.010	348.608	807.903	162.748	82.274	453.912
Area (km^2)	7393	3835	4628	6668	3746	7025
Vascular plant taxa	2623[a]	1430[c]	1373[b]	2569[a]	539	2091[a]
Endemics	198[a]	110[c]	127[b]	326[a]	60[a]	177[a]
Medicinal	408	304	392	420	118	355

[a]Anonymous (2014–2017)
[b]Terzioğlu (1999)
[c]Güner et al. (1987)

that 501 vascular plant taxa, 10 of which are endemic to Turkey are distributed in NE Anatolia (Appendix 11.1).

The floristic composition and some other useful information related to northeast Anatolia as pooled up from the published material is presented in Table 11.1.

Literature survey shows that Artvin and Gümüşhane have the highest number of medicinal plant taxa among the cities of northeast Anatolia (Table 11.1); however, no comprehensive ethnobotanical study has been undertaken in these cities. The folk medicine in the northwest (Yeşilada et al. 1999) and middle sections (Türkan et al. 2006; Fujita et al. 1995; Sezik et al. 1992) has been published earlier. In addition, many papers related to the medicinal use and ethnobotanical aspects of plants distributed in the northeast section, and a selected list is given here in alphabetical order: Alpınar (1979), Akbulut and Özkan (2014), Arslan (2005), Cansaran and Kaya (2010), Çubukçu and Melikoğlu (1999), Ezer and Mumcu Arısan (2006), Fujita et al. (1995), Kandemir and Beyazoğlu (2002), Karaköse and Çolak Karaköse (2017), Polat et al. (2015), Sağıroğlu et al. (2012), Yazıcıoğlu and Tuzlacı (1995) and Yazıcıoğlu and Tuzlacı (1996). Most of these are related to medicinal and aromatic plants used in the northeast section of Turkey. According to Yeşilyurt et al. (2017), among the 150 wild plants used in total, 106 were documented to be used in the treatment of disorders of respiratory, dermatological, gastrointestinal, endocrine and urinary problems in this region of Turkey. However, we found that 510 medicinal plant taxa belonging to 103 families which are distributed in the northeast Anatolia (Appendix 11.1).

The distribution of medicinal plant taxa on the family basis is summarised in Table 11.2. The majority of the plant species here belong to Asteraceae (10.58%), Lamiaceae (8.23%), Apiaceae (7.84%), Rosaceae (6.66%) and Fabaceae (6.90%). The rest of the families consist of 315 medicinal plants.

In NE Anatolia, there are lots of cultivated or naturalized plants which are also used for medicinal purposes (Table 11.3).

Our survey also shows that leaves (27.50%), fruits (14.37%), roots (13.77%), flowers (10.77%) and seeds (5.98%) are the most commonly used part of plants for medicinal purpose in this region (Table 11.4).

Table 11.2 Distribution of the medicinal plant taxa determined on the basis of families

Family	No. of taxa	Percentages (%)	Family	No. of taxa	Percentages (%)
Asteraceae	54	10.58	Betulaceae	6	1.17
Lamiaceae	42	8.23	Caryophyllaceae	6	1.17
Apiaceae	40	7.84	Crassulaceae	6	1.17
Rosaceae	34	6.66	Poaceae	6	1.17
Fabaceae	25	6.90	Papaveraceae	6	1.17
Brassicaceae	19	3.72	Apocynaceae	5	0.98
Ranunculaceae	16	3.13	Caprifoliaceae	5	0.98
Ericaceae	13	2.54	Malvaceae	5	0.98
Polygonaceae	11	2.15	Asparagaceae	5	0.98
Plantaginaceae	10	1.96	Cupressaceae	5	0.98
Boraginaceae	9	1.76	Amaranthaceae	5	0.98
Primulaceae	9	1.76	Hypericaceae	5	0.98
Euphorbiaceae	8	1.56	Nitrariaceae	5	0.98
Solanaceae	8	1.56	Amaryllidaceae	5	0.98

According to Toksoy et al. (2010), 50 plant species including 14 endemics were sold in the herbal market in NE Anatolia, and the average annual income from these was about 33,333 dollars. Trabzon has a major position in the trade of medicinal plants in Turkey. Additionally, beekeeping is an important income source for local people. Anzer honey and mad honey known as "deli bal" are among the famous honey in this region as well as throughout Turkey and worldwide (Ozturk et al. 2010, 2014). Mad honey is produced from the nectar of the *Rhododendron ponticum* or *R. luteum*, which contain grayanotoxin, a poisonous compound occurring in mad honey (Gündüz et al. 2011; Gündüz 2015); however, Gündüz et al. (2012) have also reported that grayanotoxin is not directly responsible for mad honey poisoning-associated seizures from a clinical point of view. According to Çakıcı (2017) mad honey will be useful if its consumption does not exceed one teaspoon. Generally, some local beekeepers sell their natural unprocessed mad honey in local and regional markets as a folk medicine against bowel disorders, diabetes, gastric pains and high blood pressure and more commonly for its aphrodisiac effects (Gami and Dhakal 2017). However, people can still suffer from mad honey poisoning, especially in northeast Turkey or the Black Sea region of Turkey on the whole. Some of the symptoms exhibited by people who consume pure mad hone are nausea, vomiting, dizziness, confusion, low blood pressure and low heart rate (Demir Akca and Kahveci 2012). Images of some medicinal plants distributed in NE Anatolia are presented in Figs. 11.2, 11.3 and 11.4.

Table 11.3 Cultivated/naturalized plant taxa used for medicinal purposes in northeast Anatolia

Family	Plant taxa	Local name	Part(s) used
Amaranthaceae	*Spinachia oleracea* L.	Ispanak	Leaf
Amaryllidaceae	*Allium cepa* L.	Soğan	Bulb, seed
Amaryllidaceae	*Allium sativum* L.	Sarımsak	Bulb
Apiaceae	*Coriandrum sativum*L.	Kişniş	Leaf, fruit, seed
Apiaceae	*Petroselinum crispum* (Mill.) A.W. Hill	Maydanoz	Aerial part
Asteraceae	*Lactuca sativa* L.	Marul	Aerial part
Betulaceae	*Corylus maxima* Mill.	Tombul Fındık	Leaf, seed
Brassicaceae	*Brassica oleracea* L.	Lahana	Whole plant
Commelinaceae	*Tradescantia fluminenesis* Vell.	Ak Telgrafçiçeği	Aerial parts
Cucurbitaceae	*Cucurbita maxima* Lam.	Helvacı Kabağı	Raw seed
Ebenaceae	*Diospyros kaki* Thunb.	Trabzon Hurması	Fruit
Fabaceae	*Phaseolus vulgaris* L.	Fasulye	Meyve
Fabaceae	*Robinia pseudoacacia* L.	Yalancı Akasya	Flower
Fabaceae	*Ulex europaeus* L.	Dikenli Katırtırnağı	Aerial parts
Lythraceae	*Punica granatum* L.	Nar	Flower, fruit
Moraceae	*Morus alba* L.	Akdut	Leaf
Moraceae	*Morus nigra* L.	Karadut	Leaf, stem and fruit
Moraceae	*Morus rubra* L.	Mordut	Fruit
Phytolaccaceae	*Phytolacca americana* L.	Şekerciboyası	Root, fruit
Poaceae	*Triticum aestivum* L.	Ekmeklik Buğday	Shoot
Poaceae	*Zea mays* L. subsp. *mays*	Mısır	Kernel and fiber
Rosaceae	*Cydonia oblonga* Mill.	Ayva	Seed, leaf
Rosaceae	*Eriobotrya japonica* L.	Yeni Dünya	Leaf, flower
Rutaceae	*Citrus limon* (L.) Burm. f	Limon	Fruit
Rutaceae	*Citrus sinensis* (L.) Osbeck	Portakal	Leaf
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Kokar Ağaç	Leaf
Vitaceae	*Vitis vinifera* L.	Asma	Fruit, leaf

Table 11.4 The most commonly used parts of medicinal plants in northeast Anatolia

Plant part(s) used	Number of plant species	Percentage (%)	Plant part(s) used	Number of plant species	Percentage (%)
Leaf	139	27.25	Rhizome	10	1.96
Fruit	72	14.11	Tuber	9	1.76
Root	72	14.11	Bulb	7	1.37
Flower	57	11.17	Shoot	5	0.98
Seed	30	5.88	Foliage	4	0.78
Whole plant	26	5.09	Petiole	2	0.39
Bark	25	4.90	Wood	2	0.39
Aerial part	18	3.52	Tar	2	0.39
Stem	11	2.15	Arillus	1	0.19

Appendix 11.1: Vascular Medicinal Plants Distributed in Northeast Anatolia According to Literature Survey

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Aceraceae	***Acer campestre*** L. subsp. ***campestre***	Ova akçaağacı	Bark	Inflamed wound (56)
Aceraceae	***Acer monpessulanum*** L.	Fransız akçaağacı	Leaf	Antihelmintic (87), food pain (93)
Aceraceae	***Acer platanoides*** L.	Çınar akçaağacı	Leaf, flower	Gingival diseases (68), astringent, diarrhoea (75)
Adoxaceae	***Sambucus ebulus*** L.	Mürver otu	Aerial parts	Laxative, diuretic, diaphoretic (4), colds (42), rheumatic pain (84), diarrhoea, intestines (109)
Adoxaceae	***Sambucus nigra*** L.	Ağaç mürver	Leaf, flower	Abscess, asthma (2), diuretic, diaphoretic, laxative (4), antitussive (30), bronchitis (30,86), anticatarrhal (79), common colds (86), fungal itches, eczema (111)
Adoxaceae	***Viburnum lantana*** L.	Germeşe	Fruit	Diabetes, diarrhoea (2), blood pressure, cold, hypertension, inflammation (110)
Adoxaceae	***Viburnum opulus*** L.	Gilaburu	Fruit	Diuretic, sedative, laxative (1,4), antitussive, nephralgia (2), cough, heart (109)
Adoxaceae	***Viburnum orientale*** Pall.	Katkat çalısı	Fruit	Antibacterial (119), diuretic (119,121)
Alismataceae	***Alisma plantago-aquatica*** L. subsp. ***plantago-aquatica***	Çobandüdüğü	Root, seed	Constipation, diuretic (4)
Amaranthaceae	***Amaranthus retroflexus*** L.	Tilkikuyruğu	Leaf	Sterility (2), digestive, stomachache, diarrhoea (55)
Amaranthaceae	***Beta trigyna*** Waldst. & Kit.	Kır pazısı	Flowering branch	Asthma, bronchitis (66)
Amaranthaceae	***Chenopodium album*** L.	Aksirken	Aerial parts	Diuretic (2,4), laxative (4), women' sterility (2,74), anaemia (74)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Amaranthaceae	***Chenopodium foliosum*** Asch.	Cülek	Seed	Jaundice (93)
Amaranthaceae	*****Spinachia oleracea*** L.	Ispanak	Leaf	Diuretic, laxative (4), wound (27)
Amaryllidaceae	*****Allium cepa*** L.	Soğan	Bulb, seed	Abscess, rheumatism (6), cicatrizant (6,103), otitis, anuria (30), whitlow (38), sprain, bruise, oedema, wound (100)
Amaryllidaceae	*****Allium ampeloprasum*** L.	Pırasa	Aerial parts	Sore throat (38)
Amaryllidaceae	*****Allium sativum*** L.	Sarımsak	Bulb	Antihypertensive (6), alopecia areata, appetizer, anthelmintic (30), influenza, headache (34), froncle (45), cold, flu (110), hypertension, taeniafuge, wound (123)
Amaryllidaceae	***Allium scorodoprassum*** L. subsp. ***rotundum*** (L.) Stearn	İt soğanı	Bulb, seed	Orexigenic, hypertension, anthelmintic, diuretic, antiseptic, goiter (2), hepatitis, tonic (46), antihypertensive, high cholesterol (103)
Amaryllidaceae	***Galanthus rizehensis*** Stearn	Rize kardeleni	Bulb	Alzheimer (61)
Amaryllidaceae	***Galanthus woronowii*** Losinsk.	Akçabardak	Bulb	Poliomyelitis (4,54)
Anacardiaceae	***Cotinus coggygria*** Scop.	Boyacı sumağı	Powdered wood	Anticancer (30), analgesic (49), stomachache, burns, swelling, goiter, diabetes, haemorrhoids, asthma, mushroom poisoning (82)
Anacardiaceae	***Pistacia terebinthus*** L.	Menengiç	Fruit	Antiseptic (1), colds, flu, urinary system, cough (2), diuretic (2,39), expectorant (30), stomachache (72,80,84), asthma (80)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Anacardiaceae	***Rhus coriaria*** L.	Sumak	Fruit, leaf	Antiseptic (2,4,39), constipant (4), liver diseases, diarrhoea, urinary system (6), ulcer, kidney stones (43)
Apiaceae	***Ammi visnaga*** (L.) Lam.	Hıltan	Fruit	Cough, kidney stones, intestinal diseases, dental diseases, atherosclerosis (3), diuretic (4), tonic, gingivitis, digestive, carminative, appetizer (113)
Apiaceae	****Anethum graveolens*** L.	Dereotu	Aerial parts	Gynaecological disorders, goiter, dyspepsia, kidney ailments, against hiccup (3), digestive (3,4,113), galactagogue, antihyperlipidemia, carminative, diabetes, infertility (113)
Apiaceae	*****Angelica sylvestris*** L. var. ***stenoptera*** Avé-Lall.	Kekire	Root	Antidiarrhoeal, sedative (1), asthma (4)
Apiaceae	***Anthriscus nemorosa*** (M. Bieb.) Spreng.	Peçek	Fruit	Digestive (3)
Apiaceae	***Apium nodiflorum*** (L.) Lag.	Bendik	Aerial parts	Appetizer, antihypertensive (3,74)
Apiaceae	***Bifora radians*** M. Bieb	Gısbana	Aerial parts	Digestive (3)
Apiaceae	***Bupleurum falcatum*** L.	Çataltavşan	Leaf, seed	Fever, dermal wound, Joint pain, inflammations (113)
Apiaceae	***Carum carvi*** L.	Kimyon	Fruit	Kidney stones (2), appetizer, digestive, aphrodisiac (3)
Apiaceae	***Caucalis platycarpos*** L.	Kavkal	Aerial parts, root	Hemorrhoids, rheumatism, wound, eczema (3)
Apiaceae	***Chaerophyllum bulbosum*** L.	Hondak	Rhizome, leaves	Appetizer, diabetes, high cholesterol, antihypertensive (3)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Apiaceae	***Conium maculatum*** L.	Baldıran	Fruit, aerial parts	Analgesic, sedative, aphrodisiac (1), rheumatism (3), analgesic (4)
Apiaceae	*****Coriandrum sativum***L.	Kişniş	Leaf, fruit, seed	Carminative (1), digestive (1,3), stomachic (1,30), dizziness (3), gastritis, ulcer (30)
Apiaceae	***Daucus carota*** L.	Yabani havuç	Whole plant	Carminative, antihelminthic (1), diuretic (1,4), diabetes (3), eye disorders (22)
Apiaceae	***Eryngium billardierei*** F. Delaroche	Hıyarok	Root, aerial parts	Wound, cold, sinusitis, haemorrhoids, toothache, aphrodisiac (3), bronchitis, stomachache (65), constipation (93)
Apiaceae	***Eryngium campestre*** L.	Kırsenet	Aerial parts, root	Antitussive, stomachic (1), diuretic, aphrodisiac (1,4), vulnerary, jaundice (2), leucemi (3)
Apiaceae	***Eryngium giganteum*** M. Bieb.	Boğadikeni	Aerial parts	Wound (3)
Apiaceae	***Eryngium maritimum*** L.	Kum boğadikeni	Aerial parts	Diuretic, antiscorbutic, cytotonic, urethritis remedy, stone inhibitor, aphrodisiac, expectorant, anthelmintic (74)
Apiaceae	***Ferulago cassia*** Boiss.	Şeytan kişnişi	Fruit	Eye diseases, increasing milk secretion (3)
Apiaceae	***Foeniculum vulgare*** Mill.	Rezene	Fruit, leaf, aerial parts	Carminative (1,30), insomnia, dyspepsia, bronchitis (3), abdominal pain (36), blood glucose (38), stomachache (65), analgesic, antispasmodic, rheumatism, lactation (117)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Apiaceae	***Heracleum antasiaticum*** Manden	Kamşam	Leaf	Wound (3)
Apiaceae	***Heracleum pastinacifolium*** K. Koch subsp. ***incanum*** (Boiss. & A.Huet) P.H. Davis	Kuru öğrek	Leaf	Rheumatism (3)
Apiaceae	***Laser trilobum***(L.) Borkh.	Kefe kimyonu	Fruit	Digestive, abdominal pain (3,84)
Apiaceae	***Oenanthe pimpinelloides*** L.	Deli maydanoz	Aerial parts	Burned, antihypertensive, analgesic (74)
Apiaceae	***Pastinaca sativa*** L.	Şeker havucu	Aerial parts	Diuretic, carminative, calmative (4)
Apiaceae	*****Petroselinum crispum*** (Mill.) A.W. Hill	Maydanoz	Aerial parts	Diabetes, anaemia, eczema, diuretic, haemorrhoids, cholesterol (3,66), stomach ailments (3,30)
Apiaceae	***Peucedanum longifolium*** Waldst. & Kit.	Domuz rezenesi	Aerial parts	Diabetes, hypercholesterolemia (2), menstrual, stomachic, diuretic, diaphoretic (4)
Apiaceae	***Pimpinella saxifraga*** L.	Taş anasonu	Root	Cicatrising, diuretic, antimicrobial, appetizer, anti-inflammatory, wound, ascites, urinary disorders, hernia, cough, anorexia (75)
Apiaceae	***Prangos ferulacea*** (L.) lindl.	Eşek cakşırı	Root, aerial parts	Aprodisiac, diabetes, antihypertensive (3)
Apiaceae	******Prangos meliocarpoides*** Boiss. var. ***arcis-romanae*** (Boiss. & Huet) Herrnst	Sultanteresi	Root	Aprodisiac (3)
Apiaceae	***Sanicula europaea*** L.	Sanikel	Leaf	Constipant, stomachic, wound (4), abdominal pain, shortness of breath (50), diarrhoea, urinary, liver disorders, internal bleeding (74)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (***Literatures*)
Apiaceae	***Scandix pecten-veneris*** L.	Zühretarağı	Aerial parts	Bad breath (3)
Apiaceae	***Smyrnium olusatrum*** L.	Deli kereviz	Root, leaf	Abortive (3), dyspnoea, diuretic (4)
Apiaceae	***Sison amomum*** L.	Kara maydanoz	Fruit	Diuretic, carminative, stomachic (4)
Apiaceae	***Torilis arvensis*** (Huds.) Link	Dercikotu	Aerial parts	Abdominal pain for children (3)
Apiaceae	***Torilis leptophylla*** (L.) Rchb.f.	İnce dercikotu	Leaf, aerial parts	Bad breath, asthma, toothache (3)
Apiaceae	***Turgenia latifolia*** (L.) Hoffm.	Karaheci	Aerial parts	Rheumatism (3)
Apiaceae	***Zosima absinthifolia*** (Vent.) Link	Peynirotu	Leaf	Diabetes (2), stomach ailments, restlessness, dysentery, diarrhoea, tonsilitis, loss of voice (115)
Apocynaceae	***Cynanchum acutum*** L. subsp. ***acutum***	Bacırgan	Root, leaf	Emetic (4), vulnerary (74)
Apocynaceae	***Periploca graeca*** L. var. ***graeca***	Gariplerurganı	Bark	Stimulant (4)
Apocynaceae	***Vinca major*** L. subsp. ***hirsuta*** (boiss.) Stearn	Pervane çiçeği	Leaf	Constipation, diuretic, antipyretic, appetizer (4), astringent, menstrual regulator, ulcer, sore throat (74)
Apocynaceae	***Vincetoxicum canescens*** (Willd.) Decne subsp. ***canescens***	Zilasur	Aerial parts	Scabies, fungal infection (2)
Apocynaceae	***Vincetoxicum tmoleum*** Boiss.	Hıyaluk	Aerial parts	Scabies (2)
Araceae	***Arum italicum*** Mill.	Domuz lahanası	Tuber, flower	Vesicant (1), laxative (1,4), haemorrhoids (4,56), wound (27), pain in the waist (48), women's diseases (56)
Araliacaee	***Hedera colchica*** (K.Koch) K.Koch	Kara sarmaşık	Leaf, fruit	Ddiaphoretic (4), laxative (4,91), intestinal parasites, constipation, diarrhoea (91)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures)
Araliacaee	***Hedera helix*** L.	Duvar sarmaşığı	Leaf, fruit	Vesicant (1), diaphoretic (4), laxative (4,90), wound (27), stomachache (50), menstrual regulator, anthelmintic, exudative (90)
Aristolochiaceae	***Aristolochia clematitis*** L.	Lohusaotu	Rhizome	Skin diseases (4), anti-inflammatory, antiseptic, analgesic, cytostatic, rheumatism, leucorrhoea, digestive (75), haemorrhoids (77)
Aristolochiaceae	***Asarum europaeum*** L.	Afşarotu	Root	Mucolytic, anti-inflammatory, laxative, emmenagogue (1), emetic, diuretic (1,4), expectorant (4,75), antitussive, sedative (75)
Asparagaceae	***Muscari neglectum*** Guss. ex Ten.	Arapüzümü	Fruit	Rheumatism (43), rheumatism (57)
Asparagaceae	***Ornithogalum sigmoideum*** Freyn & Sint.	Sakarca	Bulb	Appetizer, nerve tonic, laxative (5,57), stomachic (57)
Asparagaceae	***Polygonatum multiflorum*** (L.) All.	Mührüsüleyman	Root	Antidiarrhoeal, analgesic (1), antidiabetes (1,4), constipant, rheumatism, gout, aphrodisiach (4)
Asparagaceae	***Ruscus aculeatus*** L.	Tavşanmemesi	Root, leaf, stem	Diuretic, diaphoretic, stomachic (1), cholesterol (6), asthma, (30), varix (56)
Asparagaceae	***Ruscus colchicus*** Yeo	Zermek	Rhizome	Lactogenic (118)
Asparagaceae	***Scilla bifolia*** L.	Orman sümbülü	Bulbus	Wound, lumbago (100)
Aspleniaceae	***Asplenium adianthum-nigrum*** L.	Kara şaçakotu	Whole plant	Analgesic (49)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Aspleniaceae	***Asplenium ceterach*** L.	Dalakotu	Aerial parts	Diuretic, constipant (4), diarrhoea, cystitis, hemostatic (30), kidney stone (51)
Aspleniaceae	***Asplenium scolopendrium*** L.	Geyikdili	Aerial parts	Diuretic, constipation (4)
Asteraceae	***Achillea arabica*** Kotschy	Hanzabel	Flower	Diuretic, asthma, cardiotonic, stomachic, carminative, orexigenic, tonic, nephralgia (2)
Asteraceae	***Achillea millefolium*** L.	Civanperçemi	Aerial parts	Antidermatosic, anti haemorrhoids (1,6,88), diuretic (4,54), wound (11,76), antianemic (6,71), inflammation, wound (109)
Asteraceae	***Achillea santolinoides*** Lag. subsp. ***wilhelmsii*** (K.Koch) Greuter	Kardeşkınası	Aerial parts	Migraine, anorexia, gynaecological (68)
Asteraceae	***Antennaria dioica*** (L.) Gaertner	Kediayağı	Aerial parts	Constipant, cough (4), digestive (88)
Asteraceae	***Anthemis cretica*** L.	Dağ papatyası	Flower	Painkiller (49)
Asteraceae	***Arctium platylepis*** (Boiss. & Balansa) Sosn. ex Grossh.	Hanımyaması	Root, basal leaf	Edema, inflamed wound, calcification (knee), backache, snakebites (2)
Asteraceae	***Artemisia absinthium*** L.	Acı pelin	Flower, leaf	Antihaemorrhoidal (1), diuretic (2,4), stomachic (2,4,54,72,83), anti-hypertensive (6,88), malaria (17), wound (27), cold (43), diabetes (65), ulcer (71)
Asteraceae	***Bellis perennis*** L.	Koyungözü	Flowers	Purgative (2), stomachache, cold, bronchitis, tonsilitis, eye diseases (7,87), haemorrhoids (43), headache (97)
Asteraceae	****Bidens tripartita*** L.	Üç suketeni	Aerial parts	Anti-inflammatory, cicatrising, vermifuge, wound (75)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Asteraceae	***Carduus acanthoides*** L. subsp. ***sintenisii*** Kazmi	Saka dikeni	Flower	Gynaecological disease (50)
Asteraceae	***Cyanus segetum*** Hill.	Gelintacı	Flower	Nervine, stomachic (1), antidiarrhoeal (1,4), appetiser (4)
Asteraceae	***Cenaturea glastifolia*** L.	Kotankıran	Flower, leaf	Orexigenic, astringent (2)
Asteraceae	***Centaurea iberica*** Trev.	Deligözdikeni	Leaf	Vulnerary (2,74)
Asteraceae	***Cichorium intybus*** L.	Hindiba	Aerial parts	Nervine (1), diuretic, laxative, diaphoretic (1,4), asthma (2), icterus disease, galactagogue (14), stomachache, gastritis, ulcer (30,41), epistaxis, hyperlipidemia (93)
Asteraceae	***Cirsium arvense*** (L.) Scop.	Köygöçerten	Whole plant	Orexigenic, tonic, antihaemorrhoidal, cough, bronchitis (2), tonic, appetiser (4), diabetes (50)
Asteraceae	***Cirsium hypoleucum*** DC.	Vişne kangalı	Leaf	Cardio-vascular complaints (35)
Asteraceae	***Cota tinctoria*** (L.) J. Gay ex Guss.	Boyacı papatyası	Flower	Stomache pain, cough, intestinal disorders, hair care (2), gingivitis (36), gynaecological disease (50), cold, flu (103)
Asteraceae	***Crepis foetida*** L.	Kohum	Aerial part	Cardiovascular diseases (2,74)
Asteraceae	***Doronicum orientale*** Hoffm.	Kaplanotu	Aerial parts	Against infertility (4), diuretic (43)
Asteraceae	***Eupatorium cannabinum*** L.	Koyuntırpağı	Aerial parts	Diaphoretic, emetic (4), diuretic (4,60), choleretic, laxative, hypocholesterolemic (60)
Asteraceae	***Helichrysum pallasii*** (Spreng.) Ledeb.	Kocamançiçeği	Aerial parts	Diuretic, cough, kidney stones, nephralgia (2)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Asteraceae	***Helichrysum plicatum*** DC. subsp. ***plicatum***	Mantuvar	Aerial parts	Kidney stones, nephralgia, diabetes, cough, diarrhoea, diuretic, stomachic, antideppessant (2)
Asteraceae	***Inula helenium*** L.	Andızotu	Root	Nervine (1), diuretic, antitussive (1,2), anthelmintic, tonic, backache (2)
Asteraceae	***Jurinalle moschus*** (Habl.) Bobrov subsp. ***pinnatisecta*** (Boiss.) Danin & P.H.Davis	Yayla dedegülü	Aerial parts	Diabetes, diarrhoea (2)
Asteraceae	******Lactuca sativa**** L.	Marul	Aerial parts	Analgesic, galactagogue, diuretic (1), laxative (1,4)
Asteraceae	***Lactuca serriola*** L.	Eşekhelvası	Latex	Diuretic (4), itching, scabies, eczema (30), demulcent (39)
Asteraceae	***Lapsana communis*** L.	Şebrek	Leaf	Vulnerary (4,81)
Asteraceae	***Petasites albus*** (l.) P. Gaertn.	Lapaza çiçeği	Rhizome	Expectorant, wound (121)
Asteraceae	***Petasites hybridus*** (L.) P. Gaertn.	Kabalak	Leaf	Diuretic, diaphoretic, constipation (4), analgesic, aphthae (56)
Asteraceae	***Pulicaria dysenterica*** (L.) Bernh.	Yaraotu	Root, leaf	Constipation, diuretic, dysentery (4)
Asteraceae	***Scorzonera cana*** (C.A.Mey.) Griseb. var. ***cana***	Tekesakalı	Latex	Backache (72)
Asteraceae	***Scorzonera latifolia*** (Fish. & C.A.Mey) DC.	Dağsakızı	Root	Analgesic (1,65), backache, sterility (2)
Asteraceae	***Senecio vernalis*** Waldst. & Kit.	Kanaryaotu	Aerial parts	Anti-inflammatory (2), emmenagogue, menstrual regulator (30), menstrual pain (72)
Asteraceae	***Senecio vulgaris*** L.	Taşakcılotu	Whole plant	Expectorant (4)
Asteraceae	***Solidago virgaurea*** L.	Altıbnaşak çiçeği	Flower	Diuretic, carminative, antiseptic (4), inflammation (50)
Asteraceae	***Sonchus oleraceus*** L.	Kuzugevreği	Leaf	Galactagogue, tonic, diuretic, antipyretic (4)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Asteraceae	***Tanacetum balsamita*** L.	Gümüşdüğme	Aerial parts	Tonic, stimulant, antipyretic, headache, diuretic, stomachic, gall bladder, vulnerary, abscess (2)
Asteraceae	***Tanacetum coccineum*** (Willd.) Grierson	Pireotu	Aerial parts	Against parasites (4)
Asteraceae	***Tanacetum parthenium*** (L.) Sch. Bip.	Beyaz papatya	Flower, leaves	Tonic, stimulant, antipyretic, headache, diuretic, stomachic, gall stone (2,74), antipyretic (4)
Asteraceae	***Tanacetum polycephalum*** Sch. Bip	Yedi pireotu	Flower	Pulmonic disorders, colds, antipyretic, anti-inflammatory (2)
Asteraceae	***Taraxacum bithynicum*** DC.	Zincirotu	Flower, leaf	Stomachache, toothache (72)
Asteraceae	***Taraxacum stevenii*** DC.	Gelingöbeği	Latex	Eye diseases (2), liver fat, appetizer (71)
Asteraceae	***Tragopogon buphthalmoides*** (DC.) Boiss. var. ***buphthalmoides***	Tarla yemliği	Aeria parts	Stomach and intestinal disorders (2), constipation, warts (93)
Asteraceae	***Tragopogon coloratus*** C.A.Mey.	Katır yemliği	Aerial parts	Stomach ache (2)
Asteraceae	***Tragopogon porrifolius*** L. subsp. ***abbreviatus*** (Boiss.) Coşkunçelebi & M.Gültepe	Çayır yemliği	Aerial parts	Intestinal disorders, vulnerary (2)
Asteraceae	***Tragopogon pratensis*** L. subsp. ***orientalis*** (L.) Čelak.	Sarı salsifin	Aerial parts	Stomach ache (2)
Asteraceae	*******Tripleurospermum monticolum**** (Boiss. & A. Huet) Bornm.	Kırpapatyası	Flowers	Haircare, colds, cough, antipyretic, stomach ache (2)
Asteraceae	***Tripleurospermum sevanense*** (Manden.) Pobed.	Hanım gödesi	Flower	Haircare (2)
Asteraceae	***Tussilago farfara*** L.	Öksürükotu	Stem, petiole	Antitussive (1,2), cough (2,4,6,109), expectorant (2), asthma, bronchitis (6)
Asteraceae	***Xanthium spinosum*** L.	Pıtrak	Leaf	Diuretic, sedative, diaphoretic (1)
Asteraceae	***Xanthium strumarium*** L.	Koca pıtrak	Root	Alopecia, scurf (68), kidney pain (72)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Asteraceae	***Xeranthemum annuum*** L.	Kağıt çiçeği	Laeaf	Toothache (2), wart (36)
Balsaminaceae	***Impatiens noli-tangere*** L.	Kınaçiçeği	Aerial parts	Diuretic, laxative, emetic (4)
Berberidaceae	***Berberis vulgaris*** L.	Kızılkaramuk	Fruit	Colds, diabetes (2), appetizer, antipyretic (4)
Berberidaceae	***Epimedium pubigerum*** (DC.) C.Morren & Decne.	Tekeotu	Troot	Diaphoretic (4)
Betulaceae	***Alnus glutinosa*** (L.) Gaertner	Sakallı kızılağaç	Seed, stem, flower	Stomachdisorders (6), haemorrhoids (6,56,82), sore throat (27), diarrhoea (44), eczema (56,82), exudative (90)
Betulaceae	***Betula litwinowii*** Doluch.	Düzük	Leaf, bark	Cold, dandruff, hair loss, panacea, toothache (109)
Betulaceae	***Betula pendula*** Roth	Huş ağacı	Leaf	Diuretic, rheumatism pain (4), antibacterial for gout, antirheumatic, kidney stones (74)
Betulaceae	***Carpinus betulus*** L.	Gürgen	Leaf	Blood regulator, wound healing, astringent (4,104), cholesterol (8)
Betulaceae	***Corylus avellana*** L. var. ***avellana***	Fındık	Seed	Diuretic, aphrodisiac (4), cough, high cholesterol (6), anaemia (8)
Betulaceae	*****Corylus maxima*** Mill.	Tombul fındık	Leaf, seed	Aphrodisiac (4), diuretic (4,90), burn (7), aphrodisiac, tonic (90)
Boraginaceae	***Alkanna orientalis*** (L.) Boiss.	Sarı sormuk	Root, leaf, flower	Vulnerary, laxative, intestinal disorders (2), gynaecological (4)
Boraginaceae	***Anchusa azurea*** Mill. var. ***azurea***	Sığırdili	Root, basal leaf	Vulnerary, women' sterility (2), wound healing (6,84), hemostatic (30)
Boraginaceae	***Echium italicum*** L.	Kurtkuyruğu	Leaf, root	Wound, anti-inflammatory (2)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Boraginaceae	***Echium vulgare*** L. subsp. ***vulgare***	Engerekotu	Root	Vulnerary (2), diuretic, expectorant (4)
Boraginaceae	***Lithospermum arvense*** L.	Taşkesen	Fruit	Enuresis (56)
Boraginaceae	***Myosotis lazica*** Popov	Kuşgözü	Aerial parts	Dried and boiled for eyes (8)
Boraginaceae	***Rindera lanata*** (Lam.) Bunge var. ***lanata***	Yünlgelin	Root	Anti-inflammatory (2)
Boraginaceae	***Symphytum asperum*** Lepech.	Kaba kafesotu	Root	Cough (50)
Boraginaceae	***Trachystemon orientalis*** (L.) G. Don	Kaldirik, tomara	Stem, root	Diaphoretic, antipyretic (4), diuretic (4,5), digestive (6), intestinal, inflammation (8)
Brassicaceae	***Alliaria petiolata*** (Bieb.) Cavana & Grande	Sarımsak otu	Stem	Diuretic, diaphoretic (4), tension (64), expectorant, antiseptic, stimulant, antiasthmatic, expels worms (74), gingivitis, appetiser (76)
Brassicaceae	****Brassica oleracea*** L.	Lahana	Whole plant	Digestive, expectorant (4), meal (8)
Brassicaceae	***Bunias oriantalis*** L.	Çırşalgamı	Stem	Orexigenic (2)
Brassicaceae	***Cakile maritima*** Scop.	Kumteresi	Aerial parts	Diuretic, appetizer (4)
Brassicaceae	***Capsella bursa-pastoris*** (L.) Medik.	Çobançantası	Aerial parts	Kidney stones, astringent (2), diuretic (24), diabetes (7), intestine (8), hemostatic (30,111), Internal bleeding (111)
Brassicaceae	***Cardamine bulbifera*** (L.) Crantz	Dişlikök	Root	Constipant (4)
Brassicaceae	***Cardamine impatiens*** L.	Sultan kodimotu	Whole plant	Abdominal pain (53)
Brassicaceae	***Cardamine raphanifolia*** Pourr. subsp. ***acris*** (Griseb.) O.E:Schulz.	Çeykodim	Whole plant	Abdominal pain (53)
Brassicaceae	***Lepidium draba*** L.	Diğnik	Root	Sedative, anorexia, sleep disorder (68)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Brassicaceae	***Eruca vesicaria*** (L.) Cav.	Roka	Laeaf, seed	Cough, stimulant (4)
Brassicaceae	***Hesperis matronalis*** L. subsp. ***matronalis***	Akşamyıldızı	Aerial parts	Diuretic, diaphoretic, expectorant (4)
Brassicaceae	***Isatis tinctoria*** L.	Çivitotu	Flower, leaf	Antidiarrhoeal, antidermatosic (1), arthralgia (2), wound healing (2,4,90), constipant (4), laxative (90)
Brassicaceae	***Lepidium latifolium*** L.	Nujdar	Leaf	Vulnerary (2)
Brassicaceae	****Lepidium sativum*** L. subsp. ***sativum***	Tere	Fruit	Goiter (2)
Brassicaceae	***Nasturtium officinale*** R.Br.	Suteresi	Aerial parts	Nervine, nutritive, stomachic (1), diuretic (1,4), abdominal pain (28), sterility (43), kidney stone (73), appetizer, kidney gravels (111)
Brassicaceae	***Raphanus raphanistrum*** L. subsp. ***raphanistrum***	Eşek turpu	Aerial parts, roots	Orexigenic, diuretic (2), depilatory, weaken hairs (30)
Brassicaceae	***Sisymbrium officinale*** (L.) Scop.	Ergelen hardalı	Aerial parts	Diuretic, stimulant (4), expectorant (4,30)
Brassicaceae	*****Tchihatchewia isatidea*** Boiss.	Allıgelin	Root	Vulnerary (2)
Buxaceae	***Buxus sempervirens*** L. subsp. ***sempervirens***	Şimşir	Leaf, root bark	Diuretic, antipyretic, intestine (4), headache (97)
Campanulaceae	***Campanula glomerata*** L. subsp. ***hispida*** (Witasek) Hayek	Yumak çanı	Aerial parts	Internal medicine (74)
Campanulaceae	***Campanula rapunculus*** L.	Firenk salatası	Aerial parts	Constipant (4), wound (4,27)
Cannabaceae	***Celtis australis*** L.	Çitlenbik	Bark	Constipant (4), itching, scabies (30)
Cannabaceae	***Celtis planchoniana*** K.I.Chr.	Dahum	Fruit	Stomach ache (51)
Cannabaceae	***Humulus lupulus*** L.	Şerbetçiotu	Flower	Stomachic, diuretic (1), neuroleptic, insomnia, headache, migraine (71), digestive (83)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Capparaceae	***Capparis sicula*** Veill.	Delikarpuzu	Flowers, leaves	Anti-rheumatic (2), female infertility, deafness (15)
Caprifoliaceae	***Cephalaria gigantea*** (Ledeb.) Bobrov	Dev pelemir	Flower	Cold, uretic, menstruation regulator, rheumatism, lung diseases, cardiac diseases (64)
Caprifoliaceae	***Centranthus longiflorus*** Steven	Mahmuzçiçeği	Whole plant	Drug, sedative (4)
Caprifoliaceae	***Dipsacus laciniatus*** L.	Fesçitarağı	Stem, root	Vulnerary, astringent, cancer, diabetes (2)
Caprifoliaceae	***Scabiosa columbaria*** L.	Uyuzotu	Aerial parts	Constipant, diuretic, wound (4)
Caprifoliaceae	***Valeriana alliariifolia*** Adams	Pisot	Root	Sedative, antispasmodic, cardiostimulant (2), anti-parasite (10)
Caryophyllaceae	***Agrostemma githago*** L.	Buğday karamuğu	Seed	Anthelmintic, diuretic, expectorant (2,74)
Caryophyllaceae	***Gypsophila bicolor*** (Freyn. & Sint.) Grossh.	Alaca çöven	Rhizome	Diuretic, expectorate (4)
Caryophyllaceae	***Silene latifolia*** Poir. subsp. ***eriocalycinae*** (Boiss.) Greuter & Burdet	Gıcıme	Aerial parts	Eczema (2)
Caryophyllaceae	***Silene saxalitis*** Sims.	Simotu	Leaf	Vulnerary (2)
Caryophyllaceae	***Silene vulgaris*** (Moench.) Garcke var. ***vulgaris***	Gıcıgıcı	Aerial parts	Excretory or genitourinary system diseases (1,4)
Caryophyllaceae	***Stellaria media*** (L.) Vill.	Kuşotu	Aerial parts	Mucolytic (1), diuretic (1,4), wound (4), inflamed skin, itching eczema, psoriasis (74), headache (97)
Celastraceae	***Euonymus europaeus*** L.	İğcik ağacı	Seed, fruit	Diuretic, laxative (4), emetic (4,59), anti-ectoparasitic, anticancer, purgative (59)
Celastraceae	***Parnassia palustris*** L.	Yürekyaprağı	Aerial parts	Constipation, diuretic, tonic (4)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Cistaceae	***Cistus creticus*** L.	Laden	Flower, leaf	Constipant (4), stomachache, gastritis, ulcer, cystitis, acne (30), diabetes (36), urethra inflammation (41), diarrhoea (68), headache (97)
Cistaceae	***Cistus salviifolius*** L.	Kartli	Leaf	Sedative, expectorant (4), urethra inflammation and sterility (41), diabetes, hemostatic (94), rheumatic pain (96)
Cistaceae	***Helianthemum nummularium*** (L.) Mill.	Güngülü	Aerial parts	Constipant, blood coagulant (4)
Colchicaceae	***Colchicum speciosum*** Steven	Şepart	Whole plant	Germicide (53), rheumatic pain (96)
Commelinaceae	****Tradescantia fluminenesis*** Vell.	Ak Telgrafçiçeği	Aerial parts	Wound (27)
Convolvulaceae	***Calystegia sylvatica*** (kit.) Griseb.	Bürük	Leaf	Wound (6,104)
Convolvulaceae	***Convolvulus arvensis*** L.	Tarla sarmaşığı	Root, leaf	Laxative (1), stomachic (2,102), rheumatic pain, headache (72)
Convolvulaceae	***Cuscuta europaea*** L.	Bostanbozan	Aerial parts	Diuretic, laxative (4)
Cornaceae	***Cornus mas*** L.	Kızılcık	Fruit	Antidiarrhoeal (1,11,41), diarrhoea (2,47), diabetes (6), cold, bronchitis (9), sunstroke (66)
Crassulaceae	***Hylotelephium telephium*** (L.) H.Ohba	Mandakulağı	Leaf	Wound (2,4), constipation (4)
Crassulaceae	***Phedimus spurius*** (M. Bieb.)'t Hart	Al pisikulağı	Aerial parts	Wound (8)
Crassulaceae	***Prometheum sempervivoides*** (Fischer ex M.Bieb.) H.Ohba	Horozlelesi	Aerial parts	Piles, callus (68)
Crassulaceae	***Sedum acre*** L. subsp. ***acre***	Acı damkoruğu	Aerial parts	Diuretic, laxative (4)
Crassulaceae	***Sedum album*** L.	Çobankavurgası	Leaf	Wound (4,91)
Crassulaceae	***Sedum pallidum*** M. Bieb.	Koyunörmece	Leaf	Wound (38)
Crassulaceae	***Sempervivum* sp.**	Ömürçiçeği	Leaf	Earache (9)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Cucurbitaceae	***Bryonia alba*** L.	Akhaylin	Root	Diuretic, laxative, rheumatism pain, haemorrhoids (4)
Cucurbitaceae	****Cucurbita maxima*** Lam.	Helvacı kabağı	Raw seed	Prostate disorders, anti-helminthic (30)
Cucurbitaceae	***Ecballium elaterium*** (L.) A. Rch.	Eşek hıyarı	Fruit	Diuretic (1,2), sinusitis (2,6,30,43,101,102), haemorrhoids (30,36), hepatitis (43,56), anaemia (95)
Cupressaceae	***Juniperus communis*** L. var. ***saxatilis*** Pall.	Adi ardıç	Cone	Diaphoretic, antiseptic (1), diuretic (1,75), rheumatic pain (4,48), anti-inflammatory, antiseptic (75)
Cupressaceae	***Juniperus excelsa*** M.Bieb.	Boz ardıç	Cone	Antihaemorrhoidal (2), cough, diabetes, asthma (107), pneumonitis (111)
Cupressaceae	***Juniperus foetidissima*** willd.	Kokar ardıç	Cone	Stomach ache, diabetes, arthrosis (43), gastrointestinal pains (111)
Cupressaceae	***Juniperus oxycedrus*** L. subsp. ***oxycedrus***	Katran ardıcı	Cone	Scabies (4), cystitis (30), stomachache, ulcer (43), cold (43,74), asthma (43,77), bronchitis (43,84), antiparasitic (74), diabetes melitus (101)
Cupressaceae	***Juniperus sabina*** L.	Sabin ardıcı	Resin, cone, shoot	Expectorant, diuretic (4,110), wound (28), urinary system (53,110), detoxicant, gallbladder, prostate (110)
Cyperaceae	***Cyperus rotundus*** L.	Topalak	Root	Diuretic (2,4), expectorant, diphoretic, constipant (4)
Datiscaceae	***Datisca cannabina*** L.	Renkotu	Leaf, flower	Laxative, diuretic (91)
Dennstaedtiaceae	***Pteridium aquilinum*** (L.) Kuhn	Eğrelti	Root, aerial parts	Intestinal parasites (68), rheumatism (100)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Dioscoreaceae	***Dioscorea communis*** (L.) Caddick & Wilkin	Dolanbaç	Tuber	Diuretic, laxative, emetic (1,4), muscle joint pains, anti-diabetic (30)
Droceraceae	***Drocera rotundifolia*** L.	Güneşgülü	Aerial parts	Diuretic, diaphoretic, calmative (4)
Dryopteridaceae	***Dryopteris filix-mas*** (L.) Schott	Erkek eğrelti	Fronds	Intestinal parasites (4,50,74), stomachache (50),
Ebenaceae	*****Diospyros kaki*** Thunb.	Trabzon hurması	Fruit	Anemia (95), antioxidative, hypolipidemic, antidiabetic, antibacterial, cardiovascular disease, hemostasis, antibacterial, anti-inflammatory (108)
Ebenaceae	***Diospyros lotus*** L.	Hırnık	Fruit, leaf	Constipant (4,50), gastritis (50), hiccups, hiatal hernia, hypertension (74)
Elaeagnaceae	***Elaeagnus angustifolia*** L. var. ***angustifolia***	İğde	Flower, seed, leaf	Diarrhoea, constipant, sunstroke (2), aphrodisiac (56), kidney stone (84)
Elaeagnaceae	***Elaeagnus rhamnoides*** (L.) A. Nelson	Çıçırgan	Fruit	Cough (2), constipant, antiseptic (4)
Ephedraceae	***Ephedra major*** Host subsp. ***major***	Hum	Shoot, berry	Tooth cleaner, headache (2), diaphoretic, rheumatic pain (4)
Equisetaceae	***Equisetum fluviatile*** L.	Kırkbayır	Aerial parts	Antihypertensive, kidney disorders (65)
Equisetaceae	***Equisetum telmateia*** Ehrh.	Deredoruk	Whole plant	Urethra inflammation, constipant (4), diuretic (4,79), kidney stones (42), prostatic hypertrophy (56)
Ericaceae	***Arbutus andrachne*** L.	Sandal	Leaf, fruit, wood	Antidiarrhoeal, antiseptic (1), laxative, prostate disorders, eczema, fungal diseases (30)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Ericaceae	***Arbutus unedo*** L.	Kocayemiş	Leaf, fruit	Antidiarrhoeal (1), antiseptic, diuretic (1,4), constipant, antiseptic, urethral diseases (4), jaundice (80), cold sore, vitamin support, tonic (111)
Ericaceae	***Calluna vulgaris*** (L.) Hull	Süpürge çalısı	Aerial parts	Urethra inflammation, constipant (4), diuretic (4,71), colds, cough (50), accelerate metabolism (71), analgesic (111)
Ericaceae	***Empetrum nigrum*** L. subsp. ***hermaphroditum*** (Hagerup) Böcher	Kargaüzümü	Aerial parts	Diuretic (4)
Ericaceae	***Erica arborea*** L.	Funda	Aerial parts	Asthma (94)
Ericaceae	***Orthilia secunda*** (L.) House	Keklikdüğmesi	Whole plant	Diuretic, constipation (4), wound (4,91)
Ericaceae	***Rhododendron caucasicum*** Pall.	Dağ kumarı	Leaf	Anticancer, dyspnoea (50), anti-inflammatory, intestines (109)
Ericaceae	***Rhododendron luteum*** Sweet	Zifin	Flower	Chlorothiazide (10)
Ericaceae	***Rhododendron ponticum*** L. subsp. ***ponticum***	Mor çiçekli Orman gülü	Leaf	Analgesic, diuretic (1), headache (6,97), pruritus (8), cold (9)
Ericaceae	***Vaccinium arctostaphylos*** L.	Likarpa	Leaf	Constipant (4), laxative (90)
Ericaceae	***Vaccinium myrtillus*** L.	Ayıüzümü	Fruit, leaf	Constipant (4), diabetes (4,50,53,90,116), bronchitis (50), astringent, diarrhoea (83), laxative, antiseptic (90), cold (109), menstruation, contraceptive, diaphoretic (116)
Ericaceae	***Vaccinium uliginosum*** L.	Avcıüzümü	Fruit, leaf	Diabetes (53), catarrh, cystitis, enteritis, gastritis, intestine, liqueur, narcotic, stomachic (116)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Ericaceae	***Vaccinium vitis-idaea*** L.	Çalıçilek	Leaf	Diuretic, antiseptic (1,4), rheumatism, urinary inflammation (4)
Euphorbiaceae	***Euphorbia helioscopia*** L.	Feribanotu	Root	Anthelmintic, laxative, rheumatism (90)
Euphorbiaceae	***Euphorbia oblongifolia*** (K.Koch) K. Koch	Haladiza	Aerial parts	Wound, papilloma cancer (89)
Euphorbiaceae	***Euphorbia orientalis*** L.	Gezer sütleğen	Root	Anthelmintic, laxative, rheumatism (90)
Euphorbiaceae	***Euphorbia paralias*** L.	Kum sütleğeni	Root	Anthelmintic, laxative, rheumatism (90)
Euphorbiaceae	***Euphorbia peplis*** L.	Kıyı sütleğeni	Aerial parts	Laxative, anticancer (91)
Euphorbiaceae	***Mercurialis annua*** L.	Parşen	Aerial parts	Laxative, diuretic (4), anti-inflammatory, purgative, diuretic, depurative, heumatism, constipation, urinary disorders (75)
Euphorbiaceae	***Mercurialis perennis*** L.	Köpekmarulu	Aerial parts	Laxative, diuretic (4)
Euphorbiaceae	*****Ricinus communis*** L.	Hintyağı	Seed	Laxative (4,6), hair loss (30), rheumatism (93)
Fabaceae	***Antyllis vulneraria*** L.	Çobangülü	Aerial parts	Constipant, wound (4)
Fabaceae	***Astragalus microcephalus*** Willd.	Anadolu kitresi	Gum	Sore throat, wound (4)
Fabaceae	***Bituminaria acaulis*** (Hoffm.) C.H.Stirt.	Alacüer	Leaf	Antipyretic, menstrual, calmative (4)
Fabaceae	***Colutea cilicica*** Boiss. & Balansa	Patlangaç	Fruit	Gingival disease (2), constipant (51)
Fabaceae	***Genista tinctoria*** L.	Boyacı Katırtırnağı	Aerial parts	Diaphoretic (4), diuretic, laxative (4,90), exudative (90)
Fabaceae	***Lathyrus rotundifolius*** Willd. subsp. ***miniatus*** (M.Bieb. ex Steven) P.H. Davis	Hırıgürü	Leaf, aerial parts	Goiter, antirheumatic (2)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Fabaceae	***Lathyrus sativus*** L.	Mürdümük	Seed	Sedative, nervine, aphrodisiac (1), diuretic (1,4), analgesic (2), aphrodisiac, jaundice (4)
Fabaceae	***Lotus corniculatus*** L.	Gazalboynuzu	Aerial parts	Antihaemorrhoidal, abdominal, pain, diuretic, stomach pain, nephralgia (2), sedative (2,4)
Fabaceae	***Medicago sativa*** L. subsp. ***sativa***	Karayonca	Leaf	Wound, hemostatic, astringent (2), skin bleeding (65)
Fabaceae	***Melilotus officinalis*** (L.) Desr.	Kokulu yonca	Çiçek	Anemia, sedative, antirheumatic (2), constipant (2,4), calmative (4), joint pain (39), respiratory (112)
Fabaceae	***Onobrychis transcaucasica*** Grossh.	Kaf korungası	Aerial parts	Diuretic (2)
Fabaceae	***Ononis spinosa*** L.	Kayışkıran	Root	Lithontriptic (1), diuretic (1,4), kidney stone, eczema (4), burns (56), headache (97)
Fabaceae	*****Phaseolus vulgaris*** L.	Fasulye	Fruit	Wound (28), anti-diabetic (30)
Fabaceae	*****Robinia pseudoacacia*** L.	Yalancı akasya	Flower	Antidiarrhoeal (1), sedative (1,4), constipant (4,50), asthma (56),
Fabaceae	***Securigera orientalis*** (Mill.) Lassen	Ala körigen	Leaf	Nephralgia (2)
Fabaceae	***Spartium junceum*** L.	Katırtırnağı	Flower, seed	Anesthetic (1), diuretic (1,4,90)
Fabaceae	***Trifolium arvense*** L.	Tavşanayağı	Aerial parts	Constipation (4)
Fabaceae	***Trifolium campestre*** Schreb.	Üçgül	Leaf	Swelling (33)
Fabaceae	***Trifolium pratense*** L. var. ***pratense***	Çayır üçgülü	Leaf	Vulnerary (2), expectorant, antiseptic, calmative (4)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Fabaceae	***Trifolium repens*** L. var. ***repens***	Ak üçgül	Aerial parts	Tonic, antirheumatic (2,74), tonic, rheumatism pain (4)
Fabaceae	***Trifolium repens*** L. var. ***giganteum*** Lag.-Foss.	Ak üçgül	Aerial parts	Stomachic (2)
Fabaceae	*****Ulex europaeus*** L.	Dikenli Katırtırnağı	Aerial parts	Diuretic (4)
Fabaceae	***Vicia cracca*** L. subsp. ***cracca***	Kuş fiği	Seed	Stomach ache, headache (2)
Fabaceae	***Vicia sativa*** L.	Fiğ	Aerial parts	Diuretic, urinary diseases, aphrodisiac, tonic (91)
Fagaceae	***Castanea sativa*** Miller	Anadolu kestanesi	Leaf, bark, shoot	Antidiarrhoeal (1), hypotensive (4,45), constipant (4,90), skin rubbing, bee culture, hair dye, chlorothiazide (45)
Fagaceae	***Fagus orientalis*** Lipsky	Doğu kayını	Cortex	Constipant, antipyretic (4), analgesic (49), stomachache, intestinal worm (50)
Fagaceae	***Quercus petraea*** (Mattuschka) Liebl.	Meşe	Fruit	Wound, inflammation (55), haemostatic (79)
Gentianaceae	***Centaurium erythraea*** Rafn.	Kırmızı kantaron	Flower	Digestive, appetizer, antipyretic (4), analgesic (49), haemorrhoids (50), stomachache (56,72), waist pain (72), influenza (79)
Gentianaceae	***Cenataurium pulchellum*** (Sw.) Druce	Pembe tukul	Flower	Diarrhoea (42)
Gentianaceae	***Gentiana asclepiadea*** L.	Sütlü güşad	Aerial parts	Appetizer, antipyretic (4), orexigenic (4,104)
Geraniaceae	***Geranium robertianum*** L.	Dağ itırı	Leaf and root	Constipant, blood coagulant, tonic, stomachic, diabetes (4)
Geraniaceae	***Pelargonium endlicherianum*** Fenzl	Solucanotu	Flower	Against intestinal parasite (4)
Geraniaceae	***Geranium sanguineum*** L.	Ece itırı	Aerial parts	Constipant, blood coagulant (4)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Grossulariaceae	***Ribes alpinum*** L.	Çalıçileği	Fruit	Diuretic, diaphoretic, antifebrile (45)
Grossulariaceae	***Ribes orientale*** Desf.	Çeçem	Fruit	Diuretic, diaphoretic, constipation, rheumatism (91)
Grossulariaceae	***Ribes uva-crispa*** L.	Bektaşi üzümü	Fruit	Laxative, diuretic, stomachic, appetizer (4)
Hypericaceae	***Hypericum calycinum*** L.	Koyunkıran	Aerial parts	Antispas-modic, laxative, anthelmintic, antiseptic (90)
Hypericaceae	***Hypericum lydium*** Boiss.	Cayesancıyan	Aerial parts	Menstrual disorders, stomachic (2)
Hypericaceae	***Hypericum montbretii*** Spach	Çay kantaronu	Aerial parts	Kidney stones, ulcer, antihaemorrhoidal (2), stomachache (2,47)
Hypericaceae	***Hypericum orientale*** L.	Sandık çiçeği	Flower	Sedative (66)
Hypericaceae	***Hypericum perforatum*** L.	Binbirdelik, kantaron	Aerial parts	Antiseptic (1,4), antidiarrhoeal, sedative, antihelminthic (1), stomach pains (2,30), neoplastic disease (35), diabetes (47), digestive (112), cancer (124)
Iridaceae	***Iris caucasica*** Hoffm. subsp. ***turcica*** B. Mathew	Türk navruzu	Whole plant	Cold (2)
Iridaceae	***Iris pseudocorus*** L.	Bataksüseni	Seed, rhizome	Carminative, antidiarrhoeal (1), stomachic (1,4), diuretic, emetic, constipant (4), tooth-ache, menstrual regulator (74)
Iridaceae	***Iris sari*** Schott ex Baker	Ana kurtkulağı	Whole plant	Cold (2)
Juglandaceae	***Juglans regia*** L.	Ceviz	Leaf, fruit	Anti-diabetic (1,6,30,80), eczema (2,30), antiseptic (4), appetizer (4,30), goiter (43), cholesterol (102)
Juncaceae	***Juncus effusus*** L. subsp. ***effusus***	Has kofa	Root	Urinary diseases (99)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Lamiaceae	***Ajuga chamaepitys*** (L.) Schreb.	Acıgıcı	Aerial parts	Tonic, antipyretic, emmenagogue, antihaemorrhoidal, diuretic, tonic, vulnerary (2), painkiller (72)
Lamiaceae	***Ajuga orientalis*** L.	Dağ mayasılı	Aerial parts	Skin diseases (105)
Lamiaceae	***Ballota nigra*** L.	Yalancı ısırgan	Aerial parts	Jaundice (2), diuretic, digestive, against intestinal parasites, expectorant (4)
Lamiaceae	***Calamintha nepeta*** (L.) Kuntze subsp. ***glandulosum*** (Req.) Govaerts	Sümüklü fesleğen	Root, aerial parts	Snakebites (56,82), insect bites, appetizer (76)
Lamiaceae	***Clinopodium vulgare*** L.	Yabani fesleğen	Leaf	Hypertension (110)
Lamiaceae	***Glechoma hederacea*** L.	Yernanesi	Leaf	Wound, tonic (4), blood cleanser, diuretic, anti-inflammatory (74)
Lamiaceae	***Hyssopus officinalis*** L.	Zufaotu	Aerial parts	Purgative (2), stomachic, stimulant, carminative (4)
Lamiaceae	***Lamium album*** L.	Balıcak	Aerial parts	Constipant (4), rheumatism, arthritis (48)
Lamiaceae	***Lamium garganicum*** L.	Bol balıcak	Aerial parts	Laxative, emmenagogue, menstrual regulator (30)
Lamiaceae	***Lamium purpureum*** L. var. ***purpureum***	Ballıbaba	Aerial parts	Constipant, tonic (45), cholesterol (50)
Lamiaceae	***Lycopus europaeus*** L.	Kurtayağı	Whole plant	Constipant, antipyretic, blood coagulant (4), thyroid (90)
Lamiaceae	***Marrubium astracanicum*** Jacq. subsp. ***astracanicum***	Mor yayotu	Aerial parts	Colds, antipyretic (2)
Lamiaceae	***Mentha aquatica*** L.	Su nanesi	Aerial parts	Stomachic, gastritis (50)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Lamiaceae	***Mentha longifolia*** (L.) L.	Pünk	Aerial parts	Colds, cough, catarrh, stomachic (2), flu (2,30), nausea, colic spasm, colds, antitussive (30)
Lamiaceae	***Mentha pulegium*** L.	Yarpuz	Aerial parts	Vulnerary, gall bladder (2), cystitis, muscle joint pains, colic spasms (30), asthma (51), stomachache (72,124), qualm (124)
Lamiaceae	*******Origanum acutidens*** (Hand.-Mazz.) Ietsw.	Zemul	Aerial parts	Abdominal pain (2)
Lamiaceae	***Origanum vulgare*** L. subsp. ***gracile*** (K.Koch.) Ietsw.	Karakınık	Flower	Vulnerary, stomach pains, hypertension, epilepsy, headache, asthma (2), digestive (31)
Lamiaceae	***Prunella vulgaris*** L.	Gelinciklemeotu	Whole plant	Expectorate, diuretic, diaphoretic, eye diseases (4), wound (42), abdominal pain (65)
Lamiaceae	***Salvia divaricata*** Montbret & Aucher ex Benth.	Saplı şalba	Leaf	Constipation, stomachic, calmatine (92)
Lamiaceae	***Salvia forskahlei*** L.	Dolma yaprağı	Leaf	Influenza (38), constipant, stomach, calmative (123)
Lamiaceae	***Salvia glutinosa*** L.	Oklu şalba	Leaf	Wound (50,75), antimicrobial, immunostimulant, anti-inflammatory, astringent, vermifuge, cicatrising, mouth disease (75)
Lamiaceae	***Salvia multicaulis*** Vahl	Adaçayı	Leaf	Wound (90)
Lamiaceae	***Salvia nemorosa*** Vahl.	Gehareş	Aerial parts	Hemostatic, cold, catarrh (2)
Lamiaceae	***Salvia sclarea*** L.	Paskulak	Leaf	Colds (2), stomachic, constipant (4), treatment of sunstroke (28), sore throat (72)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Lamiaceae	***Salvia verticillata*** L.	Dadırak	Aerial parts	Catarrah, laxative, nausea (2), colds (2,105), stomachache (105)
Lamiaceae	***Salvia virgata*** Jacq.	Fatmanaotu	Aerial parts	Wound (4,27), haemorrhoids (66)
Lamiaceae	***Salvia viridis*** L.	Zarif şalba	Aerial parts	Stomachic, constipant (4)
Lamiaceae	***Satureja hortensis*** L.	Çibriska	Aerial parts	Immunostimulant (2)
Lamiaceae	***Satureja spicigera*** (K.Koch.) Boiss.	Çorba kekiği	Aerial parts	Antihypertensive, abdominal pains (6), inflammation (89), diabetes (110)
Lamiaceae	***Scutellaria orientalis*** L.	Sarı kaside	Aerial parts	Blood coagulant, wound, tonic (4)
Lamiaceae	***Stachys annua*** (L.) L. subsp. ***annua***	Hacıosmanotu	Aerial parts	Colds, antipyretic (2)
Lamiaceae	***Stachys byzantina*** K.Koch	Boz karabaş	Aerial parts	Common cold (105)
Lamiaceae	***Stachys iberica*** M. Bieb. subsp. ***stenostacya***(Boiss.) Rech.f	Benli deliçay	Aerial parts	Colds, antipyretic, stomach ache (2)
Lamiaceae	***Stachys macrantha*** (K.Koch) Stearn	Koca soğulcan	Aerial parts	Stomachic (50)
Lamiaceae	***Teucrium chamaedrys*** L.	Kısamahmut	Aerial parts	Toothache, (2), stomachache (2,6, 43,124), intestine pain, jaundice (29), anti-diabetic (30), abdominal pain, haemorrhoids (124)
Lamiaceae	***Teucrium polium*** L. subsp. ***polium***	Acıyavşan	Aerial parts	Diabetes (2,6), kidney, stomachache, inflammation (6), appetizer (30), headache, cold (43), abortion, gynaecological, carminative, toothache (93), wound (117)
Lamiaceae	***Thymus nummularius*** M.Bieb.	Limon kekiği	Laef, flower	Stomach diseases, bronchial, antitussive (45)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Lamiaceae	***Thymus praecox*** Opiz. subsp. ***grossheimii*** (Ronniger) Jalas var. ***grossheimii***	Yayla kekiği	Aerial parts	Hypertension, enteralgia, anti-inflammatory, cancer, vermifuge, colds (2)
Lamiaceae	***Thymus sipyleus*** Boiss.	Sipil kekiği	Aerial parts	Diabetes, colds, abdominal ailments (2), stomachache (66)
Lamiaceae	***Vitex agnus-castus***L.	Hayıt	Seed, flower, fruit	Carminative (1), sedative, diuretic (1,4), abdominal pains (22), arteriosclerosis, depilatory (30), headache (97)
Lamiaceae	***Ziziphora clinopodioides*** Lam.	Dağ reyhanı	Aerial parts	Stomach ache, carminative, orexigenic, colds (2)
Lauraceae	***Laurus nobilis*** L.	Defne	Leaf	Diaphoretic (4), analgesic, anti-diabetic, haemorrhoids, itching (30), appetizer (31), dyspnoea (45), sweaty, enteritis, antiseptic (123)
Lentibulariaceae	***Pinguicula balcanica*** Casper	Deliyağotu	Whole plant	Calmative, laxative, emetic (4)
Liliaceae	***Lilium monadelphum*** M.Bieb.	Beyzambağı	Bulb	Sedative, expectorant, menstrual regulator (83)
Lycopodiaceae	***Huperzia selago*** (L.) Bernh. Ex Schrank & Mart.	Dik kibritotu	Aerial parts	Diuretic, calmative, rheumatism pain (91)
Lycopodiaceae	***Lycopodium clavatum*** L.	Göbektozu	Spore	Diuretic, sedative, rheumatism pain (4), dermatologic (50)
Lythraceae	***Lythrum salicaria*** L.	Hevhulma	Leaf	Constipant, haemorrhoids, eczema, blood coagulant (4)
Lythraceae	*****Punica granatum*** L.	Nar	Flower, fruit	Antidiabetic, hypotensive, colds, flu (30), cardiovascular diseases, constipant (45), anti-diarrhoeal (87)
Malvaceae	***Alcea hohenackeri*** (Boiss. & Huet) Boiss.	Hevur	Leaf, flower	Diuretic, kidney pain (64), gynaecological disease, wound (93)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Malvaceae	***Malva neglecta*** Wallr.	Çobançöreği	Whole plant	Asthma, abdominal, pain, ulcer, colds, stomachic, digestive, sore, constipant (2), throat ache (72)
Malvaceae	***Malva sylvestris*** L.	Ebegümeci	Whole plant	Gargle (1), sore throat, skin disorders, wound, maturation, abscess, abortive (2), colds, flu (30), cough (101)
Malvaceae	***Tilia platyphyllos*** Scop. subsp. ***platyphyllos***	Yaz ihlamuru	Leaf, flower	Malaria, sweaty, calmatine, colds (22,45,47), hypnotic (45,62), throat ache (72), sedative (79)
Malvaceae	***Tilia rubra*** DC. subsp. ***caucasica*** (Rupr.) V. Engl.	Kafkas ihlamuru	Leaf, flower	Diuretic, diaphoretic, cough, asthma (50), common cold (62,107), tachycardia, liver disease, sedative, digestive (71), sore throat (73)
Melanthiaceae	***Veratrum album*** L.	Dokuztepeli	Rhizome	Diarrhoea, scabies, cold (4), laxative, skin diseases (91), epilepsy, blood pressure (98)
Moraceae	***Ficus carica*** L. subsp. ***carica***	İncir	Stem, fruit, latex	Ulcer, inflamed wound (2), laxative (4,30), warts (26,30,67), analgesic (30), cough, cold (31), anaemia (95)
Moraceae	****Morus alba*** L.	Akdut	Leaf	Diuretic, anti-inflammatory (1), stomachic, gastritis, ulcer (2), anthelmintic (30), aphthae (56)
Moraceae	****Morus nigra*** L.	Karadut	Leaf, stem and fruit	Gargle (1), oral wound (2), diabetes (6,12,56), odour (30), gingival disease (124)
Moraceae	****Morus rubra*** L.	Mordut	Fruit	Anthelmintic, diuretic, anti-edemic (30), aphtha, mouth wound, throat disorder (90)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Nitrariaceae	***Peganum harmala*** L.	Üzerlik	Root, seed	Anti-rheumatic, anti-hemorrhoidal (2,26), rheumatic pain (62), neuroexcitatory, expectorant, stomachache (71), toothache, gynaecological infections, menstruation (93)
Oleaceae	***Fraxinus angustifolia*** Vahl. subsp. ***oxycarpa*** (Willd.) Franco & Rocha Afonso	Anadolu dişbudağı	Leaf, fruit	Hepatitis (7)
Oleaceae	***Fraxinus excelsior*** L.	Dişbudak	Leaf, bark	Diuretic, laxative, constipant, antipyretic (4)
Oleaceae	***Ligustrum vulgare*** L.	Kurtbağrı	Leaf, fruit	Constipant, wound, laxative (4)
Oleaceae	***Olea europaea*** L. subsp. ***europaea***	Zeytin	Leaf, fruit, bark	Diabetes (107), lowering cholesterol (30), bronchitis, toothache (33)
Oleaceae	***Phillyrea latifolia*** L.	Akçakesme	Leaf	Diuretic, menstrual (4)
Onagraceae	***Epilobium angustifolium*** L.	Yakıotu	Whole plants	Constipation (4), prostate, gastrointestinal, menstrual disorders, analgesic, anti-inflammatory (58)
Orchidaceae	***Orchis* spp., *Ophyrys* spp., *Dactylorhiza* spp., *Spiranthes* spp.**	Salep, orkide	Tuber	Aphrodisiac, antidiarrhoeal (1,4,91), warts (56), tonic (91)
Orobanchaceae	***Euphrasia pectinata*** Ten.	Gözotu	Aerial parts	Wound (4)
Orobanchaceae	***Lathraea squamaria*** L.	Gizliot	Whole plant	Sedative, calmative (4)
Osmundaceae	***Osmunda regalis*** L.	Kıral eğreltisi	Rhizome	Diuretic, constipant (4)
Oxalidaceae	***Oxalis acetoslla*** L.	Ekşiyonca	Aerial parts	Diuretic (4), wounding closure (89)
Oxalidaceae	***Oxalis corniculata*** L.	Sarıekşiyonca	Aerial parts	Constipant (50)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Paeoniaceae	***Paeonia arietina*** G. Anderson	Şakayık	Root	Sedative, antidiarrhoeal (1), diabetes (2)
Papaveraceae	***Chelidonium majus*** L.	Kırlangıçotu	Aerial parts	Diuretic, laxative, sedative (1), eczema, acne (50), warts (50,86), hepatitis (87)
Papaveraceae	***Fumaria asepala*** Boiss.	Akşahtere	Aerial parts	Abdominal pain, headache, itching antiseptic (2)
Papaveraceae	***Glaucium flavum*** Crantz	Gündürmelâlesi	Leaf, seed	Sedative, cough, drug (4)
Papaveraceae	******Papaver lateritium*** K.Koch subsp. ***lateritium***	Potot	Flower	Calmative, antitussive, bronchial, hypnotic (123)
Papaveraceae	***Papaver macrostomum*** Boiss. & A. Huet	Minimitçe	Flower	Cough (2)
Papaveraceae	***Papaver rhoeas*** L.	Gelincik	Flower, root	Sedative, (1,2), antitussive (1,43), anti-pyretic (30), antihelmintic (43), haemorrhoids (56)
Phytolaccaceae	*****Phytolacca americana*** L.	Şekerciboyası	Root, fruit	Stomachic, laxative, constipant (4)
Pinaceae	***Abies nordmanniana*** (Stev.) Spach subsp. ***nordmanniana***	Doğu karadeniz Göknarı	Tar, leaf	Vulnerary (2,91), antiseptic, expectorant, constipation (91)
Pinaceae	***Picea orientalis*** (L.) Peterm.	Doğu ladini	Resin, leaf	Lung tuberculosis, pneumonia, eczema (7), skin diseases, diabetes, gastric ulcer, intestinal, disorder, kindling (45), bronchitis, wound (109)
Pinaceae	***Pinus sylvestris*** L.	Sarıçam	Shoot, tar	Vulnerary, snake bites, panacea, tuberculosis (2), expectorant (4,91), antitussive, pertussis (30), calmative, antiseptic (91)
Pinaceae	***Pinus pinea*** L.	Fıstık çamı	Seed, gum	Nervine (1), tonic (4,106), wound (26), semen enhancer (30)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Plantaginaceae	***Digitalis ferruginea*** L. subsp. ***schischkinii*** (Ivanina) Werner	Ayımısırı	Leaf	Urinary system (50), wounding closure (89)
Plantaginaceae	*****Digitalis lamarckii*** Ivanina	Yüksükotu	Aerial parts	Diuretic, cardiotonic (81)
Plantaginaceae	***Plantago lanceolata*** L.	Damarlıca	Aerial parts	Gynaecological diseases, stomachic, ulcer (2), wound, antiseptic, acne, mouth sores odour (30), appetizer, digestive (88)
Plantaginaceae	***Plantago major*** L.	Sinirotu	Aerial parts	Vulnerary, inflamed (2), abscess, wound (2,43,65,86), antiseptic, acne (30), rheumatism (43), stomachache, cough, acne (86)
Plantaginaceae	***Plantago maritima*** L.	Yılandili	Leaf	Cancerous uterus (2)
Plantaginaceae	***Plantago media*** L.	Şimşekyaprağı	Leaf	Astringent, anti-inflammatory (2), expectorant, antitussive, emollient, anti-inflammatory, astringent, antimicrobial, cicatrising (75)
Plantaginaceae	***Veronica beccabunga*** L.	Atteresi	Aerial parts	Constipation, antipyretic, stimuşant, tonic (4)
Plantaginaceae	***Veronica officinalis*** L.	Oropaçayı	Aerial parts	Diuretic, vulnerary (4)
Plantaginaceae	***Veronica orientalis*** Mill.	Gözmumcuğu	Aerial parts	Kidney stones, pulmonic disorders (2)
Platanaceae	***Platanus orientalis*** L.	Çınar	Leaf, fruit, bark	Constipant (4), antipyretic (4,67), oedema (26), wound (27), diuretic (43), mouthwash (52), diabetes (56), rheumatic pain (96)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Poaceae	***Cynodon dactylon*** (L.) Pers.	Köpekdişi	Aerial parts, rhizome	Rheumatism pains, calcification, invigorating, anticancer, antipyretic (30), diuretic (31), kidney stone, prostate cancer, rheumatism (99)
Poaceae	***Hordeum vulgare*** L.	Arpa	Fruit	Antirheumatic, diuretic, against itching (2), maturation abscess (2,28)
Poaceae	***Phragmites australis*** (Cav.) Trin. ex Steud.	Kamış	Rhizome	Diuretic, diaphoretic, antiseptic, gout, rheumatism (4)
Poaceae	***Sorghum halepense*** (L.) Pers. var. ***halepense***	Ekin süpürgesi	Aerial parts, rhizome	Cystitis, colic spasms (30), diuretic (43)
Poaceae	*****Triticum aestivum*** L.	Ekmeklik buğday	Shoot	Cancer (6)
Poaceae	*****Zea mays*** L. subsp. ***mays***	Mısır	Kernel and fiber	Urinary system, kidney stones, blood pressure, prostate cancer (6), pyelonephritis (7), diuretic (30,43,87), gonorrhoea (45)
Polygonaceae	***Polygonum alpinum*** All.	Elayaz	Aerial parts	Rheumatic pain (48)
Polygonaceae	***Polygonum aviculare*** L.	Köyotu	Leaf, stem, flower	Anemia, cough (2), kidney stones, prostate disorders (30)
Polygonaceae	***Polygonium amphibium*** L.	Yerdeğiştiren	Aerial parts	Cold, flu (6)
Polygonaceae	***Polygonum bistorta*** L. subsp. ***carneum*** (Koch) Coode & Cullen.	Madımak	Root	Antidiarrhoeal, antiseptic, diuretic, mouth ulcers, antifibrinolytic (1), sore throat, expectorant (2), gingival disease (4)
Polygonaceae	***Polygonum hydropiper*** L.	Su biberi	Aerial parts	Astringent, cicatrising; gastric, pulmonary, uterine haemorrhages (75)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Polygonaceae	***Polygonum persicaria*** L.	Söğütotu	Aerial parts	Hemorrhoids, gingival disease (50), astringent, diuretic, antibacterial, cicatrising, metrorrhagia, leucorrhoea, wound (75)
Polygonaceae	***Rumex acetosella*** L.	Kuzukulağı	Whole plant	Anti-inflammatory, cholagogue/vesicant (1), diuretic (1,4), abscess, stomachic (2), sinusitis (50)
Polygonaceae	***Rumex alpinus*** L.	Şortah	Leaf	Hemorrhoids, against the skin redness (45)
Polygonaceae	***Rumex crispus*** L.	Labada	Leaf, fruit	Cough, colds, asthma, antihaemorrhoidal, antiphlogistic, antirheumatic, goiter (2)
Polygonaceae	***Rumex scutatus*** L.	Ekşikulak	Root, leaf	Diuretic, antipyretic, orexigenic (2)
Polygonaceae	***Rumex tuberosus*** L. subsp. ***horizontalis*** (K.Koch.) Rec.f.	Kömeturşusu	Root, leaf	Antipyretic, orexigenic (2), diuretic (2,55,81), antihypertensive (55), wound healing (65), bile expectorant (81)
Polypodiaceae	***Polypodium vulgare*** L. subsp. ***vulgare***	Benli eğrelti	Root	Laxative, expectorant (4)
Portulacaceae	***Portulaca oleracea*** L.	Semizotu	Aerial parts, seed	Orexigenic, antihelmintic, diuretic (2), anaphrodisiac (30), anaemia (95)
Primulaceae	***Anagallis arvensis*** L.	Farekulağı	Aerial parts	Eye infections, crusty eye (30)
Primulaceae	***Androsace villosa*** L.	Catili	Aerial parts	Abdominal pain (2)
Primulaceae	***Cyclamen coum*** Lam.	Yersomunu	Tuber	Laxative, stimulant (1), emetic (1,4), sunburn, gout (54)
Primulaceae	***Lysimachia vulgaris*** L.	Kargaotu	Whole plant	Expectorant, antipyretic, wound (4)
Primulaceae	***Primula acaulis*** (L.) L.	Çuhaçiçeği	Root, aerial parts	Mucolytic, sedative (1), diuretic (1,50), expectorant (2), cough (50), headache (97)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Primulaceae	***Primula algida*** Adams	Dağtutyası	Aerial parts	Eye diseases, pulmonary disorders (2)
Primulaceae	***Primula auriculata*** Lam.	Felçotu	Aerial parts	Stomachic (2), flu (28)
Primulaceae	***Primula elatior*** (L.) L.	Yaylatutyası	Root, flower	Expectorate, diuretic, diaphoretic, eye diseases (4)
Primulaceae	***Primula veris*** L.	Tutya	Root, flower	Expectorate, diuretic, diaphoretic, eye diseases (4)
Pteridaceae	***Adianthum capillus-veneris*** L.	Baldırıkara	Aerial parts	Kidney stones, tonic, intestinal disorders, orexigenic (2), expectorant (4), diuretic (41,103), menstrual cramps, abdominal pain (78)
Ranunculaceae	***Aconitum orientale*** Mill.	Kurtboğan	Aerial parts	Analgesic (91)
Ranunculaceae	***Actaea spicata*** L.	Domuzüzümü	Leaf	Anti-inflammatory, antiseptic, antiparasitic; cutaneous disorders, scab (75)
Ranunculaceae	***Anemone blanda*** Schott & Kotschy	Dağlalesi	Whole plant	Rheumatic pain, toothache, diuretic, expectorant (4,121)
Ranunculaceae	***Anemone narcissiflora*** L. subsp. ***narcissiflora***	Dağ lalesi	Aerial parts	Rheumatism (85)
Ranunculaceae	***Aquilegia olympica*** Boiss.	Haseki küpesi	Aerial parts	Diuretic (2,4,91), diaphoretic, xonstipation (4)
Ranunculaceae	***Caltha palustris*** L.	Lilpar	Petiole	Internal medicine (2), calmative (4), haemorrhoids, lung disease (64), diuretic, laxative, sedative, renal disorders (75)
Ranunculaceae	***Clematis vitalba*** L.	Akasma	Leaf, peeled bark	Rheumatism (4,96), toothache, (56)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Ranunculaceae	***Helleborus orientalis*** Lam.	Çöpleme	Rhizome	Sunstroke in veterinary medicine (41), toothache (42), ecchymosis, whitlow (56), antibiotic (89)
Ranunculaceae	***Nigella segetalis*** M.Bieb.	Kara çörekotu	Seed	Diabetes, ulcer (2)
Ranunculaceae	***Pulsatilla violacea*** Rupr.	Rüzgar gülü	Base leaf	Headache, sinusitis (64)
Ranunculaceae	***Ranunculus arvensis*** L.	Mustafaçiçeği	Whole plant	Swollen wound, antirheumatic (2)
Ranunculaceae	***Ranunculus caucasicus*** M.Bieb. subsp. ***subleiocarpus*** (Sommier & Levier) P.H.Davis	Sarı yaraotu	Whole plant	Swollen wound, antirheumatic (2)
Ranunculaceae	***Ranunculus costantinopolitanus*** (DC.) d'Urv.	Kağıthane çiçeği	Leaf	Rheumatism (14,81)
Ranunculaceae	***Ranunculus kotschyi*** Boiss.	Giritlâlesi	Leaf	Rheumatism (65)
Ranunculaceae	***Ranunculus ficaria*** L. subsp. ***bulbifera***	Buğdaycık	Whole plant	Antihaemorrhoidal (1,30), constipant, wound, haemorrhoids (4,73), eczema (73)
Ranunculaceae	***Ranunculus repens*** L.	Tiktakdana	Aerial parts	Antirheumatic, oedema (2)
Ranunculaceae	***Thalictrum minus*** L. var. ***minus***	Çayır Sedefi	Aerial parts	Eye diseases, diuretic, abscess (2)
Resedaceae	***Reseda lutea*** L. var. ***lutea***	Muhabbet Çiçeği	Root	Stomach disorders (2), diuretic, laxative (4), psoriasis, skin diseases (68)
Rhamnaceae	******Frangula dodonei*** Ard. subsp. ***pontica*** (Boiss.) Soldano	Has barutağacı	Bark	Antirheumatic (2), laxative, stomachic (4)
Rhamnaceae	***Paliurus spina-christi*** P. Mill.	Karaçalı	Leaf, fruit	Antidiarrhoeal, lithontriptic (1), diuretic (1,2,4), wound, furuncle (26), stomachache (94)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Rhamnaceae	***Rhamnus alaternus*** L.	Geyikdikeni	Aerial parts	Nervous system disorders, hypoglycemic, cholesterol, dermatological problems, cancer, headache, liver diseases (117)
Rhamnaceae	***Ziziphus jujuba*** Mill.	Hünnap	Aerial parts, bark	Antidiarrhoeal (1), stomachic (1,4), diabetes, constipant (4), laxative (4,124), diuretic, diarrhoea (124)
Rosaceae	***Agrimonia eupatoria*** L.	Fıtıkotu	Root, aerial parts	Constipant, diuretic, hernia (2), respiratory diseases (63), emollient, expectorant (77)
Rosaceae	***Alchemilla pseudocartalinica*** Juz.	Kartal pençesi	Leaf	Anthelmintic, expectorant (2), diuretic (2,4), constipant (4), against breast, uterus, adenoid cancers (71)
Rosaceae	***Cerasus mahaleb*** (L.) Mill.	Mahlep	Seed	Diabetic, kidney stones (2), prostate cancer (2,123), expectorant, diuretic, asthma (2,4), aphrodisiac (2,4,123), tonic, dyspnea (123)
Rosaceae	***Cotoneaster integerrimus*** L.	Garagat	Bark	Jaundice, cough (2)
Rosaceae	***Cotoneaster nummularius*** Fisch. & C.A. Mey.	Dağ muşmulası	Fruit	Orexigenic, stomachic, expectorant (2)
Rosaceae	***Crataegus microphylla*** K. Koch	Kocakarı armudu	Fruit, leaf	Diabetes, cold (89)
Rosaceae	***Crataegus monogyna*** Jacq.	Yemişen	Leaf, flower	Hypotensive, antidiarrhoeal (1), diuretic (1,71), sedative (1,2,4,71), antispasmodic (2), palpitation (30), antihypertensive, toothache (36)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Rosaceae	***Crataegus orientalis*** Pall. ex M. Bieb. subsp. ***orientalis***	Alıç	Fruit, root	Tonic, cardiotonic, oedema, antihypertensive, antirheumatic (2), stomach disorders (28)
Rosaceae	****Cydonia oblonga*** Mill.	Ayva	Seed, leaf	Gargle (1), antidiarrhoeal (1,28,29), constipant (4), cough, haemorrhoids, influenza (56)
Rosaceae	****Eriobotrya japonica*** L.	Yeni dünya	Leaf, flower	Antitussive (30), rheumatism (80)
Rosaceae	***Filipendula ulmaria*** (L.) Maxim. subsp. ***ulmaria***	Çayırkraliçesi	Aerial parts	Diuretic, diaphoretic, constipation (4)
Rosaceae	***Filipendula vulgaris*** Moench	Çayırmelikesi	Aerial parts	Diaphoretic, constipation (4), diuretic (4,75), antitussive, astringent, antiseptic, asthma, oedema, diarrhoea, haemorrhoids (75)
Rosaceae	***Fragaria vesca*** L.	Dağ çileği	Root, aerial parts	Constipant, appetizing, diuretic (4), urinary and cardiovascular systems (63), anaemia (95)
Rosaceae	***Geum urbanum*** L.	Meryemotu	Root	Antidiarrhoeal, nervine, stomachic (1), cardiovascular system disorder (63)
Rosaceae	***Laurocerasus officinalis*** M.Roem.	Karayemiş	Leaf, fruit	Cough, abdominal pain (4), headache, hypertension (6), metabolic disease (35), expectorant, food, diabetes, ingrown, antitussive (45), anaemia (95)
Rosaceae	***Malus sylvestris*** (L.) Mill. subsp. ***orientalis*** (Uglitzk.) Browicz var. ***orientalis***	Acı Elma	Fruit	Colds (2), diabetes (2,29), earache (29), panacea (110)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Rosaceae	***Mespilus germanica*** L.	Muşmula	Fruit, leaf	Antidiarrhoeal (1), abdominal pain (9), diarrhoea (38,73,114), asthma (47), gastric (73), diuretic, kidney stone, bladder stone, anti-hemorrhages (114)
Rosaceae	***Potentilla reptans*** L.	Reşatınotu	Aerial parts	Constipant, tonic (2), antipyretic (2,4), haemorrhoids (4), cardiovascular disorder (63)
Rosaceae	***Prunus avium*** L.	Kiraz	Flower, fruit, bark	Antidiarrhoeal, anti-inflammatory, laxative (1), expectorant, anti-edemic (30), diuretic (30,43)
Rosaceae	***Prunus x domestica*** L.	Erik	Fruit	Laxative (1,4)
Rosaceae	***Prunus spinosa*** L.	Çakal eriği	Leaf, flower, fruit	Antidiarrhoeal, diuretic, antihelminthic (1), constipant (4), diabetes (42,56), asthma (56), pleurisy (77), anaemia (95)
Rosaceae	***Pyracantha coccinea*** M. Roem.	Ateşdikeni	Fruit	Cardiotonic (4)
Rosaceae	***Pyrus elaeagnifolia*** Pall.	Ahlat	Fruit	Diuretic (2), diarrhoea (28,102), diabetes, goitre (73),
Rosaceae	***Rosa boissieri*** Crép.	Has gül	Root	Antiseptic (2)
Rosaceae	***Rosa canina*** L.	Kuşburnu	Fruit, root	Antidiarrhoeal (1), antidiabetes (1,2), bronchitis (29), flu, haemorrhoids (30), colds (30,65), kidney stones (43), tonic, constipation, glycemia (92)
Rosaceae	***Rosa pulverulanta*** M.Bieb.	Bodur gül	Fruit	Colds, cough (2)
Rosaceae	***Rosa spinosissima*** L.	Karakuşburnu	Fruit, root	Colds, stomach pain, cardiotonic, antiseptic (2), antihaemorrhoidal (2,70)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Rosaceae	***Rubus canescens*** DC.	Çobanköstegi	Root	Diuretic, diabetes, hypertension (2), gonorrhoea, haemorrhoids (6), treat infertility (9), stomachic, cough (29), haematopoietic (35)
Rosaceae	***Rubus hirtus*** Waldst. & Kit.	Tüntürük	Root	Diabetes (2)
Rosaceae	***Rubus idaeus*** L. subsp. ***idaeus***	Ahududu	Fruits, leaf	Antidiarrhoeal, antidiabetes (1), diuretic (1,4), sterility (2), constipant (4), haematinic (10)
Rosaceae	***Rubus sanctus*** Schreb.	Böğürtlen	Leaf, flower, fruit	Colds (2), haemorrhoids (30), ulcer (43), asthma, liver diseases, tooth disease, cancer (56)
Rosaceae	***Sanguisorba minor*** L.	Çayırdüğmesi	Whole plant	Constipant, orexigenic (2), diuretic, stomachic (2,4), appetiser (4), ulcer (6), goiter (43)
Rosaceae	***Sorbus aucuparia*** L.	Kuşüvezi	Aerial parts	Laxative (4,91), respiratory diseases (63), diarrhoea, cough (101)
Rosaceae	***Sorbus torminalis*** (L.) Crantz var. ***torminalis***	Pitlicen	Leaf, fruit	Expectorant, bronchitis, asthma (43), cardiac diseases (43,63), coughs, diarrhoea, fever, diuretic, kidney stone, bronchitis, colic (114)
Rubiaceae	***Galium aparine*** L.	Çobansüzgeci	Aerial parts	Appetiser, diuretic (4), rheumatic pain (96)
Rubiaceae	***Galium verum*** L.	Boyalık	Flower	Treating burns, cancer (2), constipant, calmative (4)
Rutaceae	*****Citrus limon*** (L.) Burm.f	Limon	Fruit	Stomachache, colds, cough (8), hypertension, food, qualm (45)
Rutaceae	*****Citrus sinensis*** (L.) Osbeck	Portakal	Leaf	Palpitation (30)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Rutaceae	***Dictamnus albus*** L.	Gazelotu	Root	Invigorating, antidote, plague, induce childbirth, worms, colds (32), antifebrile, tonic (45)
Salicaceae	***Populus tremula*** L.	Titrek kavak	Leaf, bark	Diabetes, analgesic (56), constipation, antipyretic (91), nephritis (100)
Salicaceae	***Salix alba*** L.	Ak söğüt	Leaf, bark	Sedative, analgesic, nervine, antidiarrhoeal (1), tonic (2), rheumatism (2,4,43), antifebrile (45), toothache (65), headache (70), flu (78)
Salicaceae	***Salix caprea*** L.	Sorgun	Bark	Calmative, tonic, antipyretic, constipation, rheumatism (91)
Salicaceae	***Salix triandra*** L. subsp. ***triandra***	Bağ söğüdü	Stem bark, leaf	Remove warts, antipyretic (28)
Santalaceae	***Arceuthobium oxycedri*** (DC.) M. Bieb.	Ardıç güveleği	Whole plant	Hemorrhoids (28,56), coughs, internal diseases, haemorrhoids, common cold (56,84), abdominal pain, bronchitis (84,85)
Santalaceae	***Viscum album*** L.	Ökseotu	Fruits, leaf	Analgesic (1), diabetes (2,51), diuretic (4), diarrhoea (28), bronchitis (43), hypotensive (66)
Saxifragaceae	***Saxifraga paniculata*** Mill. subsp. ***paniculata***	Nasırlı taşkıran	Aerial parts	Constipant, diuretic, kidney stone (4)
Scrophulariaceae	*****Budleja davidii*** Franch	Kelebek çalısı	Aerial parts	Cancer, snakebite, infections, haemorrhoids, cardiac disease, kidney disorders, sedative, digestive, arthritis, rheumatism, skin (122)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (*Literatures*)
Scrophulariaceae	***Scrophularia nodosa*** L.	Tavuk sıracası	Aerial parts	Diuretic, wound, haemorrhoids, antidermatosic (4)
Scrophulariaceae	***Verbascum cheiranthifolium*** Boiss.	Bozkulak	Aerial parts	Women' sterility, arthralgia (2)
Scrophulariaceae	***Verbascum speciosum*** Schrad.	Zelve	Leaf	Mycodermatitis (2), rheumatism (65)
Simaroubaceae	*****Ailanthus altissima*** (Mill.) Swingle	Kokarağaç	Leaf	Constipation, sedative, antipyretic, emetic (121)
Smilacaceae	***Smilax excelsa*** L.	Dikenucu	Fruit	Digestive (6), acne, anti-wrinkle, facial blemishes (30), neurologic (50), eczema (50,62), rheumatic pain (96)
Solanaceae	***Atropa belladonna*** L.	Güzelavratotu	Leaf	Analgesic, antispasmodic (1,4)
Solanaceae	***Datura stramonium*** L.	Boru çiçeği	Seed, leaf	Toothache, antipyretic, antirheumatic, sedative (2), asthma, wound (56)
Solanaceae	***Hyoscyamus niger*** L.	Banotu	Leaf	Analgesic (1), sedative (1,114), against itching in the eyes, stomatitis (2), toohache (2,72,114), earache, headache (72), antitumour, febrifuge, neuralgia, rheumatic pain (114)
Solanaceae	***Hyoscyamus reticulatus*** L.	Kumacıkotu	Root, seed	Toothache (2)
Solanaceae	***Physalis alkekengi*** L.	Güveyfeneri	Fruit	Diuretic, antipyretic, sedative (4)
Solanaceae	***Solanum americanum*** Mill.	İtüzümü	Fruit, leaf	Analgesic, antidermatosic (1), antihaemorrhoidal (1,4), skin diseases (6)
Solanaceae	***Solanum dulcamara*** L.	Sofur	Aerial parts	Burn (2), expectorant (2,4), diuretic, analgesic, diaphoretic, laxative (4)
Solanaceae	*****Solanum tuberosum*** L.	Patates	Tuber	Skin lenitive (31)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Tamaricaceae	***Myricaria germanica***(L.) Desv.	Harbakotu	Leaf, bark	Diuretic, appetizer, constipation (4)
Tamaricaceae	***Tamarix tetrandra*** Pall.	Gezik	Leaf, bark	Appetiser, diuretic, constipant (4)
Taxaceae	***Taxus baccata*** L.	Adi porsuk	Leaf, arillus	Sedative, carminative (1,4), expectorant, digestive (4), calmative (91)
Theaceae	****Camellia sinensis*** (L.) Kuntze	Çay	Leaf	Eye diseases (46), strengthen the immune system, equalize cholesterol, anti-aging (71), prophylaxis (86)
Thymelaeaceae	***Daphne mezereum*** L.	Kirkat	Bark	Laxative, diaphoretic, diuretic (1,4)
Thymelaeaceae	***Daphne oleoides*** Schreb.	Gövçek	Bark	Abortion, treat bones (2), wound (36)
Thymelaeaceae	***Daphne pontica*** L.	Sırımağu	Aerial parts	Diuretic, diaphoretic, purgative, abortive, expectorant (83)
Ulmaceae	***Ulmus glabra*** Huds.	Dağ karaağacı	Bark	Soften blood vessels (28)
Ulmaceae	***Ulmus minor*** Mill.	Ova karaağacı	Root, bark, leaf	Anti-inflammatory, wound, cough, asthma (2), diuretic, diaphoretic, constipation, diabetes (4), haemostatic, depurative (75)
Urticaceae	***Parietaria judaica*** L.	Duvarfesleğeni	Foliage	Mouth wound (26), hemostatic (30)
Urticaceae	***Urtica dioica*** L.	Isırgan	Leaf, seed	Diuretic (1), stomachic (1,10), anticancer (2,22), measles (10), rheumatism (10,70), anti-dandruff (30), anaemia (77), diabetes (102)
Verbenaceae	***Verbena officinalis*** L. var. ***officinalis***	Mineçiçeği	Foliage, root	Constipation, antipyretic, stimulant, tonic (4), liver diseases, stomach pain, menstrual cramps (6), emmenagogue (30), toothache (33)

(continued)

Family	Plant name	Local name	Plant part(s) used	Local usages (**Literatures*)
Violaceae	***Viola odorata***L.	Kokulu menekşe	Foliage	Gargle (1), diaphoretic (1,4), intestine inflammation (6), antitussive (30,75), expectorant, emollient, laxative, diuretic (75)
Violaceae	***Viola sieheana*** W. Becker	Çayır menekşesi	Flower	Cold, flu, cough (100)
Vitaceae	****Vitis vinifera*** L.	Asma	Fruit, leaf	Menstrual cramps (6), anaemia (6,8,68,103,110), blood pressure (110)

*Cited references, **cultivated or naturalized taxa, ***taxa endemic to Turkey

*(**1**) Ozturk et al. (2012b), (**2**) Altundağ and Ozturk (2011), (**3**) Bulut et al. (2014), (**4**) Baytop (1999), (**5**) Arslanoğlu (2016), (**6**) Polat et al. (2015), (**7**) Yazıcıoğlu and Tuzlacı (1995), (**8**) Sağıroğlu et al. (2012), (**9**) Yeşilada et al. (1999), (**10**) Akbulut and Özkan (2014), (**11**) Sezik et al. (1997), (**12**) Çakılcıoğlu and Türkoğlu (2009), (**13**) Arı et al. (2015), (**14**) Demirci and Özhatay (2012), (**15**) Güzel et al. (2015), (**16**) Özüdoğru et al. (2011), (**17**) Faydaoğlu and Sürücüoğlu (2011), (**18**) Şimşek et al. (2004), (**19**) Doğru Koca and Yıldırımlı (2010), (**20**) Korkmaz and Alpaslan (2014), (**21**) Sezik et al. (1992), (**22**) Bulut and Tuzlacı (2013), (**23**) Akgül et al. (2018), (**24**) Türkan et al. (2006), (**25**) Aydın and Yeşil (2018), (**26**) Ugulu (2011), (**27**) Tümen et al. (2005), (**28**) Yeşilada et al. (1995), (**29**) Hürkul (2019), (**30**) Güzel et al. (2015), (**31**) Leporatti and Guarrera (2005), (**32**) Francés et al. (2015), (**33**) Moravec et al. (2014), (**34**) Giday (2001), (**35**) Yeşilada (2002), (**36**) Bulut et al. (2017a), (**37**) Tetik et al. (2013), (**38**) Karcı et al. (2017), (**39**) Çakılcıoğlu and Türkoğlu (2010), (**40**) Han and Bulut (2015), (**41**) Koçyiğit and Özhatay (2006), (**42**) Tuzlacı and Tolon (2000), (**43**) Tuzlacı and Erol (1999), (**44**) Di Novella et al. (2013), (**45**) Akbulut and Bayramoğlu (2014), (**46**) Yazıcıoğlu and Tuzlacı (1996), (**47**) Bulut (2011), (**48**) Öz Aydın et al. (2006), (**49**) Erbay et al. (2017a), (**50**) Saraç et al. (2013), (**51**) Nacakcı and Dutkuner (2018), (**52**) Tuzlacı and Sadıkoğlu (2007), (**53**) Baykal and Atamov (2017), (**54**) Korkmaz and Karakuş (2015), (**55**) Polat (2018), (**56**) Küpeli et al. (2007), (**57**) Sargın et al. (2013), (**58**) Ostrovska et al. (2017), (**59**) Sevastre et al. (2017), (**60**) Lexa et al. (1990), (61) Bozkurt et al. (2012), (**62**) Kargıoğlu et al. (2008), (**63**) Doğan et al. (2016), (**64**) Güneş and Özhatay (2011), (**65**) Kaval et al. (2014), (**66**) Ezer and Mumcu Arısan (2006), (**67**) Bulut et al. (2017b), (**68**) Sağıroğlu et al. (2013), (**69**) Bulut et al. (2017c), (**70**) Güler (2004), (**71**) Korkmaz et al. (2016), (**72**) Fakir et al. (2016), (**73**) Uysal et al. (2010), (**74**) Mumcu and Korkmaz (2018), (**75**) Tită et al. (2009), (**76**) Ranfa and Bodesmo (2017), (**77**) Vokoua et al. (1993), (**78**) Idolo et al. (2010), (**79**) Bonet et al. (1999), (**80**) Kocabaş and Gedik (2016), (**81**) Çakılcıoğlu et al. (2007), (**82**) Ecevit Genç and Özhatay (2006), (**83**) Yaldız et al. (2010), (**84**) Honda et al. (1996), (**85**) Fujita et al. (1995), (**86**) Koleva et al. (2015), (**87**) Pieroni et al. (2005), (**88**) Pieroni and Giusti (2009), (**89**) Eminağaoğlu et al. (2017), (**90**) Ozturk et al. (2013), (**91**) Eminağaoğlu (2005), (**92**) Toksoy et al. (2010), (**93**) Mosaddegh et al. (2012), (**94**) Polat and Satıl (2012), (**95**) Erbay et al. (2016), (**96**) Erbay et al. (2018), (**97**) Erbay et al. (2017b), (**98**) Allen et al. (2014), (**99**) Güneş (2018), (**100**) Kültür (2007), (**101**) Yeşilyurt et al. (2017), (**102**) Cansaran and Kaya (2006), (**103**) Hayta et al. (2014), (**104**) Karaköse and Çolak Karaköse (2017), (**105**) Koyuncu et al. (2010), (**106**) Altundağ Çakır (2017), (**107**) Akaydın et al. (2013), (**108**) Xie et al. (2015), (**109**) Bussmann et al. (2017), (**110**) Bussmann et al. (2016), (**111**) Sargın and Büyükcengiz (2018), (**112**) Ozturk et al. (2018e, f), (**113**) Amiri and Joharchi (2016), (**114**) Nejad et al. (2013), (**115**) Goodman and Ghafoor (1992), (**116**) Abreu et al.

(2014), (**117**) Ouelbani et al. (2016), (**118**) Kemertelidze et al. (2012), (**119**) Eryılmaz et al. (2013), (**120)** Bağcı and Özçelik (2002), (**121**) Birinci (2008), (**122**) Tallent-Halsell and Watt (2009), (**123**) Akbulut and Bayramoğlu (2013), (**124**) Akbulut et al. (2019)

References

Abreu AO, Barreto G, Prieto S (2014) *Vaccinium* (Ericaceae): ethnobotany and pharmacological potentials. Emir J Food Agric 26(7):577–591

Akaydın G, Şimşek I, Arıtuluk ZC, Yeşilada E (2013) An ethnobotanical survey in selected towns of the Mediterranean subregion (Turkey). Turkish J Biol 37:230–247

Akbulut S, Bayramoğlu MM (2013) The trade and use of some medical and aromatic herbs in Turkey. Ethno Med 7(2):67–77

Akbulut S, Bayramoğlu MM (2014) Reflections of socio-economic and demographic structure of urban and rural on the use of medicinal and aromatic plants: the sample of Trabzon Province. Ethno Med 8(1):89–100

Akbulut S, Özkan ZC (2014) Traditional usage of some wild plants in Trabzon Region (Turkey). Kastamonu Univ J For Facul 14(1):135–145

Akbulut S, Karaköse M, Özkan ZC (2019) Traditional uses of some wild plants in Kale and Acıpayam Provinces in Denizli. Kastamonu Univ J For Facul 19(1):72–81

Akgül A, Şenol SG, Yıldırım H et al (2018) An ethnobotanical study in Midyat (Turkey), a city on the silk road where cultures meet. J Ethnobiol Ethnomed 14:12

Akman Y, Ketenoğlu O (1986) The climate and vegetation of Turkey. Proc R Soc Edinburgh 89B:123–134

Allen D, Bilz M, Leaman DJ et al (2014) European red list of medicinal plants. Publications office of the EU, Luxembourg, 64 p

Alpınar K (1979) Amasya yoresi bitkilerinin yerli ad ve tıbbi kullanılışları. Bitki 6:243–249

Altay V, Çelik O (2011) Antakya semt pazarlarındaki bazı doğal bitkilerin etnobotanik yönden araştırılması. Res J Biol Sci 4(2):137–139

Altay V, Karahan F (2012) Tayfur Sökmen Kampüsü (Antakya-Hatay) ve çevresinde bulunan bitkiler üzerine etnobotanik bir araştırma. Karadeniz Fen Bilimleri Dergisi 3(2):13–28

Altay V, Karahan F (2017) Anadolu geleneksel tıbbında güneş çarpması ve güneş yanığı tedavisinde kullanılan tıbbi bitkiler. Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi 10(1):124–137

Altay V, Karahan F, Sarcan YB, İlçim A (2015) An ethnobotanical research on wild plants sold in Kırıkhan district (Hatay/Turkey) herbalists and local markets. Biol Divers Conserv 8(2):81–91

Altundağ Çakır E (2017) A comprehensive review on ethnomedicinal utilization of Gymnospermae in Turkey. Eur J For Sci 5(1):35–47

Altundağ E, Ozturk M (2011) Ethnomedicinal studies on the plant resources of east Anatolia, Turkey. Proc Soc Behav Sci 19:756–777

Amiri MS, Joharchi MR (2016) Ethnobotanical knowledge of Apiaceae family in Iran: a review. Avicenna J Phytomed 6(6):621–635

Anonymous (2014–2017) Doğa Koruma ve Milli Parklar Genel Müdürlüğü Ulusal Biyolojik Çeşitlilik Envanter ve İzleme Proje raporları, 12. Bölge (Rize-2014, Artvin-2016, Giresun-2016, Gümüşhame-2016 ve Trabzon-2014), 13. Bölge (Bayburt-2017), Turkiye

Anşin R (1981) Saf Doğu Ladini ormanı florası ile tıraşlama kesimleri yöntemine göre açılan Doğu Ladini alanlarında oluşan yabani floranın kıyaslanması. KTÜ Orman Fakültesi Dergisi 4(2):239–252

Arı S, Temel M, Kargıoğlu M, Konuk M (2015) Ethnobotanical survey of plants used in Afyonkarahisar-Turkey. J Ethnobiol Ethnomed 11:84

Arslan Ö (2005) Dereli (Giresun) yöresinin geleneksel halk ilacı olarak kullanılan bitkileri. Master Thesis, Marmara Üniversity, Istanbul

Arslanoğlu ŞF (2016) Some medicinal plants gathered from natural areas. Lucrări Ştiinţifice 59(2):173–176

Avcı S (2014) In: Güner A, Ekim T (eds) Coğrafya, Resimli Türkiye Florası, vol 1. Ali Nihat Gökyiğit Vakfı, Flora Araştırmaları Derneği ve Türkiye İş Bankası Kültür Yayınları, İstanbul

Avcı M, Avcı S (2014) In: Güner A, Ekim T (eds) Yer şekilleri, Resimli Türkiye Florası, vol 1. Ali Nihat Gökyiğit Vakfı, Flora Araştırmaları Derneği ve Türkiye İş Bankası Kültür Yayınları, İstanbul

Aydın A, Yeşil Y (2018) İkizce (Ordu-Türkiye) ilçesinde etnobotanik bir ön çalışma. Bağbahçe Bilim Dergisi 5(3):25–43

Bağcı E, Özçelik H (2002) Fatty acid composition of *Aconitum orientale* Miller and *A. nasutum* Fisch. ex Reichb Seeds, a chemotaxonomic approach. In: Şener B (ed) Biodiversity. Springer, Boston

Başer KHC (2000) Sustainable wild harvesting of medicinal and aromatic plants: an educational aproach, harvesting on non-wood forest products. In: Seminar Proceedings, Menemen/Izmir, Turkey

Baykal H, Atamov V (2017) Ethnobotanical documantation of plants of Başhemşin valley, Kaçkar Mountains National Park, Rize, Turkey. Bangladesh J Bot 46(2):767–773

Bayramaoğlu MM, Toksoy D, Şen G (2009) Türkiye'de tıbbi bitki ticareti I. Ormancılıkta Sosyo-Ekonomik Sorunlar Kongresi 19–21 Şubat 2009. SDÜ, Isparta

Baytop T (1999) Türkiye'de bitkiler ile tedavi, geçmişte ve bugün, Nobel Tıp Kitabevi, vol 2. Baskı, İstanbul

Birinci S (2008) Beneficial plants naturally found in Eastern Black Sea Region and their usage fields. MSc Thesis. Çukurova University, Adana

Bonet MA, Parada M, Selga A, Valle`s J (1999) Studies on pharmaceutical ethnobotany in the regions of L'Alt Emporda` and Les Guilleries (Catalonia, Iberian Peninsula). J Ethnopharmacol 68:145–168

Bozkurt B, Ünver Somer N, Önür MA (2012) Quantitative determinations on *Galanthus rizehensis*. Turk J Pharm Sci 9(1):61–66

Bulut G (2011) Folk medicinal plants of Silivri (İstanbul, Turkey). Marmara Pharm J 15:25–29

Bulut G, Tuzlacı E (2013) An ethnobotanical study of medicinal plants in Turgutlu (Manisa-Turkey). J Ethnopharmacol 149:633–647

Bulut G, Tuzlacı E, Doğan A, Şenkardeş İ (2014) An ethnopharmacological review on the Turkish Apiaceae species. İstanbul J Pharm 44(2):163–179

Bulut G, Haznedaroğlu MZ, Doğan A et al (2017a) An ethnobotanical study of medicinal plants in Acıpayam (Denizli-Turkey). J Herb Med 10:64–81

Bulut G, Korkmaz A, Tuzlacı E (2017b) The ethnobotanical notes from Nizip (Gaziantep-Turkey). Istanbul J Pharm 47(2):57–62

Bulut G, Bozkurt MZ, Tuzlacı E (2017c) The preliminary ethnobotanical study of medicinal plants in Uşak (Turkey). Marmara Pharm J 21(2):305–310

Bussmann RW, Paniagua ZNY, Sikharulidze S et al (2016) Medicinal and food plants of Svaneti and Lechkhumi, Sakartvelo (Republic of Georgia), Caucasus. Med Aroma Plants (Los Angel) 5:266

Bussmann RW, Paniagua ZNY, Sikharulidze S et al (2017) Ethnobotany of Samtskhe-Javakheti, Sakartvelo (Republic of Georgia), Caucasus. Indian J Trad Knowl 16(1):7–24

Çakıcı O (2017) Mad honey: is it useful or dangerous? Immunother J Rese 1(1):5

Çakılcıoğlu U, Türkoğlu İ (2009) Ethnobotanical features of Çitli Lowland (Elazığ) and its vicinity. Ecol Life Sci 4(2):81–85

Çakılcıoğlu U, Türkoğlu İ (2010) An ethnobotanical survey of medicinal plants in Sivrice (Elazığ-Turkey). J Ethnopharmacol 132(1):165–175

Çakılcıoğlu U, Türkoğlu İ, Kürşat M (2007) Harput (Elazığ) ve çevresinin etnobotanik özellikleri. Doğu Anadolu Bölgesi Araştırmaları 5(2):22–28

Calixto JB (2005) Twenty-five years of research on medicinal plants in Latin America a personal view. J Ethnopharmacol 100:131–134

Cansaran A, Kaya ÖF (2006) Amasya merkez ilçe, Bağlarüstü, Boğaköy ve Vermiş köyleri ile Yassıçal ve Ziyaret Beldeleri etnobotanik envanteri 2005. TÜBA Kültür Enva/ilan Dergisi 5:135–170

Cansaran A, Kaya ÖF (2010) Contributions of the ethnobotanical investigation carried out in Amasya District of Turkey (Amasya-Center, Bağlarustu, Boğakoy and Vermiş villages; Yassıcal and Ziyaret towns). Biol Divers Conserv 3:97–116

Çubukçu B, Melikoğlu G (1999) Giresun ili bitkileri ve halk ilaçları. J Tradit Folkloric Drugs 6:1–104

Davis PH (1965) Flora of Turkey and the East Aegean Islands., vol 1. University Press, Edinburgh

Davis PH (1971) Distribution patternsin Anatolia with particular reference to endemism. In: Davis PH, Harper PC, Hedge IC (eds) Plant life of South-West Asia. University Press, Edinburgh, pp 15–27

Demir Akca AS, Kahveci FO (2012) An indispensable toxin known for 2500 years: victims of mad honey. Turk J Med Sci 42(Sup 2):1499–1504

Demirci S, Özhatay N (2012) An ethnobotanical study in Kahramanmaraş (Turkey); wild plants used for medicinal purpose in Andırın, Kahramanmaraş. Turk J Pharm Sci 9(1):75–92

Di Novella R, Di Novella N, De Martino L et al (2013) Traditional plant use in the National Park of Cilento and Vallo di Diano, Campania, Southern, Italy. J Ethnopharmacol 145:328–342

Doğan A, Bulut G, Şenkardeş I, Tuzlacı E (2016) An ethnopharmacological analysis of Rosaceae taxa in Turkey. The 2016 WEI International Academic Conference Proceedings, Boston, pp 44–51

Doğru Koca A, Yıldırımlı Ş (2010) Ethnobotanical properties of Akçakoca District in Düzce (Turkey). Hacettepe J Biol Chem 38(1):63–69

Ecevit Genç G, Özhatay N (2006) An etnobotanical study in Çatalca (European part of İstanbul) II. Turkish J Pharm Sci 3(2):73–89

Eminağaoğlu Ö (2005) The medicinal and commercial plants of Şavşat District (Artvin). İstanbul Üniversitesi Orman Fakültesi Dergisi B55(1):87–111

Eminağaoğlu Ö, Göktürk T, Akyıldırım Beğen H (2017) Traditional uses of medicinal plants and animals of Hatila Valley National Park, Artvin. Biol Divers Conserv 10(3):26–35

Erbay MŞ, Anıl S, Melikoğlu G (2016) Plants used in traditional treatment against anemia in Turkey. Marmara Pharm J 20:164–171

Erbay MŞ, Anıl S, Melikoğlu G (2017a) Plants used as painkiller in folk medicine in Turkey-I Stomachache. Marmara Pharm J 21(4):741–755

Erbay MŞ, Anıl S, Melikoğlu G (2017b) Plants used as painkiller in traditional treatment in Turkey-II headache. Marmara Pharm J 22(1):29–36

Erbay MŞ, Anıl S, Melikoğlu G (2018) Plants used as painkiller in folk medicine in Turkey-III: rheumatic pain. Marmara Pharm J 22(2):133–141

Ertuğ F (2003) Wild edible plants of the Bodrum area (Muğla, Turkey). Turk J Bot 28:161–174

Ertuğ F (2014) Etnobotanik. In: Güner A, Ekim T (eds) Resimli Türkiye Florası, vol 1. Ali Nihat Gökyiğit Vakfı, Flora Araştırmaları Derneği ve Türkiye İş Bankası Kültür Yayınları, İstanbul

Eryılmaz M, Ozbilgin S, Ergene B et al (2013) Antimicrobial activity of Turkish *Viburnum* species. Bangladesh J Bot 42(2):355–360

Eyüboğlu Y, Bektaş O, Şeren A et al (2006) Three-directional extensional deformation and formation of the liassic rift basins in the Eastern Pontides (NE Turkey). Geol Carpathica 57:337–346

Ezer N, Mumcu Arısan Ö (2006) Folk medicines in Merzifon (Amasya, Turkey). Turk J Bot 30:223–230

Fakir H, Korkmaz M, İçel B (2016) Medicinal plants traditionally used for pain alleviation in Antalya Province, Turkey. Stud Ethno-Med 10(3):314–324

Faydaoğlu E, Sürücüoğlu MS (2011) Geçmisten günümüze tıbbi ve aromatik bitkilerin kullanılması ve ekonomik önemi. Kastamonu Üniv Orman Fakültesi Dergisi 11(1):52–67

Francés VM, Rivera D, Heinrich M, Ríos S (2015) An ethnopharmacological and historical analysis of "Dictamnus", a European traditional herbal medicine. J Ethnopharm 175:390–406

Fujita T, Sezik E, Tabata M et al (1995) Traditional medicine in Turkey VII. Folk medicine in Middle and West Black Sea Regions. Econ Bot 49(4):406–422
Gami R, Dhakal P (2017) Mad honey poisoning: a review. J Clin Toxicol 7(1):5
Giday M (2001) An ethnobotanical study of medicinal plants used by teh Zay people in Ethiopia. CBM: s Skriftserie 3:81–99
Goodman SM, Ghafoor A (1992) The ethnobotany of Southern Balochistan, Pakistan, with particular reference to medicinal plants, Fieldiana: botany, new series, no: 31. Field Museum of Natral History, Boston, pp 1–84
Güler S (2004) Erzurum yöresinde doğal yayılış gösteren bazı tıbbi ve aromatik bitkilerin etnobotanik özellikleri. Eastern Anatolia For Res Inst, Tech Bull 5:51
Gündüz A (2015) Bal ve deli bal. Nobel Tıp Kitabevleri Tic. Ltd, Şti, 162 p
Gündüz A, Türedi S, Ayaz FA (2011) Deli balın içindeki zehir: Grayanotoxin. Acil Tıp Dergisi 2011:95–96
Gündüz A, Aydın M, Akca M et al (2012) Is grayanotoxin directly responsible for mad honey poisoning-associated seizures. Turk J Med Sci 42(6):1086–1092
Güner A, Vural M, Sorun K (1987) Rize florası, vejetasyonu ve yöre ballarının polen analizi, TÜBİTAK-TBAG Proje No:650. Raporu, Sonuç, 269 p
Güner A, Aslan S, Ekim T et al (2012) Türkiye Bitkileri Listesi (Damarlı Bitkiler), Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği. Yayını, İstanbul
Güneş F (2018) An Ethnobotany Study in Enez Town from Edirne. Curr Perspect Med Aromatic Plants 1:28–35
Güneş F, Özhatay N (2011) An ethnobotanical study from Kars (Eastern) Turkey. Biol Divers Conserv 4(1):30–41
Gürbüz İ, Üstün O, Yeşilada E et al (2003) Anti-ulcerogenic activity of some plants used as folk remedy in Turkey. J Ethnopharmacol 88:93–97
Güzel Y, Güzelşemme M, Miski M (2015) Ethnobotany of medicinal plants used in Antakya: A multicultural district in Hatay Province of Turkey. J Ethnopharmacol 174:118–152
Han Mİ, Bulut G (2015) The folk-medicinal plants of Kadişehri (Yozgat-Turkey). Acta Societatis Botanicorum Poloniae 84(2):237–248
Hayta Ş, Polat R, Selvi S (2014) Traditional uses of medicinal plants in Elazığ (Turkey). J Ethnopharmacol 154:613–623
Honda G, Yeşilada E, Tabata M et al (1996) Traditional medicine in Turkey VI. Folk medicine in West Anatolia: Afyon, Kütahya, Denizli, Muğla, Aydın provinces. J Ethnopharmacol 53:75–87
Hürkul MM (2019) A ethnobotanical review: the subfamily amygdaloideae (Rosaceae). FABAD J Pharm Sci 44(1):35–46
Idolo M, Motti R, Mazzoleni S (2010) Ethnobotanical and phytomedicinal knowledge in a long-history protected area, the Abruzzo, Lazio and Molise National Park (Italian Apennines). J Ethnopharmacol 127:379–395
Kandemir A, Beyazoğlu O (2002) Köse Dağları'nın (Gümüşhane) tıbbi ve ekonomik bitkileri. SDÜ Fen Bilimleri Enstitüsü Dergisi 6:148–157
Karaköse M, Çolak Karaköse G (2017) Medicinal snd aromatic plants of Esenli (Giresun) forest planning unit. Int J Secondary Metabol 4(3):285–305
Karcı E, Gürbüz İ, Akaydın G, Günbatan T (2017) Folk medicines of Bafra (Samsun-Turkey). Turk J Biochem 42(4):381–399
Kargıoğlu M, Cenkci S, Serteser A et al (2008) An ethnobotanical survey of Inner-West Anatolia, Turkey. Hum Ecol 36:763–777
Kaval İ, Behçet L, Çakılcıoğlu U (2014) Ethnobotanical study on medicinal plants in Geçitli and its surrounding (Hakkari-Turkey). J Ethnopharmacol 155:171–184
Kaval İ, Behçet L, Çakılcıoğlu U (2015) Survey of wild food plants for human consumption in Geçitli (Hakkari, Turkey). Indian J Tradit Know 14(2):183–190
Kemertelidze E, Musashvili T, Benidze M et al (2012) Chemical composition and pharmaceutical activity of *Ruscus colchicus* leaves. Pharma Chem J 46(6):372–375

Kocabaş YZ, Gedik O (2016) Kahramanmaraş İl merkezi semt pazarlarında satılan bitkiler hakkında etnobotanik araştırmalar. Iğdır Univ J Inst Sci Technol 6(4):41–50

Koçyiğit M, Özhatay N (2006) Wild plants used as medicinal purpose in Yalova (Northwest Turkey). Turkish J Pharm Sci 3(2):91–103

Koleva V, Dragoeva A, Nanova Z et al (2015) An ethnobotanical study on current status of some medicinal plants used in Bulgaria. Int J Curr Microbiol Appl Sci 4(4):297–305

Korkmaz M, Alpaslan Z (2014) Ergan Dağı (Erzincan-Türkiye)'nın etnobotanik özellikleri. Bağbahçe Bilim Dergisi 1(3):1–31

Korkmaz M, Karakuş S (2015) Traditional uses of medicinal plants of Üzümlü district, Erzincan, Turkey. Pak J Bot 47(1):125–134

Korkmaz M, Karakuş S, Özçelik H, Selvi S (2016) An ethnobotanical study on medicinal plants in Erzincan, Turkey. Indian J Tradit Knowl 15(2):192–202

Koyuncu M (1990) Türkiye florasının tibbi bitkiler yönünden önemi. Tarım Orman ve Köyişleri Bakanlığı Dergisi 1990:53

Koyuncu O, Yaylacı ÖK, Öztürk D et al (2010) Risk categories and ethnobotanical features of the Lamiaceae taxa growing naturally in Osmaneli (Bilecik/Turkey) and environs. Biol Divers Conserv 3(3):31–45

Kültür Ş (2007) Medicinal plants used in Kırklareli Province (Turkey). J Ethnopharmacol 111:341–364

Küpeli E, Orhan İ, Yeşilada E (2007) Evaluation of some plants used in Turkish folk medicine for their anti-inflammatory and antinociceptive activities. Pharm Biol 45(7):547–555

Leporatti ML, Guarrera PM (2005) Ethnobotanical remarks in Capitanata and Salento Areas (Puglia, Southern Italy). Etnobiologia 5:51–64

Lexa A, Fleurentin J, Younos C, Mortier F (1990) Study of antihepatotoxicity of *Eupatorium cannabinum* L. in mice. an adequate method of screening in vivo antihepatotoxic natural principles. Phytother Res 4:148–151

Moravec I, Fernandez E, Vlkova M, Milella L (2014) Ethnobotany of medicinal plants of northern Ethiopia. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas 13(2):126–134

Mosaddegh M, Naghibi F, Moazzeni H et al (2012) Ethnobotanical survey of herbal remedies traditionally used in Kohghiluyeh va Boyer Ahmad province of Iran. J Ethnopharmacol 141:80–95

Mumcu Ü, Korkmaz H (2018) Ethnobotanical uses of alien and native plant species of Yeşilırmak Delta, Samsun, Turkey. Acta Biologica Turcica 31(3):102–113

Nacakcı FM, Dutkuner İ (2018) A study of ethnobotany in Kumluca (Antalya). Turkish J For 19(2):113–119

Nejad ASM, Kamkar A, Giri A, Pourmahmoudi AA (2013) Ethnobotany and folk medicinal uses of major trees and shrubs in Northern Iran. J Med Plants Res 7(7):284–289

Ostrovska H, Oleshchuk O, Vannini S et al (2017) *Epilobium angustifolium* L.: a medicinal plant with therapeutic properties. EuroBiotech J 1(2):126–131

Ouelbani R, Bensari S, Mouas TN, Khelifi D (2016) Ethnobotanical investigations on plants used in folk medicine in the regions of Constantine and Mila (North-East of Algeria). J Ethnopharmacol 194:196–218

Öz Aydın S, Dirmenci T, Tümen G, Başer KHC (2006) Plants used as analgesic in the folk medicine of Turkey. In: Proceedings of the IVth International Congress of Ethnobotany (ICEB 2005), Yeditepe University, August 21–26 2005, pp 167–172

Özbucak TB, Akçin ÖE, Yalçın S (2007) Nutrition contents of the some wild edible plants in Central Black Sea Region of Turkey. Int J Nat Eng Sci 1:11–13

Özgüven M, Sekin S, Gürbüz B et al (2005) Tütün, tibbi ve aromatik bitkiler üretimi ve ticareti. Türkiye Ziraat Mühendisleri Odasi Teknik Kongresi, 3–7 Ocak 2005, Ankara

Özhatay N, Koyuncu M, Atay M, Byfield A (1997) Türkiye'nin Dogal Tibbi Bitkilerinin Ticareti Hakkında Bir Calısma. Dogal Hayati Koruma Dernegi, Istanbul

Ozturk M, Hakeem KR (eds) (2018) Plant and human health, Ethnobotay and physiology, vol 1. Springer Science+Business Media, New York, 805 p

Ozturk M, Hakeem KR (eds) (2019a) Plant and human health, Phytochemistry and molecular aspects, vol 2. Springer Science+Business Media, New York, 697 p
Ozturk M, Hakeem KR (2019b) Plant and human health, Phytochemistry and therapeutic uses, vol 3. Springer+Business Media, New York, 385 p
Ozturk M, Ozdemir F, Yucel E (1997) An overview of the environmental issues in the Black Sea region. In: Glantz MH, Zonn IS (eds) Scientific, environmental and political issues in the circum Caspian Region. NATO-ARW, Kluwer Acad Publ, New York, pp 213–226
Ozturk M, Yucel E, Yarci C et al (1998) In: Kotlyakov V, Uppenbrink M, Metreveli V (eds) Plant diversity in the Turkish black searegion and strategies for its conservation. NATO-ARW, Batumi-Georgia, Kluwer Acad Publ, New York, pp 155–173
Ozturk M, Guvensen A, Akcicek E, Dalgic R (2010) Mad Honey. Ballı Yazılar (Nilhan Aras). Metro Kultur Yayınları, Gastro Dizisi IV, Turkey, pp 95–103
Ozturk M, Altundağ E, Gücel S (2012a) Medicinal and aromatic plants (Turkey). Ethnopharmacol Encycl Life Support Syst 6:181–206
Ozturk M, Gücel S, Altundağ E et al (2012b) An overview of the medicinal plants of Turkey. In: Singh R (ed) Genetic resources, chromosome engineering and crop improvement: medicinal plants. CRC Press, LLC, Taylor & Francis, New York, pp 181–206
Ozturk M, Uysal I, Gücel S et al (2013) Medicinal uses of natural dye-yielding plants in Turkey. RJTA 17(2):69–80
Ozturk M, Dalgic R, Guvensen A et al (2014) Honey – pollen – health: palinochemical analysis of honey from Turkey. In: Ghaemghami J et al (eds) Proc IS on Medicinal Plants and Natural Products, Acta Hort 1030, ISHS 2014
Ozturk M, Akçiçek E, Güvensen A, Altay V (2016) Mantarların Tıbbi Değeri. In: Ötleş S, Akçiçek E (eds) Kanserden Korunmada Gıdalar ve Beslenme. Sidas Medya Ltd. şti, İzmir, pp 213–220
Ozturk M, Altay V, Gücel S, Altundağ E (2017a) Plant Diversity of the Drylands in Southeast Anatolia-Turkey: Role in Human Health and Food Security. In: Ansari AA, Gill SS (eds) Plant biodiversity: monitoring, assessment and conservation. CABI, London, pp 83–124
Ozturk M, Altay V, Gonenç TM (2017b) Herbal from high mountains in the East Mediterranean. In: Bhojraj S et al (eds) Drug discovery from herbs – approaches and applications. DAYA Publishing House, New Delhi, pp 327–367
Ozturk M, Gökler I, Altay V (2018a) Medicinal bryophytes distributed in Turkey. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 323–348
Ozturk M, Altay V, Latiff A et al (2018b) A comparative analysis of the medicinal pteridophytes in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 349–390
Ozturk M, Altay V, Latiff A et al (2018c) A comparative analysis of the medicinal plants used for diabetes mellitus in the traditional medicine in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 409–461
Ozturk M, Altay V, Latiff A et al (2018d) Potential medicinal plants used in the hypertension in Turkey, Pakistan, and Malaysia. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 595–618
Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018e) A comperative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343
Ozturk M, Altay V, Altundağ E et al (2018f) Herbal in Iğdır (Turkey), Nakhcivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer International Publishing AG, part of Springer Nature, Cham, pp 197–266
Özüdoğru B, Akaydın G, Erik S, Yesilada E (2011) Inferences from an ethnobotanical field expedition in the selected locations of Sivas and Yozgat provinces (Turkey). J Ethnopharmacol 137:85–98

Pieroni A, Giusti ME (2009) Alpine ethnobotany in Italy: traditional knowledge of gastronomic and medicinal plants among the Occitans of the upper Varaita valley, Piedmont. J Ethnobiol Ethnomed 5(1):32
Pieroni A, Dibra B, Grishaj G et al (2005) Traditional phytotherapy of the Albanians of Lepushe, Northern Albanian Alps. Fitoterapia 76:379–399
Polat R (2018) Ethnobotanical study on medicinal plants in Bingol (City center) (Turkey). J Herb Med 16:100211
Polat R, Satıl F (2012) An ethnobotanical survey of medicinal plants in Edremit Gulf (Balıkesir-Turkey). J Ethnopharmacol 139:626–641
Polat R, Çakılcıoğlu U, Kaltalioğlu K et al (2015) An ethnobotanical study on medicinal plants in Espiye and its surrounding (Giresun-Turkey). J Ethnopharmacol 163:1–11
Prajapati ND, Purohit SS, Sharma AK, Kumar T (2003) A handbook of medical plants. Agrobios, New Delhi
Ranfa A, Bodesmo M (2017) An Ethnobotanical investigation of traditional knowledge and uses of edible wild plants in the Umbria Region, Central Italy. J Appl Bot Food Qual 90:246–258
Rates SMK (2001) Plants as source of drugs. Toxicon 39:603–613
RBG Kew (2017) The State of the World's Plants Report. Royal Botanic Garden. https://stateoftheworldsplants.org/. Accessed on 04 May 2018
Sağıroğlu M, Arslantürk A, Akdemir ZK, Turna M (2012) An ethnobotanical survey from Hayrat (Trabzon) and Kalkandere (Rize/Turkey). Biol Divers Conserv 5(1):31–43
Sağıroğlu M, Topuz T, Ceylan K, Turna M (2013) An ethnobotanical survey from Yahyalı (Kayseri) and Tarsus (Mersin). SAÜ Fen Edebiyat Dergisi 2:13–37
Saraç DU, Özkan ZC, Akbulut S (2013) Ethnobotanic features of Rize/Turkey province. Biol Divers Conserv 6(3):57–66
Sargın SA, Büyükcengiz M (2018) Plants used in ethnomedicinal practices in Gülnar district of Mersin, Turkey. J Herb Med 15:100224
Sargın SA, Selvi S, Akçiçek E (2013) Investigations of ethnobotanical aspect of some geophytes growing in Alaşehir (Manisa) and surrounding area. Erciyes Univ J Inst Sci Technol 29(2):170–177
Şekercioğlu N, Özkutlu F, Deveci M et al (2006) Evalution of some wild plants aspect of their nutritional values used as vegetable in the Eastern Black Sea Region of Turkey. Asian J Plant Sci 5(2):185–189
Şengül Ç, Kaya S (2017) Türkiye endemik bitkilerinin coğrafi dağılışı. Türk Coğrafya Dergisi 69:109–120
Şensoy S, Demircan M (2016) Climate of Turkey. Ministry of Forestry and Water Affairs Turkish State Meteorological Service, Turkey
Sevastre B, Sárpatakı O, Stan RL et al (2017) Anticancer activity of *Euonymus europaeus* fruits extract on human melanoma cells. Farmacia 65(1):56–62
Sezik E, Tabatab M, Yeşilada E et al (1991) Traditional medicine in Turkey I. Folk medicine in Northeast Anatolia. J Ethnopharmacol 35:191–196
Sezik E, Zor M, Yeşilada E (1992) Traditional medicine in Turkey II. Folk medicine in Kastamonu. Int J Pharmacogn 30(3):233–239
Sezik E, Yeşilada E, Tabata M et al (1997) Traditional medicine in Turkey VIII. Folk medicine in East Anatolia; Erzurum, Erzincan, Ağrı, Kars, Iğdır, Ardahan provinces. Econ Bot 51(3):195–211
Şimsek I, Aytekin F, Yeşilada E, Yıldırımlı Ş (2004) An ethnobotanical survey of the Beypazarı, Ayas, and Güdül district towns of Ankara Province (Turkey). Econ Bot 58(4):705–720
Tallent-Halsell NG, Watt M (2009) The Invasive *Buddleja davidii* (Butterfly Bush). Bot Rev 75:292–325
Temel M, Tınmaz AB, Öztürk M, Gündüz O (2018) Dünyada ve Türkiye'de tıbbi-aromatik bitkilerin üretimi ve ticareti. KSÜ Tarım ve Doğa Dergisi 21(SP):198–214
Terzioğlu S (1999) Trabzon İlinin endemik bitkileri. Trabzon Valiliği İl Çevre Müdürlüğü Çevre Durum Raporu, Trabzon

Terzioğlu S, Tüfekçioğlu A, Küçük M (2015) Vegetation and plant diversity of high-altitude mountains in Eastern Karadeniz (Black Sea) region of Turkey and climate change interactions. In: Ozturk M, Hakeem KR, Faridah-Hanum I, Efe R (eds) Climate change impacts on high-altitude ecosystems. Springer International Publishing, Cham

Tetik F, Civelek Ş, Cakılcıoğlu U (2013) Traditional uses of some medicinal plants in Malatya (Turkey). J Ethnopharmacol 146:331–346

Tită I, Dan Mogoşanu G, Tită MG (2009) Ethnobotanical inventory of medicinal plants from the South-west of Romania. Farmacia 57(2):141–156

Toksoy D, Bayramoğlu M, Hacisalihoğlu S (2010) Usage and the economic potential of the medicinal plants in Eastern Black Sea Region of Turkey. J Environ Biol 31(5):623–628

Tümen G, Malyer H, Başer KHC, Öz Aydın S (2005) Plants used in Anatolia for wound healing. In: Proceedings of the IVth International Congress of Ethnobotany (ICEB 2005), pp 217–221

Türkan Ş, Malyer H, Öz Aydın S, Tümen G (2006) Ordu İli ve çevresinde yetişen bazı bitkilerin etnobotanik özellikleri. Süleyman Demirel Üniv Fen Bilimleri Enstitüsü Dergisi 10-02:162–166

Tuzlacı E, Erol MK (1999) Turkish folk medicinal plants. Part II: Eğirdir (Isparta). Fitoterapia 70:593–610

Tuzlacı E, Sadıkoğlu E (2007) Turkish folk medicinal plants, part VI: Koçarlı (Aydın). J Fac Pharm İstanbul 39:25–37

Tuzlacı E, Tolon E (2000) Turkish folk medicinal plants, part III: Şile (İstanbul). Fitoterapia 71:673–685

Ugulu İ (2011) Traditional ethnobotanical knowledge about medicinal plants used for external therapies in Alasehir, Turkey. Int J Med Aromat Plants 1(2):101–106

Uğurlu S (2011) Traditional folk medicine in the Turkish Folk Culture. Int Period Lang, Literat Hist Turkic 6(4):317–327

UICN, OMS, WWF (1993) Directrices sobre conservacion de plantas medicinales Organizasion Mundial de la Salud (OMS). Union Internacional para la Conservacion de la Naturaleza (UICN) and World Wildlife Fund (WWF), Gland

Uysal İ, Onar S, Karabacak E, Çelik S (2010) Ethnobotanical aspects of Kapıdağ Peninsula (Turkey). Biol Divers Conserv 3(3):15–22

Vokoua D, Katradi K, Kokkinib S (1993) Ethnobotanical survey of Zagori (Epirus, Greece), a renowned centre of folk medicine in the past. J Ethnopharmacol 39:187–196

WHO (2002) WHO traditional medicine strategy 2002-2005. WHO, Geneva

Xie C, Xie Z, Xu X, Yang D (2015) Persimmon (*Diospyros kaki* L.) leaves: A review on traditional uses, phytochemistry and pharmacological properties. J Ethnopharmacol 163:229–240

Yaldız G, Yüksek T, Şekeroğlu N (2010) Rize İli florasında bulunan tıbbi ve aromatik bitkiler ve kullanım alanları. III. Ulusal Karadeniz Ormancılık Kongresi, Artvin 20-22 Mayıs 2010, III, 1100-1114

Yazıcıoğlu A, Tuzlacı E (1995) Folk Medicinal plants of Trabzon (Turkey). J Pharm Univ Mar 11(1-2):333–342

Yazıcıoğlu A, Tuzlacı E (1996) Folk medicinal plants of Trabzon (Turkey). Fitoterapia 67(4):307–318

Yeşilada E (2002) Biodiversity in Turkish folk medicine. In: Şener B (ed) Biodiversity: BIOMOLECULAR aspects of biodiversity and innovative utilization. Kluwer Academic/ Plenum Publishers, New York

Yeşilada E, Honda G, Sezik E et al (1995) Traditional medicine in Turkey. V. folk medicine in the inner Taurus Mountains. J Ethnopharmacol 46:133–152

Yeşilada E, Sezik E, Honda G et al (1999) Traditional medicine in Turkey IX: Folk medicine in North-West Anatolia. J Ethnopharmacol 64:195–210

Yeşilyurt EB, Şimşek I, Akaydın G, Yeşilada E (2017) An ethnobotanical survey in selected districts of the Black Sea region (Turkey). Turk J Bot 41:47–62

Chapter 12
Main Problems of the Sustainable Development of South Caucasus and Processes of Transformation of Landscape (Ecosystem) Biodiversity

Nodar Elizbarashvili, Nino Sulkhanishvili, and Rusudan Elizbarashvili

12.1 Introduction

South Caucasus (Azerbaijan, Armenia, and Georgia) is a mountainous country located at 602 m above sea level on average in one of the most seismically active zones of the world, on the border between the moderate, subtropical, and tropical climatic zones, in the southern part of Holarctic floristic kingdom (Anonymous 2002). The region has all kinds of problems (shortage of land, geodynamic processes, distribution of water resources, development of transport infrastructure, population migration from the mountain to lowland, etc.) typical to almost any mountainous region of the world.

With the *biodiversity index*, South Caucasus ranks one of the first in the Northern Hemisphere with over 6000 plant varieties, which, if given in terms of a unit area, gives the region the status an important Global Biodiversity Center (Fig. 12.1) (Anonymous 2000).

South Caucasus is also distinguished for its high *endemism*: 1/4 of the plants and animals in the region are endemic. For example, the mammals alone are represented by 152 species, with 30 of them being endemic. There are also many relict species in the region. South Caucasus is outstanding with its *landscape diversity*: although it occupies 0.5% of the world's land, it has 40% of the world's types of landscapes. It should also be noted that 1/10 of the landscapes in South Caucasus belong to the category of intact or insignificantly transformed landscapes. It is also interesting to note that homogenous or transboundary landscapes, irrespective of their political appropriation, are characterized by the similar forms of economy and environmental problems. The historical, ethnic, socioeconomic, and cultural development and ecological reasoning of the peoples living in South Caucasus show certain similarities.

The countries of South Caucasus, despite their relatively small areas (they occupy only 1/3 of the ecoregion), have a central and *key geographical position* in

N. Elizbarashvili (✉) · N. Sulkhanishvili · R. Elizbarashvili
Tbilisi State University, Tbilisi, Georgia

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_12

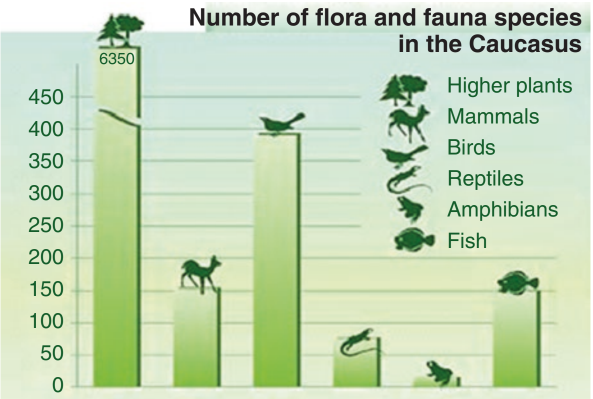


Fig. 12.1 Species number in Caucasus (Anonymous 2011)

Fig. 12.2 Caucasus ecoregion (WWF 2018)

Caucasus. High population density with higher concentrations in the intermountain plain, river gorges, and mountain basins results in the high anthropogenic impact in these areas (Elizbarashvili 2016).

The modern economic and social problems typical to the countries of South Caucasus *influence* the sustainable development of the *region* in general and (Fig. 12.2) the sustainable ecological development in particular. On the one hand, the scales of the technogenic impact on the natural environment have diminished, while on the other hand, an interest in "easily accessible" natural resources (forests, water, land, recreational resources, etc.) has increased. Such state of affairs further aggravates the environmental problems.

In the countries of South Caucasus, they *feel alarmed* at the increased number and scales of the catastrophic geodynamic processes, desertification, reduction of the forest areas, secondary bogging and salinization, pollution of water objects, water and wind erosion, degradation of land resources, extinction or reduced number of certain animal species, etc.

Presently, tens of higher plant species, about 100 mammal species, over 100 bird species, up to 30 reptile species *are at the brink of extinction*. Despite the positive trend in expanding the protected areas, the problem of biodiversity conservation is still one of the severest issues.

The *European values* are being actively introduced to the countries of South Caucasus. Georgia, Azerbaijan, and Armenia have ratified many of the international environmental conventions and have adopted tens of environmental laws; they are establishing the network of the protected areas (including transboundary areas) and jointly realize large-scale regional economic and environmental projects (Fig. 12.3).

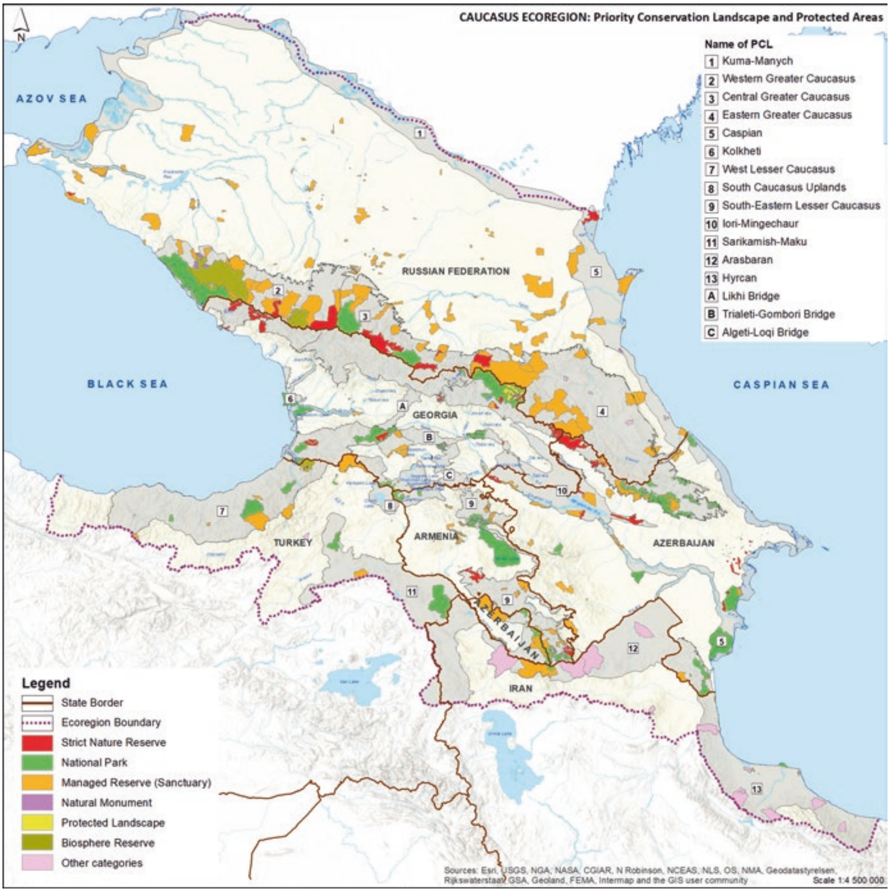


Fig. 12.3 Priority conservation landscape and protected areas (WWF 2018)

12.2 Some Problems of the Sustainable Development of South Caucasus

The problems of sustainable development of South Caucasus are associated with a number of reasons, with the following ones being important:

12.2.1 Historical Particularities of the Socioeconomic Development

For decades, the countries of South Caucasus were concerned with the goals and objectives of the political and economic development of the former Soviet Union, and as a result, the economics of the countries of this region depended on one another and have centralized system. In recent decades, a shift to the market economy takes a successful course gradually promoting the new and extensive economic cooperation. Nevertheless, the influence of the economic specialization of the Soviet era is still strong in the countries of South Caucasus, and it is particularly significant in industry and agriculture. The development of the resort economy is also slow, as it experienced a total fiasco on the background of the geopolitical processes and military oppositions in the last decade of the twentieth century.

At the beginning of the twenty-first century, the impact of plant sources has increased drastically with negative impact on the prospects to develop local production and contribute to the growing unemployment.

The specialization and geography of the economy had an essentially negative impact. Its production was mainly destined to meet the demands of the Soviet countries and failed to consider the local resources or potential. The disruption of the economic links resulted in the destruction of a number of branches and disqualification of the relevant personnel. The geographical specifics of the distribution of the economy were associated with the intermountain plain (large settled areas) and transport mains in South Caucasus, and as a result, the mountain regions got virtually devastated and the preconditions for the demographic crisis developed there.

Many of economy areas (oil processing, metallurgy, chemical industry, mining, transport, agriculture, etc.) have failed to consider the ecological demands of the population and this has become a precondition for the environmental degradation in several regions. Despite the quite thorough legislation, the environmental problems (e.g., erosion, desertification) have become one of the hampering factors on the way of the local socioeconomic development.

12.2.2 Modern Trends in the Development of Economy

In recent decades, the focus of the socioeconomic processes on the field of service, trade, and communications has become evident in the countries of South Caucasus. The aspiration of the countries to have their independent food policy is noteworthy; however, extensive agriculture fails to meet the local demands. Such processes and state of affairs make the local economy even more dependent on the imported goods, leading to the unreasonable expenditure of the currency resources. The majority of the population is employed in agriculture and as a result they have no stable incomes.

Agriculture remains the major specialization of the economy in the countries of South Caucasus. Its development is promoted by favorable and diversified agroclimatic and soil resources. In these countries, it is possible to grow almost all kinds of food and industrial agricultural crops. The production traditions making such products even more attractive are also essential. The raw materials produced in agriculture are the precondition for the food industry to develop what gradually acquires an ecological profile. Despite the high potential, a significant portion of meat, dairy, wheat, vegetable, and many other food products are imported to the region. The problems of soil salinization, erosion, and reduced fertility are still topical in the area. The specialization of agriculture is still chaotic and has not yet made a matter of the state policy.

The summer pastures of the Caucasioni and Lesser Caucasioni are actively used to develop cattle breeding which is hardly true with the limited areas of winter pastures. It is known that due to the intense grazing there (the heads of cattle are four to five times more the admissible level), the problems of desertification and decreased fertility of the pastures are topical in the region.

Extensive agriculture has a negative impact on the natural ecosystems and habitats of a number of wildlife species. The problem is aggravated by the trends of the climate change, which may become a precondition for the reduced natural productivity of the landscapes in the intermountain plain.

12.2.3 Trends of Using Natural Resources

The energy resources are distributed unevenly in South Caucasus. For instance, Azerbaijan is rich in fuel deposits, while Georgia is rich in hydropower resources. Consequently, the two countries generate the electrical power by employing the resources available to them, while Armenia generates the electrical power mostly by processing the nuclear energy. The principal consumer of the electrical power is the population. However, in recent decades, an increased consumption of the electrical power is seen in industrial and transport fields. Georgia has good prospects to develop hydropower energy. However, the associated environmental problems (including an issue to maintain the Black Sea coastline) and the protest of the local population (in the regions, which are short of lands even so) are still topical.

12.2.4 Trends in Transport Development

South Caucasus owes its well-developed transport network to its favorable geopolitical location and natural conditions. South Caucasus has already become an essential section of the Great Silk Road, a bridge connecting Europe and Asia and a

Fig. 12.4 Landscapes of Caucasus (WWF 2018)

transport artery between Russia and Western Asia. The Caspian and Black seas play an extremely important role by connecting the countries of Europe, Near East, and Central Asia by means of their rivers and channels (Figs. 12.4 and 12.5).

High specific weight of the mountain regions makes for the high traffic passenger and freight turnover, which is the precondition for the aggravation of the ecological state. The problem of atmospheric pollution in the basin-type settlements (Tbilisi, Yerevan, Vanadzor, etc.) is particularly severe (Anonymous 2009). In addition to the traffic flows, atmospheric pollution is promoted by the poor technical state of vehicles and poor quality of fuel.

The oil and gas transport mains intensely used by humans for more than one century acquire a world geopolitical importance. The oil and gas flows are of both east-western (Central Asia-Azerbaijan-Georgia-Turkey-Europe) and north-southern (Russia-Georgia-Armenia-Iran) directions. The transportation of energy resources via pipelines has increased the risks in environmental safety risk which are associated with possible technogenic accidents and high seismic activity. An increasing freight turnover in South Caucasus is also a precondition for the pollution of the Black and Caspian seas.

Fig. 12.5 Priority conservation landscapes and key diversity areas (WWF 2018)

12.2.5 Scales of the Forest Resources Use

The forest resources are of particular importance for the residents of mountain villages. The more the population density in such villages, the more forest resources they use. The anthropogenic factor has become a reason for the modern deforestation of the largest areas of Javakheti volcanic plateau and Yerevan basin, where the forests have been replaced by semi-deserts or mountain steppes.

In the twentieth century, the forests of South Caucasus "were left alone," as mostly the inexpensive timber imported from Russia was used in the region. Irregular and rapacious exploitation of the forests was the case in the last decades followed by the activation of the geodynamic processes in many regions. The exploitation of forests in Armenia, Azerbaijan, and East Georgia needs special care, as the productive moisture needed for the self-restoration of the forests is particularly low in these regions (particularly, in summer, i.e., in the active vegetation period).

Georgia is rich in forest resources following the country's favorable location and the given kind of the distribution pattern of heat and moisture. Forests regulate air humidity; distribution of precipitations; amount of underground waters; thermal exchange; wind velocity; amount of oxygen, dust, and carbonic acid; and many other geo-ecological processes. Forests are the best shelters for the wildlife and thus have a particular ecological importance.

The standard of life of the locals together with a high demand from neighboring countries are directly associated with the types and methods of the forest use. These are still the major problems for the sustainable development of South Caucasus.

12.2.6 Trends of the Population Dynamics

There are about 17 million residents in South Caucasus. The population of Azerbaijan increases relatively rapidly, but this is not the same with Georgia and Armenia. Migration and armed conflicts in the region have acquired extremely hazardous scales recently, which have become the reason for the depopulation of a number of regions. As various sources suggest, up to four million residents have left South Caucasian countries, which essentially changed the demographic background and people's age structure in the region. The trend of the population's mass concentration in large cities (Tbilisi, Yerevan) is absolutely evident, which aggravates the socioeconomic situation and hampers the regular development of the peripheries of the countries (Anonymous 2009). According to the official information, 1/3 of the total population of the region lives in the capitals of Georgia and Armenia. However, this situation is five or six times more in other large cities namely; Batumi and Gyumri, of these countries, as per the indicator values.

Large scales of urbanization aggravate the ecological background and socioeconomic situation. The pollution of air, soil, and waters and degradation of agricultural lands as well as the biodiversity around the territories of large settled areas are very high.

12.2.7 Geopolitical Situation and Military Conflicts

A significant factor hampering the sustainable development of South Caucasus is both open and nonmanifest political conflicts, which have become the reason for a number of permanent military oppositions in recent decades. All three countries of the region are in a state of war, which has an effect on their economic, social and ecological situation. The majority of the conflicts come from the territorial claims, which is in fact an unsolved problem for the sustainable development of the region.

12.2.8 Natural Risks and Disasters

South Caucasus is located in the active seismic zone. This situation together with the geographical factors poses high natural risks affiliated to catastrophic and diversified nature of the natural phenomena. Almost all kinds of catastrophic events and processes known to date are common in the region. These phenomena in the region include volcanic activities, tropical cyclones, and big floods. In this respect, the mountains are serving as a kind of protective function. The frequent landslide and mudflow processes, snow and stone avalanches, intense frosts and droughts, hail and tornados also are observed on their mountains. These processes can bring a huge economic damage. Too little is done in the region to prevent or forecast natural disasters. The network of meteorological and hydrological observations is almost totally devastated, thus complicating the monitoring of the environmental processes.

Landslide processes mostly develop in average mountains, in terms of intense humidification, and are promoted by earthquakes, underground waters (near the water reservoirs in the first instance), human economic activities, and geology and exposition of the relief. Mudflow currents can cause a great damage or lead to the activation of the secondary processes (formation of landslide bodies). Their intensity depends on the amount of the talus material accumulated in the river gorges as a result of physical weathering and intensity of water mass movement. The mudflow processes are mostly common in areas with average and low mountains, easily degradable rocks, degraded forests, and intense rains. Floods are mostly common in the regions with low-mountain and plain reliefs with a high proportion of atmospheric precipitations (snow particularly) in the alimentation of their rivers. The floods occurring at the beginning of spring or summer sometimes last for some months. The flood intensity increases when heavy rains coincide with snowmelt. The floods can be regulated only by means of water reservoirs or coast-protecting structures. Snow avalanches are one of the significant natural calamities in the high-mountain areas of South Caucasus. The main areas where snow avalanches are commonly formed are highly inclined slopes without any forest at 2000 to 4000 m altitude. Avalanches are also frequent at other altitudes, bringing a great material damage to the population and transport communication. The intensity and frequency of earthquakes are associated with the seismic activity of the Caucasian region. They often ended in catastrophes. A number of famous lakes (Ritsa, Amtkeli, Göygöl, etc.) were formed as a result of blocking-up the area with the mountain rocks collapsing as a result of earthquakes. The frequency and intensity of the earthquakes have drastically increased for the last half the century. Earthquakes' epicenter in Caucasus is located relatively nearer (20–30 km) to the Earth's surface than in other seismically active regions of the world causing particularly great material damage. Drought is a natural disaster common in the eastern and southern regions of Caucasia, occurring in the arid and semiarid climatic zones. The topicality of droughts increases following climate change. The negative outcomes of intense droughts associated with desertification and depopulation are clearly seen in many regions of Armenia and Azerbaijan. Drought prevention is associated with the rational and efficient use of water resources. This aspect will gain more importance in the future (as the climatic forecasts suggest).

As the trends of the economic development in the countries of South Caucasus are not based on the single principles of nature use and do not consider a single methodology of territorial planning, they may become a significant barrier on the way of both sustainable development and regional cooperation. Landscape planning, as an approved and important instrument in Europe for environmentally oriented territorial planning, is capable of *harmonizing the processes* associated with the nature use in the countries of South Caucasus.

12.3 Methodology of Assessment of Indicators of Sustainable Development and Landscape Condition

The indicators of sustainable development are the indices used *to evaluate and show* the levels and trends of national, regional, and global development. The analysis of such indicators is used to forecast the peculiarities of political, economic, social, and ecological development of the geographical environment.

The *main environmental indicators* of sustainable development are considered to be:

- Level of degradation of land, water, atmospheric air, plants and animals, ecosystems, and landscapes
- Scales of using the natural resources
- Scales of ecological policy and ecology-oriented territorial planning and realization
- Outcomes of realization of the national environmental legislation and international conventions

The indicators of sustainable development can be *classified* based on various approaches (systemic, complex, target) and the country's strategic policy (view). The classification units may be associated with:

- The level and state of development (characterizing the processes, efficiency, safety, freedom of action, responsibility, and outcomes of the public activities)
- The planning and management perspectives (characterizing the opportunity to respond and forecast)

The national indicators of sustainable development are desirable to be based on the international experience, methodology, and specifics. Such an approach is the precondition for the successful (efficient) comparative analysis. The difference may be seen in such indicators, which characterize the local ethnic culture (values of views), ethnic and historical values, legal traditions, specifics of individual branches of economy, etc.

The environmental problems may also be viewed depending on the individual components of *the geographical layer* (lithosphere, atmosphere, hydrosphere, biosphere, pedosphere). Such an approach is efficient when the natural components are evaluated by considering their resource potential. For instance, the lithosphere may be assessed according to the relief forms or site altitude and opportunities to develop ore deposits or various branches of economy.

A meeting was held on April 10, 2018, with the aim of developing and planning a regional dialogue and cooperation between scientists and practitioners regarding natural calamities and climate change impacts in the Caucasian region. The meeting identified the priorities of the actions, which will diminish the population's vulnerability to the abovementioned problems and support the regional cooperation to overcome the challenges of adaptation. Among them are the improvement of the efficiency of the educational disciplines associated with the natural calamities (landslide, mudflow, avalanche, earthquake, etc.) and implementation of the international experience in this field at higher educational establishments.

The main goals of the environmental impact assessment are:

1. Protection of human health, natural environment, as well as cultural and material values
2. Consideration of the ecological and socioeconomic interests of the state and public.

Environmental impact assessment *envisages* the procedure of studying the planned activity and responses of the environmental elements. It is used to make direct and indirect assessments of the impacts of the activity on the environmental components, landscape and ecosystems, natural and cultural heritage, and socioeconomic development.

In assessing the impacts on the landscape, the geographical peculiarities of the landscapes, scales of natural and anthropogenic impacts, sustainability features, and transformation parameters *are taken into account*, in particular:

- Type, sub-type, and genera of the landscape
- Geographical location: geographical units (river basin, orographic units), settlement areas, and altitude of the site
- Relief: dominant slope gradients, forms, and types of the relief
- Geomorphology: dominant type of a geomorphological process (what is it associated with), geology (what does it support), nature, and intensity of the geodynamic processes
- Climate: general features, average seasonal temperatures, average annual amounts and seasonal distribution of precipitations, dryness index, and comfort/discomfort indices of the climatic characteristics
- Soil: type and strength and vertical and mechanical structure
- Vegetation: type, strength, and frequency and degree of transformation
- Type of economic use
- Degree of stability
- Degree of the landscape transformation

Up-to-date condition of landscape (Beruchashvili 1995; Brown and Vivas 2005; Willemen et al. 2008; Elizbarashvili 2009, 2016; Elizbarashvili and Meessen 2018) is the most important among geoecologic characteristics. It can be shown by landscape transformation scales and application forms. Among the basic ones are current structure of landscape, existence of specific geomasses, and influence of forms and intensity. According to what kind of influence (natural, socioeconomic, or mixed) is redundant, there is a determined character of the corresponding process.

Moreover, the impacts on the landscape can be time related as well e.g., short, periodic, constant; or procedural e.g., on components, complexity and process; scaled such as feeble, average, strong and others. The influence can be considered by modification of source, intensity, periodicity, forms, and results. Consequently, a geographic analysis of each type of influence and its results is a labor-consuming scientific research process which is noted as landscape related influence with variety and scale differences.

The condition of landscapes is defined by forms and scales of external influence. Character of influence can be considered by the ability of self-regeneration of the landscape structure. It is admitted that if the influence touches to the biologic components only, the landscape preserves the self-generation ability. Preservation of the self-regeneration mechanism is impossible if:

1. The influence coincides or stimulates (increase) the negative natural processes (machines, salinity, ravines, erosion, and so on)
2. There is influenced basic landscape creator component or relief and climate
3. When one ecosystem is exchanged by other, equivalent to one

Any arbitrary influence can produce negative or positive results. For every nature the extreme influence causes a destruction of dynamic balance, conversion systemic connections among components, exchange of structure and functioning, and so on. In spite of the above mentioned aspects, these need to be evaluated two ways; first, how well ate the preserved structural-functional features of any landscape after influence; second, how well a given landscape carries out the socioeconomic functions.

In the case of natural influence the results can be considered as direct and indirect. First is considered in the case of extreme hydrothermal conditions e.g., drought and redundant humidity as these are directly exchanged between the bio-geo-horizons and other bio-masses such as; hydro masses, herbal masses, soil masses; all these are modified step by step. In the landscape, there are passive relief created processes as well as active one like; water cycle, bio-geo-cycle, transformation of solar energy and others.

An analysis of anthropogenic influence reveals that, we must consider the landscape needs self-generation ability for recovery of initial ability. This especially concerns to these landscapes, which have a recourse reproduction and environment recovery functions. Anthropogenic influence differs by form of agriculture, technogenic (industry, building, transport, and others), techno-ecological (exploitation of the forests, conflagration, and others), recreational, and other activities. Anthropogenic influence can be synchronous (various at the same time – in case of many-sided applications of the territory) or iterate (when one kind of influence is exchanged from other). Synchronous influence basically is observed on the urban territory, in such landscapes agriculture, forest, and water exploitation are followed at the some time. The influence is iterated in these regions where the seasonal agricultural and recreational loading is great. Such landscapes are represented basically in mountains. The plane landscapes among the mountains of Georgia must be considered as area with synchronous influence where are represented various agricultural and social activities of the population, which includes 80% of the society. Here we come across a living environment, industrial activities, agricultural production and a better transport infrastructure. Influence of agricultural activities is intensive but it carries a periodic character. In spite of the periodicity of agro-technical influence, it is essential that agrarian landscapes are completely dependent on such influences. In the agricultural landscapes, the agricultural influence is directed for the preservation of desired stable development of agriculture and functioning. The less the agriculture gets involved in the landscape-ecologic conditions, the less stable it will be to the environmental influences and more will be the agro-technical influence, but the production will be less profitable.

12.4 Results

Determinants of the environmental conditions include a mixed influence which is characterized for such landscapes, because anthropogenic influence bears an episodic character. In this case, the structure and functioning of the landscape are stipulated as natural, so are anthropogenic factors. The basic criterion of the determination of current condition of natural environment, we have to stipulate structural, functional, ethological-physiognomic features. These can be considered by the following groups (Table 12.1 and Fig. 12.6):

1. *Practically invariable landscapes* – is transformed less than 5% of horizontal structure, are preserved specific geo-masses, elementary landscapes are changed unimportant, practically there are invariable geo-horizons, the landscape condition is completely determined by natural processes.
2. *Insignificantly modified landscapes* – is transformed 5–20% of horizontal structure, partially has been changed specific geo-masses, vertical structure is changed inconsiderably (1/4), the functional parameters are changed, landscapes condition is determined by natural, partially socioeconomic processes.
3. *Middling changed landscapes* – is transformed half of horizontal structure, partially or considerably has been changed specific geo-masses, geo-horizons are changed middling, landscapes condition is determined as by natural, so socioeconomic processes.
4. *Strongly modified landscapes* – is transformed more than half of horizontal structure, considerably has been changed specific geo-masses, considerably has been changed or ecocides vertical structure, has been transformed natural mode, landscapes condition is determined by socioeconomic (partially natural) processes.

Table 12.1 Mine landscape types of South Caucasus and its value of condition for sustainable development

Types of landscapes	Natural landscape diversity, number of ecosystem species	% of transformation of natural structure	Determined processes of landscape	Current condition	Value of condition for sustainable development
1. Plain and foothills-hill subtropical humid	10 (high)	80	Human	4	Low
2. Plain and foothills sub-Mediterranean semi-humid	6 (middle)	70	Human and Natural	4	Middle
3. Plain and hilly subtropical semiarid	2 (low)	73	Human and Natural	4	Low
4. Plain and foothills subtropical arid	1 (low)	65	Human and Natural	4	Middle
5. Plain thermo-moderate semi-humid	2 (low)	55	Human and Natural	4	Middle
6. Hydromorphic and sub-hydromorphic	2 (low)	40	Natural	3	High
7. Low mountainous subtropical semiarid	2 (low)	85	Human	5	Low
8. Low mountainous subtropical arid	1 (low)	60	Human and Natural	4	Middle
9. Low mountainous thermo-moderate humid	18 (high)	65	Human and Natural	4	Middle
10. Middle mountainous thermo-moderate semi-humid	1 (low)	70	Human and Natural	4	Middle
11. Middle mountainous thermo-moderate semiarid	2 (low)	85	Human	5	Low
12. Middle mountainous cold-moderate	4 (low)	30	Natural	3	High
13. High mountain alpine	8 (middle)	10	Natural	2	High

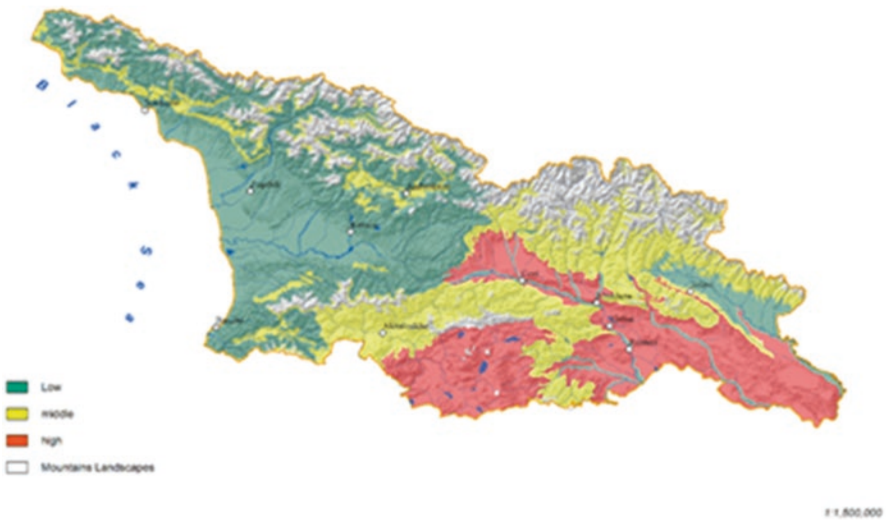


Fig. 12.6 Degree of possible change of landscapes of Georgia

5. *Practically transformed landscapes* – almost completely has been transformed the horizontal structure (more than 80%), essentially has been changed (transformed) specific geo-masses, vertical structure has been geocide's, landscape has been changed, there has been transformed all landscape-ethologic characteristics, landscapes condition is determined by socioeconomic processes (Elizbarashvili 2005).

Therefore, a majority of landscapes of South Caucasus belong to categories of very strongly changed landscapes. These are followed by little or completely influenced and changed, some are practically transformed types of landscapes.

12.5 Discussion

An assessment of the conditions of landscapes has an important link with landscape planning and sustainable development. In it, the main role is also played naturally by socioeconomic factors. Human activities determine a condition of 20% of landscapes of South Caucasus. At the present stage, an important task is determination of the current state of the changed landscapes among which the main part is occupied by agricultural modifications.

Conditions of the transformed landscapes in many cases depend on the natural potential, which is gradually considered with specializations into separate directions such as; agricultural industry, economy, and urbanization in the region. Therefore, at this stage, the major scientific task is creation of methodology of determination of not only conditions but also potential of the transformed landscapes.

12.6 Conclusions

In South Caucasus, in the scientific and practical plan, the processes connected with introduction of methodology and experience of sustainable ecology development and landscape planning are actively conducted. These processes are connected with the ratification of European landscape convention (European Landscape Convention 2000) as well in countries of South Caucasus. On the basis of the principles of sustainable development and landscape planning, in the last 4 years, new protected territories were created (in the southern Georgia, two national parks, cross-border with Armenia and Turkey, and in northern Georgia, two new national parks with cross-border prospect with Russia). In the future is planned to accept participation in scientific practical activities in countries of South Caucasus, connected with creation of ecological corridors, landscape governance, and landscape services.

Similar activity demands more universal methodologies of the landscape and ecological researches focusing on assessment of condition of landscapes.

References

Anonymous (2000) Biological and landscape diversity of Georgia (2000). Published by WWF Georgia Country Office, Tbilisi. 312 p

Anonymous (2002) Caucasus environmental outlook. UNEP, GRID. Tbilisi, 100 p

Anonymous (2009) Piloting landscape planning in the countries of the South Caucasus. Baku, Tbilisi, Yerevan, 121 p

Anonymous (2011) Geopolitical atlas of Caucasus. Pub. House"Bakur Sulakauri", Tbilisi. 80 p

Beruchashvili N (1995) Caucasus: landscapes, models, experiments. Tbilisi, 315 p

Brown MT, Vivas MB (2005) Landscape development intensity index. Environ Monit Assess 101:289–309

Elizbarashvili N (2005) Geo-ecological basics of landscape planning. Tbilisi, 300 p

Elizbarashvili N (2009) Landscape planning: methodology and experience in implementation. Publish by TJS-Caucasus, Tbilisi-Bonn-Irkutsk. 188 p

Elizbarashvili N (2016) Fundamentals of applied Geography. Tbilisi, 503 p

Elizbarashvili N, Meessen H (2018) Sustainable development of Mountain regions and resource management. Tbilisi, 304 p

European Landscape Convention (2000) Opening for signature on 20 October 2000 (European Treaty Series – No. 176). Florence, 9 p

Willemen L, Verburg P, Hein L, van Mensvoort MEF (2008) Spatial characterization of landscape functions. Landsc Urban Plan 88(1:34–43

WWF (World Wildlife Fund) (2018) An ecoregional conservation plan for the Caucasus. Tbilisi. http://www.wwf.de/fileadmin/fm-wwf/Publikationen. Accessed 05 May 2019

Chapter 13
Forest Cover for the Safety of Biosphere and Environment

Tsisana Basilashvili

13.1 Introduction

Nowadays, one of the main concerns of the world society is the anomaly of cataclysmic processes caused by global warming on our planet, which has resulted in increasing catastrophic disastrous events leading to large destructions and casualties. In addition, with increase in population, predicted to be 11 billion in 2050, demand for food, water, housing, energy, and mobile equipment and other requirements will increase. The occupation of forest areas and irrational cutting of trees leads to a reduction in the photosynthetic process, increasing heat from the sun beams, which cause all leading to global warming, and reduce in oxygen, together with the emergence of new viral, bacterial, and chronic diseases.

In the twenty-first century the temperature on Earth is expected to increase, which will lead to the melting of Antarctic and Greenland ice caps, followed by a sharp rise of the world's ocean level, flooding the coastlines in many countries, leading to large economic and social shocks, loss of crops, deficit of drinking water, storms, and coastal erosion. Since climate change is global, it is necessary to find ways to solve this problem through joint efforts on an international level (Imanberdieva et al. 2018).

Currently, for biosphere and environmental protection, for softening the climate change process for all countries in the world, most important task is to carry out protective activities. First of these is the rational use of natural resources, ensuring the sustainability of environmental and ecological balance. It is worth mentioning that for climate change regulations, stabilization of oxygen balance and the maintenance of biodiversity are of particular importance, and the forests are leading in this connection.

T. Basilashvili (✉)
Institute of Hydrometeorology at the Georgian Technical University, Tbilisi, Georgia

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_13

13.2 Biosphere

It is a combination of live and nonmotile substances in dynamic equilibrium, where the living organism transforms this environment in accordance with its demands. The history of the development of biosphere is 2.5–3 billion years old. During this time, living organisms have been developing under different environmental conditions. Some single-celled seaweeds and bacteria grow in hot water springs of up to 75–100 °C and others at minus 6–7 °C and mushroom spores can endure 120–180 °C (Miqadze 2006). Thus, the biosphere is the layer of the Earth where life exists and develops. It covers the hydrosphere, lithosphere, and atmosphere. The hydrosphere is an aqueous layer of the Earth. The oceans cover 7/10 of the Earth's surface. It is used by living organisms up to 100–200 m depth, where the sunbeams can reach. Only bacteria can live deeper. The lithosphere is a thick layer, where life is up to a few tens of centimeters. Some organisms live in 2–3 km depth depending on the conditions of the land and 1–2 km from the bottom of the ocean. The simplest anaerobic bacteria live in an underground watershed and oil-containing horizons at a depth of 3–5 km. The biosphere is a combination of plants, animals, microorganisms, and nonliving components of the environment. The main biomes of the biosphere are the land, sea, and freshwater (Dre 1976). Its upper boundary reaches 6 km in the atmosphere, where chlorophyllous plants grow. Some arthropods live above that are nourished by the plant dust, spores, and microorganisms brought by the wind (Eliava et al. 1992).

About 600 million years ago, the lowest autotrophic plants emerged, 500 million years ago – plants and insects, and 350 million years ago – angiosperms and mammals. The development of plants containing chlorophyll on the ground along with the increase of oxygen contributed to the formation of soils. Later, with the increased amount of oxygen, a variety of flora and fauna, including humans, have developed on Earth. The existence of biosphere before human origin is called biogenesis, while the developmental stage of society is called noogenesis. At present, there are about 2 million species of plants and animals. The animal species are up to 1.5 million. Among the plants, angiosperms with over 300,000 species occupy the first place followed by mushrooms which are about 100,000 in number. Out of the number of animal species, the insects occupy the first place with 1 million taxa followed by mollusks with about 100,000 taxa followed by the vertebrates with about 50,000 taxa (Qajaia 2008).

13.3 Atmosphere

The atmosphere comprises the Earth's surrounding gases together with water vapor and dust. According to the strata, the individual layers are troposphere (thickness 8–18 km), stratosphere (55–60 km), mesosphere (80–85 km), thermosphere (80–1000 km), and above that lies the exosphere.

In the troposphere, atmospheric air mass is 90% with 4% to 0.5% water vapor, which extends up to 8–10 km at the poles and 16–18 km at the equator. Here, the air temperature decreases by 5 °C at every kilometer height. This layer entirely passes short-wavelength solar radiation and detects the Earth's long-wavelength radiation.

The stratosphere represents 40–60-km-thick layer above the troposphere. Here, the air is dry and rare; temperature rises from the bottom upward in the summer from 0 to 15 °C and in winter from −10 to −5 °C (Qajaia 2008). In the layer of the atmosphere at the height of 20–30 km, there is a variety of oxygen gas – ozone which absorbs a large portion of the ultraviolet radiation coming from the sun. It can destroy living organisms. So the ozone layer is considered to be the protective shield of the biosphere in the Earth (Budiko 1965).

The mesosphere is a 20–25-km-thick layer, where temperatures in summer fall to −80 °C and in winter −100 °C. Because of the strong turbulent movement, wind speed exceeds 50–100 km/h.

The temperature starting from a height of 80 km in the thermosphere increases by 5 °C per 1 km and above 1000 km reaches 2000 °C. Anything including meteors run here at a speed of 100–130 km/h burning down a mesosphere which is located at a depth of about 80 km.

The exosphere extends to thousands of kilometers, where temperature rises by 1 °C per 1 km; here spacecraft are flying and radio communication is possible.

Near the surface of the Earth, dry air composition consists of 78% nitrogen, 21% oxygen, 10^{-6} ozone, 0.9% argon, 0.03% carbon dioxide, and 0.1% other gases. This composition of the air does not change up to 90–100 km in the atmosphere and is called the homosphere. About 200 km above the main part of the air is nitrogen, from 600 km helium, and above 2000 km the hydrogen.

The atmosphere holds part of the space beams and the majority of meteorites. Only 48% of solar radiation reaches the Earth. If there was no atmosphere, the average temperature of the air on the surface of the Earth would be 23 °C, not 15 °C (Miqadze 2006). Almost half of the radiating energy on our planet is spent on evaporation of water, and this water returns to the Earth as precipitation.

13.4 Forests and Life on Earth

At the start our planet, the atmosphere lacking in oxygen but was rich in carbon dioxide, methane, and nitrogen compounds. Nearly 3 billion years ago, the first living organisms on the Earth were created at the bottom of the non-deep parts of the hydrosphere, where the sunbeams and warmth were reaching. Such conditions are near the tropical belt where with the carbon dioxide absorbed by the plant's chlorophyll and from the weather with the help of solar energy, carbohydrates are synthesized and free oxygen is released. This process is called photosynthesis, or production of organic substances from the inorganic components of the environment via green plants. Schematically it looks like this (Qajaia 2008):

$$6CO_2 + 6H_2O \xrightarrow[\text{Green plants}]{\text{Sun's radiation energy}} C_6H_2O_6 + 6O_2 \tag{13.1}$$

Here, carbon dioxide and water molecules are diluted and the combination of glucose molecules is formed during this process, and then the free oxygen is released.

The first species of the earliest times were the blue-green seaweeds, which transformed the solar energy into chemical energy, thus contributing in the growth and development of plants. Scientists estimate that over a year, there are more than 10 billion kcal of solar radiation per 1 Ha on Earth, which is used by the plants for photosynthesis (Budiko 1965). Every year, with the solar effect, about 83 billion tons of organic substances are formed on the Earth, and 53 billion tons are created on land and the rest in marine environments. It is noteworthy that plants accumulate only 0.3% of solar energy. The quantity of carbon dioxide in the atmosphere is reduced to 0.03% due to photosynthesis, and the number of free oxygen increases to 21% or 1000 times (Qajaia 2008).

According to Ramad (1981), 2 billion years ago, the first organisms emerged and these were able to carry out photosynthesis (prokaryotes: blue-green plants, bacteria, viruses), and after 0.5 billion years, the highest organisms (eukaryotes) emerged. Nearly 1 billion year ago, the oxygen content in the atmosphere constituted 1% of the present. Phytoplanktons increased, and as a result of photosynthetic intensity, atmospheric ozone was created, which stopped the adverse effect of ultraviolet light from the sun. This contributed to the development of the first organic world in the upper layers of water and then on land. Millions of years later, various species of plants developed which were the primary products for animal and human nutrition (Dre 1976). The vegetation of the Earth annually assimilates around 5×0^{10} tons of carbon or absorbs 1.8×10^{11} tons of carbon dioxide, decomposes 1.3×10^{11} tons of water, separates 1.2×10^{11} tons of molecular oxygen, and gathers 4×10^{17} kcal of solar energy (Eliava et al. 1992).

It is estimated that 50–60% of oxygen is released by land vegetation and the rest by the phytoplanktons. One hectare of forest in 1 h absorbs so much carbon dioxide as 200 people breath out in 1 h. During 1 year, 1 ha of mixed forest absorbs 15 tons of carbon dioxide and releases 13 tons of oxygen. The use of oxygen by humans depends on the physiological condition of his body, age, weight, and sex. In medicine, it is known that the person in a waiting period in 1 min spends 0.35–0.40 liters of oxygen and 5 l/min during work. A person needs 500–600 liters of oxygen in a day; therefore, a forest area per person should consist of at least 0.3 ha (Dre 1976).

Although trees are less than 1% of all plant species, they form almost 90% of land phytosome and 64% of its productivity (Miqadze 2006). So, the vegetation cover is the source of oxygen, food, and energy. Therefore, the existence of humans and animals depends on the condition of the forest cover. In the Bible, it is known that God during the seven-day cycle of creation of universe; among many wonders; on the third day forests were created. By doing so, he defined the right to use the timber. But the forest is ruined unmercifully by people for the last hundreds of years (Basilashvili 2016a).

13.5 Climate and Global Warming

Global warming is the process of the fastest growth of average annual temperatures in the Earth's atmosphere. Scientists are presenting two different versions for this situation. According to the first version, it is a periodically repetitive natural cataclysm of solar activity, determined at 11-, 22-, and 80–90-year periodical (Glaisberg) changes. The current global warming is likely associated with a higher rate of sunlight, which can be changed via reduction. In the second version, the warming in the Earth is because of human anthropogenic activities. These include the heat radiation containment, reflected from the Earth by the gases which expand in the atmosphere. From such gases, it is noteworthy that carbon dioxide, methane, nitrogen monoxide, ozone, and Freons (hydrocarbon halogen) freely pass solar beams on the Earth but hold the heat reflected by it (Tkemaladze 2015).

From 1880 to 1930, the average annual air temperature has increased by 0.5 °C. Since 1940, the increase in temperature has changed, and since 1960s, an intensive growth of temperature has begun on Earth (Elizbarashvili et al. 2013; Imanberdieva et al. 2018). Following the techniques developed during last 1.5 years, the amount of carbon dioxide (CO_2) appears to have increased in the atmosphere by 1/3, and methane by 2.5 times, which excites the Earth 20–25 times more, rather than carbon dioxide. The increase of methane is associated with pipelines and leakage from bogs and livestock. Methane is formed by means of special bacteria in the stomach of the livestock. From the dung, methane is released which is used for fuel. 1.5 billion cows living on the planet allocate 18% of the greenhouse gases, which exceeds all types of transport systems. That is why the eco-activists of the world propagate the vegetarian diet and claim that if there is no livestock, there will be no problems. A third of the methane in the atmosphere is created by the livestock (Buchkovska et al. 2015; Imanberdieva et al. 2018).

The increase in carbon dioxide is associated with the development of industry, as well as wood and coal burning. Every year humans burn 4.5 billion tons of coal and 3.2 billion tons of oil, gas, peat, and other fuels. The concentration of carbon dioxide increases especially with cars and aircraft fumes. The main source of harmful substances is outdated transport and the suspicious quality of their fuel.

Nearly 27 billion tons of carbon dioxide is estimated to enter the Earth's atmosphere annually through industrial activity. Its concentration in the atmosphere has grown up to 38%, where 30% is absorbed by the world's oceans, 13% by biosphere, and soil, 57% remains in the atmosphere, which contributes toward an increase in the global warming. From the beginning of the industrial era, the atmosphere has accumulated 770 billion anthropogenic carbon dioxide (Barkalaia et al. 2015; Imanberdieva et al. 2018).

As a result of photosynthesis, 1 ha of forests absorbs 5–10 tons of carbon dioxide and releases 10–20 t of oxygen. The thermal energy of solar radiation falls on Earth every year, and it is estimated to be on 1 ha area of 10 billion kcal, 93.8% of which is absorbed by the green cover (Aress 1982).

The excessive amount of harmful gases added by anthropogenic activities expands the ozone layers in the atmosphere, which is a very dangerous phenomenon for living organisms and is directly related to global warming. These processes are further enhanced when people use various technologies in the space. It is estimated that launching space missiles causes damage and disruption of the ozone layer, which will lead to increased solar radiation and temperature.

13.6 Ozone Layer and Its Change

Ozone is blue air and its molecule consists of three atoms of oxygen (O_3). It occurs when the ultraviolet radiation of the sun affects the oxygen molecule, leading it to collapse into atoms, and oxygen atoms are linked to the oxygen molecule (Zhorzholiani and Gorgadze 2008):

$$O + O_2 = O_3 \tag{13.2}$$

There is “bad ozone” and “good ozone.” Scientists call the “bad ozone” photochemical smoke, which is located in the lowest layer of the atmosphere in the troposphere. Under certain concentrations, it is dangerous for human health: irritates the upper respiratory tract and causes vegetative disturbances, pulmonary edema, dizziness, eye cataracts, etc. Such “bad ozone” is only 10% of the Earth’s ozone, and the remaining 90% is good ozone.

“Good ozone” is located in the stratosphere and protects the Earth from the devastating impact of ultraviolet radiation. Ozone content is variable at different altitudes. Sixty percent of it comes from the layer that is situated 16 km to 32 km, and the maximum concentration is at approximately 25 km. There is a 3.5-mm-thick protective ozone layer on our Earth that makes the planet more suitable for our existence. The amount of ozone in the stratosphere depends on the geographical range, the height of the distance from the Earth’s surface, and the time of year. The effects of solar radiation and oxygen, nitrogen, hydrogen, chlorine, and bromine cause the dissolution of the ozone molecule and the ozone layer. The main reason for this is the fact that many chemical compounds are used in household and agriculture, especially Freons ($CFCL_3$ and $CFCL_2$), which were previously used successfully in refrigerators and air conditioners.

As a result, the ozone layer has got reduced twice its content in many parts of the world. In the Arctic in summers and above the Antarctic in winters, some holes have been detected. The subsequent degradation of the ozone layer facilitates the penetration of ultraviolet radiation into the atmosphere that dramatically affects living organisms and causes climatic anomalies and natural disasters. In 1996, factories of ozone disbanding substances (Freons) were closed, resulting in a reduction in the ozone hole by 34% in 2014, and this hole is expected to get reduced by 10% by 2020. By 2030, the ozone layer will be filled in the Northern Hemisphere, by 2040 in the Southern Hemisphere, and by 2050 at the Earth’s poles. It is noteworthy that since the 1950s of the twentieth century, space has accumulated a lot of cosmic trash, which comprises 25,000 items of various sizes ranging from the smallest particles to the total spacecraft. They are moving about 25,000 km/h speed and their collision with any moving spacecraft can cause a huge catastrophe.

13.7 Forests: Importance and Impacts

The forest is a vital component of the biosphere and represents a complex combination of ecosystems of trees, bushes, and herbs, animals, birds, and microorganisms that are interconnected in their developmental process and affect both the environment and each other (Ozturk et al. 2010; Karahan et al. 2015; Altay 2019; Rajpar et al. 2020). A forest has substantial impact on the processes that are occurring in the atmosphere, on the surface of the Earth, and below its depths. The forest cover participates in the support of different activities. It plays an important role in economic activity and is a source of raw material, which is widely used in different industries (Karahan et al. 2015). The timber is used both as building material and fuel (Ozturk et al. 2017). It also provides food and medicinal products, paper, cardboard, furniture, and parquet. Fifteen thousand types of products are made from trees, so the increase in the world's population and technical progress are the reasons demand for forest resources incredibly increases.

13.7.1 Forests and Climate Interactions

The importance of forest is first revealed in the regulation of air elements (air temperature, humidity, air currents, and speed). All these affect human health. For example, in summer, temperatures in the treeless areas are 3–5 times higher, which results in the acceleration of human pulse, overheating of the body, and decrease of labor ability. Dry air is also harmful in areas where there is lack of forest as it causes mouth, throat, and nose dryness and deterioration of antiinfective capacities. The high speed of wind in treeless areas has a negative impact on breathing, blood circulation, and the nervous system. The most comfortable conditions for people to relax and rejuvenate are created by the forests. Besides, the beauty and attractiveness of the natural landscapes of forests have a positive impact on the mental condition of humans, improvement of mood, restoration of labor skills, and spiritual conditions.

13.7.2 Sanitary-Hygienic Role of Forest

In the cities, industrial centers and other settlements, the atmosphere is systematically being polluted by harmful chemical contaminants. In this environment; for the protection and improvement of the sanitary and hygienic standards; the greatest role is played by the forests, where almost all forest tree absorb emissions as these possess aromatic essential substances like phytocides, which add to the disappearance of many microbes and viruses, thus cleaning and making the air healthier. In general, bacteria and microbes are reduced in the woods. 1 m^3 of air contains up to 500 pathogenic bacteria, while 1 m^3 of air in the city has 36,000 bacteria. It is estimated that land vegetation annually releases 175 million tons of aromatic oils, which protect us (Kandelaki 2013).

13.7.3 Forest as a Filter

The lower layers of the atmosphere in our era, except carbon dioxide, are systematically polluted by harmful chemical and mechanical additions. Dust reduces the sun's ultraviolet radiation and air transparency and changes the level of ionization. A person breathes 20 m^3 of air overnight, and if the air is dusty, it causes several illnesses like; asthma, nasal mucosal atrophy and few others. Forest is the strong air filter from dust. It is estimated that 1 ha of forest every year filters 50–70 tons of dust. 1 ha area of beech copse filters about 68 tons of dust; oak copse, 56 t; pine copse, 36 t; and spruce copse, 32 t (Kandelaki 2013).

13.7.4 Forests and Technogenic Pollution

Today, a large scale of technological applications have caused an accumulation of harmful chemical substances in our environment. Contamination of air, water, and soil with different substances has reached a level that threatened the many regions of the living world, including forests, and degradation of massive forests has started. Experiments have revealed that plants have the ability to remove pollutants from air and can serve in detoxification. Oleaster, ash tree, acacia, oak, plane tree, maple, and willow are distinguished for having resistance against harmful gases, but the pine cannot stand them, that is why it is damaged.

13.7.5 Forest and Noise

The forests absorb various kinds of noise, depending on the composition, structure, frequency, and their mixed composition. Multistory high-frequency copse is characterized by high noise absorption. For example, a tree with high radius (0.8 m) which is 80–100 m away from the source of noise (highway) reduces the level to 30 decibels in the forest copse.

13.7.6 Forest and Yield

The forests have a great influence on the cultivation of agricultural crops. A forest cover increases yield by 20–25% (Armand 1964), which clearly indicates the importance of forests. Each hectare of forest strip protects on an average 30–40 hectares of the field, from which the grain yield increases with 2–3 centner per hectares. Such protected areas can additionally add 60–80 centner of crops and 8–10 years after the expenses incurred on the construction of forest stripes will be fully compensated. The impact of forest stripes is particularly pronounced in the months leading to drought. “The forest produces water, the water produces a harvest, and the harvest produces life.”

13.7.7 Water Management and Soil Protection with Forest

Part of the atmospheric precipitation falling on the land surface enters the soil which feeds the rivers all year round. The higher is the seepage in the river, the less is the flood and erosion of soil. Therefore, forests also perform watershed and protective functions. In this regard, the importance of forest is huge in mountainous areas where there are many other defensive features added to the multilateral purposes of the forest. The forest in the mountains regulates the flow of rivers. The high frequency (>0.8) of mountain forest is the main factor that facilitates the transfer of atmospheric precipitations to the depths of soil, thus regulating the liquid surface runoff, improving the water balance, and protecting the rivers from drying (Kharaishvili 2001). The forests mainly protect the inhabited areas and populations, roads, fields, and soils from dangerous disasters such as floods, mudflows, landslides, avalanches, erosion, etc.

13.8 World Forests

13.8.1 Past

The oldest vegetation cover is found in Australia, said to be approximately 395 million years old. About 370 million years ago, vegetation was in the form of bushes. Primary forests were low. The tallest trees were 7.5 m, and these were the primitive ferns. 345 million years ago, the Stone Age began, when dense, wide forests were present on Earth with 30-meter tall trees and primitive plants with seeds. During the dry climate 280 million years ago, primitive conifers appeared and got widely distributed.

Sequoia trees and floral seed plants are present there from over 225 million years. 135–165 million years ago, the ancestors of modern rubber trees, magnolias, oaks, willows, and maples were dominating the Earth. During the Paleogene period, Northern Hemisphere forests were similar to modern tropical and moderate belts of forests. In the north, there was arctic-type flora. In the Tertiary, the tropical flora spread near the equator.

During the dry climate of the Neogene period, forests decreased and the herbaceous vegetation dominated, followed by the dominance of coniferous plants. The Quaternary period began 1.8 million years ago and is still going on. The peculiarity of this period is the alternation of the ice ages with warm glacial intervals. Because of this, the forest areas have got reduced everywhere.

13.8.2 Forests in the Epoch of Civilization

Over the last 800 thousand years ago, humans have removed around 50% of the forest area. These have been replaced with crops, pastures, settlements, and others. Several hundreds of years ago, the forest areas were 7.2 billion hectares, covering 48% of the land. At present, the area covered by the plants is 12.2 billion hectares, 4.1 billion of which are forests. Out of this, only 3.8 billion hectares are covered with woody plants, while the rest are bushes, marshes, and cliffs (Gulisashvili 1973). Seventy-five percent of forest destruction has taken place during the twentieth century following a global demographic explosion. Eighty percent of forests have been replaced with cultural trees.

According to FAO estimates (Table 13.1), forests were covering 4000 million ha of land or 31% of its total area. 1488 million ha represents sparse forests, bushes, and roadside trees that are not included in the forest category. In the world's forests, up to 30,000 species of trees and shrubs grow and thousands of animals and birds live there. In the early twentieth century, the forest area was about 2 ha per capita. In 2015, the per capita has come down to just 0.6 ha of forests. The total produce of live forest is 1509 billion tons, of which 25% (377 billion tons) comes from the roots, leaves, and fruits, and the remaining 1132 billion tons represent timber. The world's timber reserves in cubic meters are 360 billion m^3, and the annual increment (productivity) is 3200 million m^3 (Kandelaki 2013).

With regular inventory prepared by FAO, forestry has decreased at higher rates from 1990 to 2000. The annual decrease was 16 million hectares and in 2000–2010, 13 million hectares, and in 2010–2015, the forest area decreased by 16.5 mln ha or yearly forests got decreased by 3.3 mln ha. In 2016, the destroyed forest area was 29.7 million hectares (Kandelaki 2013).

The Forest destructions are increasing geometrically every year. The reason being tree cutting as well as turning forest areas into other land use categories (arable, towns, roads, etc.). Natural disasters like landslides and avalanches also destroy forests as these trees are not restored. According to the National Geographic, 80,000 m^2 of green cover is damaged annually, causing great material loss. Fires have resulted in 100,000 deaths in Indonesia. In 2017, about 100 people were killed in California, Portugal, and Spain because of forest fires. Fires were hugely

Table 13.1 Areas of the world's forests and their dynamics

Region	Common area (mln ha)	Forests of local species, (mln ha)	Forest (% from the total area)	Dynamics of forest areas (mln ha)		
				Change of forest area (2010–2015)		Forest plant area
				Total	Annual	2015
World	3999	1277	31	−17	−3.0	290
Africa	624	135	23	−14.2	−2.4	16
Asia	593	117	19	−3.4	0.8	129
Europe	1015	277	34	1.9	0.3	82
North and Central America	751	320	33	0.4	0	43
South America	842	400	49	−10.1	−2	15
Oceania	174	27	23	1.5	0.3	4

destructive in California in November 2018 when more than 70 people got killed, 1400 people were lost, up to 100 ha forest was burned, and about 80,000 houses were destroyed. It is important to note that during fires, besides people, a lot of other living organisms in the woods also die. In addition, fires cause much addition of excessive carbon in the atmosphere, which negatively affects water quality, forest structure, and biodiversity.

Following the earlier forest destructions, from the beginning of the twenty-first century, forest cover has increased by artificial forests (3.3 million hectares) or naturally restored forests (27 million ha a year). From 2000 to 2010, the forest area in Asia grew by 2.2 million ha, mainly due to the intensive cultivation of forests in China. Forest areas in Europe have grown annually by 700 thousand ha.

13.9 Forests in Georgia

13.9.1 Layout and Composition

Georgia is located in the southwest of Caucasus, with diverse climates and landscapes. It is wet-oceanic in the subtropics to the west, steppe-continental to the south and constant snow and glaciers in the highlands of north. Mountain slopes in Georgia were covered with dense forests, where many varieties of fruits were produced and many species of animals and birds lived there. The Georgian peasants were allowed to live there, and they were defended and fed by the forest. As such, the forest industry has been created there long back.

The forests in the country start from the seashore, extending to 2100–2200 m and in some cases up to 2500 m. The total forest cover lies around 3,007,600 hectares as per 2010 records, which is 43.2% of the country's territory. It is spread unequally, 58% in the west and 42% in the east. Seventy-three percent of the forests are located at a height of 1000 m above, 80% of these are spread over the slopes of over 20°.

Forests cover 2,770,000 ha of the state forest fund of Georgia, with 86 protected areas covering 600,000 ha (Anonymous 2012, 2018).

The forests in Georgia include coniferous, deciduous, evergreen, and leafless trees, shrubs, giant sized (up to 60 m and 2 m in diameter) trees, lianas, parasitic plants, mushrooms, fruits, berries, and medicinal and technical raw material plants. There are many relict and endemic species. Out of the 400 taxa, 61 are Georgian and 43 Caucasian endemics. In the forests, the coniferous palms are 16%, the hardwood deciduous 68%, softwood leaflets 7%, and other species 10%. The giant (70 m high and 2.5 m diameter) Caucasian Sochi beeches together with 50 m high and 2 m diameter east beech are considered as a phenomenon for the moderate climate zone. Chestnut, oak, maple, zelkova, walnut, box tree, and other types of tree timbers are economically important (Gigauri 2004).

In the valleys of high mountains and hard-to-reach gorges, the untouched forests (566,000 ha) are still seen. According to the World Bank experts, in Europe, we can hardly find a country where the natural landscapes of unique beauty are so exquisitely replaced by old cultural landscapes. It is noteworthy that the forests of Georgia are a shelter of pre-Ice Age flora and fauna, or relicts, all connecting us with ancient geological epochs, and their area will be a huge loss not only for Georgia but for the humanity as a whole.

13.9.2 Forest Resource Potential of Georgia

Forest resources are very important in terms of average forest characteristics like age 98 years, height 22 m, diameter 36 cm, Bonita III, and frequency 0.54. Timber supplies lie around 176 m^3 per hectare, ripe and overripe copse 244 m^3, and conifers 288 m^3. Total timber reserves in the forests are more than 535 million m^3. Almost 66% of reserves are in the unattainable zone, where the slope incline is greater than 25 °C (Anonymous 2012, 2018).

Along with timber, more than 150 species of plants in the forests bear fruits, berries, walnuts, and other resources, which are used much and make significant contributions to economic development. More than 110 species of plants are used in medicine. 2/3 of the 48 medicinal and 200 recreational resorts of Georgia are located or surrounded by forest. Their existence in the forest is justified by an aesthetic viewpoint. Therefore, ecotourism and resort-recreational farming are developed in Georgia. The potential of hunting tourism is also great in Georgian forests.

13.10 Results of Anthropogenic Impact on Forest

No one argues about the great importance of green forest cover, but for the proper attention to it, it is not yet visible. The reason for this is the enormous increase in demand for forest resources as a result of population growth and technical advancements. Therefore, the extraction and use of forest resources in the world are increasing annually. Such attitude toward forests leads to their destruction, especially in the tropical and coniferous (taiga) areas. It is noteworthy that the use of forest areas has helped not only the plant but also the reduction of unique representatives of animals and birds.

Particularly negative consequences are expected from cutting of forests in mountainous areas where the river water regime changes, catastrophic floods and torrents increase, erosive and landslide phenomena develop, soil erosion occurs with stone erosion, and snow-glacier evolution all take place (Basilashvili 2016b; Altay 2019).

In addition, trees are usually cut into forest copse as well as in the towns and planting strips, which, in addition to the lack of oxygen, result in the reduction of water keeping and catchment function, causing drying of some springs, rivers, and lakes. The areas that aren't covered by the forest begin to become a desert, accompanied by the reduction of food production (Ozturk et al. 2010; Altay et al. 2012; Basilashvili 2015; Ozyıgıt et al. 2015; Sezer et al. 2015).

A reduced green cover in the world is no longer capable of the use and regulation of solar energy. This increases the amount of carbon dioxide in the atmosphere and the climate warms up intensively. Consequently, ecological disasters are activated, leading not only to destruction but also casualty of humans and other living beings.

The accumulated excess quantities of harmful gases allotted by the anthropogenic impact return to our Earth's atmosphere as acidic rains and radiation compounds. The sources of acidic rainfall (rain, snow, fog) come from fuel and biomass burning, metallurgy, motor transport, etc. During the past 100 years, the acidity of precipitation has significantly increased. Acid precipitations have a negative effect on ecosystems since such water drops on the spawns and phytoplankton, reducing the types of hydrophones in the reservoirs. Such precipitations also cause corrosion of tools, buildings, and art samples, and plants are damaged that is expressed by the falling of leaves and the rotting of roots. In 1990s, the area of damaged forests in Germany and Netherlands was 50%, Switzerland 35%, Austria 30%, and Russia 600,000 ha (Qajaia 2008). Thus, the cosmic ecological function of forests got weakened. It is estimated that the cosmic environmental effect performed by the forest green cover exceeds 3–5 times the natural revenue received by the use of forest resources (Chagelishvili and Gvazava 2015).

13.11 Conclusions and Recommendations

Forest are a complex ecosystem of trees, plants, and other living organisms (Ozturk et al. 2010; Altay et al. 2012; Karahan et al. 2015; Ozyıgıt et al. 2015; Sezer et al. 2015; Altay 2019; Rajpar et al. 2020). All these are a guarantee of preservation of cosmic-ecological-economic-sustainable environment of the biosphere on Earth, along with water, air, and soil. The forests absorb carbon dioxide and releases large amounts of oxygen, at the same time regulating microclimate (humidity, temperature, and wind). The forest is a powerful filter for cleaning air and water from harmful impurities, characterized by antimicrobial, ionization, and sterilization features. By doing so, it makes the environment healthy and friendly, which in turn affects humans and other living organisms. The forests also provide many types of food and medicinal products. Thus, the forest is a powerful factor in improving environmental sanitation-hygienic conditions with a broad spectrum of biodiversity, hence named as vital “green lungs.”

Moreover, the forests protect agriculture and populated areas from strong wind. They are also the main factor for regulating water resources, improving groundwater quality, and increasing their storage. In the mountains, forests protect communities, roads, and fields from floods and mudflows, erosion, landslides, and avalanches, promoting an increase in the yield.

A forest has great importance in agricultural activities. It is a source of raw timber used in various industries. With an increase in population and farming activities, the demand on timber has increased much. As such, forests are cut and forest area is getting reduced by 0.3% annually in the world. Over the last decade, 25,000 plants and more than a thousand species of animals are completely lost. The reason is wrong approach toward the forests. In fact, nature is a gift that we must use to benefit from. Due to pollution, the forests are dying.

In addition to tree cutting and diseases, forests are also damaged by fires, which have become more frequent in different countries due to the negligence of the people in terms of climate warming. It is noteworthy that fire prevention is much cheaper than elimination of its results, which is not fulfilled. Because of this, the world’s lost green cover is no longer able to regulate the heat energy of solar radiation. Oxygen is decreasing and carbon dioxide is increasing in the atmosphere, and climate is warming up intensively.

According to the conclusions from experts, global warming in the twenty-first century will continue, and the temperature of Earth may increase by 2–4 °C, which will seriously damage the ecosystems and most of the countries’ economies. The technical progress on the one hand is improving the conditions of human well-being, but on the other hand, it threatens our future. The process of weakening of self-purification, self-regulation, and self-restoration is underway not only in a specific environment but also on a planetary scale.

Today, the protection of nature and the rational use of its resources is our primary problem. It is a necessary precondition for the existence of the biosphere. Therefore, in all countries of the world, special attention should be paid toward the protection and expansion of forest cover. The people and administration in every settlement should take care of his forest cover and work for its renovation. Useful plant varieties should be selected for renovation, and, if necessary, their selective cuts should be carried out in a number of annual increments so as to ensure that their natural recovery is restored. In agricultural fields, the protective lines of the forests should be planted, which will help to increase yield. In order to ensure rational use of forest resources, measures must be undertaken with complex non-waste technologies.

In order to protect the biodiversity of forests, the system of biomonitoring should be followed and timely restoration of forests and their management carried out. It is necessary to develop long-term programs for the rational use of forest resources in order to improve forest productivity and their qualitative composition. Complex production of timber raw materials, introduction of techniques of progressive methods of processing and non-waste technologies, and finally creating protected areas for the purpose of maintaining biological and landscape diversity are very important steps in this connection.

It is also necessary to raise the knowledge of the society on the whole to increase their positive role towards nature and its rational use. Proper education of youth and their love for nature can save the biosphere and our natural environment from destruction and bring us economic prosperity.

References

Altay V (2019) Ecology of *Pinus sylvestris* L. forests – a case study from Istanbul (Turkey). Pak J Bot 51(5):1711–1718

Altay V, Serin M, Yarcı C, Severoglu Z (2012) Phytoecological and phytosociological investigations of the vegetation of Gölcuk (Kocaeli/Turkey). Ekoloji 21(84):74–89

Anonymous (2012) National Atlas of Georgia. Publishing House, Tbilisi

Anonymous (2018) Geography Atlas of Georgia. Franz Steiner Verlag, Tbilisi

Aress P (1982) Spring of ecology. Moscow: L

Armand D (1964) To us and grandchildren. Moscow: Mysl

Barkalaia R, Tsereteli G, Beruashvili M, Saralidze M (2015) Towards the issue on the impact of global warming on biodiversity. Global Warming and Agrobiodiversity, Tbilisi, pp 72–75

Basilashvili T (2015) Forest and problems caused by global warming. Global Warming and Agrobiodiversity, Tbilisi, pp 75–78

Basilashvili T (2016a) The role of forests in the development of the biosphere in the context of global warming. Sci Technol Tbilisi 1(721):15–23

Basilashvili T (2016b) Modern challenges of biosphere safety. Scie Technol Tbilisi 3(721):36–46

Budiko M (1965) Radiation factors modern climate changes. News Acad Sci Soviet Union 5:17–22

Buchkovska V, Evstafieva J, Sayenko V (2015) The problem of heat stress in livestock production and global warming. Global Warming and Agrobiodiversity, Tbilisi, pp 386–387

Chagelishvili R, Gvazava L (2015) Global warming technological progress and green cover. Global Warming and Agrobiodiversity, Tbilisi, pp 352–354

Dre F (1976) Ecology. Moscow: Mysl

Elizbarashvili E, Tatishvili M, Elizbarashvili M et al (2013) Climate change in Georgia under global warming conditions. Tbilisi

Eliava I, Nakhutsrishvili G, Qajaia G (1992) Foundations of ecology. Tbilisi

Gigauri G (2004) Forests of Georgia. Tbilisi

Gulisashvili (1973) Nature protection basics. Tbilisi

Imanberdieva N, Severoğlu Z, Kurmanbekova G et al (2018) Plant diversity of Ala-Archa Nature Park in Kyrgyzstan with emphasis on its economic potential. In: Egamberdieva D, Öztürk M (eds) Vegetation of Central Asia and environs. Springer Nature Switzerland AG, Cham, pp 365–381

Kandelaki T (2013) Forests resources of Georgia. Science and Culture V(II):91–109

Karahan F, Altay V, Keskin M (2015) An ethnobotanical study on woody plants benefits from handicrafts in Antakya District (Hatay-Turkey). Int J Sci Technol Res 1(1):1–18

Kharaishvili G (2001) Water control and antierosion role of mountain forests of Georgia. Erosion-debris flows phenomena and some adjacent. Problems 83:237–241

Miqadze I (2006) Ecology. Tbilisi: TSU

Qajaia G (2008) Ecological principles of environment protection. Tbilisi: TSU

Ramad F (1981) Foundations of applied ecology. Moscow: Mysl
Ozturk M, Gucel S, Kucuk M, Sakcali S (2010) Forest diversity, climate change and forest fires in the Mediterranean region of Turkey. J Environ Biol 31(1):1–9
Ozturk M, Saba N, Altay V et al (2017) Biomass and bioenergy: an overview of the development potential in Turkey and Malaysia. Renew Sust Energ Rev 79:1285–1302
Ozyıgıt S, Altay V, Ozyığıt II, Yarcı C (2015) Vegetation ecology of the princes' islands, Istanbul-Turkey. J Environ Biol 36:113–120
Rajpar MN, Ozturk M, Altay V et al (2020) Species composition of dry-temperate forest as an important habitat for wildlife fauna species. J Environ Biol 41:328–336
Sezer Y, Altay V, Ozyıgıt II, Yarcı C (2015) Woody vegetation of Şile and its environs (Istanbul/Turkey) and destruction of the area. J Environ Biol 36:163–170
Tkemaladze G (2015) Biochemical fundamentals of protecting the world from global warming. Global Warming and Agrobiodiversity, Tbilisi, pp 32–41
Zhorzholiani T, Gorgadze E (2008) Medical ecology. Tbilisi: TSU

Chapter 14
Agrodiversity and Sustainable Development

Davit Sartania and Dali Nikolaishvili

14.1 Introduction

Georgia is an important center of diversity not only because of its natural plants, but also because of its agricultural crops. This diversity is because of the diversified natural conditions together with centuries-old history and cultural and historical-ethnographic peculiarities of the country.

The diversity of the ancient agricultural crops has survived to date, and their morphological and genetic features clearly suggest that Georgia is one of the most important hearths of many agricultural crops such as vine. This is fully supported by the botanical, archeological, and ethnographic studies (Dekaprelevitch 1941; Menabde 1948; Vavilov 1965; Dorofeev 1971; Zhukovskyi 1971; Lisitsina and Prishepenko 1977; Gorgidze 1979; Bregadze 1980, 2004). The diversified natural conditions are responsible for the great variety and rich genetic sources of agricultural crops. The development of these sources has been influenced much by the geographical location of Georgia. It lies on the trade and traveling route between Europe and Asia. The migration processes have taken place here for centuries resulting in regular flow of new genetic material into the country and further diversification of the genetic sources of agricultural crops (Rehman et al. 2020; Ruqia et al. 2020). For instance, the crops imported from other continents are corn, kidney beans, soya, and a few others. These crops have got adapted to the local environmental conditions successfully, and many new species are obtained through hybridization and selection (Mercimek et al. 2019; Raza et al. 2019; Taşpınar et al. 2019; Ayub et al. 2020; Rehman et al. 2020; Ruqia et al. 2020).

D. Sartania
Museum of TSU, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia

D. Nikolaishvili (✉)
Department of Geography, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
e-mail: dali.nikolaishvili@tsu.ge

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_14

A great role in the formation of a rich genetic pool has been played by wild species and their national and selective varieties and populations as well. This is also important from today's view, as they have particularly good adaptability to the environment and good resistance to diseases and pests (Rehman et al. 2020; Ruqia et al. 2020). Almost all through the twentieth century, during the introduction of high-productive selective agricultural crops, including the imported ones and high specialization of agriculture, the local species and populations have gone to the backyard. The tea-, citrus-, laurel-, and ether-bearing and tung-growing crops have been established as the major branches of agricultural specialization. Besides, the collections found at various research establishments have decreased a lot, as most of them have been shifted to the gene banks of other countries. This is recorded clearly by the scientists as genetic erosion (Rehman et al. 2020; Ruqia et al. 2020).

The sustainable economic development depends much on the identification of the traditional agricultural crops, which historically brought a great profit to the population and contributed to the socioeconomic progress of Georgia. The local species adapt well to the local environmental conditions and are distinguished for having a particular resistance to bad weather, pests, and various diseases, thus having a great importance for the selective and long-term food provision of the country. The natural diversity of Georgia helped a lot in the adaptation of new agricultural crops to the local environment, resulting in the establishment of a great variety of local species of many advents of introduced cultures.

14.2 Historical Context

Historically, agriculture has played a great role in the socioeconomic development of Georgia. This issue is important for evaluation in many respects. First, it gives a clear idea about the interconnectigon between humans and nature – what and how human beings have used agricultural potential or which agricultural crops have been preferred; second, the traditional knowledge and experience bring economic benefit to the population in the past and identify possible efficient uses for today. Considering the centuries-old traditions, modern economic planning can be considered as one of the most important preconditions for sustainable development.

Agriculture was the leading system in Georgia. Grain-growing, viticulture (together with wine-making), and fruit-growing have determined the farming structure in the country since the ancient times; however, the spatial distribution of agriculture was not even. The historical processes, followed by frequent wars, changes in the political situation, and migration of people to other lands, have changed the centuries-old diversity and genetic content of the agricultural crops: some cultures became dominant and developed, while others diminished or disappeared. This has influenced the agricultural branches to a great extent. The historical sources provide little data on the distribution of cultures in different corners of Georgia and their export systems, but it is still possible to paint a retrospective picture and show the historical aspects of agrodiversity. These topics can be judged quite well by using such sources as old historical documents, historical-literary works, toponyms, terms related to some agricultural crops, artificial terraces, etc.

The archeological findings prove that as early as from the fifth to sixth century BC, people on the territory of Georgia were engaged in agriculture; they sowed wheat, barley, Panicoideae, and oil and fiber crops and grew vine and fruit trees (Menabde 1948; Gorgidze 1979; Anonymous 2008). The Arkhulo archeological monument in Kvemo Kartli shows a cultural layer with the remnants of cultivated wheat crops dated in the sixth century BC. These are initial varieties of cultural wheat: skinned wheat, *Triticum macha*, *T. palco-colchicum*, *T. monococcum*, *T. dicoccum*, *T. spelta* (with its ancient remnants found in Georgia), *T. aestivum* (soft wheat, so-called dwarf wheat, hard wheat), wild goat grass plant (considered as a participant of the cultural wheat phylogenesis), barley (skinned and naked, two- and six-rowed), panic grass, foxtail, barley, lentil, beans, and weeds accompanying the cultural plants (including rye) (Chubinashvili 1973; Gorgidze 1979; Lisitsina and Prishepenko 1977). The latter (weeds left after threshing, together with wheat ears and stubble parts as well as remains of hard wheat mixed with green brick or sheaves) are the evidence of the local cultivation of the varieties typical to different stages of *Triticum* development (Yanushevitch and Rusishvili 1984). Besides, the finding on highly developed naked species in the monument dated back to sixth century BC providing evidences that people then were following a later stage of the development of farming culture. As for the initial stage, i.e., the primary hearths of land cultivation, they must be searched for much earlier, in a more ancient past (Bregadze 1982). It is also noteworthy that such a diversity of cultural wheat (eight species) found on the above-named monument has not been found in any of the early hearths of land cultivation explored in Near East (Lisitsina and Prishepenko 1977).

Italian missioner Arcangelo Lamberti, living and working in Georgia during 1630–1649, has written about the great variety of fruits and vines in Georgia. He mentions about large gardens in Samegrelo, with different fruit trees planted between the shadow trees around them (Lamberti 1939). Other important data about the agricultural crops of Georgia is presented in the works by Johann Güldenstädt (1745–1781). He has listed various fruit species and described these from different corners of Georgia. According to him, the main activity of the locals in Kartli and Kakheti was wine-making and fruit-growing, while field husbandry, vegetable-growing, and cattle-breeding were the activities to meet their personal needs. As major fruit varieties, he named fig, pomegranate, apple, pear, plum, cherry, cornel, quince, almond, peach, apricot, walnut, etc. (Javakhishvili 1986, 1996).

The first thorough analysis of the agriculture of Georgia belongs to Vakhushti Bagrationi (1696–1784). His work "Description of the Kingdom of Kartli" mentions and describes several cultures. Particularly interesting are those which have gradually lost their economic importance, first of all, cotton, rice, and some subtropical, forest, and subalpine meadow plants. This author was the first to notice the regional differences in the economic specialization and described them in his work. In the eighteenth century, when he lived and worked in the country, he emphasizes wine was one of the most important products of natural exchange with other countries; besides, corn, kidney beans, and tobacco which were spreading gradually, people intensely grew wheat (hard wheat, Persian wheat, summer wheat), foxtail, barley, and oats and a number of technical cultures. Of the wild-growing (laborless) food products, he has written about kaki, watermelon, melon, apples and peaches, walnut, and mushrooms. With his records together with other historical sources, Ivane Javakhishvili has drawn a retrospective picture of the historical distribution of agricultural crops. He has identified peculiarities in the distribution of different agricultural crops in different corners of Georgia and identified the link between these and the local conditions. According to him, the diversified environmental conditions of Georgia resulted in the establishment of an absolutely different agricultural specialization on the territory of the country: vineyard-and-fruit botanical-agronomical area over the plains of West Georgia substituted by non-vineyard-or-fruit areas or pomelo-and-bitter orange areas at some places, while vineyard-and-fruit botanical-agronomical areas were common on the plains of East Georgia and replaced by winter pastures in the extreme eastern part of this corner of the country. In the mountains, non-vineyard-or-fruit and grass-and-flower areas were common with the cattle-breeding playing the leading role (Javakhishvili 1986, 1996).

A map by I. Javakhishvili gives a clear picture about agrofloristic zoning of Georgia in the historical past (1930), which was compiled based on the old historical sources. He identified six botanical-agronomical areas (Table 14.1). This map is one of the most important sources giving us an idea about the study of the agrarian zones of Georgia and the economic links in ancient Georgia. Here we see six botanical-agrarian areas (Sartania et al. 2017): a pomelo-and-bitter orange area, a rice-cotton area, a vineyard-and-fruit area, a non-vineyard-or-fruit area, a grass-flowery area, and winter pastures.

The pomelo-and-bitter orange botanical-agrarian area is presented as small fragments in the zone of Kolkheti Valley (Apkhazeti, Guria, Ajara). This is the area where subtropical cultures grow with favorable orographic, climatic, and soil conditions and these yielded rich harvest of these crops. The rice-cotton botanical-agrarian area spreads only in the lowlands of both West and East Georgia. It is noteworthy that these two crops, which grew in certain zones in the past, virtually, today are not grown in any location of Georgia. The vineyard-and-fruit botanical-agrarian area is spread over to a much greater area, both over lowlands and foothills of West and East Georgia.

Vine-growing has played a greater role in the economic development of the country since the ancient times, as evidenced by a number of circumstances. The non-vineyard-or-fruit botanical-agrarian area spreads both in West and East Georgia, forming an almost continuous area. It covers the zones of the middle mountain within the limits of the mountainous areas of the Great Caucasus (Kaucasioni) and the Lesser Caucasus (Mtsire Kaukasioni). The grass-flowery botanical-agrarian area stretches in the high-mountainous zone of the Great Caucasus and the Lesser Caucasus. It is the area with high-mountainous alpine and subalpine meadows used as summer pastures since the ancient times. This area occupies quite a large territory on Javakheti Plateau. The winter pastures of botanical-agrarian area are spread on

Table 14.1 Territorial coverage of the botanical-agronomical areas of Georgia

#	Botanical-agronomical areas of Georgia	Distribution		
		Main orographic units	Modern regions of Georgia	Historical regions of Georgia
1	Pomelo-and-bitter orange	Kolkheti lowland and foothills, Black Seashore	Abkhazeti, Samegrelo, Guria, Atchara	Erge and Ligani Gorges
2	Rice-cotton	East Depression of Georgia	Abkhazeti (limited), Samegrelo (limited), Guria (limited), Kvemo Kartli, Kakheti, etc.	Chaneti, Hereti
3	Vineyard-and-fruit	West Depression of Georgia	Abkhazeti, Samegrelo, Racha, Imereti, Guria, Atchara, Samtskhe, Shida Kartli, Kvemo Kartli, Kakheti, East Georgian Mountainous Area (fragmentately)	Tortomi, Klarjeti, Tao, Shavsheti, Chaneti, Djiketi, Hereti
4	Non-vineyard-or-fruit	Middle-mountain zone of Great Caucasus and Lesser Caucasus	Abkhazeti, Samegrelo, Svaneti, Racha, Imereti, Guria, Atchara, Samtskhe, Shida Kartli, Kvemo Kartli, Kakheti, East Georgian Mountainous Area	Gugareti, Dvaleti, Klarjeti, Tao, Kazakh-Shamshadilo, Shavsheti, Chaneti, Djiketi, Hereti
5	Grass-flowery	Subalpine and alpine zones of Great Caucasus and Lesser Caucasus, Javakheti Plateau	Abkhazeti, Svaneti, Racha, Imereti, Atchara, Samtskhe, Javakheti, Shida Kartli, Kvemo Kartli, Kakheti, East Georgian Mountainous Area	Abotsi, Artaani, Bambaki, Dvaleti, Tortomi, Klarjeti, Kola, Tao, Sgvsheti, Chaneti Hereti
6	Winter pastures	East Georgian Mountainous Area – Iori Plateau, Mtkvari and Iori Gorges	Kakheti, Kartli	Gugareti, Kazakh-Shamshadilo, Hereti

Prepared according to the data of Iv. Javakhishvili

the lowland of East Georgia. In the economic respect, this area has played a major role, as it was the only vast area for cattle wintering beneficial for cattle-breeding in the mountains.

The Georgian agricultural fund has suffered a great loss during the Soviet period (particularly during 1950–1960) because of high specialization of agriculture and a shift to the production of monocultures, all resulting in the depletion of rich agricultural resources of the country. This process continued even after the 1990s, as the economic crisis yielded deplorable results because the local varieties could hardly survive here and there or in the collections of some scientific institutes (Anonymous 2019).

In recent years, the species from foreign countries (introduced varieties) have played an important role in the plant diversity of Georgia. The Black Sea coastline, piedmont, low mountains, and areas of alpine pastures in high mountains are particularly rich in such plants (Elizbarashvili et al. 2000). Their least numbers grow in the middle-mountain forest (beech) areas, where complex orographic conditions prevent them from penetrating and widely spreading in these areas. A part of the introduced plants have already escaped and are found in the wild.

The introduction of plants became a common practice at the end of the nineteenth century, but the introduced plants do not always have a positive impact on the nature of host country. Often, the valuable introduced species were accompanied by certain weeds (Yarcı et al. 2007; Yarcı and Altay 2016; Mushtaq et al. 2020; ur Rehman et al. 2020). As an example, we can site paspalum grass, horseweed, ragweed, and cocklebur. Some of the introduced plants adapted to the new environment better and turned out stronger than the local edifiers.

14.3 Influence of Environmental Conditions on Agrodiversity

The temperature and moisture ratio are one of the most important factors influencing the growth and development of agricultural crops; others are absolute minimum temperature, sum of active temperatures, amount of atmospheric precipitations, duration of sunshine, wind direction and strength, duration of the vegetation period, edaphic conditions (type of soil, amount of humus), and many other factors (Yarcı and Altay 2016; Raza et al. 2019; Ayub et al. 2020; ur Rehman et al. 2020).

Complex orographic conditions of Georgia, big hypsometric range, as well as the relief of mountains and gorges, alternating basins, and plateaus have resulted in extremely contrasting natural conditions in the country. Despite its small area, Georgia experiences almost all climate types known on the Earth, starting with the sea humid subtropical climate, dry field subtropical climate in East Georgia, and through the mountain climate of all altitudinal zones. The diverse nature of Georgia has had a great influence on the farming structures and their territorial distribution and agrodiversity. The major agricultural areas are on the lowland zone of Georgia, which is also much diversified.

Kolkheti Valley and the area of adjacent hills (up to 600–700 m above sea level) have humid subtropical climate with relatively warm winter. The average temperature in January at an altitude of 600–700 m asl never falls below 0 °C; the annual amount of atmospheric precipitations do not exceed 1000 mm (Javakhishvili 1981). Warm sunny weather lasts for longer period even in winter. Such conditions support the wide spread of humid subtropical cultures in the area. The further we go from the Black Sea coastline, the less is the average January temperature and the less the areas occupied with the said cultures, which finally disappear. The soil cover is diversified on the lowland of Georgia. As for exploitation, boggy soils can be used only after accomplishing certain amelioration measures. In such a case, corn and vegetables can be grown here. As for the red and yellow soils, which are found only in the piedmont zone, up to 500 m asl, they have high concentrations of iron and oxides, making them fertile and possible to use intensely in agriculture. The principal agricultural crops in this area are tea, citruses (mostly tangerine trees, orange, lemon), tung, tobacco, various fruits, etc.

The annual amount of precipitation on the lowland of East Georgia is much less around 400–600 mm on Shida Kartli lowland and its adjoining piedmont, 360–380 mm on Kvemo Kartli lowland, 450–500 mm on Iori Plateau and Shiraki Valley, and 600 mm on Alazani Valley (Anonymous 2004a) and is minimal on Eldari lowland. Consequently, the areas with agricultural crops are limited and the lands are mostly used as winter pastures. One of the most important agricultural areas in East Georgia lowland is formed by a zone of alluvial soils – "the silts" – along the gorges of the lower reaches of big rivers. In an agrarian respect, these soils are highly fertile, and the following crops are cultivated here: cereals, vine, fruit, vegetable, etc. The Chernozems on the lowlands of East Georgia are also important which are mostly spread on Iori Plateau. It is considered as the most fertile area due to its high humus content and mainly used to grow cereals and perennial crops (Elizbarashvili et al. 2000).

During the penetration of cold air masses, the weather conditions are much unfavorable for the agricultural crops. The temperature on some days may fall to −10 to −15 °C in West Georgia and −20 to −25 °C on the lowland of East Georgia (Anonymous 1967, 1970, 2004b). The dates of onset and end of frosts, as well as the duration of the period without frosts, are very important for agriculture. The frosts on the lowlands of West Georgia end in March at the earliest and in April in the mountains and piedmont zones, up to 1500 m asl, while in East Georgia, the frosts end from March 20 to April 20 and from April 15 to June 15 in the mountains and piedmont zones (Anonymous 1961, 1990).

As the absolute altitude increases, in terms of cold and colder climate, the area of the agricultural crops becomes somewhat limited and we find less diversity. Javakheti Plateau in South Georgia has a drier continental climate. Besides, the duration of the period without frosts is much less here (150–220 days) as compared to the lowland of East and West Georgia, where it is 250–300 days. Due to this, despite highly fertile mountain Chernozems spread on the said plateau, the vegetation period of agricultural crops is shorter, and only certain kinds of crops are grown here, mostly cereals, forage grass, potato, etc. The duration of sunshine on the territory of Georgia is longest on the lowland of East Georgia (Shiraki Valley and Gardabani Plain) and on Javakheti Plateau (2400–2500 hrs). Maximum duration of sunshine (200–310 hrs) is in July, and the minimum value (80–140 hrs) is in January (Anonymous 1978, 1990; Gvasalia, 1986). The average duration of the period without frosts varies within quite great limits, from 70 to 300 days. The most durable period without frosts is fixed on the coastline of the Black Sea in West Georgia and in plain regions (250–300 days). The duration of the period without frosts in the piedmont and plain regions of East Georgia varies from 180 to 250 days (Anonymous 1967, 1990).

A particular damage to the agricultural crops is caused by downpours, often followed by hail. Downpours and hail are most common in East Georgia, in the basins of the rivers Mtkvari, Alazani, and Aragvi in particular, where the number of days with hail is 35–40 a year and even more at some locations (mostly in the warm period of the year). Hail is also very common in the mountains of South Georgia where it occurs for 60 days a year on average or even more in some years (e.g., hail occurred 85 times in 1972) (Alpenidze et al. 1999).

14.4 Biodiversity of Agrofloristic Zoning

According to the thermal conditions and humidification, N. Ketskhoveli has identified 11 agricultural zones and 22 agricultural sub-zones in Georgia (Fig. 14.1) (Ketskhoveli 1957).

I. **Zone of subtropical plants**

1. Sub-zone of technical subtropical plants
2. Sub-zone of fruit-growing and tea-growing
3. Sub-zone of tea-growing and subtropical fruit-growing
4. Sub-zone of tea-growing, winter vegetable-growing, and fruit-growing
5. Sub-zone of tea-growing and subtropical fruit-growing and viticulture
6. Sub-zone of tea-growing, fruit-growing, and viticulture
7. Sub-zone of viticulture (table and champagne wine-making), vegetable-growing, and continental fruit-growing

II. **Viticulture and dry subtropical fruit-growing zone**

8. Sub-zone of viticulture (table quality wine-making)
9. Sub-zone of viticulture and dry subtropical fruit-growing (presently field husbandry and cattle-breeding)
10. Sub-zone of viticulture (table grapes and strong wine-making), dry subtropical fruit-growing, and vegetable-growing

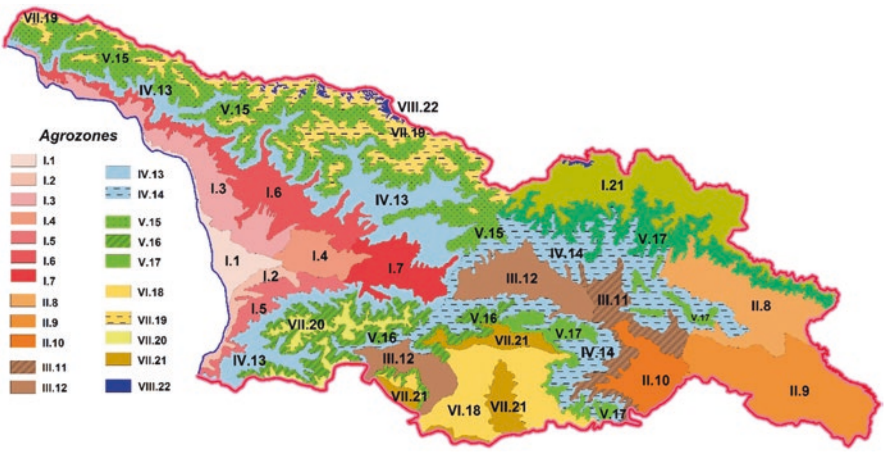


Fig. 14.1 Map of agricultural zones of Georgia. (After N. Ketskhoveli 1957)

III. **Viticulture and fruit-growing zone**

11. Sub-zone of fruit-growing and vine-making (table storage farming)
12. Sub-zone of fruit-growing and vine-making (table and champagne wine-making)

IV. **Fruit-growing, field husbandry, and vine-making zone**

13. Sub-zone of continental fruit-growing and viticulture
14. Sub-zone of continental fruit-growing and field husbandry

V. **Zone of mountain forests (forestry) of Georgia**

15. Sub-zone of the Caucasioni mountain forests of West Georgia
16. Zone of the mountain forests (forestry) of South Georgia
17. Sub-zone of the mountain forests (forestry) of East Georgia

VI. **Zone of field husbandry and cattle-breeding**

18. Sub-zone of field husbandry and mostly cattle-breeding

VII. **Zone of mountain hayfields and pastures**

19. Sub-zone of the Caucasioni hayfields and pastures of West Georgia
20. Sub-zone of hayfields and pastures of Ajara-Imereti Ridge
21. Sub-zone of the Caucasioni hayfields and pastures of East Georgia

VIII. **Zone of eternal snow, glaciers, and ruins**

22. The same

Each of the above-listed zones/sub-zones is distinguished for their peculiar agro-climatic features, and consequently, the composition of agricultural crops and their growth peculiarities are also different. The agroclimatic zones with the sum of active temperatures of more than 4000 °C are favorable to grow cereals, vine, fruit, dry subtropical technical crops, ether-bearing crops, tobacco, vegetables, as well as tea and citruses (in the humid subtropical zone of West Georgia). The agroclimatic zones with the sum of active temperatures of 3000–4000 °C are favorable for grain-growing (winter and spring wheat, corn, soya), fruit-growing, viticulture, ether-bearing crops and technical cultures growing, and vegetable-growing; in the zone with temperatures of 2000–3000 °C, cereals (wheat, barley, corn), fruit, potato, and vegetables are the leading agricultural crops; barley, oats, potato, vegetables, and berries favorably grow in the zones with the temperatures of 1000–2000 °C, while oats and some vegetables can be grown in the zones with temperatures of less than 1000 °C (Anonymous 1964; Meladze and Meladze 2009).

The following peculiarities have been identified through the study of distribution of agricultural zones and sub-zones on the territory of Georgia: the total number of varieties of the agricultural crops in 14 agricultural sub-zones of Georgia (except vine) is more than 100 at all locations – another clear evidence of the great variety of agricultural crops of Georgia (Fig. 14.2). This is more clear when considering that these 14 sub-zones occupy 436,000 km^2, making almost 63% of the total territory of

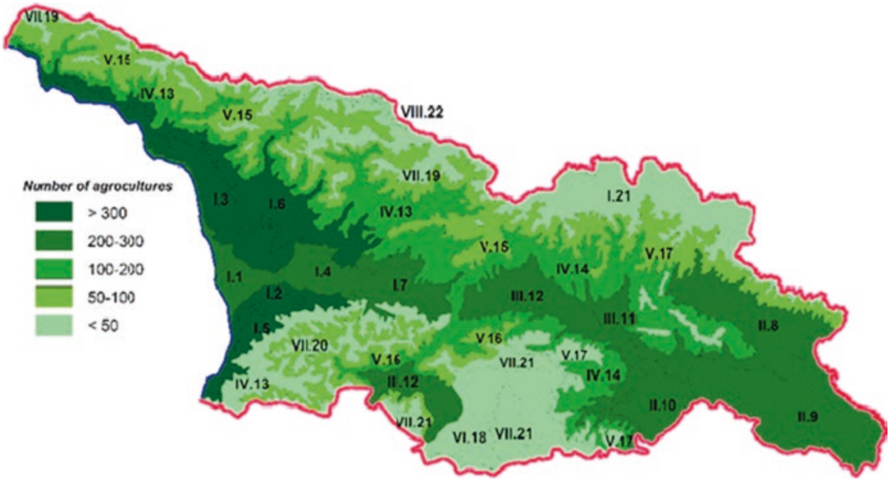


Fig. 14.2 Diversity of the agricultural crops in Georgia (except vine)

the country. Particularly diversified are the varieties in the four sub-zones (2, 3, 4 and 5), where the number of plant varieties is more than 330. This index is maximal in sub-zones 2 and 3, with number of varieties approximately 400 in each sub-zone. All the abovementioned four zones are found in the lowland of West Georgia. Leaving aside vine, with the number of flowers, decorative, wind-belt and park plants, this zone ranks first in Georgia, as well as with the number of fruit, technical crops, textile and forage plants, but with the number of cereals and other starch-bearing plants, fall much back from other zones. The number of varieties of agricultural crops is also great (200–300) in the following eight sub-zones: 1, 4, 7, 8, 9, 10, 11, and 12. It covers certain lowland areas both in West and East Georgia.

The ranges of agricultural zones according to the abundance of starch-bearing plants are absolutely different. In this respect, four sub-zones (12, 13, 10, 11) clearly dominate, which are found in the lowland of East and West Georgia.

It is clear that the mountains are not so much rich in agricultural crops as before. However, the number of agricultural crops in the agricultural zones of the lower- and middle-mountain areas exceeds 75 everywhere. It is true that the areas covered with agricultural crops are small here, but where they are grown, the natural conditions favor the growth of various crops.

Some sub-zones are distinguished for their abundance of a variety of not only agricultural crops but also individual crops. In this respect, zone 3 ranks the first. More specifically, it ranks the first with seven groups of plants (Table 14.2). As is clear, there are five more zones in Georgia distinguished in this respect.

Table 14.2 The first five agrizones distinguished by diversity of agricultures

#	Fruits	Cereals and plants rich in starch	Fabaceae	Vegetables	Technical crops	Textile plants	Food for the domestic animals	Flowers, decorative, windy, park plants
1	+	–	–	–	+	+	–	+
2	+	–	+	–	+	+	+	+
3	+	–	+	+	+	+	+	+
4	–	–	–	+	–	–	–	–
5	+	–	–	+	+	+	+	+
6	+	–	+	+	+	+	+	+
7	–	–	+	+	–	–	–	–
8	–	+	+	–	–	–	+	–
9	–	–	–	–	–	–	–	–
10	–	+	–	–	–	–	–	–
11	–	+	–	–	–	–	–	–
12	–	+	–	–	–	–	–	–
13	–	+	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–

14.5 Some Agricultural Crops of Georgia

There are about 700 agricultural crops (excluding vine) registered in Georgia. The most diversified groups are flowering, decorative, wind-belt, and park plants (Fig. 14.3). The second are cereals and starch-bearing plants with their number exceeding 150. The number of fruits, vegetables, and technical crop varieties is also high, which is almost 250.

Historically, wheat has been one of the leading global crops (Ozturk and Gul 2020). Like in some other countries, it is considered as one of the greatest achievements of Georgian cultivators. Depending on the natural conditions, they have grown different wheat varieties in Georgia. Their composition is much diversified and they have different names. The agricultural practice established in Georgia has preserved to date the varieties of all stages of wheat development, starting from the wild and primary cultural skinned paleorelict forms to secondary high-developed naked cereals which originated from these (Bregadze 1987).

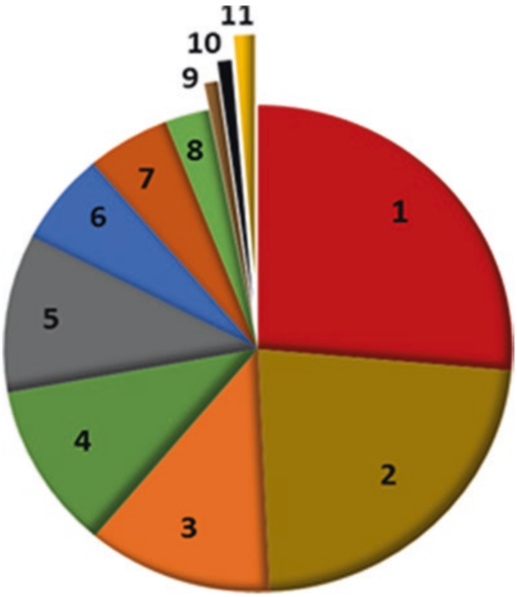


Fig. 14.3 Diversity of agriculture in Georgia **(1) Flowering, decorative, wind-belt, and park plants, (2) cereals and other starch-bearing plants, (3) fruit, (4) vegetables, (5) technical crops, (6) textile plants, (7) forage plants, (8) legumes, (9) Juglandaceae, (10) narcotic plants and stimulants, (11) oil-bearing plants**

The following *Triticum* taxa are widespread in Georgia: *T. dicoccum*, *T. carthicum*, *T. vulgare*, *T. durum*, *T. macha*, *T. vulgare* var. *milturum*, etc. It is interesting to note that the names of many wheat varieties show the morphological signs of the given agricultural crops based on the long-term observations of farmers over the color, awn-bearing, ear brittleness, and size of wheat. Such names are Shavtavtava (translated as black ear), Shavphka (black awn), Tsiteli Doli (red Persian wheat), Upkho (without awn), Khotora ("without hair"), Chveneburi Puri (our local bread), Gomborula (of Gomboric origin), Lagodekhis Grdzeltavtava (long-eared wheat of Lagodekhi), and Rachula (of Racha origin). Today, many of the above-listed taxa are either totally extinct or have survived at some rare locations only. According to the archeological studies, wheat was grown in Georgia from the fourth to the sixth century BC (Arukhlo, Khramis Gora, Shulaveri, Chikhori, Kheltubani), and many varieties have been identified (Maisaia et al. 2005).

In all, there are 14 natural wheat varieties registered in Georgia, making 70% of the cultural varieties of the wheat and 57% if wild species are considered. There are 150 wheat varieties described and registered. The five most famous wheat varieties of the world are Georgian endemics (Bregadze 1980; Anonymous 2011): *T. carthicum*, *T. zhukovskyi*, *T. georgicum*, *T. macha*, and *T. timopheevii*. Some of the named varieties are valuable selection materials, and the world has obtained new varieties from these: Lepard SRPC 67, Mengavi, Steinwedel, Timstein, etc. (Anonymous 2011). They include some interesting endemics, which are the best specimens of public selection (secondary cultures): *T. zhukovskyi* and *T. carthicum*. The former is the variety bred in the piedmont and middle-mountain zones, while the latter variety is bred for high-mountain areas. These provide evidence for continuous and intense process of origination of varieties and formats on the territory of Georgia. Due to

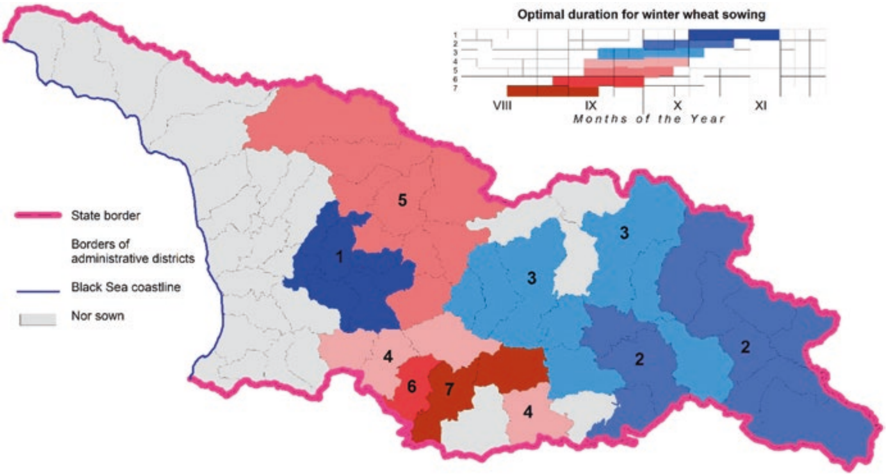


Fig. 14.4 Wheat-growing periods in Georgia

much contrasting natural conditions of Georgia, wheat-growing periods are different (Fig. 14.4).

Since the ancient times, *vine* has been one of the most important cultures in Georgia. In addition to historical sources, the archeological excavations in Georgia provide evidence that the country has been a hearth of viticulture and wine-making since the ancient times, as evidenced by the prints of vine leaves, grape pips, pitchers, and wine bowls found buried in the ground in Mtskheta, Trialeti, and Vani, on Alazani Valley, and in different locations of Kolkheti, the oldest of which is dated back to the third century BC. Recently, archeologists have found a wine bowl aged 7,000 years. Georgian wine has been exported to many countries since the ancient times and even during the economic hardships of the country. The ampelographic works of the nineteenth century describing the vine varieties in different corners of Georgia give valuable data.

The diversified natural conditions have resulted in a very irregular distribution of the vine varieties across Georgia. Most of the vine varieties grow in Kakheti, Kartli, Imereti, and Racha-Lechkhumi (Fig. 14.5) with the total number exceeding 100. A particularly outstanding administrative region with over 50 vine varieties is Ambrolauri (Nikolaishvili 2007). Vine grows on many landscapes and within a large hypsometric range of Georgia, starting from the sea level up to 1200 (1340) m. Its hypsometric range is quite wide in West Georgia (Ajara, Guria, and Samegrelo), but it is in Ajara where the vine grows exceptionally on all altitudinal ranges.

Kartli is also outstanding in this respect. The least altitudinal range where the vine grows is seen in Racha-Lechkhumi despite the fact that this region ranks the first with the number of vine varieties in Georgia (Nikolaishvili et al. 2016).

Based on the historical and other sources, it has been established that in the past, vine varieties drew the border between the mountains and the lowlands not only geographically but also due to the distribution areas of vine and viticulture generally.

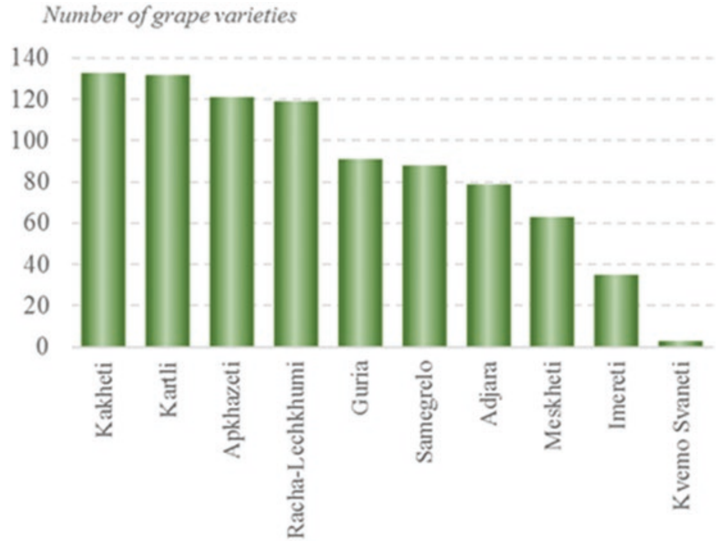


Fig. 14.5 Grape varieties according to the regions of Georgia

The primary evidence of this fact is in the article on the "Description of the Kingdom of Kartli" by Vakhushti Bagrationi (Vakhushti 1941), where it says that the mountainous zone is characterized by the lack of vineyards and fruits and little yield of cereals, while the lowland zone is rich in grapes and fruits and has good crop capacity: "To the point the viticulture was possible, the land was considered the lowland and the land beyond that, where vine could not be grown, was mountains." And Iv. Javakhishvili also noted the same circumstances (Javakhishvili 1986, 1996). In agricultural respect too, the only exception from the old tradition of demarcation is the mountains and the lowlands of Racha-Lechkhumi, where the vine grows above 500 m above sea level. Therefore, Vakhushti attributed this area to mountains, but he noted: "Lechkhumi is a mountainous area, but is famous for good harvest of grapes, fruit and all kinds of cereals."

Nut culture is also known in Georgia since the ancient times, but as to when the locals of Georgia start to grow nuts is not exactly known; however, the eastern shores of the Black Sea are considered the first hearth of the nut cultivation. From this location, the nuts probably spread along the Mediterranean coastal line, where many new varieties originated through natural hybridization and selection (Khomizurashvili and Esistavi 1939). The historical sources provide evidence that in the sixth century BC, locals grew wild nut varieties. Later, through hybridization and selection, high-yielding nut varieties were developed, and these were well-adapted to the natural conditions, characterized by great diversity. There are several dozens of aboriginal nut varieties that exist in Georgia: Anakliuri (of Anaklia origin), Gulshishvela (with a naked kerel), Dedoplis Titi (queen's finger), Vanis Tetri (white nut from Vani), Vanis Tsiteli (red nut from Vani), Imeruli (of Imeretian origin), Nemsa (needlelike, Ucha Tkhili (nut named "Ucha"), Shveliskura (roe deer's ears), Chkhikvistava (jay's head), Kharistvala (ox's eye), Khachapura (like a Khachapuri), etc. (Anonymous 2016; Tsereteli and Dundua 2009).

Nuts have played a great role in the life of the population in Georgia. These have provided great economic benefits to the country. For centuries up to now, nuts have been grown as export agricultural crops with varying trends: the number of nut trees got reduced by 8–10 times in the Soviet period, and their export reduced as well. Since the 1990s, there has been a new start for mass nut plantations in West Georgia – in Abkhazia, Ajara, Guria, Imereti, and Samegrelo. In 2017, the areas of nut plantations increased significantly, reaching a productivity of up to 21.4 thousand tons (Anonymous 2018), and Samegrelo is an evident leader in nut production in the country (Fig. 14.6). The areas of nut plantations have drastically increased during the last 10–15 years (Tsereteli and Dundua 2009; Anonymous 2015). But these have suffered much from pests and various diseases.

Apple is one of the most widely spread fruits in Georgia. *Malus* is the only wild-growing apple variety in Georgia. It grows up to 1800 m asl in the mountain forests. Apple was cultivated by taking it from the forest, hybridization, and selection. It is interesting to note that as early as at the beginning of the nineteenth century, in the gardens of Kartli, in the gorges of the rivers Didi Liakhvi and Patara Liakhvi, there still grew apple trees taken from the forest (Ketskhoveli 1957). Based on different sources, Ivane Javakhishvili has made a list of different fruits, naming 17 apple varieties (Javakhishvili 1986, 1996).

As a result of selection, many apple varieties are available now: Abilauri, Goruli, Zertula, Sinnap, Kitra, Meretula (species of Kartli), Bostana, Turashauli, Mkhara, Mepis Vashla, Roketula, Konavashla, Shakara (species of Meskheti), Kakhetian Turashauli, Lagodekhian Renet, Revasberg (Kakhetian species), etc.; in addition to the local species, from the second half of nineteenth century, European and American apple varieties were widely spread in the country. There are also many apple varieties in the country. In Samtskhe-Javakheti alone, Iv. Javakhishvili named

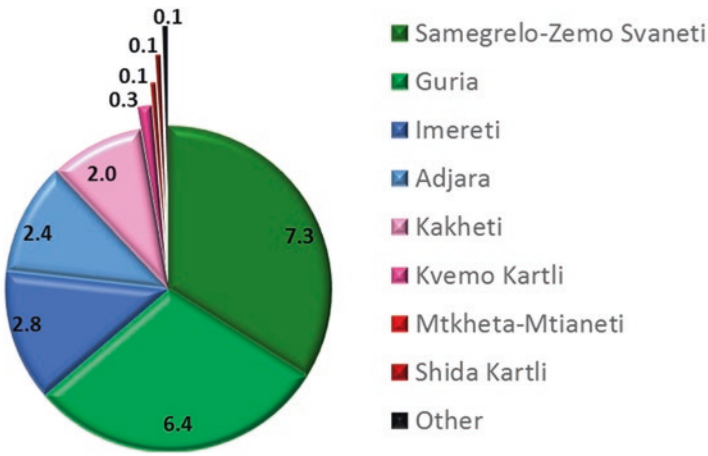


Fig. 14.6 Production of hazelnut by regions in Georgia (thousands of tons)

Table 14.3 Apple varieties in Samtskhe-Javakheti

Harvesting time	Apple varieties
Summer	Iazalma, Uzunlama
Winter	Alialma, Atcharula
Autumn	Iagalma, Koprutsula
Undefined	Devrishbegi

18 apple varieties (Table 14.3), most of which are winter or autumn forms, i.e., people gathered their harvest late to make winter supply. It is interesting to note that many apple varieties were sweet and had high content of sugar as is indicative of their names, e.g., Shakarvashla and Shakarnabada ("Shakari" is "sugar" for Georgian).

Mulberry has been important in Georgia not only as a fruit but also as the main raw material for sericulture since the ancient times. Owing to the wide distribution of mulberry, sericulture has a long history in Georgia. It grows almost in all agricultural zones of the country. Of the two naturally growing species, *Morus alba* occupies principally large areas in 17 agrozones and grows up to 1200–1300 m asl, sometimes reaching an altitude of 1700 m asl. Another species is *Morus nigra*, which grows in the same agrozones, but is less adapted to severe climatic conditions and prefers only the lowlands in the piedmonts. Since the 1930s, Georgia has started to propagate mulberry by way of selection, and imported varieties from other countries have been used as well (European countries, Japan, Russia, China). Presently, there are 21 mulberry varieties identified and bred in Georgia. Some bred varieties are excellent raw materials for sericulture; in particular, a coarse thread made from such varieties has a minimum linear density (1.56 texes), and the thread knitted with their cocoons is long (2000–2500 m) and very compact (Anonymous 2012).

Corn was imported to Georgia in the seventeenth century and has almost totally replaced the foxtail, a crop widely spread in Georgia at one time. For three centuries, the Georgians have bred local corn varieties, hybrids, populations, and heterotic forms, which spread in different agricultural zones. However, corn grows unevenly in the country. 70–74% of the total corn-sown areas are on the lowlands of West Georgia (Zarandia 2008). The largest areas are occupied by the corn variety Ajametis Tetri, which grows on Kolkheti lowland. It is the most high-yielding variety in Georgia.

The historical sources and other works contain a bulk of data about the distribution of citruses in Georgia, in particular along the Black Sea shore. Most information available about the subtropical group of plants is about **citruses**. Clearly, the main distribution area of citruses both in the old and modern times is the humid subtropical zone of West Georgia (Abkhazia, Samegrelo, Imereti, Guria, Ajara). These are spread evenly in the areas where apple, pear, or vine is grown.

Mass cultivation of **tea** in Georgia has started in the 1930s and became an industrial crop. Georgia is the extreme northern region of tea-growing in the world. For many decades, the country supplied the Soviet Union with tea (90–95% of tea of the Soviet Union was produced in Georgia) (Beruchashvili et al. 2002).

Fig. 14.7 Fresco of Nabakhtevi, East Georgia (Georgian National Museum)

Georgia is also rich in **vegetables** and **greens**. They have always played an important role in everyday life of Georgian farmers, and this is seen in the great number of varieties in the country. A number of vegetables and greens have been bred via selection with the support of local conditions. The evidence can be sited from Iv. Javakhishvili's interesting observation: "Since ancient times, a Georgian man never imagined having a tasty and graceful dinner without greens; the greens were the necessary attribute and decoration of the table. An amazing evidence is the wall painting of the first half of the XV century in the Nabakhtevi Church (Fig. 14.7): the picture of the Last Supper, unlike the traditional composition with bread, fish and wine, it shows the greens, garden radishes and onions as well" (Javakhishvili 1986, 1996). This fact proves the importance of the given agricultural crops for Georgian farmers and provides the basis to breed a great number of new varieties and populations.

14.6 Traditional Nature Management: One of the Important Bases of Sustainable Development

The strategy of the sustainable development in the country is basically based on some principles, implying achievement of the economic benefits with minimum environmental damage. Georgia has many-centuries-long traditional experience based on the good knowledge of the local natural conditions, observations over them, and undertaking economic activities by considering these principles. It is necessary to share this knowledge and experience and introduce these as a practice. This is one of the optimal ways to achieve sustainable development. There are many methods which were used by the local people in the past to gain rich harvest of agricultural crops, which ensured the ecological balance of the environment without possible negative impacts. One of the most vivid examples is **terrace farming**, which was an accepted practice in almost all over Georgia, where orographic conditions were complicated or made the cultivation of agricultural crops impossible.

Terrace farming was intensely used in Samtskhe-Javakheti, Ajara, Kartli, Khevsureti, and in other parts of Georgia. The territories of Samtskhe-Javakheti and the northwestern and western parts of Akhalkalaki Plateau, up to 1200–1600 m asl, where the temperature of the coldest month of the year is −5 to −6 °C, the sum of active temperatures is 2800, and the period without frosts lasts for 4.5 months, are fully capable of growing early or mid-grape varieties, but complex orographic conditions do not favor this activity. Therefore, terrace farming has been developed in this area: for many centuries, in this area, at 1700 m asl, over the slopes of the southern exposition, people grew vine. As for Akhalkalaki Plateau, in the eastern part of this area, with an average air temperature falling to −1.8 °C and the absolute minimum temperature of −38 °C, it is impossible to grow even early grape varieties. Therefore, in winter, they used the method of burying the vine (Sartania et al. 2016).

Terracing the slope suitable for farming was opened carefully and protected for a long time. This significantly increased the agrodiversity in the country as well as the areas of agricultural lands and yielded sustainable and rational natural management practices. These practices have played an important role in the economic development of the country. From the modern point of view, this type of farming corresponds to the expedient and sustainable principles, as it guaranteed a rich harvest of agricultural crops on the one hand and maintained the ecological balance in the environment on the other hand. Such an effect was owed to the deep knowledge of natural conditions gained by the people through many years of long observations and analysis (Sartania 2015).

In Georgia, two kinds of terraces are observed: one without walls (*lari*) and another with stone walls (*Dariji/Oroki/Sakve*). These terraces were due to the local conditions. The stone wall terraces were built over the slopes with great inclination (over 10°), mostly near the bottom of the river and where there was a sufficient reserve of stones to build the terrace walls. The terraces without walls were built over the slopes with a less inclination (5°–10°). Here they built artificial steps gradually, by soil plowing for several years. The analysis of different historical sources has revealed that mostly fruit trees, vine, vegetable varieties, and rarely crops were grown on the terraces. Terrace farming allowed not only cultivating the land and gaining stable harvest, but it was an important means to achieve the diversity of agricultural crops. In the case of lower solar energy, where it was impossible to grow some of the agricultural crops on a plain surface, terracing the southern slopes was followed. In addition, a farmer could observe which species gave better harvest and used the method of selection.

The traditional practice used by the local farmers during the crop failure is very important. The centuries-long observations over the cereals helped the farmers to develop the habit of using practical methods to gain **new selective varieties**, which were more resistant to unfavorable environmental conditions, making the agricultural sources more versatile. For example, on the lowland of East Georgia, winter Persian wheat dominated. It gave rich harvest and was resistant to the frost and drought well and the grains did not fall. However, in some years, it tended to lodge and was easily subject to yellow or brown rust (Tedoradze 1978). If it was destroyed, farmers sowed spring Persian wheat, which was not frost-resistant. Therefore, its major part perished. However, its survived minor portion formed a crop field anyway, and the harvest gained from it was used by the farmer as seeds to sow in autumn. It was "this Persian wheat (Triticum carthicum), which was frost-resistant, made shoots and crop field finally. As for the gained ears, they were Triticum vulgare var. div. rather than Triticum carthicum" (Chitaia 2000). These observations have been a question of dispute among the scientists, as they consider such seed transformation impossible. Despite the fact that in the fields they found *Triticum vulgare* var. div. instead of *Triticum carthicum*, they explained this by simple mixing of the seeds or by carrying the seeds by birds. However, as early as in the 1950s, the transformation of seeds of *Triticum carthicum* into *Triticum vulgare* var. *div.* was proved experimentally (Lisenko 1951).

Another common practice was to use **mixed seeds**. This practice was common throughout Georgia and is used even today. It means sowing different species of agricultural crops together, e.g., in a cornfield on Kolkheti lowland, they sow kidney beans, beans, and pumpkin together. They harvest each of these crops at different times: first, they harvest corn and kidney beans and then beans and pumpkin after 2 or 3 weeks. However, another practice of mixed sowing has been forgotten and if restored will be economically beneficial even today. In the piedmont zone of Kartli, they used to mix the grains of barley and Persian wheat and sowed them together. It is interesting to note that such a field was called barley-Persian wheat, or Qerchreli (translated as "mixed with barley"). The agricultural crops in the mentioned areas often got damaged due to frequent droughts, particularly on the lands not requiring irrigation. Therefore, the way out was the mixed sowing of the fields with barley and Persian wheat, which withstand droughts much better. Barley, which ripens earlier and is taller than the Persian wheat, shaded the Persian wheat to persist droughts easily (Chitaia 2001).

The local people found an efficient means to fight **weeds**. One of such means was substituting the seeds. They sowed the seeds, e.g., panic grass, which facilitated combating the weeds. The point is that panic grass ripens earlier than wheat. Therefore, they sowed it late in spring when the weeds were grown. At this time, they tilled the land to sow panic grass. The plow eradicated the weeds and destroyed them in this way. Consequently, panic grass gave rich harvest. At other times, peasants used certain kinds of weeds for their benefit. They noticed that bread tasted better and had greater stickiness if mixed with *Cephalaria* seeds (the dough of sticky bread did not fall in ember when baked in the shield (a cylindrical clay bread oven) and bringing no damage) (Chitaia 2001).

References

Alpenidze M, Beruchashvili N, Gongadze M et al (1999) Geography of Georgia. Kabadoni, Tbilisi

Anonymous (1961) Agroclimatic reference book for the Georgian SSR. Hydrometeoizdat, Leningrad

Anonymous (1964) Atlas of Georgia. Tbilisi-Moscow

Anonymous (1967) Reference books of the climate of the USSR. Issue 14. Georgian SSR, Part II. Air and soil temperatures. Hydrometeoizdat, Leningrad

Anonymous (1970) Reference books of the climate of the USSR. Issue 14. Georgian SSR, Part IV. Air humidity, atmospheric precipitations and snow cover. Hydrometeoizdat, Leningrad

Anonymous (1978) Agroclimatic resources of the Georgian SSR. Hydrometeoizdat, Leningrad

Anonymous (1990) Applied scientific reference book of the climate in the USSR. Parts 1–6, Issue 14, Georgian SSR. Hydrometeoizdat, Leningrad

Anonymous (2004a) Scientific-applied reference book of Georgi. Part I, Separate climatic characters. Bakur Sulakauri Publishing House, Tblisi

Anonymous (2004b) Scientific-climatic reference book of Georgia. Part I, Some climatic characteristics, Tbilisi

Anonymous (2008) National report on the state of plant genetic resources for food and agriculture in Georgia. Tbilisi Georgia September 29

Anonymous (2011) Wheat culture – our values. # 1. Tsignieri, Tbilisi

Anonymous (2012) Silk in Georgia. Our values. Tsignieri, Tbilisi

Anonymous (2015) How to grow and care of the nut garden. Ministry of Agriculture for Farmers, Tbilisi

Anonymous (2016) Nut Growing, caring and primary tillage of nut gardens. UNDP Georgia, Tbilisi

Anonymous (2018) Agriculture of Georgia. Statistical Publication. Natural Statistics Office of Georgia, Tbilisi

Anonymous (2019) Agrarian biodiversity of Georgia. Association of Agricultures “Elkana”. http://www.elkana.org.ge/?action=page&page=169&lang=geo. Accessed 25 May 2019

Ayub M, Ashraf MY, Kausar A, Saleem S, Anwar S, Altay V, Ozturk M (2020) Growth and physio-biochemical responses of maize (*Zea mays* L.) to drought and heat stresses. Plant Biosyst Int J Dealing Aspects Plant Biol 1–13

Beruchashvili N, Shotadze M, Nikolaishvili D, Melikidze V (2002) Caucasus environmental outlook (CEO 2002). UNEP, Grid-Tbilisi

Bregadze N (1980) Wheat – historical-ethnographic atlas of Georgia. Metsniereba, Tbilisi

Bregadze N (1982) Essays of agro-ethnography of Georgia, Tbilisi

Bregadze N (1987) For the origination of farming in Georgia. Materials for the ethnography of Georgia, vol 23. Metsniereba, Tbilisi

Bregadze N (2004) Georgia as an independent hearth of farming, Tbilisi

Chitaia G (2000) The Woks, vol 2. Metsniereba, Tbilisi

Chitaia G (2001) The Woks, vol 3. Metsniereba, Tbilisi

Chubinashvili G (1973) Monuments of early land cultivation in Kvemo Kartli. Journal «Matsne», Historical Series, 4

Dekaprelevitch LL (1941) Role of Georgia in the origination of wheat. Rep Acad Sci USSR 2(10)

Dorofeev VF (1971) Wheats of Trans-Caucasia. The Works of Applied Botany, Genetics and Selection, vol 47, Issue 1, Leningrad

Elizbarashvili N, Machavariani L, Nikolaishvili D et al (2000) Geography of Georgia, Tbilisi

Gorgidze AD (1979) Live relict of cultural wheat. Reports Acad Sci USSR 96(2)

Gvasalia HV (1986) Thermal balance of Georgia. Metsniereba, Tbilisi

Javakhishvili S (1981) Atmospheric precipitations on the Territory of Georgia, Tbilisi

Javakhishvili Iv (1986, 1996) Economic history of Georgia. Works in twelve volumes, vol IV–V, Tbilisi

Ketskhoveli N (1957) Zones of cultural crops in Georgia. Publishing House of the Academy of Sciences of the Georgian SSR, Tbilisi
Khomizurashvili N, Esistavi E (1939) Fruit-growing in Georgia, vol IV, Tbilisi
Lamberti A (1939) Description of Samegrelo, Tbilisi
Lisenko T (1951) The novelty of the science about the biological species. Herald of the Academy of Sciences of the USSR
Lisitsina GN, Prishepenko LV (1977) Paleobotanic findings of the Caucasus and Middle East. Moscow
Maisaia I, Shanshiashvili T, Rusishvili T (2005) Agrarian culture of Kolkheti. Metsniereba, Tbilisi
Meladze G, Meladze M (2009) Agroclimatic zone scenarios of the distribution of crops with account of global warming. Bull Georgian Natl Acad Sci 3(1)
Menabde VL (1948) Wheat varieties of Georgia, Tbilisi
Mercimek HV, Altay V, Ozturk M, Akçiçek E, Gucel S (2019) An overutilised industrial crop tobacco – *Nicotiana tabacum* L. case study from Turkey. In: Ozturk M et al (eds) Crop production technologies for sustainable use and conservation. Apple Academic Press Chapter 15, pp 365–394
Mushtaq W, Mehdizade M, Siddiqui MB, Ozturk M, Jabran K, Altay V (2020) Phytotoxicity of above – ground weed residue against some crops and weeds. Pak J Bot 52(3):851–860
Nikolaishvili D (2007) Ancient and modern vine varieties – their distribution and geographical names. International Scientific Conference: Georgia and France: two civilizations of wine. Tbilisi, pp 143–167
Nikolaishvili D, Sartania D, Ujmajuridze A (2016) Vine Culture in Samtskhe-Javakheti. Materials of scientific conference "Perspectives of regional development: Samtskhe-Javakheti", collection of works. Tbilisi, pp 43–60
Ozturk M, Gul A (2020) Climate Change and Food Security with Emphasis on Wheat. AP-Academic Press-Elsevier Inc., 370 p
Raza MM, Ullah S, Tariq A, Abbas T, Yousaf MM, Altay V, Ozturk M (2019) Alleviation of salinity stress in maize using silicon nutrition. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 47(4):1340–1347
Rehman R, Tarıq A, Haq N, Gul A, Altay V, Ozturk M (2020) Mutations leading to a better tomorrow in the production of improved crop varieties. In: Cambridge Scholar, Chapter 5 (in press)
Ruqia S, Haq SN, Ilyas M, Ilyas A, Gul A, Ozturk M, Altay V (2020) Plant metabolomics: role in crop improvement. In: Cambridge Scholar, Chapter 9 (in press)
Sartania D (2015) Traditional culture of nature management in Samtskhe-Javakheti. Proceedings of international conference "Applied ecology: problems, innovations" (ICAE-2015), 7–10 May 2015, Tbilisi-Batumi
Sartania D, Nikolaishvili D, Ujmajuridze A (2016) The retrospective image of vine distribution on the background of Samtskhe-Javakheti. Int J Sci Res, March
Sartania D, Nikolaishvili D, Ujmajuridze A, Chkhikvishvili G (2017) A Map by Ivane Javakhishvili, as the basis to study the agrarian zones of Georgia. The agrarian zones of Georgia according to the map by Ivane Javakhishvili. Ann Agrarian Sci 15(3):352–355
Taşpınar K, Ozturk M, Altay V, Polat H (2019) Sugar beet – an overutilised ancient crop. In: Ozturk M et al (eds) Crop production technologies for sustainable use and conservation. Apple Academic Press Chapter 14, pp 321–363
Tedoradze S (1978) Georgian Soviet encyclopedia. vol. 3, Tbilisi, 609 p
Tsereteli G, Dundua T (2009) Nut – usage and growing and caring technologies. Tbilisi, "Elkana" – Association of Biological Farms
ur Rehman T, Khan MA, Khan H, Shah WA, Altay V, Ozturk M (2020) Tillage, nutrients and weed control affects yield of sugar beet. Fresenius Environ Bull 29(5):3380–3387
Vakhushti B (1941) Description of the Kingdom of Kartli. In: Lomouri T, Berdzenishvili N (eds) Geography of Georgia, Tbilisi, p 356
Vavilov RI (1965) Centers of origin of cultural crops. Selected works, vol 5, Moscow – Leningrad

Yanushevitch ZV, Rusishvili NS (1984) New paleo-botanic findings on the eneolithic settlement of Arkhulo 1, collection “A Man and his environment”, Tbilisi
Yarcı C, Altay V (2016) Kocaeli ve çevresindeki tarım alanlarının yabani ot florası. Erzincan Univ J Sci Technol 9(2):148–171
Yarcı C, Serin M, Altay V (2007) The segetal vegetation of Kocaeli Province (Turkey). Ekoloji 16(63):23–33
Zarandia T (2008) Biological peculiarities of some corn hybrids and populations, Tbilisi, p 70
Zhukovskyi PM (1971) Cultural Crops and their Congeners, Leningrad

Chapter 15
Plant Diversity and General Vegetation of Georgia

Dali Nikolaishvili

15.1 Introduction

The vegetation cover changes permanently and is subject to vigorous transformations even now. This is associated with the climate change and anthropogenic factors, and it has become a key issue for different scientific studies. The scientists think that one of the most complex problems in ecology and biogeography is the correlation between the vegetation and the climate (Collinson 1988; Ozturk et al. 2012; Ozyıgıt et al. 2015; Sezer et al. 2015; Imanberdieva et al. 2018; Altay 2019; Altay et al. 2012a, b, 2020). The changes in the vegetation cover have influenced and are influencing its territorial distribution which is taking place more or less intensely globally. The climate change is affecting South Caucasus and Georgia too; there is a strong evidence of increased warming over the last century in these areas. The influence of climate change is visible in the transformation of some parameters, such as changes in the forest area and share of agricultural lands, degree of fragmentation of landscapes, and productivity of vegetation (Nikolaishvili et al. 2015). The vegetation cover in Georgia is diverse and full of contrasts as a result of the physical-geographical peculiarities as well as the course of paleographic history of the country. This is the reason why we find that many species have survived from the ancient geological past in the country. The country is rich in endemic species, and its diversity is changing due to interventions and introduction of nonnative species.

The Georgian forests and high-mountain meadows are an important natural resource with varying economic values. They play an important role for the economy of the country, in particular, in the development of such branches as tourism, forestry, cattle-breeding, etc. At the same time, together with the forest massifs these provide a special natural protection and natural restoration function. In view of this, a thorough assessment of the vegetation cover of Georgia is very important.

D. Nikolaishvili (✉)
Department of Geography, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
e-mail: dali.nikolaishvili@tsu.ge

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_15

15.2 History of Geological Development and Vegetation Cover of Georgia

Millions of years ago, many significant changes have taken place in the present-day Georgia, which were caused by planetary or local events. The relief, climatic conditions, and plant and animal species were altogether subjected to evolution, extinction, or transformation. Moreover, owing to the narrow Caucasian isthmus, plant and animal species typical only to Georgia appeared and developed in isolation. The modern relief of Caucasus started to develop in the Neogene period, as before that, some 30–40 million years ago, all of its territory was occupied by the sea (Maruashvili 1981). The only landmass was a small island that got elevated along the mountains of the Great Caucasus (Kavkasioni), with a low-mountainous relief (Gvozdetsky 1963). Starting from the end of the Paleogene and during the Neogene, large landmasses were formed in this area, and vegetation unusual for the present-day Georgia known as Poltavian flora appeared in the territory. Tropical and subtropical thermophytes were common in this type of vegetation represented by the palms (Palmae), eucalyptus (Myrtaceae), magnolias (Magnoliaceae), camphor tree, (Lauraceae), camellia, and several others. There were also other deciduous plants which got adapted to the moderate climate such as ash tree (*Alnus*), birch (*Betula subpubescens*), hornbeam, nut tree, elm (Ulmaceae), willow (*Salix*), and aspen (*Populus*) and some xerophilous plants (Maruashvili 1981; Panova et al. 1984; Avakova 1989).

The fossilized flora remnants of the old geological past have survived at many locations in Georgia: in the basin of the Khanistskali River (left tributary of the Rioni River), in the environs of Goderdzi Pass, in Borjomi region, and in some other localities. The location of fossilized flora in the environs of Goderdzi Pass located in the gorge of the River Dzindze (the right tributary of the Kvabliani) is very unusual. This flora is known as “Goderdzi flora” (Anonymous 2001a, b; Nikolaishvili et al. 2016). Millions of years ago, before humans’ appearance on Earth, the volcanic flow and ash buried a strong and dense tropical forest with diversified species below the lava flows. After a passage of suitable period, the territory got covered by soil and vegetation cover, while the remnants of Tertiary flora survived below the present-day pine (*Pinus*) and fir (*Abies*) forests as is clear from the tree trunks and branches fossilized in the ground. Some trees still stand vertical and have their annual growth circles preserved (Fig. 15.1).

At the end of the Neogene, the climatic conditions changed and the “Glaciation” started in the Pleistocene. The glaciers in East Georgia descended up to an altitude of 1100–1500 m asl (800–1000 m asl in Apkhazeti) and to 1800–2200 m above sea level in East Georgia, i.e., in the western part of the country, penetrating the forest zone quite deeply.

As the climate changed, the flora and fauna changed to a great extent with the climate change. The thermophilic plants and animals were replaced by psychrophilic taxa. The whole organic world got enriched with boreal-psychrophilic plants which penetrated the area from the Taigas of Eurasia and spread widely. These plants

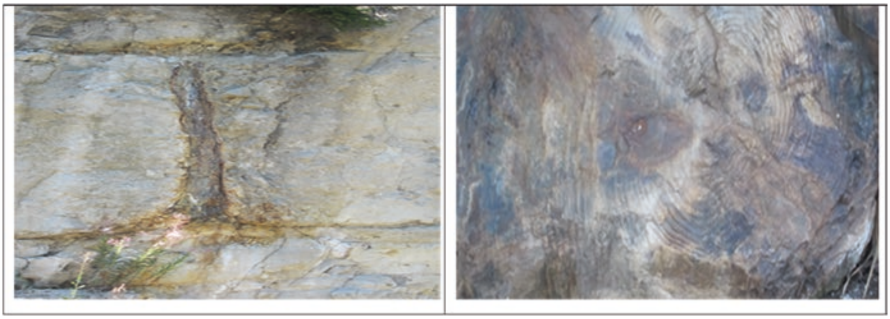


Fig. 15.1 Tertiary flora near Goderdzi Pass

spread most widely in the northwestern part of Georgia, Great Caucasus high-mountainous zones, and environs of lakes and marshes. The vegetation cover was also enriched by the Mediterranean (mostly in West Georgia) and southwest Asian (in the extreme southeastern part of Georgia) elements. In the mountains, mesophilous elements, such as spruce, fir, willow, cherry laurel, and ivy, spread more widely as compared to the current species. Thus, in the Pleistocene, the vegetation cover changed thoroughly. The tropical forests common in the Tertiary period became extinct almost totally and survived only in sheltered areas, so-called refugia. Inspite of all these changes in the vegetation cover, archaic elements of flora survived in the country and were more common in West Georgia, such as thuja, dawn redwood, hickory, tsuga, sweetgum, old species of cedar, oak and maple, and horse chestnut (*Aesculus hippocastanum*), together with a few other species.

15.3 Floristic Zoning

Many attempts made to provide floristic zoning in Georgia, but all similar to each other in floristic diversity and uniqueness. According to Gagnidze and Davitadze (2000), Georgia is a part of the ancient Trans-Mediterranean Floristic Kingdom, West Georgia is a part of the Trans-Mediterranean Zone, and East Georgia is a part of Trans-Caucasia-Southwest Asia-Turan zone, and these zones are divided into 7 provinces and 18 districts (okrugs) (Fig. 15.2).

Colchic or East Euxine Province (I) has the largest area, covering the whole territory of West Georgia. It is bordered by the Main Ridge of Great Caucasus from the north, by Shavsheti Ridge from the south, Likhi and Arsiani Ridges from the east, and by the Black Sea from the west. The borders of the province go beyond the territory of Georgia both in the north-west and south-west directions. A common feature of this province is the richness in Colchic relict and endemic species together with clear vertical zoning and widely spread limestone flora. There are about 2500 species recorded from this province (Gagnidze and Davitadze 2000), with 80% of them growing in Georgia. The vegetation cover found in the province includes many

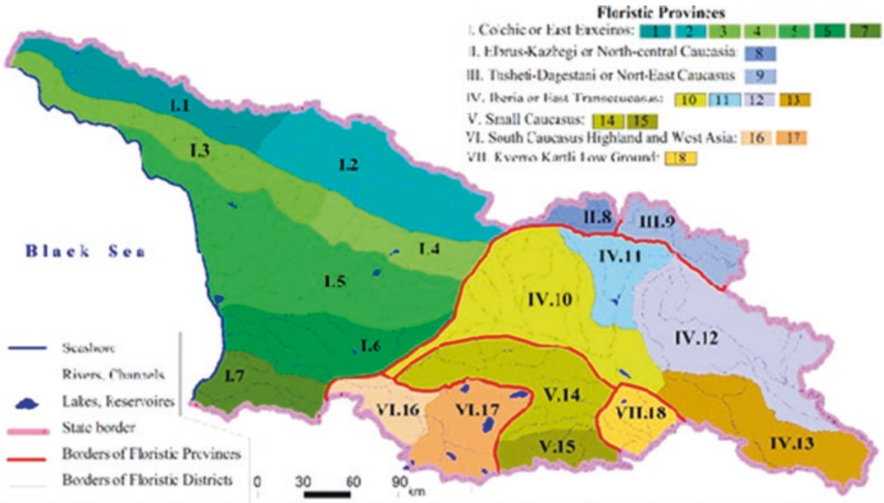


Fig. 15.2 Floristic division of Georgia. (Developed from Gagnidze and Davitadze 2000)

great Tertiary-relict (Colchic) thermo-mesophilous species, which spread in the adjoining areas as well, but are having restricted distribution and are less rich and diverse (Kvachakhidze 2010).

Elbrus-Kazbegi or North-Central and Tusheti-Dagestani or North-East Caucasia Provinces (II, III) cover the northern slope of Great Caucasus, with the southern slope running across the basins of the rivers Tergi, Asa, Argun, and Sulaki upper reaches. The province is located totally in a high-mountainous region and as a result is rich in high-mountainous flora. It is particularly rich in endemic species found among the vegetation of cliff-talus, subalpine, and alpine zones.

Iberia or East Transcaucasus Province (IV) is the second largest zone in Georgia, covering Shida Kartli-Alazani plains and adjacent piedmonts together with the mountain slopes, as well as Gombori Ridge. This zone has a clear vertical zoning, which is outstanding with the zoning typical to the Colchic or East Euxin Province. Here, Colchic elements have a limited propagation, while dark-coniferous forests are more widespread in the western part of the province. In the lowlands and the valleys, sparse arid forests are spread widely on its territory, while semi-desert plants are widely spread at certain locations. Particularly, xerophytic plants are widespread in the extreme south-east part of the province, within the limits of Iori Plateau and Eldari Lowland. Due to the circulation of dry air masses in the lowland zone, this impact is seen all over the adjacent mountain slopes as well. Consequently, the altitudinal zones are located higher here than in Colchic or East Euxin Province.

Small Caucasus Province (V) covers Trialeti and Loki Ridges, the mountain block of Shua Khrami, from the north and south, bordered by Shida and Kvemo Kartli Planes, by Loki Ridge from the south, and by Javakheti and Samsari Ridges, as well as Borjomi Gorges from the west. In orographic and landscape respects, the bordering location of such different elements has a great impact on the floral peculiarities in the peripheral areas. The peculiar feature of its central and eastern part in particular is the presence of semiarid and arid elements, while elements of Colchic flora are found more in its western part.

South Caucasus Highland and West Asia Province is located within the limits of West Georgia and covers Javakheti Plateau and its adjoining Javakheti, Samsari, and Erusheti Ridges and the southern part of Ajara-Imereti Ridge. The climate here is arid and as a result, xerophytic elements dominate over most of the territory here. In the western part, these elements are gradually replaced by the elements of humid flora as the absolute altitude increases. Mountain steppe vegetation dominates.

Kvemo Kartli Lowland Province covers the lowland area and adjacent mountain slopes, as well as Iagluja Plateau. The area is dominated by the steppe and phrygana plants. A small area of the Province is covered with natural vegetation, which is one of the least among the regions of East Georgia (Kvachakhidze 2009, 2010).

15.4 Factors Determining the Diversity of the Vegetation Cover

The diversity of the vegetation cover of Georgia and its distribution patterns are determined by a set of physicogeographical factors as well as history of paleographic development in the area. It is the periodic changes in climate in the past geological ages which determine the diversity and a number of peculiarities of the biological resources in this region. The vegetation of Georgia presents an extremely contrasting picture being at the crossroads of the geographical-genetic elements typical to Colchic, Mediterranean, Iranian-Turkish, and Northern Hemisphere flora. An important factor influencing the spatial distribution and diversity of the vegetation cover in Georgia is the absolute altitude. As the altitude increases, the type of the vegetation cover and its floristic composition change sharply. The vegetation cover features are as follow: many different types of vegetation cover exist in small areas, starting from marshes or steppes to phrygana or shibliak together with high-mountain alpine meadows and nival flora. At higher absolute altitudes, the air temperature falls, and the forest formations change into subalpine and then alpine meadows, followed by sub-nival vegetation. As for Javakheti Plateau, the altitudinal zoning is different there, and mostly desert, steppe, and alpine meadow-steppe vegetation grows.

A decisive role in the territorial distribution of vegetation cover is played by a thermo-humidity, which is determined by the presence/absence of orographic barriers. In Samtskhe-Javakheti region, the major role is played by the presence of barrier ridges (Main Great Caucasus Ridge, Likhi, Arsiani, and Javakheti Ridges), plateaus, and intermountain lowlands of Georgia, which restrict the movement of cold air masses. The above-listed ridges, owing to their orientation, block the humid air masses penetrating from the west. As a result, the areas with quite different humidifications are formed. There are both hydrophilous Colchic forests with evergreen bushes, lianas, and ferns and dry-resistant vegetation, phrygana, and semi-desert elements.

15.5 Vertical Zoning of the Vegetation Cover

The vegetation cover of Georgia is diverse, changing both in the vertical and horizontal directions. The difference between East and West Georgia is mainly the result of the difference between the atmospheric precipitations, while the difference at different absolute altitudes results from air temperature. The lowland of West Georgia receives more abundant precipitation than East Georgia. Consequently, the plants adapted to humid and extra-humid conditions are more widely spread here, whereas xerophytic plants grow over quite vast areas in East Georgia. The change of absolute altitude of a location determines the vertical zoning of the vegetation cover in Georgia, starting from humid Colchic subtropical forests and semi-desert arid vegetation and through the high-mountain alpine meadows and sub-nival vegetation (Fig. 15.3).

1. Plain and foothills-hill zone with swamp, alder forest, and sphagnum bogs and oak forest, somewhere with an evergreen understory (West Georgia), and semi-humid forest and dry shrubs, steppe, and open woodlands.
2. The low-mountain zone (600–1200 m) with hornbeam and beach forest.
3. The middle-mountain zone (800–1.500 m) is mainly arable lands. The natural vegetation survives as floodplain forests, oak-and-hornbeam forests, mountain bushes, and mountain steppes.
4. Upper-mountain zone (1.200–2.050 m) presents beech-and-coniferous mixed forests.
5. Subalpine zone (1.900–2.500 m) is with high-herbaceous plants of upper forest limit, bushes, and subalpine multidominant graminaceous herb meadows. This zone is diverse typologically.

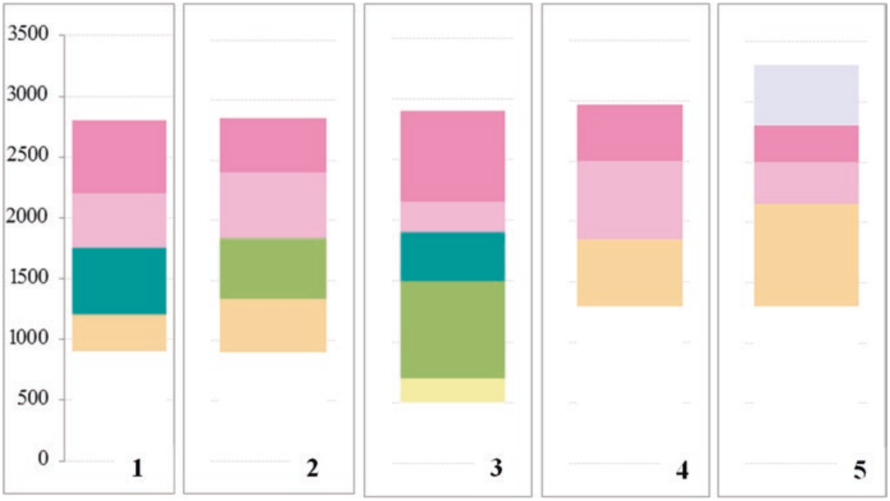


Fig. 15.3 Vertical structure of vegetation of Georgia
1: Trialeti Range; 2: Akhaltsikhe Depression; 3: Borjomi Gorge; 4: Erusheti Range; 5: Javakheti Plateau

6. Alpine zone (2.500–2.900 m): alpine meadows are mostly used as pastures. The vegetation here is not as rich as in the subalpine zone with its diversity of both biomass and typology.
7. Sub-nival zone (2.900–3.300 m) is present only on Abul Samsari Ridge.

Azonal vegetation grows only as wetlands rich in boreal species and fragments of desert halophilic and cliffy communities; xerophytes on cliffy locations include many endemic species.

Borjomi Gorge is one of the unique locations in Georgia in floristic respect, as the general structure of clear vertical zoning of the vegetation cover is different here as pointed out by other authors (Grossgame 1928). One of the factors determining this peculiarity is a greater influence of the slope exposition on the vegetation cover as compared to the hypsometric factor. Therefore, coniferous forests often grow up to 700 m asl (surroundings of Akhaldaba, Nedzvi Gorge, etc.), while hornbeam forests often reach up to an altitude of 1.650 m asl.

In the lower zone of the middle-mountain forests, within the altitudinal range of 700–1000 m, there are hornbeam forest-oak forests, oak forests, and hornbeam forests. The major forest species are Caucasian hornbeam (*Carpinus caucasica*) and Georgian oak (*Quercus iberica*). There are also such species like Oriental beech (*Fagus orientalis*), common ash tree (*Alnus barbata*), etc. Higher, in the average mountain zone, beech forests and spruce-and-fir forests dominate. Beech forests occupy particularly a large area in the gorges of rivers Baniskhevi (the left tributary of the Mtkvari River) and Nedzvistskali (the right tributary of the Mtkvari River). These forests have Colchic appearance and are distinguished by their abundant relict species. The great number of Colchic elements decreases to the east.

15.6 Landscape Diversity

Georgia is much diversified in biological and landscape respects. As a part of the Caucasus, it is on the list of Global Environmental Protection (Anonymous 2005); An Ecoregional conservation (Anonymous 2006) and Biodiversity of the Caucasus (Anonymous 2001a) together with 25 biologically richest and endangered "hot spots" of the world (CI, CEPF), 200 sensitive and vulnerable eco-regions of the world, locations of endemic bird habitats (BirdLife International), one of the world centers of agrodiversity and "hot spots" of large herbivores.

This list can be made longer when considering such factors as well-preserved diversity of species and ecosystems in the country; richness of Georgia in endemics, relict taxa, and medicinal and decorative plant species; forests occupying over 40% of the territory; and the natural environment of the country not subjected to major changes as in many other regions of the world. From an environmental viewpoint, Georgia looks like a much "cleaner" region in the world (Beruchashvili et al. 2002). It is one of the outstanding global countries as regards the landscape diversity as well as rich biodiversity. The country is ahead of many countries, with its diverse geographical conditions and natural landscapes, and recorded as "the world's landscape laboratory" (Beruchashvili 2000). Except savannas, deserts, and humid tropical forests, almost all landscapes found on the Earth exist in Georgia in miniature sizes.

With the landscape diversity ranks the 12th in the world, it falls back only to such countries as China, USA, Russia, Australia, Mexico, India, Canada, Brazil, Argentina, Turkey, and Chile. The territory of Georgia is 10 to 100–250 times less than the territories of these countries, but with the landscape diversity per unit area, this small country ranks the first in the world (Beruchashvili 2000). All over the world, the territories equal to the territory of Georgia contain approximately one type of landscape, while there are 22 landscape types, i.e., ten times more, in Georgia. This is the reason for naming the natural and diversified landscapes of Georgia as original and unique. It is an invaluable wealth and a treasure of national importance. The landscape diversity gets richer from planes toward the mountains, with a total number of types of vertical structures of the NTCs (natural-territorial complexes) and mountain landscapes exceeding twice the plane landscapes. In addition, an increase in the landscape diversity as the absolute altitude increases mostly occurs from planes to piedmont and low-mountain landscapes, and at higher altitudes, on the contrary, the landscape diversity decreases from the middle-mountains, and this is logical. However, in some cases, some landscapes show higher diversity than mountain landscapes. This is true not only with high-mountain subalpine, alpine, sub-nival, or nival landscapes but also with piedmonts and low-mountain landscapes. Therefore, not in every area does the landscape diversity increases together with the absolute altitudinal increase (Fig. 15.4). This is particularly true with some landscapes of West Georgia as a result of their distribution over vast areas and high degree of transformation.

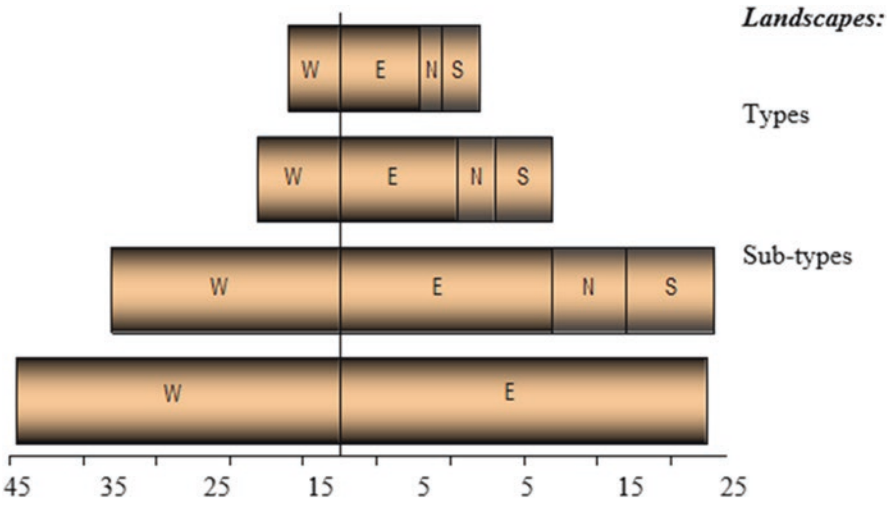


Fig. 15.4 Landscape diversity of Georgia according to the sea level
W West Georgia, *E* East Georgia, *N* North Georgia, *S* South Georgia

The comparison between the landscapes of East and West Georgia has made it clear that East Georgia is distinguished for its diversity of NTCs. Only arid and hydromorphic landscapes are an exception, which are much more homogenous. A high degree of diversity is common in the lowland landscapes of West Georgia, which are significantly transformed as a result of economic activities. Clearly, these landscapes will not be considered unique, as such high index is the result of the strong anthropogenic diversification of the area and not by natural diversity.

Among mountain landscapes, the most diversified are low-mountain forest landscapes with dominant oak forest and oak-and-hornbeam forests. This is the result of both natural and anthropogenic factors. First, the low-mountain landscapes are located between the piedmont and middle-mountain landscapes. Consequently, the NTCs typical to both are seen here. Second, the low-mountain forest landscapes are more transformed than the middle-mountain forest landscapes located at higher hypsometric altitudes. This is why the defragmentation of the low-mountain forest landscapes is stronger.

The highest diversity is observed in the low-mountain forest landscapes in Shida Kartli, which are stretched on the southern slope of the Great Caucasus and northern slope of the Small Caucasus. These landscapes are located between the semi-humid piedmont and middle-mountain moderately warm humid landscapes. The near location of the piedmont semi-humid landscapes results in the presence of semi-humid NTCs near its lower limits, while the near location of the middle-mountain forest landscapes results in the presence of humid NTCs at its upper limit.

The middle-mountain forest landscapes with dominant beech forests and dark-coniferous plants are much more homogenous. However, the difference between the landscape genera is seen even here. The greatest diversity is observed in the middle-mountain forest landscapes spread on the northern slope of the Small Caucasus. The least diversified landscapes are observed along Adjara-Guria section, with dominant beech forest ecosystems with Colchic sub-forest or hemihiles. A kind of exception from the above-described general picture of homogeneity is the middle- and middle-mountain landscapes of the Great Caucasus of Kakheti with dominant beech forests, which are relatively homogenous. This is due to the result that said landscapes are spread as a narrow strip and oroclimatic barriers are less seen here. An exposition difference between the territorial distributions of NTCs is less seen at the level of a study. More diversified are the upper-mountain forest landscapes of West Georgia. The reason must be investigated in the relatively uneven humidification of these landscapes because of the oroclimatic barriers. A certain part of the territories of these landscapes is under a direct impact of “rain shadows,” and the other part is under the direct impact of humid air masses. This is the reason why both humid and semi-humid vegetation covers are distributed over this territory.

15.7 Floristic Diversity

The periodic climate change and diversity of relief, climatic and edaphic conditions in the past geological periods, as well as the location on the borders of different floristic zones have resulted in floristic diversity and richness of Georgia. We have

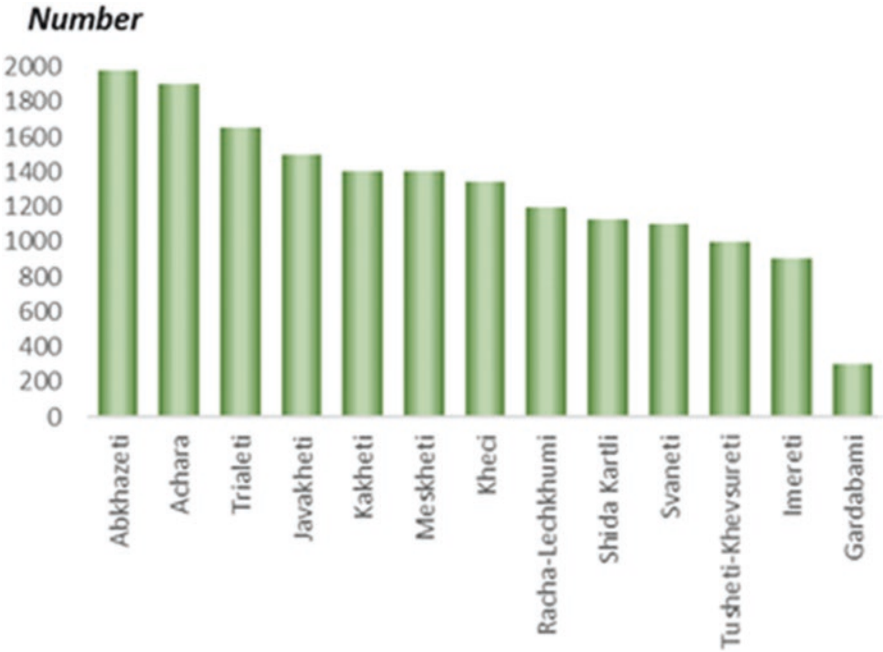


Fig. 15.5 Number of vascular plants

seen clearly the impact of various floristic zones: Colchic, pure Caucasian, and xerophytic zone of Asia Minor (Anatolia). The total number of vascular plants is approximately 4200, including over 300 species of trees and bushes (Gagnidze and Davitadze 2000), 260 species are endemic, while the flora of the Caucasus comprises 6.350 species of vascular plants, of which 1.600 species are endemics (Nakhutsrishvli 2013). The number of fungi and algae is also impressive (Figs. 15.5 and 15.6).

The vegetation cover is rich in relict species. One of the two refugia of the Tertiary flora on the territory of Caucasia is found in Georgia; one of these is the Kolkheti in particular (in relatively inaccessible and deep gorges). In the past, the flora of this area was spread over quite a large territory and formed a single area. The following ancient species have survived in Kolkheti: *Rhododendron* (*Rhododendron ponticum*), common chestnut (*Castanea sativa*), Bichvinta pine (*Pinus pithyusa*), cherry laurel (*Laurocerasus officinalis*), Pontine oak (*Quercus pontica*), Medvedev *Phillyrea* (*Phillyrea medwedewii*), willow (*Buxus colchica*), elm *Zelkova* (*Zelkova carpinifolia*), yew (*Taxus baccata*), Israeli ruscus (*Ruscus hypophyllum*), Chinese yam (*Dioscorea batatas*), and others. In addition to Kolkheti, the elements of the Tertiary flora have survived only as fragments in other regions of Georgia: Kakheti and Kartli. At the same time, the Great Caucasus of Kakheti is the only location in the world where the elements of Colchic and Hyrcanian flora grow together (Gagnidze and Davitadze 2000; Elizbarashvili et al. 2000).

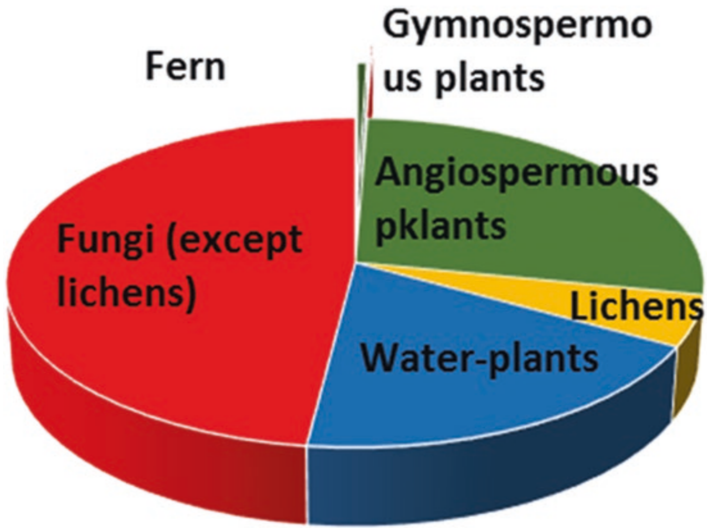


Fig. 15.6 Floristic diversity of Georgia

Not only individual species of relict flora survive in Georgia but also their ecosystems. They are preserved in Batsara, Lagodekhi, and Tusheti Reserves and in the gorges of rivers Kodori and Kintrishi. The yew forest, an ancient relict forest, has survived in Batsara Reserve and forms the only yew plantation in the world today. On the other hand, in the past geological epochs, together with sequoia, it grew over vast areas.

There are a great number of endemic plant taxa in Georgia (about 400), such as the following: seven oak species, water nut (*Trapa colchica*), lady's mantle (*Alchemilla* spp.), Abkhazian peony (*Paeonia abchasica*), Bichvinta pine (*Pinus pithyusa*), Eldari pine (*Pinus eldarica*), Colchic hawthorn (*Crataegus colchica*), Sosnovsky maple (*Acer sosnowsky*), common juniper (*Juniperus pygmaea*), willow-leaved pear (*Pyrus sachokiana*), willow (*Salix kazbekensis*), Megrelian birch (*Betula megrelica*), Georgian almond (*Amygdalus georgica*), Georgian elm (*Ulmus georgica*), giant fleabane (*Inula magnifica*), granny's bonnet (*Aquilegia gegica*), Colchic granny's bonnet (*A. colchica*), whitlow-grasses (*Draba mingrelica*, *D. ossetica*, *D. imeretika*, *D. meskhetica*), etc. These plant species are endemics not only in Georgia but also in Caucasus.

An important role in the vegetation cover of Georgia has been played by the species imported from abroad (introduced species). Particularly, the great number of such plants is found along the Black Sea coast, on piedmont and low mountains, and on areas of alpine pastures in high mountains. The areas with their least number are the middle-mountain forest areas, where complex orographic conditions restrict the introduction and spread of alien taxa. Some introduced species have become wild by now, e.g., oil tree, fig tree, garget, false acacia, etc. The introduced species do not always have a positive impact on the local nature. Often, together with the valuable cultures, some “accompanying” weeds have been introduced; as an example, we can cite subtropical graminaceous plant such as paspalum grass, which has occupied vast humid areas of sandy soils. Other widely spread plants are horseweed, *Datura*, ragwort, cocklebur, and a few other weeds. Some introduced plants have adapted to the new environment better and turned out to be stronger as compared to the local edifiers, e.g., silver wattle, which was first introduced in Sokhumi region and has spread widely to other areas after some years.

15.8 Principal Biomes

On the sea beaches and sandy-and-shingle bunds with altitudes of 4–10 m, vegetation “unusual” for Kolkheti is found: xerophilous xerophytic-psammophilous grasses. These form quite a uniform vegetation cover along the sandy coastline. These plants are spurge, eryngo, bindweed, mustard plant, sea daffodil, mayweed, catchfly, stachys, field poppy, etc. On the dunes away from the sea, outside the sea waves, hemi-xerophytic bushes grow: blackberry, Christ’s thorn, hawthorn, butcher’s-broom, barberry piperidge, medlar, etc. There are also advent and wild growing alien crops: ragwort, horseweed, acacia, *Gleditschia*, ailanthus, etc. These bushes are gradually replaced by oriental hornbeam forests with the following main plant species: traveller’s joy, silkvine, and cat briar.

In the areas following the strip of dunes, the dominants are water-and-marsh vegetation found on boggy soils but isolated from the sea. It is presented by grassy, grassy-bushy, and grassy-woody marshes. Such areas are mostly typical to the territories with a poor drainage and are present in the central and western parts of Kolkheti Lowland. The main plant species in the grassy marshes are deer grass, cattail, reed, *Sparganium*, buckwheat, pale persicaria, white bent, sedge, and rush. At the confluences of slow-flowing rivers and on the surfaces of some watercourses, we come across duckweeds, bladderwort, *Potamogeton* spp., *Nymphaea alba*, brandy bottle, etc. In the bays of Bebesiri forest, there are relict water nut, hibiscus, etc. The most widely spread are sedge-and-rush, reed-cattail, and grassy-sphagnum vegetation. The turf *Sphagnum* marshes do not form a strong single cover, as these are common for the northern marshes of Eurasia. Concomitant existence of boreal grasses and southern bushes is a common feature, making it unique. Besides, it is very much diversified and presents the relict and endemic species in great numbers.

Woody plants are also common for the grassy-and-bushy marshes: common ash tree, liber, arrowwood, buckthorn, etc. They occupied larger areas in the past, but at present, they survive as fragments only; however, they form a large single massif in Kolkheti.

On the area adjacent to the Black Sea, in the basins of the lower reaches of the rivers (within the limits of Kolkheti Lowland), there are marsh alder forests and also oak-and-hornbeam forests and hornbeam-beech forests growing at higher and dry locations, which are better drained. Alder forests mostly form pure populations. However, sometimes, they contain other species too. For example, we see Colchic oak, elm, box elder, European hornbeam, fig, red hawthorn, etc. As for the abundantly humidified, lowered areas, together with the alder forests, there are white willow, weeping willow, plain willow, abele, black poplar, mulberry, and liber as well. Introduced species, such as paspalum grass, Japanese stiltgrass, buckwheat, etc., frequently grow in the grass cover.

The forests formed with ash trees are dense and impenetrable. This is particularly true along the roadsides, riverbanks, and areas of cut-down trees. Such forests are mixed with lianas: catbriar, silkvine, hop, black bryony, traveller's joy, blackberry, and ipomoea. The density of the lianas decreases deeper in the forest. On the Black Sea coast, between the mouths of the rivers Kodori and Psou, in the environs of Bichvinta Cape, there is a plantation of Bichvinta pine of the same age (their average age is 110–120 years). It is a "dying" cenosis, with its spreading area decreasing gradually. This was much influenced by fires and the washout of the coastline with sea waves. In the prehistorical epoch, these forests must have spread at many places of West Georgia, but they have survived only at the given location today. However, some Bichvinta pine trees grow at some places. The plane-and-lowland forests of Kolkheti have been destroyed at many locations as a result of cultivation of the subtropical cultures. The vegetation cover of Kolkheti hilly zone is one of the richest in Georgia. In natural conditions, it is presented by polydominant Colchic forest: evergreen bushes and lianas. The main forest edifiers are Georgian oak (*Quercus iberica*), common chestnut (*Castanea sativa*), Caucasian hornbeam (*Carpinus Caucasica*), Oriental beech (*Fagus orientalis*), and common ash tree (*Alnus barbata*). The following species grow here as admixtures: plane (*Acer pseudoplatanus*), Norway maple (*A. platanoides*), common maple (*A. campestre*), Caucasian lime (*Tilia caucasica*), etc. There are yew (*Taxus baccata*) forests in some gorges.

Tertiary relict evergreen elements are many in number: *Rhododendron* (*R. ponticum*), cherry laurel (*Laurocerasus officinalis*), ilex (*Ilex colchica*), and Israeli ruscus (*Ruscus hypophyllum*). Together with these, we find deciduous bushes: Colchis bladdernut (*Staphylea colchica*), Turkish hazel (*Corylus colurna*), common nut tree (*C. avellana*), sumach (*Rhus coriaria*), etc. There are many lianas in the forest, which are widely spread along the forest edge: catbriar (*Smilax excelsa*), Colchis ivy (*Hedera colchica*), common ivy (*H. helix*), silkvine (*P. graeca*), black bryony (*Tamus communis*), traveller's joy (*C. vitalba*), blackberry (*R. lepidulus*, *R. anatolicus*, *R. discredendus*), etc. (Ketskhoveli 1959; Elizbarashvili et al. 2000). The hilly areas of Kolkheti have almost been totally destroyed, and their place is occupied by settled areas and plantations of subtropical cultures. Some forests have survived as fragments only over the steep slopes and deep inaccessible gorges.

The vegetation cover which has developed on the lowland of East Georgia is absolutely different. Semi-desert vegetation forms a very different type of Kolkheti water-and-marsh vegetation. In the extreme southeastern parts of East Georgia, on Iori Plateau, and within the borders of Eldari Valley in particular, we find semi-desert vegetation. It is poor with its floristic composition and xerophytic thorny grass plants which are common here. The most widely spread are *Atriplex cana* and wormwood semi-deserts, which alternate with semi-deserts with *Elytrigia repens* and solonchaks; ephemers and ephemeroids are also widely spread. The main vegetation species are wormwood (*Artemisia phyllostachys*, *A. fragrans*), pea shrub (*Salsola dendroides*), carani (*S. ericoides*), *Elytrigia repens*, *Salsola nodulosa*, salsola (*S. crassa*), wheatgrass (*Agropyron*), etc. (Ketskhoveli 1959; Elizbarashvili et al. 2000). There are fragments of solonetz desert at some locations. Due to the widespread grassy plants having nutritive value, the area where semi-deserts are spread is intensely used as winter pastures (mostly, for sheep). The ecology has been damaged much along the roadsides and near the settled areas. The areas of many rare species (*Tulipa eichleri*, *Iris iberica*) are decreasing in numbers, and the structure of vegetation cover has been destroyed. Irrigation systems and use of land for agriculture (to grow cotton grass, wheat, barley, corn, and vines and orchards) have changed the ecosystem significantly.

Valley plants are distributed on the lowland of East Georgia (Shida and Kvemo Kartli Lowland, Iori Plateau), from 300 to 700–800 m asl and even higher at some locations. They occupy large areas; however, no pure steppes exist (similar to those spread in the European part of Eurasia). The valley plants are dominated by drought- and frost-resistant perennial grasses. The main species here is the yellow bluestem (*Andropogon ischaemum*), which forms a yellow bluestem steppe. Other common species are feather grass (*Stipa lessingiana*), European feather grass (*S. pennata*), narrow-leafed campion (*S. stenophylla*), mountain fescue (*Festuca valesiaca*), and clasp (*Artemisia absinthium*). At some locations, instead of yellow bluestem steppes we come across clasp-feather-grass, *Festuca supina*-feather-grass, and *Elytrigia repens* steppes (Ketskhoveli 1959; Elizbarashvili et al. 2000). The original type of this vegetation has changed a lot, and it has been replaced by cultural crops and annual and perennial cropping and plantings (vineyards, orchards, wheat, corn, tobacco, watermelons, and vegetables). As a result of anthropogenic impact, the forest vegetation and bushes have got mixed with it.

Light arid forests are spread only in East Georgia, at an altitude of 400 to 1000–1400 m asl. They often replace other vegetation formations of East Transcaucasia. In the past, they occupied quite large areas, but today, they have been destroyed and survive at some locations of Iori Plateau as individual fragments only (e.g., on Shiraki Lowland, Vashlovani Reserve). They are characterized by xerophilous plants and quite drought-resistant grasses. *Pistacia mutica* and various kinds of junipers dominate, but other species also grow here. Their vegetation is represented by both hardwood and coniferous wood plants. The main plant edifiers are Mt. Atlas mastic tree (*Pistacia mutica*), foetid juniper (*Juniperus foetidissima*), and Turkestan juniper (*J. polycarpos*). Among them, Mt. Atlas mastic tree is a rare relict and forms the largest plantation in Georgia, on the territory of Vashlovani Reserve. The following species also grow in the light forests: Caucasian hackberry, bare hackberry, Georgian maple, willow-leaved pear, pomegranate, Georgian almond, fustic, etc. As the species with high-valued timber were cut down (*Pistacia mutica*, hackberry) and due to the near location of the agricultural plots and intense use of this ecosystem as winter pastures, the process of restoration is difficult, particularly with the Mt. Atlas mastic tree (Nakhutsrishvili 2000). The Christ's thorn and buckthorn have renewed better. As a result, the areas of Mt. Atlas mastic tree decrease. Grassy cover is well developed under the forest cover.

In the area of steppes and light forests, we find thornbushes with the following species: Georgian barberry (*Berberis iberica*), common barberry (*B. vulgaris*), spiraea (*Spiraea*), etc.

In the lowland zones and piedmonts of East Georgia; along the gorges of rivers Mtkvari, Iori, Alazani, and Ktsia; in the floodplains; and on the terraces, we see Tugai forests. The main forest-forming species here are floodplain oak (*Quercus longipes*), aspen or abele (*Populus hybrida*), black poplar (*P. nigra*), poplar (*P. gracilis*), common ash tree (*Alnus barbata*), box elder (*Fraxinus excelsior*), white willow (*Salix alba*), etc., which are trees with a height of 25–30 m with understory, lianas, and strong grassy cover, forming single grassy cover at some locations (Elizbarashvili et al. 2000; Nakhutsrishvili 2000). In the past, these forests grew along almost all big rivers, but at present, majority of these areas have been destroyed, and they survive as individual fragments only, all replaced by secondary meadows, bushes, and agricultural plots of field: cereals, orchards, and vineyards giving quite rich harvest.

The water-and-marsh vegetation also commonly grows along the banks of the mountain lakes and water reservoirs and at some locations in the cut-down forests. Horsetail thickets and cereals are widely spread here and elements of boreal flora survive in large numbers. In the environs of high-mountain lakes, at inaccessible locations, their original natural appearance has changed less.

Alazani Plain, as compared to other territories of East Georgia, is the most humid area, and this has had its impact on the vegetation cover. Historically, Alazani Plain forests were spread here, while today, we find secondary thornbushes, forest-steppe, meadow-steppe, or cultural vegetation. The forests on the right and left banks of the Alazani River are different, as the left bank of the river is more humid and the forests on it show more similarity to the vegetation of Kolkheti. As for the forests on the right bank of the river, there are more xerophytic elements here. In addition, the forest in this location has been almost totally cut with an exception of the area along the Alazani bank in Gurjaani region.

The main vegetation edifiers in Alazani Plain forests are floodplain oak (*Quercus longipes*), pedunculate oak (*Q. pedunculata*), common box elder (*Fraxinus excelsior*), sumach-leafed box elder (*F. coriariafolia*), floodplain aspen (*P. hybrida*), black poplar (*Populus nigra*), white abele (*P. alba*), and Caucasian liber (*Pterocarya pterocarpa*). Lianas grow in great numbers in the forest: silkvine (*Periploca graeca*), common traveller's joy (*Clematis vitalba*), Caucasian *Hedera* (*Hedera caucasigena*), Russian Ivy (*Hedera pastuchovii*), catbriar (*Smilax excelsa*), and Italian woodbine (*Lonicera caprifolium*) (Nikolishvili 2009).

On the piedmonts and low-mountain slopes in Georgia, up to 1300–1500 m altitude, at the sites where climate is warm and quite humid with long summer, and in the short and primary forests, we come across hornbeam forests, oak forests, and hornbeam forest-oak forests (Georgian oak, *Quercus iberica*, *Q. imeretina*, *Q. pontica*, *Q. hartwissiana*, and Caucasian hornbeam, *Carpinus caucasica*). Other common plant species are common maple (*Acer campestre*), willow-leaved pear

(*Pyrus* spp.), elm (*Ulmus elliptica*), and elm "Karagaj" (*U. foliacea*, *U. minor*). Wild fruits also grow in great numbers: wild pear, shamrock, cherry plum, cornel, nut tree, and dog rose. A large portion of these forests have been destroyed, and vegetation growing here has diminished derivates, in particular, European smoke tree (*Cotinus coggygria*), sumach (*Rhus coriaria*), Georgian barberry (*B. iberica*), common barberry (*B. vulgaris*), spiraea (*Spiraea*), etc. (Ketskhoveli 1959; Nikolishvili 2009). At some locations, the forest is substituted by cultural vegetation, and at some places, instead of forest, there are cultural plants.

In the middle-mountain forest zone, above 800–1000 m asl, we observe beech forests (Oriental beech – *Fagus orientalis*) – as monodominant forests. However, quite often, there are some other timber species mixed with these, such as hornbeam, oak, spruce, fir, spruce, etc. The presence of Colchic flora elements is also typical (this is particularly true in West Georgia). The beech forests commonly grow under much different ecological conditions mainly over the slopes with different inclinations and expositions. The beech forests grow together with *Rhododendron*, and their vegetation composition includes *Fagetum rhododendronosum*, cherry laurel (*Fagetum laurocerasosum*), ilex (*Fagetum ilexosum*), hedera (*Fagetum hederosum*), bilberries (*Fagetum vacciniosum*), and mayvliani (*Fagetum rubosum*) (Kvachakhidze 2009).

In West Georgia, beeches are mixed with dark-coniferous plants like Caucasian fir (*Abies nordmanniana*) and Oriental spruce (*Picea orientalis*). So, the beech-and-dark-coniferous forests are formed and spread as fragments in East Georgia. Hypsometrically, they are spread at altitudes of 1400–1900 m, or even higher, reaching down the least altitudes in Apkhazeti, while on the humid slopes of Ajara, they descend to an altitude of 100–800 m. The beech forest and beech-and-dark-coniferous forests commonly have an evergreen understory and lianas in rare cases. The dark-coniferous plants form both monodominant (spruce forests, fir forests) and bidominant or polydominant (spruce-and-fir forests, beech-and-fir forests, beech-and-spruce forests, beech-and-spruce-and-fir forests) forests. In terms of an optimal combination of moisture and warmth, the height of trees is 60–65 m and the diameter is 2 m, but such specimens are rare. Usually, the trees reach a height of 45–50 m at the age of 200–250 years. The dark-coniferous plants of South Caucasia are quite different from Eurasian Taiga; they do not include the species typical to Taiga, such as European larch, Siberian larch, Siberian pine, European fir, European spruce, or Siberian spruce.

The middle-mountain forests have preserved their original natural appearance as the best of all. These have got modified less than piedmont as low-mountain forests or high-mountain meadows, because of their complex orographic conditions. However, the areas of dark-coniferous plants have got quite reduced currently, and these are disintegrated at some locations (as a result of intense cut-down in recent years). With their areas of propagation, they fall back only the beech forests. The primary cause here is the anthropogenic factors; the fires in spruce forests, wind-fallen trees, and various diseases are less important. As a result, spruce forests rarely reach the age of 260 or 280 years. The self-restoration processes of the dark-coniferous forests are to some extent hampered by the presence of beech forests in them, as the dead beech cover is a kind of pressure for the young spruce and firs to germinate. As a result, the dark-coniferous plants are first changed by beech-and-dark-coniferous plants and then by beech forests.

The orographic conditions in the area of propagation of the high-mountain subalpine meadows are more favorable (due to the presence of flattened surfaces and smooth crests for resettlement). Historically, they have been exploited in the middle-mountain forest later, only after the low-mountain forest and high-mountain forest landscapes (the local population has been using the high-mountain meadows as hayfields and pastures since the ancient times). It is for these reasons that the middle-mountain forests have preserved their original appearance best of all.

The mountain beech forests in the upper part of the middle mountains form quite large areas. They are mostly spread in the basin of the Mtkvari River (Borjomi Gorge, Tusheti Basin, Javakheti Plateau), as well as in Svaneti Basin. These forests are most common in the well-lit steep and sometimes cliffy slopes of a southern exposition in the upper-mountain zone, up to 2000 m asl and sometimes, even higher, forming sparse forests with little cohesiveness (0.3–0.5), but sometimes a strong cover. They possess a bulk of grassy, meadow, and sometimes valley plants: geranium (*Geranium silvaticum*), European goldenrod (*Solidago virgaurea*), hawkweed (*Hieracium pannoniciforme*), fern (*Asplenium pseudolanceolatum*), Caucasian bearberries (*Arctostaphylos caucasicus*), mountain fescue, fescue (*Festuca sulcata*), narrow-leafed campion (*Silene stenophylla*), sedge (*Carex buschiorum*), wood bluegrass (*Poa nemoralis*), false-brome grass (*Brachypodium sylvaticum*), etc. (Ketskhoveli 1959; Nikolishvili 2009; Shetekauri 2017). Due to centuries-long irregular cutting and intense use of subalpine zone as pastures, the mountain pine forests are sparse now, their areas have got reduced, and the upper limit of the forest has decreased.

In the high-mountain subalpine zone, between 1800–1900 m and 2350–2650 m, crooked forests dominate, characterized by high biodiversity and endemism, particularly rich in endemics and relict species in West Georgia. The main plant edifiers of the crooked forests are Oriental beech (*Fagus orientalis*), white birch (*Betula litwinowii*), high-mountain bast basket (*Acer trautvetteri*), and Pontine oak (*Quercus pontica*). Typical bushy plants are cherry laurel (*Laurocerasus officinalis*), common nut tree (*Corylus avellana*), *Rhododendron caucasicum*, bilberries (*Vaccinium myrtillus*), etc. (Shetekauri 2017). The crooked beech forests of birch too are widespread, which grow at quite high locations over the humid slopes and descend to 1200 m asl in the gorges. Pontine oak crooked forests are rare, usually typical in West Georgia, descending to 1600–2200 m asl, over the steep surfaces of the slopes and in the deep gorges. The height of trees in the crooked forests is 6–7 m at some locations. However, as the absolute altitude increases, the height of trees reduces and the length of the tree trunks is pressed to the ground surface up to 1.5–2 m only. On the lit slopes of the beech crooked forests, birch and maple are the common species, while *Rhododendron caucasicum* commonly grows over the shaded slopes. The latter is mostly common in the glacier circles and on the slopes of northern exposition with durable snow cover. At some locations due to strong humidification, *R. caucasicum* grows over the slopes of a southern exposition as well. At some places, *R. caucasicum* is quite common. Such places are called "Dekiani," and sometimes, they reach the upper limit of the alpine zone or descend to the upper limit of the pine-and-spruce forests. *R. caucasicum* forms a dense cover on the land surface. Its associates are mostly sciophytes, such as bilberries (*Vaccinium myrtillus*), red bilberries (*V. vitis-idaea*), bearberry (*Arctostaphylos uva-ursi*), high-mountain rhododendron, shinleaf (*Pyrola elliptica*), wood sorrel (*Oxalis acetosella*), etc. (Nikolishvili 2009; Shetekauri 2017). A great part of the crooked forests has changed mostly due to grazing and cutting down the forest.

The subalpine zone is characterized by a tall herbaceous cover, so-called mammoth flora, which is most common in humid gorges and slopes of a northern exposition. It is spread on the meadows found between the crooked forests and forms quite tall (2–2.5 m and more) and diversified grass cover of the following species: cow parsnip, Tatarian cephalaria, aconite, garden heliotrope, giant fleabane, larkspur, milky bellflower or *Pyrethrum*, etc. Most of these species are modified and they have hardly survived in their original form. As the optimal environment for subalpine tall herbaceous cover, within abundant atmospheric precipitations and high moisture level, the taxonomic diversity of eastern Caucasioni falls much back the Western part of the Central Caucasioni (Racha-Lechkhumi and Svaneti areas) in this respect. It is true that the tall herbaceous cover does not show great diversity, but it has high degree of endemism (Shetekauri 2017). In the subalpine zone, gramineous herb meadows are wide spread under natural conditions, where the height of the grass reaches to 60–80 cm. These grasses are reed grass (*Calamagrostis arundinacea*), globeflower (*Trollius patulus*), silverweed (*Potentilla anserina*), tormentil (*P. erecta*), common hedgenettle (*Betonica grandiflora*), anemone (*Anemone fasciculata*), geranium (*Geranium renardii*, *G. gymnocaulon*), Colchic granny's bonnet (*Aquilegia colchica*), false brome grass (*Brachypodium rupestre*), etc. (Nakhutsrishvili 2000; Shetekauri 2017).

High-mountain alpine meadows and mountains lie at 2300–3000 m asl, descending to lower altitudes (1800 m) on the glades and forming secondary meadows, which grow as fragments over the vast areas even in the mountain forest zone as well – in the high sub-nival mountain zone (Nakhutsrishvili 1988). Mostly low herbaceous cover is spread here (reaching a height of 20–30 cm under natural conditions). The real meadows are formed by graminaceous herbs and *Carex* bushes. The formation of strong turf-forming grasses (*Nardus stricta (syn.: N. glabriculmis)*, variegated *fescue*, *Kobresia humilis*, *Carex meinshauseniana*) is typical for such localities. Herbaceous meadows are rare and timber plants do not grow at all. As for bushes (mostly *Rhododendron caucasicum*, bilberries), these too are rare and grow as dwarf plants. These areas are characterized by rich biodiversity; the alpine meadows in the upper part of the alpine zone are spread as individual fragments and they are much degraded.

The altitudinal range of the bushes of *Rhododendron caucasicum* on the Caucasus coincides with high-mountain meadows and is 1800–2800 m asl. However, quite often it reaches up to 3000–3100 m. This is a feature typical both to Central and to Eastern Caucasus (Shetekauri 1999). The alpine meadows occupy larger areas and they are represented by low herbaceous cover. However, as a result of intense grazing, they have not been preserved in their original form and are classified as pure meadows and carpets. The real meadows are formed with graminaceous herbs and *Carex* bushes, while carpets are formed with herb vegetation (no graminaceous herbs, *Carex* bushes, and legumes). Alpine carpet is typical with vivid-colored flowering herbs: red chamomile, bellflower, gentian, etc., while feather grass, fescue, etc. are more common in pure meadows.

The main plant edifiers are *Bromus variegatus*, flat-leaved bent grass (*A. planifolia*), Lazi bent grass (*A. lazica*), and *Deschampsia* (*Deschampsia cespitosa*, *D. flexuosa*) and also *Festuca supina*, *F. woronowii*, and *Hordeum violaceum.* These plants grow at quite high altitudes. For instance, in the Eastern Caucasus, Pshav-Khevsureti, and Tusheti, they cover an altitudinal range of 1800 (1900)–2400 (2500) m asl and occupy the primary and secondary subalpine meadows (Shetekauri 2017). There are no permanent settlements in the areas of alpine meadows, but they have been significantly modified due to their intense use as pastures and hay meadows. As a result, they are poorly preserved in their original appearance. Secondary meadows are formed at many locations with water speedwell, wood bluegrass, horse gowan, and plantain plants playing a significant role.

Mountain steppes are most common in South Georgia, spreading on Javakheti volcanic plateau. These are mostly presented by graminaceous herb steppes. The main edifiers are sheep's fescue grass (*Festuca ovina*), fescue (*F. sulcata*), narrow-leafed campion (*Silene stenophylla*), yellow bluestem (*Bothriochloa ischaemum*), dropwort (*Filipendula vulgaris*), sickleweed (*Falcaria vulgaris*), bedstraw (*Galium criciatum*), timothy grass (*Phleum phleoides*), Caucasian thyme (*Thymus caucasicus*), etc. There are also secondary meadows formed on the sites of former forests. Over the primitive soils of cliffs and rock fills in the alpine zone, we come across the following species: bearberry (*Arctostaphylos uva-ursi*), mountain avens (*Dryas octopetala*), saxifrage (*Saxifraga colchica*, *S. juniperifolia*), together with the species of whitlow-grasses (*Draba*), silverweed (*Potentilla*), aster (*Aster*), clover (*Trifolium*), baby's breath (*Gypsophila*), chamomile (*Pyrethrum*), fescue (*Festuca*), astragalus (*Astragalus*), violet (*Viola*), and others. Although the given biomes (Lithophiles) are azonal in nature, they are common in almost all zones. However, they still show a particular diversity in high mountains (Gegechkori 2008). Lithophiles have high degree of endemism, 54% of the Lithophiles of the Central Caucasus are endemics (Gagnidze and Davitadze 2000).

Over the Great-Small Caucasus and in the mountainous regions of South Georgia, starting from 3000 to 3500 m asl altitude to the eternal snow line, we find the vegetation of sub-nival zone, which is sparse and most common with a cover of 30–40% and 10–20% at some places. The most important role in the vegetation cover is played by spore-bearing plants: mosses and lichens; however, quite often, alpine and subalpine plants also invade this zone: foxtail (*Alopecurus glacialis*), larkspur (*Delphinium caucasicum*), and a few others. The area is distinguished with high endemism, only slightly disturbed by humans, and mostly absolutely intact.

Xerophytic mountain bushes and arid vegetation are particularly widespread in South Georgia, at 900–2.200 m asl., mostly spread in the Mtkvari River gorge and over Tetrob-Chobareti limestone plateau, in Javakheti, as phryganoid, tragacanth, shibliak, and semi-desert communities. The tragacanth species include the following edifiers: Christ's thorn, *Paliurus spina-christi*; buckthorn, *Rhamnus pallasii*; European smoke tree, *Cotinus coggygria*; barberry, *Berberis vulgaris*; goats wheat, *Atraphaxis caucasica*; cotoneaster, *Cotoneaster integerrimus*; silver hawthorn, *Crataegus orientalis*; snowy mespilus, *Amelanchier ovalis*; honeysuckle, *Lonicera iberica*; etc. There are differences between the community types of middle- and upper-mountain zones. The former has 199 species of vascular plants, spreading along the Mtkvari River (900–1.300 m) and in the gorges of the rivers Otskhe, Potskhovi, Kvabliani, and Tsinubnistskali. The tragacanth vegetation invades the pine forest near village Damala. This type of vegetation is presented by rare species of locoweed, *Astragalus arguricus* and *A. raddeanus*; esparcet, *Onobrychis sosnowskyi*; vetch, *Vicia akhmacanica*; sage, *Salvia compar*; skullcap, *Scutellaria sosnovskyi*; *Psephellus meskheticus*, etc. At some locations, the tragacanth species invade the oak forest, and the following plants are distributed here: clove, *Dianthus calocephalus*; catchfly, *Silene brotherana*; wallflower, *Erysimum caucasicum*; Oriental crown vetch, *Coronilla orientalis*; thyme, *Satureja spicigera*; forest thyme, *S. laxiflora*; felty germander, *Teucrium polium*, *T. nuchens*, and *T. orientalis*, mountain ironwort, *Sideritis comosa*; rush flower, *Bupleurum exaltatum*; narrow-leaved bindweed, *Convolvulus lineatus*; Caucasian bellflower, *Campanula hohenackeri*; etc. (Ketskhoveli 1959; Gagnidze and Davitadze 2000). Mountain xerophytes have survived as natural plants mostly over the cliffy slopes, which are not good for agricultural practices.

15.9 Forests

The forests occupy the largest area in Georgia (2.767300 ha), making almost 40% of the total territory of the country growing both on the plains and in the mountains and distributed from the sea level (0 m) in West Georgia up to 600–700 m to 1900–2000 m asl in East Georgia (Kvachakhidze 2009; Nakhutsrishvili 2000).

The forest area percentage exceeds the average percentage of forests in the world by 30% and is above several countries of the world, such as France, Germany, the UK, Italy, Switzerland, Poland, the USA, Canada, and a few others (Gigauri 2000; Babunashvili 2003). Georgia ranks first in forests among the South Caucasian countries exceeding their indices twice or more. In the Northern Caucasus, they occupy larger areas (2.8 million ha), but as percentage of forest area, it is three times below Georgia. The total area of forests in Georgia as 2.7 million ha looks quite poor on the global scale. Only 0.3% of the European forests (930.7 million ha) grow in Georgia. Yes, the forest area in Georgia falls much below Latin Americas, the USA, Canada, Russia, etc., but it is ahead of Belgium, Bosnia-Herzegovina, the Czech Republic, Estonia, Hungary, Ireland, Latvia, Lithuania, Moldova, Portugal, Switzerland, the UK, and Yugoslavia, ranking 24th in Europe and 72nd in the world (Anonymous 2000–2001; Beruchashvili et al. 2002). The forest area per capita is also high in Georgia (1.56 ha), while the average world index is only 0.8 ha. With this indicator, Georgia is ahead of average European and Asian index (0.2–0.3 ha), but falls below the index from Latin Americas (2.2 ha).

On the global level, Georgia looks quite solid with its forest coefficiency. However, as for the bark use, it cannot be considered rich in forest resources due to the fact that most of the forests in Georgia grow on slopes with their primary functions as recreation and sanitary-hygienic or environmental protection rather than economic. In the 1950s, N. Ketskhoveli has noted that "as regards the immediate forest uses, Georgia can be considered as a country having no forests" (Ketskhoveli 1959). In addition, the forest resources are distributed very unevenly in different regions of the country (Fig. 15.1). There are hardly any forests in Javakheti, Tsalka, and Dedoplistskaro regions, whereas the average forest cover of some regions of Georgia (Keda, Gagra) is over 70%. The most widely distributed are the hardwood forests, while coniferous forests, with some exceptions, grow only in the mountains. These are dominated by Oriental beech, Caucasian fir, Georgian oak, and Oriental spruce, each species occupying over 5% of the total area of the county (Fig. 15.7).

Other major forests are on the lowlands of Georgia which are of a mixed floristic composition depending on the given physicogeographical environment of the area. In the mountains, the forest vegetation occupies larger areas (95% of the total territory of Georgia) (Kvachakhidze 2009). The low mountains are covered with hardwood forests, where the principal forest-forming species are oak and hornbeam and Oriental hornbeam, chestnut, lime, ash tree, etc. at some locations. In the middle mountains, beech forests and dark-coniferous plants dominate. At some places, there are pure plantations of yew forests in the upper reaches of the Alazani River basin and in the environs of Batsara Reserve, elm *Zelkova* forest near village Babaneuri (Akhmeta region), willow forest (near Kvareli), cherry laurel forest in the gorge of the river Didkhevi, and few other localities.

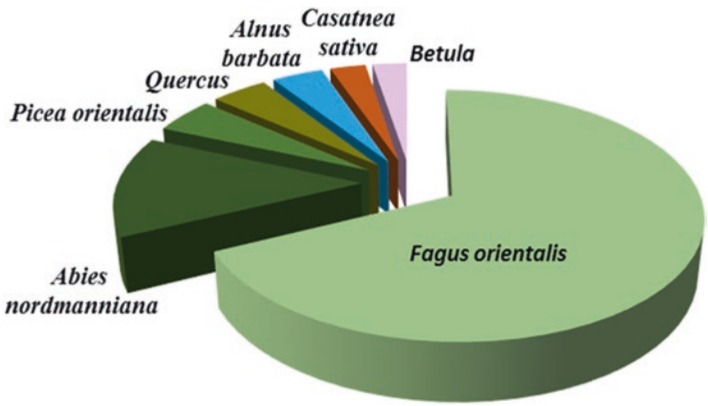


Fig. 15.7 The tree edificators of Georgia

15.10 Anthropogenic Changes of the Forest Cover

In the past, the forests occupied larger areas. This is evidenced by a number of historical documents and epigraphic monuments depicting that the country was rich in forests, game animals, and birds but was currently occupied by sparse forests, meadows and steppes, bushes, and settled areas. Ancient Greek scholars Herodotus, Hippocrates, Xenophon, and Strabo name Kolkheti Lowland as the area surrounded by valuable species (Targamadze and Chilhradze 1976). "The Great Register of Gurjistan Governorate" names 69 villages of Javakheti as the ones surrounded with forests in the sixteenth century, but these forests have got destroyed lately (Kadjaia 1999). For example, in Javakheti, the environs of villages of Akhalkalaki region, Bezhano, Azavreti, Alatubani, Lomaturtskhi, Didi Samsara, Patara Samsara, Bughasheni, and Balkho, were covered with forests in the past (Targamadze and Chilhradze 1976). Historical documents show that the edges of Tabatskuri were covered with dense pine and spruce forests. Vakhushti Bagrationi has noted that the environs of the lake were covered with "spruce forest" and "forest" generally. However, this does not mean that the whole territory of Javakheti was covered with forest (Vakhushti Bagrationi calls it no forest land), but one thing is true that the forests on this territory occupied larger areas in the past.

Large areas of forests have been destroyed in the environs of the lowlands and piedmonts of Georgia. These have been replaced by the settled areas or agricultural cultivations. For example, the palynological studies reveal that forests grew over large areas in Kolkheti Lowland (Kvavadze 1974). One of the best examples of forest destruction within the plains of Georgia is the forest massifs destroyed in the environs of Tbilisi, replaced later mostly by after-forest bushes and grass cover; therefore, we see dry steppes and even thorny shrubs in such areas, while the majority of the territory is occupied by agricultural plots (Bondirev et al. 2008). Owing to the anthropogenic impacts, the qualitative composition and productivity of Georgian forests have declined drastically. However, this process is not homogenous; some intact forests have survived but have been degraded, as a result the forest functions (water regulation, soil protection, recreation) have got reduced.

This is particularly true with the Black Sea coastline, plains and lowlands, and piedmonts. As a result of overexploitation, many oak, willow, chestnut, and beech plantations have been destroyed. Some species of trees and plants have survived only at hardly accessible locations, on the mountain slopes, in the protected areas, etc. The plants less typical to this region had spread on the cuttings. A cut forest usually changes and turns into xerophytic bushes or meadows, such as barberry, firethorn, Oriental hornbeam, European hornbeam, etc. Such plants grow not only in East but also in West Georgia, giving a peculiar appearance to the humid subtropical landscape.

The species in a forest massif restored on the cuttings differ from the original species. In particular, over the cuttings of the beech forest, mixed formations of less valuable hornbeam or other hardwood trees develop, while in the worst case, the forest perishes altogether and is substituted by bushy or grassy plants. Similar

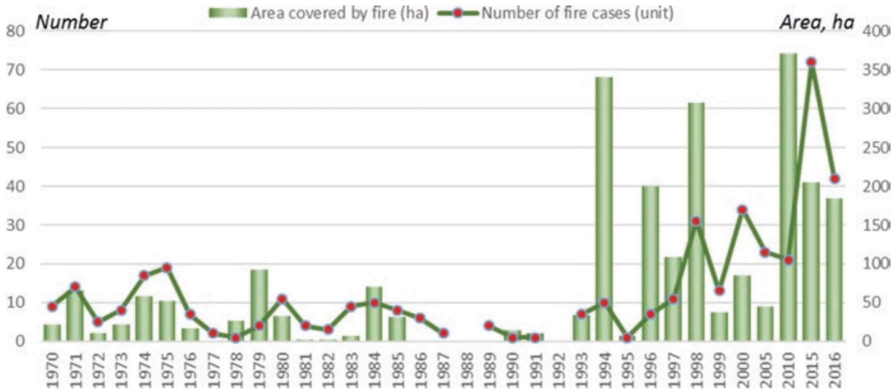


Fig. 15.8 Forest fires during 1970–2016

processes occur in the wet areas or in intense grazed areas. Many newly inhabited plants are less demanding to soil and propagate intensely. An example is grassy weeds, which suppress other grasses and form strong turfs and monodominant cover. These weeds start spreading over the fallow lands or in the polluted areas and then propagate to the agricultural plots. A negative human impact on the vegetation cover is evidenced not only by the changing composition of flora, but at some locations, the soil and vegetation cover have been completely destroyed showing a bare ground surface. Such sites are found in many regions of the country.

The natural or artificial fires produce a great damage to the forests. Large-scale forest fires are not as common in Georgia as in Siberia, Far East, Africa, or tropical countries of Latin America; but in recent years, there is a clear evidence of increasing fires in the country. The forest fires were particularly frequent before the 1970s, but in the 1980s, the number of fires and area of burned sites got reduced to a certain extent (Fig. 15.8), mainly due to the better equipment of the fire stations. We observe increasing forest fires again from the 1990s; since 1993 significant forest massifs have got destroyed. Particularly alarming is the statistics since 2000. The problematic areas have not only suffered from reduction in forest cover, but also fprest productivity ans specific weight of valuable timber trees has gone down. The forests are full of migrated animals and more active catastrophic events are expected.

15.11 Vegetation Cover on the Limestone Substrate

The vegetation cover is greatly affected by the limestone habitat and here we find calciphilous species growing. It is typical for the western part of Great Caucasus and its piedmont. The humid and warm climate of this area, quite complex karst relief (karst funnels, limestone pavements, karst depressions), carbonate rocks, and the chemical composition of the soil covering them result in a rich and diverse vegetation cover here. The number of endemics is quite high on karst substrate, in particular in the high-mountainous regions. This can be explained by the fact that the subalps are an old refugium, where the species are absolutely different than their genesis and age (*Rhododendron caucasicum*, juniper, willow), which have found a shelter. Considering the altitudinal spectrum of the vegetation cover of Georgia, we find that the impact of karst substrate is relatively small in the middle-mountain zone but quite high in the lower part of the mountain forests and on high-mountain meadows. The reason being that whereever the vegetation cover is in direct contact with the bedrock, the impact of carbonate rocks is high and it controls the nature of the vegetation. Consequently, in high-mountain landscapes with weak thermal conditions and slight chemical weathering where no clay alluvial layer is formed, the soil is formed on the carbonate immediately (Nikolishvili 2009).

In the piedmont and low-mountain zone, anthropogenic factor plays a decisive role; as a result, a number of dry hollows are formed, soil is washed down, and karst landscapes lacking soil or vegetation cover develop. From a floristic view, high-mountain limestone and non-limestone areas are much different from each other. Limestone areas show greater endemism, but the specific impact of West Asian elements is low. However, they show certain similarities as they contain elements of the Mediterranean-Jurassic flora. The following endemics can be seen on the limestone substrate of high mountains: sedge (*Carex pontica*), buttercup (*Ranunculus helenae*), and a few others. The vegetation cover on the limestone substrate in the middle-mountain forest zone is even more homogenous and poor. Almost everywhere in the area, beech dominates (with chestnut and dark-coniferous plants mixed at some locations); willow and *Rhododendron* spread widely and other species are rare. The plants typical to limestone substrate grow in a few numbers, such as Oriental hornbeam, willow, and yew. The upper forest limit in the karst areas is found at different altitudes but is artificially divided almost everywhere. The dominant species near this limit are park forests (beech, fir, spruce, high-mountain maple), with alternating bushes and tall herbaceous meadows. The anthropogenic transformation of the vegetation cover of the limestone substrate is not homogenous. In this respect, the greatest impact has been inflicted by irregular cutting of trees and grazing resulting in the total destruction of the forest in most cases. Particularly, a grave situation is observed in the area with subalpine forests and meadows, which have an anti-avalanche function. Similarly, serious changes are seen with high-mountain pastures as evidenced by the quantitative reduction of plants with nutritive value. Therefore, in order to protect the rare and endangered plants, certain types of reserves need to be made, and it is necessary to create and incorporate the vegetation cover of the limestone massifs.

15.12 Phyto-resources of the Vegetation Cover

The vegetation cover in Georgia has different phyto-resources. The maximum amount of phytomass (over 500 t/ha) is typical in the middle-mountain beech-and-dark-coniferous forests. They are followed by middle-mountain forest landscapes with dominant beech forests (300–500 t/ha), and the low-mountain Colchic landscapes rank the third (with 250–300 t/ha of phytomass) (Tediashvili 1984, 1987; Nikolishvili 2009). The minimum amount of phytomass is typical for the high-mountain sub-nival and nival, as well as semi-desert landscapes in East Georgia, with a phytomass of up to 1–2 t/ha and less. Great amounts of phytomass in the mountain forest landscapes (200–300 t/ha and more) are usually common for the vegetation cover with the annual amount of atmospheric precipitations over 750–800 mm (Nikolishvili 2009).

Such phytomasses are found in the forests of Kolkheti and Kakheti Great Caucasus. The average amount of phytomass is relatively lower where the annual amount of atmospheric precipitations is close to the lowest optimum, i.e., around 700 mm. Mountain oak and oak-and-hornbeam forests in East Georgia are such areas. The average amount of phytomass in East Georgia is 175–200 t/h, it is 300 t/ha in the middle-mountain beech forests and 80–90 t/ha in the upper-mountain beech-and-birch forest, but it is 260, 360, and 100 t/ha in West Georgia, respectively (Table 15.1).

Another important fact is that great amounts of phytomass are fixed in the areas where maximum amount of atmospheric precipitations (500–600 mm) falls during the vegetation period (from May through November). This is why the mountain forest landscapes of West Georgia have greater amounts of phytomass than East Georgia. The only exception is the landscapes of Kakheti Great Caucasus. The low-mountain forests, which have largely changed, possess different phyto-resources. At locations with strong anthropogenic effects, the amount of phytomass may be as low as 50–100 t/ha but is 600 t/ha in intact areas. Quantitative increase is recorded in the phytomasses as the absolute height increases, but this is minor. It is natural because the (relative) altitudinal range of the phytomass distribution is not so very big and is 150–250 m on average, rarely 300–500 m.

However, they still show certain peculiarities. High amount of phytomass in the low-mountain forests of West Georgia is typical at 600–750 m. Such high-productive forests show limited distribution in these landscapes and are found only in inaccessible areas, or in areas with minor anthropogenic transformation. In the low-mountain forests of East Georgia, no correlation between the absolute height and the amount of phytomass has been found. The change in the amount of phytomass depends on the absolute height as is relatively evident in the middle-mountain beech-and-dark-coniferous forests. The relationship between the absolute height and the amount of phytomass is directly proportional. They have much more altitudinal range than the low-mountains, making on average 400–500 m and often more. Besides, most of these are spread in West Georgia at altitudes of 1000 (1500)–1800 (2000) m asl and receive almost equal and strong humidification during the year. It is logical that the great amount of phytomass is typical to the full altitudinal spectrum here. However, forests with a phytomass of over 350–400 t/ha grow at higher hypsometric steps, over 1200–1400 m asl. As for the maximum amounts of phytomass (over 500 t/ha), these are usually typical to the upper limit of the said forests. The reason being it is at the high hypsometric steps where these forests have better preserved their original natural status. An absolutely different

Table 15.1 Average phytomass on the basis of landscapes of Georgia

Vegetation	Annual precipitation (mm)	Average amount of phytomass (t/ha)
Western Georgian plain and foothills	800–3000	140
Eastern Georgian plain and foothills	300–800	25
Eastern Georgian low-mountain with shibliak, dry shrublands (frigan), and steppes	400–650	50
Western Georgian low-mountain forest (with prevalence of oak and thorny forest)	1000–3000	190
Eastern Georgian low-mountain forest (with prevalence of oak and thorny forest)	800–1400	165
Western Georgian middle-mountain forest (with prevalence of beech forest)	1000–2300	400
Eastern Georgian middle-mountain forest (with prevalence of beech)	750–1000	300
Western Georgian middle-mountain forest (with prevalence of beech-coniferous forest)	900–2500	400
Eastern Georgian middle-mountain forest (with prevalence of coniferous forest)	700–1400	300
Western Georgian upper-mountain forest (with prevalence of pine, oak, beech)	1200–1500	100
Eastern Georgian upper-mountain forest (with prevalence of pine, oak, beech)	700–1200	120
Middle-mountain and mountain depression with meadow-steppes, shibliak, dry shrublands (frigan)	400–650	20
High-mountain steppes	500–700	15
Western Georgian high-mountain subalpine	1000–1600	20
Eastern Georgian high-mountain subalpine	600–1400	20
Western Georgian high-mountain alpine	1000–1600	5
Eastern Georgian high-mountain alpine	1000–1400	5
High-mountain sub-nival and nival	1200–3000	1–2

relationship between the amount of phytomass and the absolute height is seen with the upper-mountain forests. This relationship is inversely proportional, i.e., the amount of phytomass decreases as the absolute altitude increases. The maximum amount of phytomass (over 150 t/ha) is found at 1700–1750 m asl, with averages as 50–100 t/ha found at 1800–1950 m asl, and the least phytomass (less than 50 t/ha) is found at 1950–2100 m asl. This is due to the severe climatic conditions (low temperatures). This peculiarity is more evident in the areas with little or hardly any anthropogenic transformation. Even in terms of intense anthropogenic impact, the amount of phytomass is little across the whole altitudinal spectrum. As for the subalpine meadows, the amount of phytomass changes within a great range, because these landscapes border the areas with little forest or no forest at all, but the same regularity is not observed depending on the hypsometric steps.

The ranges of phytomass over the landscapes in West and East Georgia are different. Particularly diversified is the vegetation cover in East Georgia. As an example, one can see middle-mountain forest landscapes extending within the eastern part of the Small Caucasus, with beech forests and deciduous bushes, with a grass cover, as well as oak forests and oak-and-hornbeam forests with a grassy cover, and the meadows formed with semi-humid and semiarid grassy cover are not rare either. The relief conditions greatly affect the amount of phytomass: absolute altitude, surface inclination, and exposition. These factors are the result of different heat and humidity in the natural-territorial complexes which show different relief conditions. This is clearly seen in the mountain landscapes. The maximum phytomass (over 300 t/ha) with dominant beech forests in the middle-mountain forest landscapes is fixed at 1200–1400 m asl in East Georgia. Within the limits of Great Caucasus in Kakheti, it is maximum (over 450 t/ha), fixed at 1000–1800 m asl and at 1200–1400 m asl in Kolkheti (Nikolishvili 2009). High-productive natural-territorial complexes up and below these altitudinal levels are relatively rare. Moreover, the forest massifs are relatively diminished and less productive here.

The amount of phytomass is also much influenced by *slope exposition.* In terms of little anthropogenic transformation, more amounts of phytomass are typical to the slopes with northern or western exposition. Clearly, this is due to the better humidification of these slopes. Relatively fewer amounts of phytomass are found over the slopes with southern or southeastern expositions because of high insolation and resultant drier slopes. This is a general peculiarity, which is typical to most of the Georgian landscapes. However, there are certain differences in this respect too. This difference is not so great between the landscapes of the low-mountain forests and the middle-mountain forests of West Georgia. Sometimes, greater amounts of phytomass are fixed over the slopes with south or south-east expositions as compared to the slopes with north or north-west exposition. Clearly, this is associated with equal and abundant humidification of the slopes with different expositions in West Georgia.

References

Altay V (2019) Ecology of *Pinus sylvestris* L. Forests - A case study from Istanbul (Turkey). Pak J Bot 51(5):1711–1718

Altay V, Ozyıgıt II, Yarcı C (2012a) Plant communities in urban habitats of Istanbul-Turkey. Pak J Bot 44:177–186

Altay V, Serın M, Yarcı C, Severoglu Z (2012b) Phytoecological and phytosociological investigations of the vegetation of Gölcuk (Kocaeli/Turkey). Ekoloji 21(84):74–89

Altay V, Silc U, Yarcı C et al (2020) Urban vegetation of the Anatolian side of Istanbul. Phytocoenologia 50(2):101–121

Anonymous (2000–2001) World resources 2000–2001. People and ecosystems. The flaying web of life. United Nations Development Programme, World Bank, World Resources Institute. Washington

Anonymous (2001a) Biodiversity of the Caucasus ecoregion – an analysis of biodiversity and current threats and initial investment portfolio. Baku-Erevan-Gland-Moscow-Tbilisi, 132 p

Anonymous (2001b) Geography of Georgia II. Tbilisi

Anonymous (2005) Global environment protection. UNDP, GEF, MOE, 60 p

Anonymous (2006) An ecoregional conservation plan for the Caucasica. May, Tbilisi

Avakova G (1989) Eocene flora of Akhaltsikhe. Tbilisi

Babunashvili G (2003) General ecology and environment protection. TSU, Tbilisi. 226 p

Beruchashvili N (2000) Diversity of Georgia's landscapes and geographical analysis of landscape diversity of the World Biological and Landscape Diversity of Georgia. Proceedings of the First National Conference, May 28–29, 1999, Tbilisi, Georgia, Tbilisi, pp 221–250

Beruchashvili N, Shotadze M, Nickolaishvili D, Melikidze V (2002) Caucasus Environment Outlook (CEO) 2002. UNEP, 100 p
Bondirev I, Seperteladze Z, Salukvadze E et al (2008) Transformation to natural ambience of the Tbilisi City and its vicinities. Tbilisi, 157 p
Collinson AS (1988) Vegetation and climate: an introduction to world vegetation patterns. In: Introduction to World Vegetation. Springer, Dordrecht, pp 197–206
Elizbarashvili N, Matchavariani L, Nikolaishvili D et al (2000) Geography of Georgia, Tbilisi
Gagnidze R, Davitadze M (2000) Local flora, Batumi
Gegechkori A (2008) Biogeography. Chapter I, Biomes of the World. TSU, Tbilisi, 527 p
Gigauri G (2000) Biodiversity of forestry ecosystems of Georgia. Biological and landscape diversity of Georgia. Proceedings of the First National Conference, May 28–29, 1999, Tbilisi, Georgia, Tbilisi, pp 69–82
Grossgame A (1928) Flora of Caucasus, Tbilisi
Gvozdetsky N (1963) The Caucasus, Moscow
Imanberdieva N, Severoğlu Z, Kurmanbekova G et al (2018) Plant diversity of Ala-Archa Nature Park in Kyrgyzstan with emphasis on its economic potential. In: Egamberdieva D, Öztürk M (eds) Vegetation of Central Asia and Environs. Chapter 16. Springer Nature Switzerland AG, Cham, pp 365–381
Kadjaia G (1999) The fundamentals of applied ecology, Tbilisi
Ketskhoveli N (1959) Vegetation of Georgia. National Academy of Georgia, Tbilisi, 384 p
Kvachakhidze R (2009) Vegetation of Georgia, Tbilisi
Kvachakhidze R (2010) Geobotanical Districts of Georgia, Tbilisi
Kvavadze E (1974) Palynological studies of the Holocene peatbog in the Kolkhidka river mouth, West Georgia. MSU, Geography 5
Maruashvili L (1981) Physical geography of Georgia, Tbilisi
Nakhutsrishvili G (1988) Ecological characteristic of high mountain meadow vegetation (Kazbegi, central Caucasus). In: The ecology of high mountains. Metsniereba, Tbilisi, pp 175–200
Nakhutsrishvili G (2000) Georgia's basic biomes. Biological and landscape diversity of Georgia. Proceedings of the First National Conference, May 28–29, 1999, Tbilisi, Georgia, Tbilisi pp 43–68
Nakhutsrishvli G (2013) The vegetation of Georgia (South Caucasus), XVI, 236 p
Nikolishvili D (2009) Spatial-temporary analysis of landscapes of Georgia. TSU, Tbilisi, 431 p
Nikolaishvili D, Sartania D, Ujmjuridze A et al (2016) Samtskhe-Javakheti, Tbilisi
Nikolaishvili D, Trapaidze V, Kalandadze B et al (2015) Complex evaluation of climate change – an example from Georgia's landscapes. J Environ Biol 36:43–49
Ozturk M, Efe R, Çelık A et al (2012) Comparative study on biogeography of protected and degraded habitats in Dilek Peninsula, Turkey. J Balkan Ecol 15(4):383–392
Ozyıgıt S, Altay V, Ozyığıt II, Yarcı C (2015) Vegetation ecology of the Princes' Islands, Istanbul-Turkey. J Environ Biol 36:113–120
Panova LA, Maligonova EI, Tabachnikova IP (1984) Miospores and tenoplankton of the Eocene-Oligocene deposits of the northern flange of Akhaltsikhe Depression. Collection Spores and pollen in the phanerozoic deposits. The Works of Karpinsky Russian Geological Research Institute, new series 327
Sezer Y, Altay V, Ozyıgıt II, Yarcı C (2015) Woody vegetation of Şile and its environs (Istanbul/Turkey) and destruction of the area. J Environ Biol 36:163–170
Shetekauri S (1999) Biotopes of Petrophytic flora of the High-mountain Caucasus. Bull Georgian Acad Sci 159:3
Shetekauri S (2017) Flora of Tusheti, Pshavi and Khevsureti (The East Greater Caucasus). Meridiani, Tbilisi, 527 p
Targamadze K, Chilhardze V (1976) Forest resources of Georgia. Sabchota Sakartvelo, Tbilisi, 103 p
Tediashvili A (1984) Research of Phytomass as a landscape-geophysical indictor. Thesis, Tbilisi
Tediashvili A (1987) Dynamics of phytomass of Natural-territorial complexes. Tbilisi-Stational Researches, What did they give? pp 82–97

Chapter 16
Faunal Diversity in Georgia: General Perspective

Dali Nikolaishvili and Davit Sartania

16.1 Introduction

The fauna of Georgia is versatile, primarily due to the diversified natural conditions of the country. It has been serving as a corridor for animal migrations since the ancient times. Animals from both the north and south have entered the territory of Georgia, making it a kind of a "faunal center" (Natsvaladze 2004).

Besides wild animals, there is a diversity of domesticated animals. Georgian people have been following cattle breeding since the ancient times together with land cultivation. It is supposed to be one of the countries where people domesticated cattle and sheep. The evidence for this is the records by Aristotle about the Georgian cows, which, though small, gave much and rich milk. Javakhishvili et al. are of the opinion that the Georgian cow Aristotle mentioned is still surviving in Khevsureti-Georgia (Bregadze 2009; Mitichashvli 2009). The country is very rich in local varieties of birds and animals; however, their total number has decreased much lately. The areas where these are surviving are those where only local inhabitants live without any industrial activities.

The history of fauna in Georgia is found in a number of historical sources and literary writings, which describe both wild and domestic animals. But no detailed study has been undertaken in this direction covering the data found in the available sources. This issue is important in many respects not only for identifying the diversity and peculiarities of the geographical distribution of animals in the historical past but also for identifying the branches of economy people were busy with in the past together with the ways they used to maintain them. The old Georgian historical

D. Nikolaishvili (✉)
Department of Geography, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
e-mail: dali.nikolaishvili@tsu.ge

D. Sartania
Museum of TSU, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
e-mail: davit.sartania@tsu.ge

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_16

work "Life of Kartli" gives very interesting data about faunal representatives. A systematic study has started in the nineteenth century, after the establishment of the Museum of Caucasus (Radde 1899).

16.2 Anthropogenic Changes

The diversified fauna of Georgia, mostly the vertebrates, has suffered strong anthropogenic impacts during the last two centuries. The twentieth century (starting from the 1920s) was particularly effective in this respect. Some species spread almost everywhere, but others survived only at some locations. For example, a deer can be found in limited numbers only in East Georgia. The goitered gazelle, bezoar goat, striped hyena, and leopard are the endangered species as only some individuals are surviving. The main reasons for this loss are destruction of their habitats, irregular forest cutting, overgrazing, uncontrolled hunting, and poaching.

In recent decades, the values of domestic animals have significantly changed in the country, the reason being developments with modern agricultural and farming techniques and infrastructural developments. A number of species are bred to date, the same way it was centuries ago, but some domestic animals are not bred anymore either for industrial purposes or even for personal use. The horse, as a draft animal, has lost its leading role in agriculture. Consequently, the total number of horses has decreased and their genetic features have deteriorated (Anonymous 2009; Bregadze 2009). However, in some areas of Georgia, locals still use horses as saddle and packhorses or draft animals. A horse is irreplaceable for nomadic cattle breeding in the mountainous regions.

16.3 Genetic Diversity

Georgian faunal diversity belongs to the Palearctic region, mostly the Mediterranean Basin subregion. Animals typical in humid subtropics and semideserts as well as high-mountainous regions are spread in the country. In particular, the invertebrate fauna is highly diversified, rich in a number of endemics. Invertebrates have not been studied as well. The best-studied are the butterflies (Lepidoptera: Geometridae), beetles (Coleoptera: Curculionidae, Carabidae), flatworms (Nemathelminthes), Hymenopterans (Hymenoptera), and Hemiptera: Psylloidea (Anonymous 2008). Protozoa, free-living phytoparasite nematodes, and worms too have been investigated; however, Turbellaria have virtually not been studied. The number of invertebrates is presumably twice the number of identified species. Therefore, we may only have a general account of the diversity of invertebrates.

Currently, the most diversified is arthropods, with a total number of over 10,000 taxa, in particular the insects. There are only 160 species of Crustacea and Myriapoda (Fig. 16.1) followed by nematodes with over 900 species. The numbers of plant, animal, and human parasites are almost equal. The number of flatworm species is more than 460 (Badridze et al. 2000).

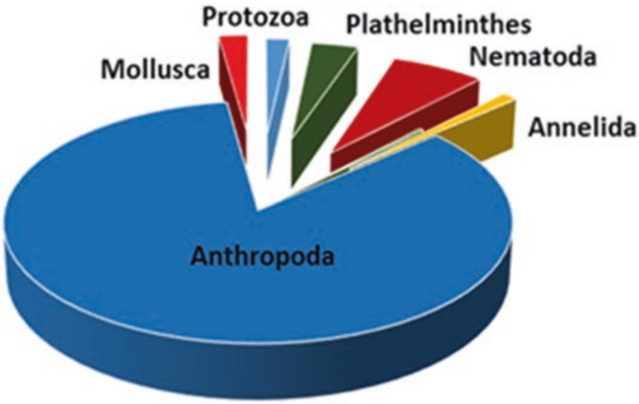


Fig. 16.1 Diversity of invertebrate fauna in Georgia

The most diversified are the butterflies (Macrolepidoptera). About 500 species of 31 Palearctic faunistic families have been recorded from Georgia, including 30% relict, endemic, and rare representatives of a scientific/esthetic value (Anonymous 2008).

Vertebrates are much better diversified and studied. There are over 100 species of mammals, over 300 bird species, 50 reptiles (including 3 species of tortoise, 27 species of lizards, and 23 species of snakes), 12 amphibian species, and up to 160 fish species in Georgia, with the total number of vertebrate animals around 650 (Anonymous 2008; Elizbarashvili et al. 2000). Out of the large mammals (carnivores, even-toed ungulates, and Cetacea), 30 species live in Georgia. Out of these two species of Caucasian goat *Capra cylindricornis* and *C. caucasica*, are of particular importance, as these are Caucasian endemics.

Mammals live in different habitats in Georgia. The greatest number is found in the mountain forests, floodplains, and steppes. Particularly rich in mammals are the mountain forests with 57 species (Fig. 16.2). The useful and hunting and industrial mammal species (80 species) exceed much the number of pest species (33 species).

The birds are also much diversified in Georgia. The country is well-known for its great number of not only local but also migrating species. The most important resting and wintering areas in Afro-Eurasian corridor for the migrating bird species are Kolkheti Valley (coastal line, marshes, environs of Paliastomi Lake), wet areas of Javakheti Plateau, and areas adjacent to the beds of the Alazani and Iori rivers. The three bird species common in Georgia are Caucasian endemics: Caucasian black grouse (*Tetrao mlokosiewiczi*), Caucasian snowcock (*Tetraogallus caspius*) and mountain chiffchaff (*Phylloscopus lorenzii*) (Anonymous 2008).

The amphibians and reptiles too are diversified. Caucasian salamander (*Mertensiella caucasica*), Syrian spadefoot (*Pelobates syriacus*), Caucasian parsley frog (*Pelodytes caucasicus*), Caucasian ratsnake (*Elaphe hohenackeri*), Caucasus viper (*Pelias kaznakovi*), etc. live in Georgia.

Over 80 fish species live in the fresh waters, many being endemics. For example, 9 of 12 fish species common in the river Mtkvari basin are endemics of the river Mtkvari and its tributaries, notable among these being the Kura barbel (*Barbus*

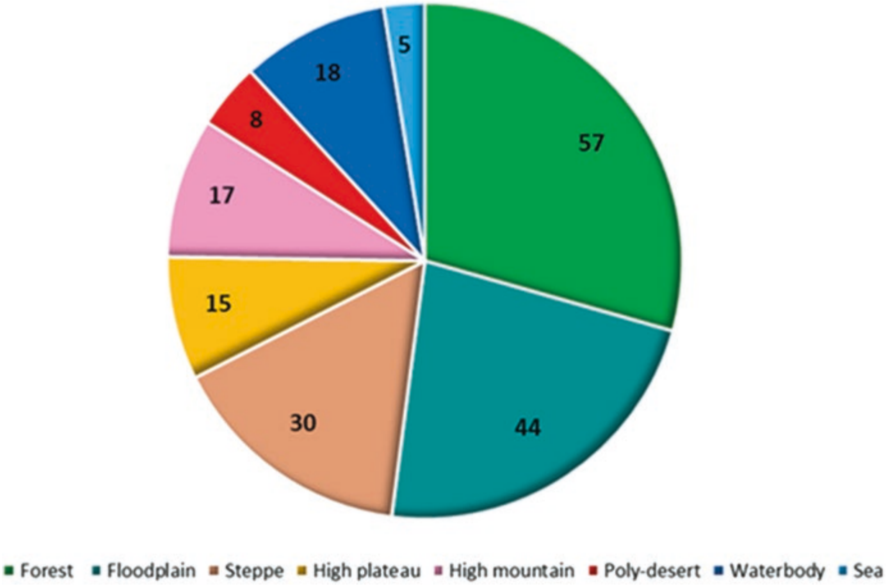


Fig. 16.2 Diversity of mammals in Georgia

lacerta), *Luciobarbus mursa* (*Barbus mursa*), Bulatmai barbel (*Barbus capito*), trout (*Salmo farie*, *S. irideus*), *Rutilus* (*Rutilus rutilus*, *R. caspicus*), *Gobio* (*Gobio persa*), etc. (Elanidze et al. 1970; Anonymous 2008).

There are many endemic faunal species such as Caucasian goats (*Capra caucasica, C. caucasica cylindricornis*), Caucasian and Caspian snowcock (*Tetraogallus*), Caucasian grouse (*Lyrurus mlokosiewiczi*), long-clawed mole vole (*Prometheomys schaposchnikowi*), pontic hedgehog and moles (*Talpa orientalis*, *T. caucasica*), ring-necked pheasant (*Phasianus colchicus*), and various lizards, insects, and mollusks. Some of these are endemics; not only in Georgia but for the whole Caucasian region. It is important to mention that between Miocene and Pliocene the Caucasian island joined the Iranian massif of Asia, which transformed it into a peninsula. So, dry climate-loving fauna has penetrated in the territory of Georgia. Typical of this fauna is the wild goat (*Capra aegagrus*) (Gegechkori 2000), which is listed in the Red Book of Georgia (1982) as an extinct species.

Kolkheti is particularly rich, where Tertiary tropical faunal relicts have survived. They are mostly predators or may eat any vegetable food. Owing to this, they could adapt to the climate change.

The animals coming from other geographical regions are also in great numbers. In particular, during climate cooling, the species common in cold climatic regions enter Georgia from the north, while during climate warming, the animals common to Turan, Central Asian steppes and deserts, such as Dipodidae, *Tetraogallus*, *Alectoris graeca*, various reptiles, goitered gazelle, etc., come to Georgia. Quite a great number of *Gazella subgutturosa* have been recorded in Kvemo Kartli lowland and in Iori Plateau in the recent past. The species has suffered much. A number of representatives of the European and Asian fauna find shelters in the high-mountain area of Georgia, as no sharp climate change ever occurred there.

The acclimatization of fish in the fresh waters of Georgia has started in the 1930s–1950s. Different fish species were introduced to the water reservoirs of the country (e.g., *Coregonus albula* Linne, *Coregonus albula* infracpecies *ladogensis* Pravdin, *Coregonus lavertus baeri natio ladogae* Pravdin, etc.), which became food species. This ensured steady importance of the water reservoirs for fishing. The importance of acclimatized fish as food has decreased lately. One of the methods to improve productivity was introducing artificially grown hatchlings to the water reservoirs. The Khrami water reservoir was one of such target reservoirs. These measures more or less secured the branch and were important for the local population (Nikolaishvili et al. 2016). Presently, there are nine introduced fish species in the fresh waters of Georgia. The most common is *Carassius carassius* (Anonymous 2008).

In West Georgia and on the southern slopes of Eastern Caucasus, many representatives of Mediterranean fauna (e.g., roe deer) and species common for Asia Minor, Iran, and Afghanistan (Hyena, European hamster, etc.) are found in the Lesser Caucasioni. In the 1930s, a valuable fur rodent was introduced, the coypu (large water rat), from Argentina. Today, it lives in many water reservoirs of Kolkheti Valley and has a great trade value. Of the valuable fur rodents, *Neovison vison* was introduced to Kvareli region. However, it got lost quite soon. In the 1950s, a Siberian squirrel got acclimatized in Borjomi region, which inflicted a great damage to the forests. *S.V. altaicus serebrennikov* was introduced from the North Caucasus, which spread widely. Sika deer and raccoon dog were introduced from the Far East. Presently, the latter dwells in Telavi, Akhmeta, and Tianeti regions. Following its acclimatization, it became a depredator.

Two ladybird species (*Aphelinus mali* and *Cryptolaemus montrouzieri*) were introduced to West Georgia, which destroyed the pests of citrus cultures. In the 1930s, fish *Gambusia* was introduced from Italy to combat malaria mosquitoes. Today, this fish species is widely spread in almost all water reservoirs of the country. In some water reservoirs of West Georgia, people grow coast rainbow trout, silver carp and grass carp, common carp in Bazaleti and Jandari lakes, and *Coregonus lavaretus* in Tabatskuri Lake.

16.4 Animal Diversity in Different Vertical Zones

An important influence on the animal habitats is exerted by the climate differences between the lowlands and mountains of East and West Georgia. This is responsible for the general geographical factor and mosaiclike structure of animal distributions over the territory. The differences are mainly seen in the uneven distribution of moisture and its gradual reduction from west to east. The factor limiting the difference between the lowland and mountains is the gradual reduction of air temperature as the absolute altitude increases with gradual replacement of forest habitats with no-forest areas.

Animal migration is very important in different seasons (this is particularly true with the birds and invertebrates). This makes it much difficult attributing them to a particular zone. From the beginning of autumn, some birds fly to southern countries and return in spring, while other birds fly to Georgia from northern countries in winter. Internal migrations change the seasonal composition of animals in individual zones. For instance, at the end of autumn, hoofed mammals and predators migrate from the high hypsometric altitudes to the lower altitudes – from alpine meadows to the forest and return to their original habitats in spring (Natsvaladze 2004). Such a migration is common for the following animals: Caucasian goat, bezoar goat, chamois, etc. Bezoar goat descends particularly low, even reaching the lowest border of the forest. It is interesting to note that the absolute height is not important for this species but the presence of cliffy areas is more important. As for the brown bear, which is a forest dweller, on the contrary, in the warm period of the year, migrates higher in the search of food reaching the subalpine and even alpine zones. The migration of some animals is influenced by an anthropogenic factor. For example, wolf and fox try to find food in settled areas, particularly if the locals breed cattle there.

Based on the comparison and analysis of various sources (Janashvili et al. 1984; Natsvaladze 2004; Anonymous 2009), a general picture of the vertical habitation of the animals has been evaluated. There seem to be five zones: plain and foothills of West Georgia, plain and foothills of East Georgia, forest zone, alpine zone, and high-mountain plateau (Fig. 16.3).

16.5 Concluding Remarks

West Georgian lowlands have more diversified faunal composition. Forest animals are more common in the lowlands of West Georgia, while the animals typical to the steppes and semideserts are more spread in the lowlands of East Georgia. The numbers of some animal species have greatly reduced and some have been destroyed. This is particularly true with West Georgian lowlands (where large mammals have been destroyed much, such as wolf, jackal, lynx, etc.). However, as regards the diversity, West Georgian lowland is outstanding. Of the mammals of West Georgian lowland, the European mole, bat, Caucasian squirrel, dormouse, forest dormouse, wood mouse, Pontiac red vole, stone marten, wild cat, and others are noteworthy. Of the reptiles, slow worm, European blind snake, various species of lizards, *Coluber*, Caucasus adder, grass snake, etc. are notable. Various turtle species live near the water reservoirs, together with the amphibians, like common newt, marsh frog, tree frog, various species of toads, many invertebrates, etc. (Bregadze 2009; Mitichashvli 2009).

West Georgian lowland is particularly rich in versatile birds which can be explained by the availability of large habitats suitable for them. The number of birds in this region is 20 times more than their number in the East Georgian lowland. The most common birds are *Phasianus colchicus*, *Columba palumbus*, *Gallinula*

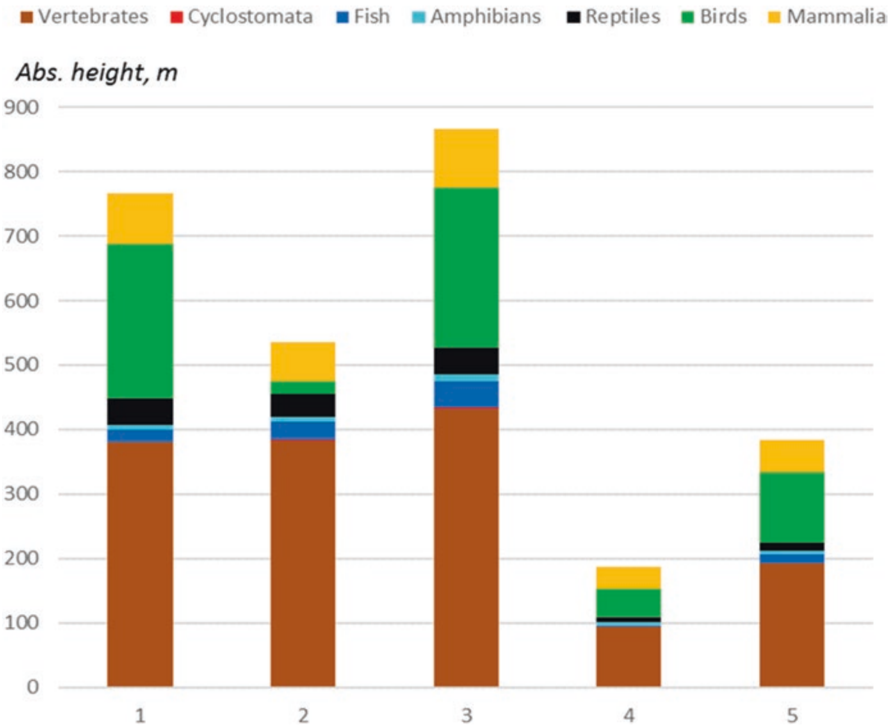


Fig. 16.3 Animal diversity of Georgia according to vertical zones. [(**1**) Plain and foothills of West Georgia, (**2**) plain and foothills of East Georgia, (**3**) forest zone, (**4**) alpine zone, (**5**) high-mountain plateau]

chloropus, *Scolopax rusticola*, various species of falcons, hoopoe, owl, jay, swallow, etc., and egrets, black storks, wild geese, wild ducks, *Gallinula chloropus*, etc. are also found in great numbers in marshes and near the water reservoirs (Natsvaladze 2004).

In the lowlands of East Georgia, the fauna is rich too. Commonly spread mammals are Eurasian hedgehog, *Caucasian mole*, long-tailed weasel, Caucasian shrew, and lesser white-toothed shrew. Etruscan shrew, the smallest mammal, is widely spread in the environs of Tbilisi. Various species of voles, Macedonian mouse, Caucasian dwarf hamster, dwarf hamster, wolf, jackal, and Eurasian fox are also found almost everywhere in Georgia. Striped hyena and Anatolian leopard are some of the endangered species. The bird fauna is more homogeneous and is represented by redleg, common pheasant, wild pigeon, ringdove, turtledove, kite, common raven, black-billed magpie, sparrow, partridge, and various species of eagles. Rudy duck (*Tadorna ferruginea*), wild duck (*Anas platyrhynchos*), *Ciconia ciconia*, egrets, rarely *Porphyrio porphyrio*, etc. dwell in the environs of water reservoirs. European pond and freshwater turtles also inhabit the areas around the water reservoirs, and Mediterranean tortoise is found at some locations. The number of amphibian species is fewer, represented by various species of frogs, toad, tree frog, while banded newt and other species are spread in the environs of Tbilisi. There are many species of invertebrates: insects, arachnids, worms, mollusks, etc.

Reptiles in particular are found in great numbers in the steppes and semideserts. The most common species are *Caucasian agama*, naked-toed gecko, Persian toad-headed agama, sheltopusik, slow worm, and various species of lizards. Common snake varieties are African tiger snake, various species of grass snakes, and rarely, Aesculapian snake and javelin sand boa. Notable among the other species are Levantine snake, European blind snake, meadow viper, horned viper, and various species of *Coluber* (Janashvili et al. 1984; Natsvaladze 2004). The steppe and semi-desert zones are relatively poor in birds and are more homogeneous.

Some varieties have equally spread in East and West Georgia: Eurasian hedgehog, hare, least weasel, mole, squirrel, vole, European badger, otter, wild boar, roe deer, quail, turtledove, ringdove, hawk, sparrowhawk, golden oriole, starling, carrion crow, pipit, lark, thrush, nightingale, woodpecker, and cuckoo of birds.

Of the above-listed zones, particularly rich in animal diversity is the mountain forest zone, mostly located between 800 and 2000 m asl. The lower area of the mountain forest zone is the area of dominant oak-and-hornbeam forests, with a quite changed primary vegetation cover. At higher hypsometric altitudes, monodominant beech forests dominate followed by dark coniferous forests at higher altitudes in West Georgia (and partially in East Georgia). Above 1800–2000 m asl, the forest cover is sparser and is mostly represented by beech, birch, pine, and Caucasian oak forests.

Mountain forests occupy quite large areas in Georgia and, as compared to the high-mountainous regions, have also diversified fauna due to more beneficial climatic conditions. However, within the borders of Georgia, there is no significant regional difference between the forest animals here. The most noteworthy of the mammals are wild boar, *Cervus elaphus*, roe deer, wolf, jackal, mountain fox, Caucasian brown bear, wildcat, lynx, European badger, beech marten, least weasel, hare, Caucasian squirrel, etc. There are many bird varieties in the forest. Widely spread species are Caucasian black grouse, turtledove, ringdove, Northern goshawk, falcon, Caucasian sparrowhawk, tawny owl, cuckoo, various species of woodpecker, carrion crow, jay, black-billed magpie, starling, lark, various species of thrush, nightingale, Eurasian wren, songbirds, etc. are found in a great number as well (Natsvaladze 2004).

There are also many reptiles in the mountain forests. The most notable species are Caucasian agama, sheltopusik, European blind snake, grass snake, different kinds of lizards, and Mediterranean tortoise at some locations. Common amphibians are Caucasian salamander (*Mertensiella caucasica*), banded newt (*Triturus vittatus ophryticus*), Caucasian parsley frog (*Pelodytes caucasicus*), and various species of frogs and toads. Invertebrates (insects, *Arachnoidea*, mollusks, etc.) are also found in great numbers.

The least diversified of the abovementioned zones is high-mountainous subalpine and alpine zone. The animals common to this zone are found in great numbers on the Caucasioni. Among them are many animal species well adapted to heavy snow and cold climate, such as chamois, Caucasian mole, and long-tailed weasel. There are also many rodents, in particular, long-clawed mole vole, which feed on alpine grass roots. Other common species are Caucasian goat, bezoar goat, Caucasian snow vole, etc. Today, bezoar goat is an endangered species and has survived only in the Caucasioni of Tusheti and Kvesureti. Common birds are snowcock, redleg, golden eagle, griffon vulture, etc., and black grouse dwells in the bushes of Caucasian rhododendron. Hematocryal animals are less common here. The most commonly spread reptiles are grass snake and Caucasus adder (*Vipera kaznakovi*); the most common amphibians are Eurasian frog, Caucasian parsley frog, etc. Some of these representatives of fauna are listed in the Red Book of Georgia (1982).

On the high-mountain forest plateau, we see the elements of both mountainous and semidesert fauna. The commonly spread mammals are Eurasian hedgehog, European mole, lesser Caucasian mole, various bat species, Caucasian squirrel, wood mouse, European badger, European stone marten, various species of voles, least weasel and wolf, and wild cat. Common birds are Caucasian black grouse, redleg, quail, *Scolopax rusticola*, various species of seagulls, falcon, hawk, sparrowhawk, kite, cuckoo, hoopoe, common raven, etc. Vulture, Caspian snowcock, and marsh owl are common in some locations. The following endangered bird species are seen only in Javakheti Plateau: common firecrest and Asian crimson-winged finch. Due to a great number of lakes in the area, there are many waterbirds there, mostly boreal species. Common reptile species are Caucasian agama, blotched snake, and various species of grass snakes and lizards. Common amphibians are Caucasian salamander, Caucasian parsley frog, marsh frog, toad, and tree frog (Nikolaishvili et al. 2016).

Despite the fact that the territory of Georgia has a clear vertical zoning of fauna, it should be considered that some animal species, due to migration, may live in different zones during the same season. Quite often, animals migrate to great distances.

References

Anonymous (2008) Assessment of capacity building needs for biodiversity conservation and sustainable use. In: Participation in clearing house mechanism and preparation of a second and third National Reports to CBD. Nacres, UNDP/GEF

Anonymous (2009) Animals of Georgia – our values, vol 2. Tsignieri, Tbilisi

Badridze I, Eliava I, Kajaia G, Cholokava A (2000) Present condition of species diversity of fauna in Georgia. In: Proceedings of the First National Conference, May 28–29, 1999, Tbilisi, Georgia, pp 221–250

Bregadze A (2009) Animal world of Georgia. Tstsinatela, Tbilisi

Elanidze R, Demetrashvili M, Burchuladze O, Kurashvili B (1970) Atlas of the freshwater fish of Georgia. "metsnereba" Publishing House, Tbilisi

Elizbarashvili N, Matchavariani L, Nikolaishvili D et al (2000) Geography of Georgia. TSU, Tbilisi

Gegechkori A (2000) Relicts and endemics and Georgia's biodiversity at the background of Caucasus orogenesis. Biological and landscape diversity of Georgia. In: Proceedings of the First National Conference, May, 28–29 1999, Tbilis, Georgia, pp 83–96

Janashvili A, Meskhidze J, Guniava L (1984) Mammals of Georgia. Sabchota Sakrtvelo, Batumi
Mitichashvli R (2009) Animal and bird species – our virtues, vol 2. MPG, Tbilisi, pp 97–130
Natsvaladze K (2004) Vertebrates of Georgia. Tsisartkela, Tbilisi
Nikolaishvili D, Sartania D, Ujmajurdze A et al (2016) Samtskhe-Javakheti. Tsisartkela, Tbilisi
Radde G (1899) Collection of Caucasian Museum, vol 1. Zoology, Tiflis, 50 p
Red Book of Georgia (1982) Sabchota Sakartvelo, Tbilisi

Chapter 17
An Overview of the Plant Diversity of Azerbaijan

Sayyara J. Ibadullayeva and Irada M. Huseynova

17.1 Introduction

The Azerbaijan Republic is the largest Eurasian country in the Caucasian region. It is located in the Caspian Sea basin at the intersection of Europe and Central Asia in the South Caucasus. Area is 86.600 km^2; out of these 11.5% are forests, 1.6% water basin, 50.0% cultivated lands including 27.0% pastures, and 36.9% farms. The diversity of the natural-historical and physical-geographical conditions of the country has led to the formation of highly diverse vegetation. The country was one of the centers of primary plant formation, and foreign botanists have always shown special interest in the flora of Talysh, Nakhchivan, Garabagh and Gobustan while studying the Caucasus flora (Ozturk et al. 2018a, b). One of the main tasks has been to study different types of natural flora from the early days of botanical studies in Azerbaijan. Detailed research on the flora of the "Republic" began following the establishment of Soviet Union. The planned and intensive studies on the flora began following the establishment of the Botanical Institute in Azerbaijan. The baseline analysis of plant collections and the collection of new materials has been undertaken only after the Second World War.

A number of publications prior to the 1950s of the last century are worth to be noted. Out of these, "Talysh flora," "Absheron flora," and the three-dimensional "Azerbaijan flora" (Grossheim 1939–1967) in Azerbaijan Language (in latin script) are of great value. The publication of eight volumes of "Azerbaijan flora" in russian was important in this direction. R. Rzazade, Y. Isayev, V. Hajiyev, H. Gadirov, G. Akhundov, and S. Agacanov together with many scientists from other countries

S. J. Ibadullayeva (✉)
Institute of Botany, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

I. M. Huseynova
Institute of Molecular Biology & Biotechnologies, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_17

as well as other Azerbaijani botanists actively participated by contributing in these volumes. Experts from foreign countries were also invited to participate in this work. The publication of "Flora of Azerbaijan" laid the foundation for further floristic-systematic studies in the Republic and helped to get closer acquaintance with the botanists of foreign countries who were interested in the regions of Caucasus. The three-dimensional "Azerbaijan flora" covers 3.357 species, the eighth volume added more, and the number was 4.072 species (more than 715 species). Finally it reached up to 5.000 species (including cultivated flora), which were included in the series on "Flora of Azerbaijan" of A.M. Asgarov in 2016. At present the researchers of the Institute of Botany of ANAS are working on the publication of new editions of flora with the addition of new species approved at the molecular level.

The studies on the flora are carried out mainly in three areas: study of genofund of rare species and their protection, study of genofund of widespread but with reduced areal species, and preservation of the main forest forming genera. The situation of our flora in the occupied territories also needs to be followed. First of all, the information about the state of rare species has been collected, and it has been shown that 20% of the Republic's flora needs protection. 140 taxa are more severely threatened and included in the first edition of the Red Book of Azerbaijan (Red Book of Azerbaijan 1989). The extent to which these species are rare and exhausted has been evaluated under 5 categories: (**1**) belavers, endangered: 22 species; (**2**) rare in smaller areas, 65 species; (**3**) gradually shrinking in own areas, 45 species; (**4**) rare ones with little knowledge, 18 species. Rare species restored as a result of additional plantings have been kept in natural view (5 species).

In all 16 species can be assigned to several categories. From 140 registered species, 4 belong to high-growth plants, 81, cotyledonous species, and 41, monocotyledons. Rare plants are more in Talysh and Nakhchivan, 35–40 species in the Greater and Lesser Caucasus regions, 16 species in Absheron, and more than 14 in the Kur-Araz lowland. Some of the species from higher plants are in danger of extinction – *Anogramma leptophylla*, *Marsilea strigosa* and the genera like *Anabasis*, *Ammochloa*, *Campanula*, *Ferula*, *Lilium*, *Tulipa*, and *Eremurus*.

The Institute of Bioresources of ANAS has published the second edition of the "Red Book" of Nakhchivan Autonomous Republic in 2010, and researchers from the Institute of Botany of ANAS have published the Red Book of Azerbaijan (Talibov and Ibrahimov 2010; Red Book of Azerbaijan 2013). About 266 species of higher plants have been mentioned in the second edition of the Red Book of Azerbaijan. According to the recent scientific expeditions, 800 species of flora in Azerbaijan need protection. So, work for publishing new edition of Red book of Azerbaijan is necessary.

17.2 Flora Spectrum

The area of Azerbaijan is characterized by unique and rich flora with dense vegetation. 4961 species belonging to 1117 genera of wild plants have been registrated in the Republic (including wild-growing cultivated plants). These make up 70% of the Caucasus flora (6350 species) (Anonymous 2003, 2006). Azerbaijan covers about 16% of the Caucasus territory. The plant wealth is explained by the diversity of natural-historical and physical-geographical conditions of the Republic. Systematic studies are required to protect the genetic resources of the country. The centers of base form diversity, the distribution nature of the hereditary diversity, and the intensity of species formation are determined by systematic studies. The systematic composition of the Flora of Azerbaijan is shown in Table 17.1.

The spread of plants in the world is a subject to general rules and evaluations, in particular the plants showing wide eco-geographical areas. The botanical, geographical, and historical dissemination of plants is basically based on the current distribution of plants. Area is divided into botanical-geographical dictricts because Flora of Azerbaijan differs in ecological conditions [(**1**) around the Caspian Sea; (**2**) Kur-Araz lowland; (**3**) Kur plain; (**4**) Lankaran-Mughan; (**5**) Nakhchivan Plain; (**6**) Absheron; (**7**) Gobustan; (**8**) Bozdag highland; (**9**) mountainous part of Nakhchivan; (**10**) Diabar (Zuvand); (**11**) Alazan-Eyrichay valley; (**12**) Samur-Devechi plains; (**13**) Lankaran plain; (**14**) Greater Caucasus (Guba mountain range); (**15**) east of the Greater Caucasus; (**16**) west of the Greater Caucasus; (**17**) north of the Lesser Caucasus; (**18**) center of the Lesser Caucasus; (**19**) south of the Lesser Caucasus; (**20**) mountainous part of Lenkoran] (Anonymous 2014). The floral zoning on the basis of botanical-geographical districts is shown in Table 17.2.

Nakhchivan mountain range is of exceptional nature, and more than half of the Flora of Azerbaijan is found in this botanical-geographical zone.

Table 17.1 Systematic composition of the Flora of Azerbaijan

No	Plant division and classes	Family (number)	Genus (number)	Species (number)
1	Lycopodiophyta	2	2	2
2	Equisetophyta	1	1	7
3	Polypodiophyta	14	21	50
4	Bryophyta	42	135	450
5	Pinophyta	3	3	14
6	Lichens	67	202	811
7	Magnoliophyta	145	839	4961
a	Magnoliopsida	120	625	4007
b	Liliopsida	25	214	956

Table 17.2 Taxonomic composition of flora of botanical-geographical districts of Azerbaijan

No	Botanical-geographical districts	Number of species	Common number of species (%)
1	Around the Caspian Sea	1200	26.6
2	Kur-Araz lowland	1215	27.0
3	Kur plain	1205	26.7
4	Lankaran-Mughan	1500	33.3
5	Nakhchivan plain	1175	26.0
6	Absheron	1000	22.0
7	Gobustan	1200	26.6
8	Bozdag highland	1190	26.4
9	Mountainous part of Nakhchivan	2700	60.0
10	Diabar (Zuvand)	1107	24,6
11	Alazan-Eyrichay valley	1100	24.4
12	Samur-Devechi plains	1145	25.4
13	Lankaran plain	1205	26.7
14	Greater Caucasus (Guba mountain range)	1700	37.8
15	East of the greater Caucasus	1205	26.7
16	West of the greater Caucasus	1105	24.5
17	North of the lesser Caucasus	1203	26.7
18	Center of the lesser Caucasus	1316	29.2
19	South of the lesser Caucasus	1250	27.7
20	Mountainous part of Lankaran	1107	24.6

17.3 Life Forms of Plants

Analysis of basic life forms of plants in Azerbaijan flora is based on two systems. I.K. Serebryakov has shown two legitimacy for life form definition: ecological-morphology and ecological-cenotics. The first method is useful for the analysis of seminal plants and second in the study of plant distribution by locality and by areal analysis in floristic studies (Serebryakov 1955). The life forms of moss, equisetum, and fern have not been analyzed in this system. Comparison of these plants with angiosperms would not be feasible due to their independent evolution. The mosses as life forms are attributed to perennial herbs "turfy monoecious" and "turfy dioecious," horsetails to "separately developing vegetative and generative branches" (*Equisetum arvense*) and "partly green vegetative branches in winter" (*Equisetum ramosissimum*), lichens to "perennial deciduous" (*Ceterach officinarum*, *Cheilanthes persica*), and "annual deciduous" (*Cystopteris fragilis*) which completely lose their upper parts in hot summers and partially same for lichens. Analyses of life forms of plants by one system in Azerbaijan flora lead to the following conclusions (Fig. 17.1).

Perennial plants have a higher role (66.4%); second place is taken by annual ephemers and ephemeroids (23.4%). Azerbaijan flora also includes 435 species of woody plants and shrubs. The largest families in Azerbaijan flora are Asteraceae

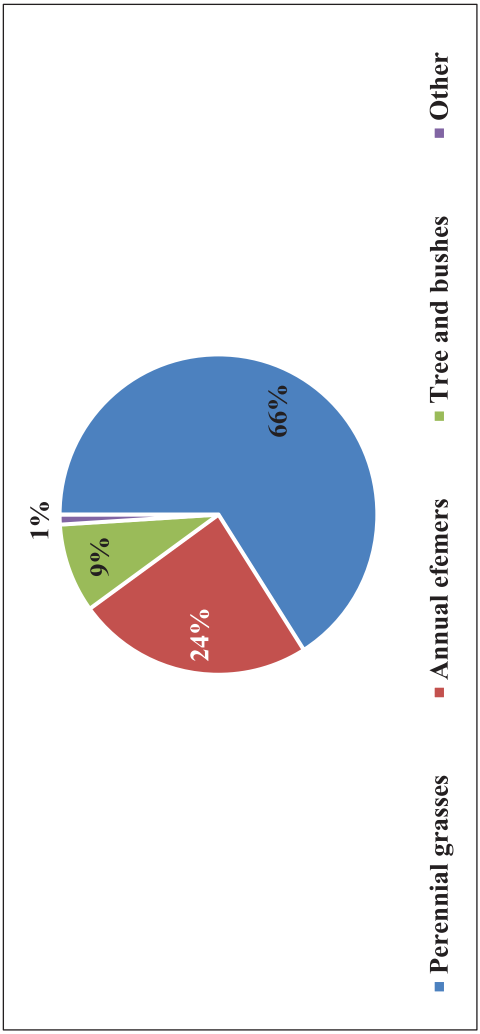


Fig. 17.1 The life forms of plants based by the Serebryakov system (1962) disseminated in the Flora of Azerbaijan (%)

(Compositae) (137 genera and 551 species), Poaceae (Gramineae) (117 genera and 477 species), and Fabaceae (Leguminosae) (70 genera and 460 species). The number of genera with a large species number is significantly above average. It is evident that the number of species in polymorph genera is about 39% of the total number, but the basis of Azerbaijan flora lies on the genera with small number of species (from 2 to 9 in each). Monotypic genera form 50% of the total number of genera; 5/1 of total number of species come under these genera. The biomorphological features of plants are quite different. The plants of the mountainous ecosystems are different from the plants of the lower zones. Small and slightly hairy herbs dominate here except the forest, subalpine and alpine tall grasses. Sometimes trees meet in lower parts of subalpine zone. Small bushes as well as evergreens and cushion plants are distributed on high mountain ranges. Although herbs are widespread in the highland zone, their adaptation to lower temperatures is not the same due to the large amount of UV radiation. As such, analysis of plants developing from buds on the surface layer of soil was carried out based on the second system (Raunkier 1934). Epilitis and epigeys have been added to moss in the classification. As shown from the diagram, more than half (53.6%) of the area's flora are hemicrythophytes. The second place (27.7%) is therophytes.

Among therophytes *Aegilops cylindrica*, *Adonis flammea*, *Senecio vernalis*, and another species develop in suitable season and spend harsh times in seed form. They begin their developmnet cycle in autumn, vegetative parts appear in winter, and seeds are produced in spring and summer, and the development cycle is completed. Phanerophytes constitute 7.3% of flora. Megaphanerophytes as subtype of phanerophytes do not have their potential dimensions in the area. *Quercus macranthera*, *Populus tremula*, *P. nigra*, *P. gracilis*, *Betula pendula* and others are attributed to phanerophytes and meet one by one in *Quercus* forest or in open places as groups. Microphanerophytes are often represented by bushes, *Rhamnus pallasii*, and nanophanerophytes, *Rosa rapinii*, *R. tuschetica*, *R. buschiana*, *R. nisami*, etc. **C**hamaephytes are small semi-bushes (4.4%). From these *Spiraea crenata*, *S. hypericifolia*, *Pyrethrum kotschyi*, and *Anthemis altissima* are distributed in alpine and subalpine zone and have important value. Cryptophytes include bulbous, root and tuberous plants with a percentage of 4.8%. Many of their subspecies, such as geophytes, hygrophytes and hydrophytes, are spread in the subalpine and alpine meadows: *Iris caucasica*, *Crocus atroviolaceus*, *Tulipa biflora*, *T. julia*, and *Lemna minor*. Epilities 1.17%, epigeys 0.95%, and epiphytes 0.11% are characteristic for moss.

17.4 Distribution of Plants by Ecological Groups

Soil-climatic factors play a major role in the life of plants. Plants are separated as megatrophic plants (evtrophs), mesotrophs, and oligotrophs depending on their relationship to the nutrient content of the soil (Fig. 17.2). Megatrophs are more demanding on foodstuffs and develop on productive soils, especially on alluvial meadows, in the marshes of the plain territories.

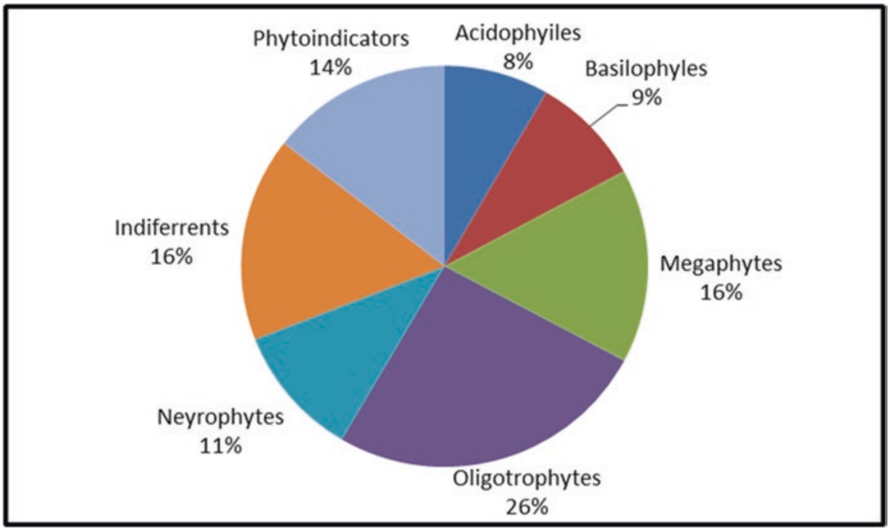


Fig. 17.2 Percentage of plants on the basis of nutrients

Perentage number of species depending on their relationship to the nutrient content of the soil varies much. These are divided as **Acidophytes**, *Rumex acetosa*, *Avena barbata*, *Ranunculus strigillosus*, *Galium verum*, and *Origanum vulgare*; **Basilophytes**, *Phleum phleoides*, and *Bromus scoparius*; and **indifferents**, *Agrostis gigantea*, *Lamium album*, and *Sambucus ebulus*. These plants are found on alkali and saline soils with a wide pH range. Some species and groups in the basin flora show essential characteristics of their environment (saline soil and ground waters, presence of chemical elements, substrate volatility, etc.). *Festuca valesiaca*, *Phleum pratense*, and *Trifolium pratense* show average or high productivity on the soil with optimal humidity and relatively poor acidity.

The analysis of Azerbaijan flora on the basis of ecological groups takes into consideration the habitat of plants with different degrees of humidity. Normal living and growth of each plant in the living environment allows them to evaluate as plant groups formed. They are a complex of environmental factors affective on plants and plant groups. Life-saving factors include changes in the amount of light, heat and humidity during the season and day.

Xerophytes play a special role in the development of flora of the area and are represented by 39.3% species. *Artemisia lerchiana*, *A. absinthium*, *Filago arvensis*, and *Marrubium vulgare* species are protected from overheating by protective pubescence. Other species restore the development cycle (ephemers and dicotyledons up to 1.5–2 months) or sharply shorten the vegetative period and restore the organs accumulating nutrients in the deep soil layer (polycarp plants and perennial monocarps). *Sempervivum transcaucasicum* and *Sedum hispanicum* are typical of the moderately damp areas. The leaves turn into thorns and reduce water vapor in many plants. *Sempervivum transcaucasicum*, *Sedum hispanicum* and others are mesophyte plants of moderately damp areas. Mesoxerophytes occupy the second place with 27% of species.

Majority of these species have following constraints to tolerate unmatched conditions: the shortening of the vegetation period, the ephemeroid rhythm of growth, and lack of moisture in the process of exploitation, leaf fall in summer. Such innovative adaptations have been used by xerophyte as well. 22% mesophytes occupy an important part of the area flora. Hygrophytes include water-marsh plants and are represented by 1.5% of species. *Festuca valesiaca*, *Trifolium pratense*, *Hordeum bulbosum*, *H. violaceum*, *Geum urbanum*, *Lotus corniculatus*, and *Lathyrus pratensis* are mesophytes between forest and shrubs. *Artemisia splendens*, *Astragalus glycyphylloides*, *A. cicer*, *Hypericum perforatum*, *Origanum vulgare*, *Medicago caucasica*, *M. caerulea*, and *Stachys macrantha* are mesophyte according to A. Sennikov's classification (1950) and are divided as psychromesophytes, hygromesophytes, mesohydrophytes, mesoxylophytes, oxylomesophytes, evmesophytes, xeromesophytes, and mesoxerophytes.

Heliophytes or according to the ecological groups heliophylous plants develop normally in full light. These include *Quercus macranthera*, *Populus tremula*, *Betula pendula*, *Acer ibericum*, *Crataegus orientalis*, *C. meyeri*, and *Sorbus boissieri*, from grasses – *Lactuca serriola*, *Herniaria glabra*, *Hieracium pilosella*, *Verbascum pyramidatum*, and *Tussilago farfara*. Shade-bearing plants or sciophytes normally develop in shade. The trees, brushes, and semi-brushes here include *Salix caprea*, *Ribes biebersteinii*, *Equisetum arvense*, and *Origanum vulgare*, from grasses in the forest – *Dryopteris filix-mas*, *Polygonatum orientale*, *Cichorium intybus*, *Platanthera chlorantha*, etc. species.

Ecological analysis of plants in the flora can be more widely conducted on the following parameters (pollination, anemogam, entomogam, obliqat-kleystogam, autogam; by diaspore distribution methods, anemochor, autochor, ballistochor, exozoochor, endozoochor, mirmekochor, hidrochor, microdiaspores, physocarps; according to flower colors: green-greenish (matt, porcelain), white, yellow, orange, red (pink, light red, from pink-purple to violet), azure-blue, purple, articular, hetero-chromium).

17.5 Species with Special Status

Out of trees 48 families and 435 species of trees and bushes 135 genera are spread in natural dendroflora of Azerbaijan. These include 10% of Republic flora. From these 119 species are trees, and 316 species are shrubs. Short bushes lie in the semi-desert and among the xerophyte Montaigne plantation and are usually included as bushes. Seventy species in Azerbaijan dendroflora are endemics, forming 16% of the flora of the Republic (most of which are relicts) (Prilipko 1970). The full edition of three volumes on "The wood and shrub of Azerbaijan" (1964–1970) has not been completed. "Grains of Azerbaijan" (Musayev 1991), "Caucasus moss" (Askerov 2001), "Caucasian Geophytes" (Ibadli 2004), "Apiaceae family of Azerbaijan flora"

(Ibadullayeva 2004), as well as books on botanical-geographical regions of Azerbaijan – Talysh, Great and Lesser Caucasus vegetation and flora written by academician V. Hajiyev – coryphaeus of the botanical science of Azerbaijan (Hajiyev 1970, 2004) are worth noting here.

Rare and endangered species also have been researched. 140 from 400 rare species found in the Flora of Azerbaijan and have been included in the Red Book of Azerbaijan (1989). They are mainly endemics and relicts belonging to the genera: *Taxus, Celtis, Nelumbo, Rubus, Ewersmannia, Convolvulus erinaceus, Pyrus, and Buxus.* More than 125 species of rare and endangered species are planted in the Central Botanical Garden of ANAS. The garden employers have obtained the seeds of some endangered species from nature and planted these as per reintroduction method. Today flora in the Republic lies in just one to two herbaria. The species are sought through floristic expeditions and recessions, and complex measures are taken to protect them. Data on 266 of higher plant species has been given in the second edition of the Red Book of the Azerbaijan in 2013. V.M. Alizadeh, Dr. V.N. Karimov, and others have played an important role in the formation of Red List of the Caucasus (Alizade 2012).

About 10% of the species found in the Flora of Azerbaijan are regional endemics and rare plants. 143 species of 77 genera and 28 families consist real present-day endemics (Askerov 2016*):*

Alliaceae: *Allium talyschense*, *A. leonidis.*

Apiaceae: *Bunium scabrellum*, *Seseli cuneifolium.*

Asphodelaceae: *Eremurus azerbajdzanicus.*

Asteraceae: *Carduus atropatanicus*, *Centaurea araxina*, *C. kobstanica*, *C. meyeriana* (*Amblyopogon meyerianus*), *Crepis karakuschensis*, *Podospermum grossheimii (Scorzonera grossheimii*), *P. kirpicznikovii* (*Scorzonera kirpicznikovii*), *Rhaponticoides razdorskyi* (*Centaurea razdorskyi*), *Scorzonera pulchra*, *Stemmacantha zardabi* (*Rhaponticum zardabi*), *Tragopogon karjaginii*, *T. macropogon.*

Brassicaceae: *Aethionema levandovskyi*, *Atropatenia* (*Apterigia*) *rostrata* (*Thlaspi rostratum*), *Crambe grossheimii*, *Cymatocarpus grossheimii*, *Erysimum argyrocarpum*, *E. capsicum*, *E. strictisiliquıım, Dichasianhus eldarica* (*Neotorularia eldarica*), *Peltariopsis grossheimii.*

Campanulaceae: *Campanula karabaghensis.*

Caryorhyllaceae: *Dianthus talyschensis*, *Silene caespitosa*, *S. grossheimii*, *S. lencoranica, S. longidens*, *S. talyschensis.*

Chenopodiaceae: *Salsola futilis.*

Euphorbiaceae: *Euphorbia hyrcana.*

Fabaceae: *Amoria bobrovii* (*Trifolium bobrovii*), *A. talyschensis* (*Trifolium talyscheme*), *Astragalus badamliensis*, *A. bakuensis*, *A. biebersteinii*, *A. conspicuus*, *A. dzhebrailicus* (~*A. schuschensis*), *A. glochideus*, *A. karakuschensıs*, *A. kubensis*, *A. maraziensis*, *A. nachitschevanicus*, *A. neoalbanicus*, *A. zangelanus*, *A. zuvanticus*, *Lathyrus atropatanus* (*Orobııs atropatanus*), *Onobrychis heterophylla*, *O. schuschajensis*, *Securigera hyrcana* (*Coronilla hyrcana*), *Trifolium biebersteinii*, *T. caucasicum* ssp. *topczibashovii*, *T. issajevii, T. grossheimii*, *T. leucanthum (T. sachokianum*), *T. zardabii.*

Geraniaceae: *Erodium schemachense.*

Hyacinthaceae: *Ornithogalum hyrcarıum.*

Hypericaceae: *Hypericum nachitshevanicum*, *H. theodori.*

Iridaceae: *Crocus polyanthus*, *Iris camillae*, *I. hyrcana*, *I. schelkownikowii* (*I. annae*), *I. schischkinii.*

Lamiaceae: *Marrubium nanum*, *Nepeta longituba (=N. sosnovskyi*), *N. noraschenica*, *Phlomis lenkoranica*, *Salvia golneviana*, *S. suffruticosa* (*S. alexandri*), *S. vergeduzica*, *Satureja borissoviae*, *S. confinis*, *S. densiflora*, *Scutellaria daniensis*, *S. grossheimiana*, *S. karjaginii*, *S. prilipkoana*, *S. rhomboidalis*, *Stachys fominii*, *S. paulii*, *S. talyschensis*, *Thymus karjaginii.*

Lythraceae: *Ammania puhiflora*, *Lythrum schelkovnikovii*, *Peplis hyrcanica.*

Malvaceae: *Alcea lenkoranica.*

Orobanchaceae: *Orobanche transcaucasica.*

Papaveraceae: *Papaver talyschense.*

Plumbaginaceae: *Acantholimon schemachense*, *Limonium fischeri.*

Poaceae: *Achnatherum roshevitzii, Bromus tzvelevii*, *Dactylis hyrcana, Elytrigia attenuatiglumis, E. heidemaniae*, *Koeleria bitczenachica*, *Stipa issaevii*, *S. katjaginii*, *S. zuvantica.*

Polygalaceae: *Polygala grossheimii*, *P. leucothyrsa*, *P. schirvanica.*

Polygonaceae: *Calligonum bakuense* (=*C. petunnikowii*), *Polygonum caspicum* (=*P. arenastrum* ssp. *caspicum*).

Ranunculaceae: *Delphinium lomakinii.*

Rosaceae: *Crataegus talyschensis*, *Alchemilla amicta*, *A. hyrcana*, *A. jaroschenkoi*, *Rosa abutafybovii*, *R. isaevii*, *R. jaroschenkoi*, *R. mandenovae*, *R. zakatalensis*, *R. zuvandica*, *Rubus hyrcanus.*

Rubiaceae: *Asperula azerbaidjanica*, *A. hirsutiuscula*, *Galium achurense*, *G. atropatanum*, *G. bullatum*, *G. kiapazi*, *G. lencoranicum*, *G. vartanii*, *Rubia transcaucasica.*

Rutaceae: *Haplophyllum schelkovnikovii.*

Santalaceae: *Thesium maritimum.*

Scrophulariaceae: *Euphrasia karjaginii*, *E. kurdica*, *E. nisami*, *Linaria cormgata*, *L. lenkoranica*, *Scrophularia hyrcana*, *S. nachitschvanica*, *Verbascum erivanicum*, *Veronica albanica*, *V. arceuthobia.*

Main areas of subendemics unlike true endemics too are located in Azerbaijan and more or less likely to be found in the territory of neighboring countries (Appendix 17.1). One of the main characterizations of the subendemics of Azerbaijan is new for science and described only from Azerbaijan.

Subendemics are also endemics but possess unique aboriginal genofound of Azerbaijan, and their comprehensive study and defense is a must to follow. Out of the subendemic species found in the country, decreased 2.8 times endemics (405 species of 54 families and 185 genus). These are also included in the list of Caucasian endemics (Anonymous 2003, 2006). Macrotaxa are given according to APG III [APG III tidies up plant family tree].

Taxonomical analysis reveals that families with 10 or more genera with endemic species are Asteraceae (32 genus), Caryophyllaceae, and Brassicaceae (13 genus) and Apiaceae and Lamiaceae (11 genus). More subendemic species are represented by *Astragalus* (44 species), *Allium* and *Rosa* (10 species), and *Cirsium* and *Campanula* (9 species). The taxonomic ratio in subendemic family and genera is almost overlapping with real endemics. The formation and sorting process in the modern flora of the country is more intense in the abovementioned taxonomic groups. Biotypical analysis shows that more distribution of endemics in most lithophilic stasis – stone-rocky and gravelly, including limestone mountain slopes and arid landscapes. Endemics are also more concentrated in highland areas than low and middle hills, depending on the hipsometric level.

17.6 Red List of CWR

Following the intensive species formation in nature, reduction of areal of many valuable ancestor species has been endangered due to antropogenic effects on the flora during the last few decades. Many genes and gene combinations created as a result of genetic erosion of local traditional varieties and wild ancestors, multicentury evolution, and selection with reduction of diversity have got lost without substitution, and most of them are not found in modern varieties and hybrids. The destructive problems have effected Azerbaijan as well. The plant genetic biodiversity has significantly decreased during the last 50–100 years; some species and varieties have got lost or are endangered. Many examples of lost wheat varieties are known: Garagilchig (blackbone wheat), Sari bughda (yellow wheat), Agh bughda (white wheat), Girmizi bughda (red wheat), Kosa bughda (kosa wheat), etc.; barley, Gara arpa (black barley), Dagh arpasi (Mountain barley), Agh arpa (white barley), etc.; corn, Zagatala, Khojali, Khudat aghdenli (white-grained), Tovuz girmizidenlisi (red-grained), Guba aghdenli (white-grained); and paddy, Anberi, Aghenberi, Payiz enberisi, Sedri, Masalli Sedrisi, etc. Same problems, especially with vegetables and fruits like melon as well as many other fruit plants have sharply occurred. Thus, diversity in natural environments and cultivated areas is reducing day by day. Possibilities of traditional selection are almost not existent. It is very difficult to prevent this process; the use of varieties obtained by scientific selection including genetic modification to feed the world population is constantly growing with the food products continuously.

The first Red List of CWR includes 187 species from 45 genera belonging to 22 families. 42 of 187 species are included in the first edition (1989) of "Red book" of the Republic of Azerbaijan and 25 species in the second edition (2013). Comparison of the species given in both editions shows that only 49 species have been included in these editions. We must include other 134 species which are rare and endangered on CWR in the abovementioned lists in the following edition of the Red Book. Most of them are endemic and subendemic plants of the flora (552 species on republic), and they must be preserved as a unique gene pool source by the laws of the Republic of Azerbaijan.

Categories of rare, endangered, and endemic plants on international scale have been determined and measures on protection prepared. 86 seed accessions covering 12 genera and 50 species of plants are given in the table, as collectors together with their descriptors. These have been given to the National GenBank for sustainable use and reproduction as a genetic material. Creation of many important (*Vicia*, *Medicago*, *Lathyrus*, *Onobrychis*) ex situ collections of CWR has started. Below in the appendix, these are mentioned with the taxonomic families, genera, and species (Appendix 17.2).

17.7 Floragenesis and Geographical Areas

Main direction in the species formation in the flora of the country possibly is xeromorphogenesis because the process of evolution in mountainous areas is the same as in Central and Frontal Asian flora. First flora appeared mainly under the influence of Atropathic and Caucasian phytochorions as shown by the analysis of endemic species and their areal type. The Flora of Azerbaijan has floragenetical relation with xerophytic floral centers of Iran and Turkey over long geological period compared with other regions of the Caucasus. However, this idea needs to be further clarified in the general floral analysis. There are many relicts from Triassic which are found all over the territory of Azerbaijan; in particular, the Talysh zone is the main center of distribution of these elements. *Parrotia persica*, *Albizia julibrissin*, *Quercus castaneifolia*, *Zelkova carpinifolia*, *Diospyros lotus*, *Danae racemosa*, *Buxus colchica*, *Ruscus colchicus*, and *Ilex hyrcana* are elements of this period. The flora is different from other regions due to the richness in the vegetation cover of Caucasus. The emergence of flora and vegetation of Azerbaijan is also related to the geological history of the Caucasus and neighboring countries. There are not many paleobotanical and paleoantological studies on Caucasus and Azerbaijan, because fewer materials have been collected.

Historically approximately 110 million years ago at the end of the Mesozoic era, Caucasian mountains range was still developing as a result of the volcanic processes in the ancient Tethys Sea. In the Miocene, the area acquired the modern form, and mountains started rising from the sea forming a large dry part (Lesser Caucasus mountains). In general, all the mountain systems appeared in the direction of successive lines.

The paleobotanical findings suggest that Sarmatian Sea was gradually drawn in the Pontus era and East Caucasus combined with the mountain slopes of Iran, and migration of xerophytes to this area started (Hajiyev 2004). The flora of Triassic in the Caucasus was similar to the Mediterranean flora and was associated with the forest cover (Kuznetsov 1909).

Grossheim (1939) supports this idea and shows two floristic centers (west, “Colchid,” and east, “Hyrcanian”), which developed independently from each other in Triassic on the Mediterranean flora fond, as author indicated that same species found in both areas. During the Sarmatian period, three major floral states have been identified in the Caucasus, two being mesophilic states, resulting in the formation of “Colchid” and “Hyrcanian” flora. Third is xerophyte flora. Relict hygrophyte elements were replaced slowly by relict xerophyte elements in this period. The composition of flora consisted primarily of evergreen plant species: *Fagus attenuata*, *Pinus saturi*, *Cinnamomum* sp., *Laurus primigenius*, *Magnolia dianae*, and *Seguoja langsdorfii*. Relict xerophytic elements have replaced relict hygrophytes in the Mediterranean region. Young xerophyte species were at the stage of progressive development during this period, while the relict hygrophytes disappeared.

The sea began to retreat, and a small lake remained in the southern part of Caspian Sea and in the western part of Azov Sea. This way a small basin was formed at the end of Ponts era. Favorable conditions were created for the formation of xerophytic flora or desert and semi-desert plant taxa in the areas left open from the sea. The sea began to expand again during the Kuyalnichko-Akchagil era, as a result, Kuyalnichko basin in the east united with the Akchagil basin and Caspian Sea area expanded significantly. The Akchagil Sea was in the gulf in the modern Kur-Araz plain.

Radical changes from tropical conditions to mild climate took place in the Sarmat and Akchagil flora. Tropical flora did not return in the Caucasus after the Akchagil flora. Now the Kur-Araz plain flora is on the place of Akchagil floras. From that period onwards Azerbaijan has not been placed separately in the nomenclature of geographical elements for unknown reasons.

Creation of younger xerophytic desert elements – Sahara-Iran and Turan – from ancient xerophytic elements on Caucasus has been shown by Grossheim (1939). Steppe flora is youngest flora as its formation began on the end Triassic and beginning of the fourth period in the Caucasus, with the first emergence of the mountain steppe elements.

The relict plants in East Transcaucasia reveal that in the area of mesothermic relicts of Triassic arctic flora diminished and in the third mesothermic flora Tugay forest started to disappear. Xerothermic relicts – *Pinus eldarica* and *Ficus carica* – of third periods on the Kur-Araz lowland territory were destroyed, and remains of this forest are found in miocene layers (Fig. 17.3).

The elements coming from the north were mainly wet plant species. This migration may have taken place through rivers. Their migration from the south was unlikely, since these were not present at this time. The boreal elements migrated from the North to the Caucasus only during ice age. Iran and Iranian Azerbaijan have a great botanical-geographical significance, and from this territory, migration of species to Smaller Asia and Caucasus has taken place. Some saline plants *Anabasis aphylla*, *Salsola brachiata*, and more species – *Delphinium speciosum*, *Papaver orientale*, *Vicia persica*, and *Biebersteinia multifida* – are characteristic only for North Iran and Caucasus. The flora of Iranian Azerbaijan and Republic of Azerbaijan are included in the same phytochorion and have same characters, but the

Fig. 17.3 *Pinus eldarica*, territory of Lesser Caucasus

fragments of geographical elements formed in the subsequently lack Azerbaijani elements. Interaction between plants and environment in phytocenosis is very complex. Phytocenoses need to be considered from the historical point of view for better understanding the relationships, because it is not a random plant stack but the adaptation of plants to the environment in which they live during the evolutionary process. An element of any ecosystem has a special regulating mechanism to ensure its normal functioning in a continuous, changing environment. All this allows to create a single geographical element system. The system of unified geographical elements in the Flora of Azerbaijan is still not fully defined, which in some sense slows the development of phytogeographical research.

The researches of Caucasian flora following A.A. Grossheim have been followed by N.N. Portenier (2012), but geographical area of type which belongs to Azerbaijan has not been indicated. The origin of dozens of plants in Azerbaijan in the nomenclature is unknown (*Rosa nisami*, *R. sosnovskyana*, *Trigonella cancellata*, *Astragalus takhtadzhjanii*, *A. kochianus*, *A. euoplus*, *A. conspicuus*, *Astracantha flavirubens*, *A. gudrathi*, *Onobrychis buhseana*, *Rhamnus spathulifolia*, *Pimpinella anthriscoides*, *Cephalaria armeniaca*, *Campanula petrophila*, *C. zangezura*, *Asyneuma salignum*, *Conyza canadensis*, *Bombycilaena erecta*, *Filago vulgaris*, *Inula mariae*, *Xanthium spinosum*, *Helianthus annuus*, *Galinsoga parviflora*, *Anthemis altissima*, *A. tinctoria*, *Pyrethrum parthenifolium*, *P. ordubadense*, *P. coccineum*, *P. uniflora*, *Chardinia orientalis*, *Carduus seminudus*, *Cirsium turkestanicum* (=*C. schelkownikowii*), *C. tricholoma*, *C. elodes*, *C. rhizocephalum*, *Onopordum acanthium*, *Serratula haussknechtii* (=*S. transcaucasica*), *Acroptilon repens*, *Centaurea solstitialis*, *Carthamus lanatus*, *Cichorium intybus*, *Scorzonera armeniaca*, *S. parviflora*, *Lactuca serriola*, *Artemisia splendens*, *A. spicigera*, *Tussilago farfara*, *Hieracium macrotrichum*, *H. lamprocomoides*, *Arctium lappa*, *A. tomentosum* (*A. transcaucasicum*), *Taraxacum prilipkoi* (= *T. praticolum*), *T. tenuisectum*, *Sonchus asper*, *Reichardia glauca*, *Cymbolaena griffithii*, *Galium czerepanovii*, *G. consanguineum*, *G. psilophyllum*, *Cruciata laevipes*, *C. articulata*, *C. pedemontana*, *C. coronata*, *Myosotis heteropoda*, *Phelipanche ramosa*, *Plantago lanceolata*, *P. saxatilis*, *Thymus transcaucasicus*, *Vulpia hirtiglumis*).

Second edition of Flora Caucasus (1939–1967) by Grossheim is one of the greatest works. The distribution of species is systematized by the "geographical type" form. At the same time, geographical elements of some species and subspecies are commonly attributed as has been pointed out in the "Flora of Turkey" (Davis 1965–1985). Detailed information on geographical distribution and origin has been included in the flora of Italy, Africa, etc. Many taxonomists have demonstrated the importance of geoelements in the study of taxonomic groups in their research. Integrated system of geographical elements of the Caucasian flora is necessary not only for florists but also for taxonomists. From this point of view, the "Conspectus of the Caucasus Flora" occupies one of the foremost places for phytogeographical data and also for systematical knowledge of geographical distribution of species. It should however be noted that Flora of Azerbaijan is not fully evaluated in this book. Azerbaijani botanists have not generally participated in the preparation of this publication, so papers have been published in central scientific journals about new Conspectus of Caucasus Flora during 2003–2006. These types of studies are now being implemented by Azerbaijani botanists. There is still no single approach to the classification and definition of geographical elements.

The classification of vegetation proposed by Braun-Blanquet (1964) was regarded as justified from the floristic point of view by the world's botanists. The term "geographical element" is given by Portineri on the taxa of different regions – as well as phylochorions of provinces and different areas of the world. Chorionic geographical elements are considered to be fundamental in the botanical-geographical zoning of the system as phytochorions and cover the hierarchical situation according to the theory of Yurtsev and Kamelin (1991). There is no need to divide elements into non-hierarchical biological regions. It is more accurate to say that the "geographical element" is a characteristic representative of flora and vegetation of some or all phytochorions with determinated area. The species included in phytocenosis are grouped according to their systematic features, and composition differs in different geographical areas as well as in the same area, but phytocenoses end up under various environmental conditions. Similar native species are included in phytocenosis and combined into the flora's geographical elements. Analyzing the phytocenosis in terms of species origin and geographical elements is possible and thus easy to assume the history of their formation.

The determination of geographical element and component of flora for a species is one of the most important tasks. The "flora of phytochorions" or regional natural flora should be taken as a basis. There is still no such system for the Flora of Azerbaijan, and the species are placed according to the areal type of Grossheim (1939) and Portenier (2012). In the new publication of "Flora of Azerbaijan," it is definitely necessary to specify the geographical types of floral collection. For example, in phytocenosis, the European steppe (Pontic), European broadleaf forest (nemoral), coniferous forest (boreal), and other elements are involved which must be grouped into regional groups; the origin should also be taken into account. To which province or provincial phytochorion Azerbaijan belongs? All three provinces – Armenia-Iran, Hyrcan, and Iran-Turan – are closely related to the phytochorion of Azerbaijan, but nowhere Azerbaijan is mentioned. Azerbaijan phytochorion is in the center of the Armenian-Iranian province, and for the first time, hundreds of species of Azerbaijani flora have been described; these species are still kept in the Herbarium of the Institute of Botany of ANAS.

The zoning is not the same as the natural phenomenon; it is also separated into territorial units, compatible with each other. For some or all of the phytochorions and their boundaries, the botanical-geographical needs to be considered for true assessment together with the single principle position and tolerance of species. At the same time, each territorial unit of the floristic zoning must express itself in a single space and point out one line on the map. In this case, the presence of transitional zones and mosaics is noticeable, and most likely, the Azerbaijani flora in the system of geographical elements is also reflected.

Different phytochorions exist, depending on the altitude of mountain system. Some workers mention that the location of mountainous areas in the botanical-geographical zoning should be taken as the main criterion (Engler 1872). Main characteristic of the Mediterranean Sea region in terms of botanical-geographical zoning is the existence of a zone consisting of evergreen forests. The main formation of the lower mountain zone of the Mediterranean Sea Region is the evergreen xerophilic *Quercetea* and *Quercetea-Pinasetum* forest formations, the xerophyte bush groups formed in the area of the phrygana plants and the broken woods. The plant types are also characterized in the Mediterranean Sea areal. *Quercus* forests are in the place named as “Mediterranean” zone near the Mediterranean Sea, at little higher places European-type long-haul forests (peanuts, chestnuts), on top-coniferous forests, subalpine bushes, and in some places which highland meadows with phrygana elements are dominating. Forest zones in the flora of Azerbaijan correspond to this system. However, other grasses are present in those forest areas which cannot be placed in this system, because their geographical range does not correspond to the same type, where extensive propagation and adaptation are also given. Some species are considered to be derivatives of the Mediterranean flora. Location and boundaries of this province in botanical-geographical distribution system cannot be regarded as fully resolved. The solution of this problem can be successfully achieved by comparing the floras on comparative geographical analysis with the approach of both the state and the separate regions. All this should be reflected in the new edition of “Flora of Azerbaijan.” The problem of transition zones among the phytochorions is important for endemism. Some authors have used the advantage of sub-Mediterranean Sea (Meusel and Jager 1989), but others take up the advantage of Mediterranean Sea (Gagnidze 1974). The Flora of Azerbaijan is closely related to both.

Conformity and proximity between the propagation of flora of phytochorion and the proliferation of species belong only to this flora. Nonconformity and discrepancy between propagation of a phytochorion and presence of two or more phytochorion are the characteristic features of the associated species. Undoubtedly these two differences between these two concepts have been chosen conditionally. For example, the associated species of a province can be regarded as full-fledged elements of that province in the floral analysis at provincial level. It is understood from this that all species that cover two states and more are associated with this or the species "may be listed as" related species in the two provinces and in the more extensively populated species. If we only determine the geographical elements in accordance with the above systems, what kind of geographical type and connection can be found? For example, *Thymus hyemalis* is an African-type species and was first described in Italy (Ibadullayeva et al. 2008, 2012, 2014; Askerova 1977; Ibragimov 2005). In our view, the boundary between the "geographical element" and "associated species" is conventional. For species belonging to one or another geographical element, we need to gather up-to-date information first about the general distribution of the species, and then the common domains of the species are to be associated with botanical-geographical zoning based not only on scientists but on personal opinion as well. There are some species whose boundaries are more or less likely to fit within the boundaries of the phytochorion, but not just the range of many species, even the centers of abundance, do not conform to the limits of such phytochorions.

A deeper analysis of the distribution of species should be carried out. For example, conditions of species in different parts of the area, collecting specific data about species distribution, ecological, phytosynthetic compatibility in different parts of the area, characteristic, and specific role of plant groups in these or other phytochorions, must be revealed. Following this analysis, the issue about the fact to which geoelement the species can be considered can be solved to some extent. In some cases, we also address the issue of kinship and the spread of nearby species "phylogenetic relationship." We think phylogenetic communication is one of the main conditions for the choice of geographical element, area groups. In fact, the proper identification of the diagnostic signs of the species is one of the directions of the development of geographical systems. Right conclusion is possible with the results from molecular studies.

Azerbaijan has 70% of the Caucasus flora, which is only 1/6 of the total. Its flora is surrounded by Iran-Turan, Frontal Asia, South-East Asia, and Caucasus; there is also a very different vegetative cover compared to the Caucasian countries. Other reasons for this wealth are different climate and soil parameters in the region. The number of endemics is much higher than other Caucasian countries (Ibadullayeva and Mammadli 2011; Ibadullayeva and Babakishiyeva 2013). The development of Flora of Azerbaijan took place as a result of migratory elements from the Mediterranean on one hand and migrations of elements from Iran, Turkey, Central Asia, and Caucasus on the other hand. Most of the areal types are found in the flora of Republic: ancient forest, boreal, steppe, xerophyle (Mediterranean Sea elements), desert, Caucasus, and adventive.

17.8 Plant Cover

Relict representatives of Triassic are high in Azerbaijan and are found everywhere in the country, but the Talysh zone is the main center of distribution of these elements: *Parrotia persica*, *Albizia julibrissin*, *Quercus castaneifolia*, *Zelkova carpinifolia*, *Diospyros lotus*, *Danae racemosa*, *Buxus colchica*, *Ruscus*, and *Ilex*.

Talysh flora differs from other regions by the number of relict and endemic species. In the territory of Diabar-Zuvand −1107, Lankaran lowland −1205, and 1107 species in mountainous parts of Lankaran. Hyrcanian territory creates exception with its forests.

From 1950 to 2010, extensive studies were done on the Lankaran mountain and Diabar botanical-geographical region. Geobotanical studies conducted in Talysh since the beginning of this period are by Prilipko (1970). The forest ecosystem of the Talysh have also been studied during the investigations:

17.8.1 Classification of Vegetation of Talysh Forest

Formation 1. *Quercetea*
Association:

1. *Quercetum nudum*
2. *Quercetum euphorbiosum-Euphorbia amygdaloides*
3. *Fageto-Quercetum mespiloso-crataegosum*
4. *Ptericaryeto-Quercetum vario-herbosum*
5. *Parrotieto-Quercetum nudum*
6. *Tilieto-Quercetum ilexosum*
7. *Carpineto-Quercetum nudum*

Formation 2. *Carpinetea*
Association:

1. *Parrotieto-Carpinetum nudum*
2. Acereto-Carpinetum *buxusosum*
3. *Parrotieto-Carpinetum carexosum*
4. *Acereto-Tilieto-Carpinetum vario-herbosum*
5. *Diospyreto-Carpinetum dryopteriosum*

Formation 3. *Parrotietea* forest
Association

1. *Carpineto-Parrotietum carexosum*
2. *Alneto-Carpineto-Parrotietum violosum*
3. *Alneto-Parrotietum ruscusosum*
4. *Parrotietum ruscuso-euphorbiosum*

Formation 4. *Fagetea* forest
Association:

1. *Acereto-Capineto-Fagetum brachypodio-carexosum*
2. *Tilieto-Querceto-Fagetum euphorbiosum*
3. *Tilieto-Acereto-Fagetum epimediosum*
4. *Tilieto-Acereto-Fage-tum asperolosum*
5. *Capineto-Fagetum rubosum*
6. *Fagetum ilexosum*
7. *Fagetum nudum*

Formation 5. *Ptericaryetea* forest
Association:

1. *Ptericaryetum vario-herbosum*

Formation 6. *Alnetea* forest
Association:

1. *Alnetum ruscusosum*
2. *Acereto-Alnetum vario-herbosum*
3. *Pteryicaryeto-Alnetum vario-herbosum*

Formation 7. *Diospyretea*
Association:

1. *Diospyretum vario-herbosum*

Formation 8. *Aceretea* forest
Association:

1. *Fageto-Aceretum rubosum*
2. *Fageto-Aceretum ilexosum*
3. *Diospyreto-Aceretum carexosum*
4. *Fageto-Aceretum festucosum*
5. *Fraxineto-Aceretum carexosum*

Formation 9. *Zelkovetea* forest
Association:

1. *Parrotieto-Zelkovetum nudum*

Formation 10. *Buxetea* forest
Association:

1. *Buxetum nudum*

Formation 11. Walnut forest – *Juglancetea*
Association:

1. *Juglancetum vario-herbosum*
2. *Juglancetum heracleosum*

The Nakhchivan Autonomous Republic is one of the regions with rich natural resources of flora and vegetation. The biodiversity of this area has reached its modern state through a very complicated historical path. The analysis of recent literature sources reveals that 2835 species from 170 families and 874 genera are found in region (Talibov and İbrahimov 2008). Endemics have a special status among these. C*arduus atropatanicus*, *Centaurea araxina*, *Crepis karakuschensis*, *Aethionema buschianum*, *Astragalus chalilovii*, *Hypericum atropatanum*, *H. nachithshevanicum*, *Ferula oopoda*, *F. szowitsiana*, *Dorema glabrum*, *Stenotaenia macrocarpa*, *Prangos acaulis*, *Heracleum albovii*, *Grammosciadium platycarpum*, *Eryngium wanaturii*, *Astragalus badamliensis*, *A. nachitschevanicus*, *A. paradoxus*, *A. szovitsii*, and *A. regelii* are the typical ones (Ganbarov 2014; Talibov and İbrahimov 2010; Ibadullayeva and Mammadli 2011; Seyidov et al. 2014).

The experiments have been done to study the plants of Nakhchivan Autonomous Republic for many years. The study of the herbaceous and herbal species has been done at length, in particular from Zangazur and Daralayaz mountain zones. Vegetation of Nakhchivan and the Gilanchay basins have been studied well (Gurbanov 2004; Ismayilov 2007). Forest and meadow vegetation has been recorded. *Festucetum sulcatae* formation near Batabat lake, in Salvarti, Ayrigar, Ag Karvansaray, and Agdaban territory, has been fully studied. For legumes-motley grass-cereal formation of high mountain meadow have been recorded; for Agdaban territory, also 17 species *Poa pratensis*, *Carex vesicaria*, *Trifolium spadiceum*, *Rumex alpinum*, *Cerastium arvense*, and *Gladiolus kotschyanus* are worth mentioning. Twenty-nine species including *Betonica grandiflora*, *Potentilla hirta*, *Trifolium canescens*, *Lotus ciliatus*, *Koeleria caucasica*, *Polygonum alpinum*, *Cerastium araraticum*, and many others constitute the mesophyllous subalpine meadow vegetation for *Betoniceto-stachydetum* formation of Salvarti territory. Classification of forest vegetation of plain, foothills, and mountain zones of Nakhchivan Autonomous Republic is listed below:

17.8.2 Formation Class: Deciduous Mountain Forests

Formation: *Quercetea macrantherae*
Association:

1. *Quercus macranthera*
2. *Quercus macranthera-Acer ibericum-Fraxinus excelsior*
3. *Quercus macranthera-Fraxinus excelsior-Ulmus minor*
4. *Quercus macranthera-Fraxinus excelsior-Sorbus aucuparia*
5. *Quercus macranthera-Crataegus meyeri-Pinus kochiana*
6. *Quercus macranthera-Crataegus meyeri-C. sanguinea*

Formation: *Crataeguetea meyeri*
Association:

1. *Crataegus meyeri-C. sanguinea-C. orientalis*
2. *Crataegus orientalis-Malus orientalis-Pyrus syriaca-P. nutans*
3. *Crataegus meyeri-C. sanguinea-Quercus macranthera-Malus orientalis-Pyrus syriaca*
4. *Crataegus meyeri-Crataegus orientalis-Quercus macranthera.*

Formation: *Fraxinetea excelsior*
Association:

1. *Fraxinus excelsior*
2. *Fraxinus excelsior-Quercus macranthera*

Formation class: *River coastal and forests*
Formation: *Salicetea albae-Salix alba*
Association:

1. *Salix alba-S. triandra-S. caprea*
2. *Populeta nigra*
3. *Salix alba-Populus nigra*
4. *Salix triandra-S. caprea-Fruticosus*

Formation: *Ulmetea glabra*
Association: *Ulmus glabra-U. scabra-Salix triandra-S. caprea*

Formation class: mountain woodland
Formation: *Junipereta foetidissima*
Association:

1. *Juniperus foetidissima-J. communis-J. excelsa*
2. *Juniperus foetidissima-Quercus macranthera*
3. *Juniperus foetidissima-J. communis-Acer ibericum-Quercus macranthera*
4. *Juniperus foetidissima-J. communis-Pyrus salicifolia-Quercus macranthera*

Formation: *Pyretea.*
Association:

1. *Pyrus nutans-P. syriaca-P. pseudosyriaca-Crataegus meyeri*
2. *Pyrus nutans-P. syriaca-Crataegus meyeri-Malus orientalis*

Formation: *Maletea orientalis*
Association:

1. *Malus orientalis-Crataegus meyeri-Quercus macranthera*

Formation class: Forest thickets
Formation: *Aceretea ibericum*
Association:

1. *Acer ibericum-Euonymus latifolia-Padus avium*
2. *Acer ibericum-Crataegus meyeri-Prunus divaricata-Quercus macranthera*

Arid rare forests (pistachio, juniper) are found on the slopes of Greater and Lesser Caucasus. The pistachio-motley grass forest is preserved in the Turyanchay Reserve; six species of juniper, each with a height of 6–7 m, are found here. Main species of open-light and rare forests on the slopes of Great and Lesser Caucasus are *Pistacia mutica* and various species of *Juniperus* sp. Cherry, lilac, sumac, nasty, and more others are included here in the rare forest.

The typical unique forest formed by the *Pinus eldarica* in the Eldar Reserve is clearly marked in the form of isolated patches. Tugay forests are spread along the large rivers (Kur, Araz, Alazan), coastal areas possess narrow, ribbon-shaped patches with mulberry, peppermint, peppers, and crown, and many are mixed with bushes. Tugay forests in Azerbaijan are sometimes represented by bushes like *Elaeagnus angustifolia*, *Tamarix ramosissima* (= *T. pentandra*), *T. smyrnensis* (= *T. hohenackeri*), *Berberis vulgaris*, *B. iberica*, *Hippophae rhamnoides*, and *Pyracantha coccinea*. Lianes often found in Tugay forest, particularly *Vitis silvestris*, *Cynanchum acutum*, *Solanum persicum*, *Pterocarya pterocarpa*, and *Alnus subcordata*. Sometimes these plants form fortified groups and develop along the coast of Talysh River. Another species *Alnus barbata* is less common in these areas but is typical for mud forests of Talysh. Local endemic species are formed in forests on the coastal parts of Talysh and include *Ficus hyrcana*, *Humulus lupulus*, *Sambucus ebulus*, *Carex* ssp., *Cardamine* ssp., and *Poa* ssp. The *Juncus grex* forms the swamp group of *Juncetum* which is quite abundant. *Quercus longipes* lies in the leafy forests in the form of spots in Guba-Khachmaz lowland, Garabagh forest massif, and Alazan-Avtoran valley. *Quercus longipes* species are mixed with *Acer velutinum* var. *van-volxemii*, *Tilia caucasica*, *Fraxinus excelsior*, *Ulmus minor* (= *U. suberosa*), and *Pyrus caucasica* in Alazan-Avtoran valley. Here the bushes are more common: *Crataegus* sp., *Mespilus germanica*. and others. The lians found here are *Smilax excelsa*, *Hedera helix*, *Clematis vitalba*, and *Vitis silvestris*. This group is reminiscent of the plain forest of Talysh.

Quercus pubescens and other forms are also found besides *Quercus longipes* in Guba-Khachmaz forest. Grapevine, sometimes *Carpinus caucasica*, *Acer campestre*, *Pyrus caucasica*, *Corylus avellana*, *Crataegus*, and *Mespilus germanica* are found in plain oak forest; from lians only *Hedera pastuchowii* is recorded here (Ibadullayeva and Mustafayev 2014).

Quercetum longipesum associations, *Morus alba*, *Elaeagnus angustifolia*, *Crataegus* ssp., *Prunus divaricata*, and *Punica granatum* are mixed in Karabakh forest massif, with lians – *Smilax excelsa* and *Vitis silvestris*, but *Tamus communis* is more in alder tree forest of Talysh. The relict types of Hirkan forest are worth mentioning here; it is found not only in Talysh but also in south part of Great Caucasus. *Parrotia persica* and *Quercus castaneifolia* are characteristic for the Talysh plains. *Carpinus caucasica*, *Zelkova carpinifolia*, *Z. hyrcana*, *Ulmus elliptica*, and *Prunus caspica* are encountered in the Hirkan forest. Evergreen bushes *Ruscus hyrcana* and *Danae racemosa* join in the lower parts of the forest. Species of *Crataegus*, *Cydonia*, *Mespilus*, *Smilax*, *Periploca*, *Rubus*, *Vitis*, and *Hedera* genera are more characteristic for bushy cover, and for this territory, grasses are more. *Diospyros lotus* typically produces woods in more shady and wet slopes. *Gleditsia* *caspica* forms a free forest in the Talysh. *Albizia julibrissin* mixes on the slopes toward the sea. *Tilia platyphyllos* and endemic *T. prilipkoana* develop here as a component. *Acer velutinum* is above the sea level, and *Fagus orientalis* flourishes on the northern slopes. *Taxus baccata* is widely seen in front and lower mountain slopes of Talysh, together with *Buxus hyrcana*.

The broad-leaved forest with the abundance of *Fagus orientalis* is spread above sea level 800–1800 m in Talysh, Greater, and Lesser Caucasus mountains. *Fagus* forest forms 32% of the total forest areas of the Republic and is described in many different variants, including *Fagus orientalis*, *Acer platanoides*, *Carpinus caucasica*, *Tilia caucasica*, *Ulmus glabra*, *Danae racemosa*, *Euonymus latifolia*, and *Sambucus nigra*, and forms associations with *Hedera pastuchovii* species. Pearl, fennel, yellow rhododendron, blackberries, and perennials – *Festuca drymeja* (=*F. montana*), *Galium odoratum* (=*Asperula odorata*), *Sanicula europaea*, *Geranium robertianum*, *Brachypodium sylvaticum*, *Viola odorata*, *Salvia glutinosa* – and other species are encountered in the *Fagus* forest.

Oak forest and peanut forests are widely spread. *Quercus iberica* and *Carpinus caucasica* are together forming a broad strip on the middle mountain ranges. They are encountered on the southern and southeastern slopes of all mountain ranges. Georgian oak is replaced by *Quercus macranthera* which forms park-type forest in the highest mountain zone between 1800–2000 (2200) m. *Betula litwinowii*, *B. pendula*, and other *Betula* sp. which are found here with *Acer trautvetteri*, and usually *Sorbus aucuparia* woodlands also develop.

Platanus orientalis forest reaches 25–30 m in height in 150–200 years old trees in the Zangilan region, Basichay valley, and its branches. Current situation is not clear because this territory has been illegally occupied.

Pinus eldarica and *P. sosnovskyi* conifers are well distributed. *Pinus eldarica* is found at 600 m a.s.l. in Steppe plateau (west part of Republic) and *P. sosnovskyi* at 1600 m a.s.l. alongside the Goygol and Kurekchay shores in the Lesser Caucasus, as well as in the middle mountain ranges of the Balkan region in the Greater Caucasus (Ibadullayeva and Babakishiyeva 2013; Ibadullayeva et al. 2014). Besides *Taxus baccata* and *Juniperus* sp. also found here. The last species is widespread in southern Lesser Caucasus. Evergreen bushes of *Rhododendron* are found in the subalpine zone of Greater Caucasus (in the Zagatala and Balkan districts) and in some places form mixed bushes with *Vaccinium myrtillus*, and *V. idae*. The last two are described from alpine zone and are found at 1800–3200 m a.s.l. in subalpine, alpine meadows, and grassy meadows. In the upper forests, we come across places covered by grass forming forest meadows together with tall grass.

Grass and forest elements included in the above forest meadows are *Calamagrostis arundinacea*, *Brachypodium sylvaticum*, *Agrostis tenuis* (=*A. capillaris*), *Poa nemoralis*, *Koeleria macrantha* (=*K. gracilis*), *Deschampsia sukatschewii* (*D. caespitosa*), *Juncus effuses*, *Vicia sepium*, *Trifolium repens*, *Cephalaria gigantea*, *Filipendula ulmaria*, and *Verbascum* sp. The primary and secondary occurrence of heifer is observed in tall grasses. The secondary tall grasses are found on polluted area of anthropogenic character, formed as a result of adverse human activities. Primary tall grasses species include *Heracleum* (13 species in Republic)

(Ibadullayeva 2004), *Aconitum orientale*, *Delphinium flexuosum*, *Knautia heterotricha*, *Cephalaria gigantean*, *Dactylis glomerata*, *Senecio platyphyllus*, *Doronicum macrophyllum*; secondary are *Urtica*, *Rumex*, *Dryopteris*, and *Cirsium* genera. Real subalpine meadows are found in all mountain zones and massifs in dozens of varieties. Subalpine plants include various grasses, mild-humid grains, mixed grains, damp diversity, mesophylls pulsed and blooming forms, excessively humid, cryoptophytic subalpine, and reinforced subalpine meadows. Characteristic meadow elements are *Bromopsis variegata*, *Koeleria albovii*, *Agrostis tenuis* (=*A. capillaris*), *Trifolium ambiguum*, *Stachys macrantha*, *Taraxacum vulgum*, *Nardus stricta*, *Festuca versicolor*, *Carex tristis*, *Plantago* sp., *Ranunculus caucasicus*, *Coronilla varia* + *Myosotis alpestris*, *Anthyllis lachnophora*, *Alchemilla* sp., *Hordeum violaceum*, *Poa alpina*, *Phleum alpinum*, *Cirsium* sp., *Potentilla* sp., *Veronica gentianoides*, *Geranium platypetalum*, *Campanula* sp., *Origanum vulgare*, *Viola purpurea*, *Rumex* sp., *Scabiosa caucasica*, *Carum carvi*, *Veratrum lobelianim*, *Colchicum speciosum* + *Allium* sp., *Pastinaca armena*, *Verbascum* sp., *Gentiana* sp., *Inula helenium*, *Silene* sp., *Anemone fasciculata*, *Thymus* sp., *Leontodon hispidus*, *Centaurea fischeri*, etc.

Meadow vegetation of subalpine zone is different in biodiversity on the bases of abundance of varying relief elements and associated microclimatic features. For example, species of subalpine meadows of Dashkasan districts is subdivided from others (Ibadullayeva 2004). Medicinal and the species of *Carum* genus – *Carum carvi*, *C. caucasicum*, *C. komarovii*, and *C. carvi* ssp. *rosellum* – are found in Khoshbulag forests of this territory.

Vegetation of the alpine zone is widespread at an altitude of 2400–3200 m above sea level and represented by the meadow and alpine mat-shaped elements. The plant occurs mainly on low slopes, on the surfacing tops, mountain slopes at such altitudes. Alpine vegetation of the Republic is represented in two variants: alpine meadows and mat formations.

Low grass alpine meadows formation through different edificators – *Carex tristis* + *Festuca ovina* and etc., mixed *Poa alpina* + *Bromopsis variegata*, *Festuca versicolor* + *Elyna schoenoides* + *E. capillifolia*, *Kobresia humilis* and etc. Low-growing plants also meet here besides these edificators: *Myosotis alpestris*, *Veronica gentianoides*, *Gnaphalium supinum*, *Taraxacum stevenii*, *Trifolium ambiguum*, *Alchemilla caucasica*, *Potentilla erecta*, *Polygala alpicola*, *Festuca airoides*, and *Koeleria albovii*.

The carpales are expressed in the two group formations: typical alpine in the soil substrate (peanut, shaggy, hawthorn, cranberry) and stone rocks in stone substrate (Ibragimov 2005). *Carum caucasicum*, *Campanula tridentata*, *Alchemilla caucasica*, *Sibbaldia parviflora*, *S. semiglabra*, *Macrotomia echioides*, *Plantago saxatilis*, *Primula algida*, and *Ranunculus oreophilus* participate in both formations. The characteristic of plants rock mass and rocks develops at an altitude of 3200 m asl. Representatives of higher plants are rarely found here. Lichens and mosses are commonly found as pioneers of rock vegetation. Mosses, lichens, and mushrooms are in lower ranges as well. The Talysh and Nakhchivan areas are flora-rich; composition of the forest plantations in these two areas differs dramatically from one another. However, sedimentary rocks are made up of similar elements.

Bushes are formed in Samur-Shabran lowland as narrow stripes compared with another botanical-geographical district of Republic in alluvial meadow-forest, meadow-steppe, and steppe soils between seaside sandy-steppe phytocenoses. Two formation classes, three formation groups, and eight associations were registered in the plant classification: *Tamarix ramosissima*, *Elaeagnus angustifolia-Tamarix ramosissima*, *Rubiseta anatolicus-Tamarix ramosissima*, *Rubiseta anatolicus*, *Tamarix ramosissima-Rubus anatolicus-Elaeagnus angustifolia*, and *Paliurus spina-christi*. Species composition of the formation of the bushes is shown in Table 17.3.

There are numerous lakes and swamps in the Kur-Araz lowlands, near the Caspian Sea and other plains with rich vegetation (Nabiyeva and Ibadullayeva 2012a, b). Water-marsh plants are well distributed in such territories. This type of vegetation is intrazonal and is found in semi-desert plants in the form of small spots along the Tugay (coastal) forests, large rivers, canals, ports, and streams. On the banks of the canals, *Arundo donax*, and, in the marsh, *Phragmites australis* (= *P. communis*) are common. The remnants form large, tall (about 3 m), and hard-to-reach jungles occur in some places. There are very few other species. *Cressa cretica*, *Alopecurus myosuroides*, *Wolffia arrhiza*, and *Typha* can be seen in these bushes. The savannah tall *Eriantus purpurascens*=*Saccharum ravennae* although rarely are also found here. *Cynodon dactylon*, *Glycyrrhiza glabra*, species of *Scirpus*, and *Bolboschoenus maritimus* are spread well in the Kur-Araz lowlands. Other plant is the cane bush. *Limonium meyeri*, *L. scoparium*, species of genus *Iris*, *Polygonum patulum*, *Stachys palustris*, *Lythrum salicaria*, and others are commonly found in Karabakh lowlands; *Halostachys caspica*, *Halocnemum strobilaceum*, *Salicornia europaea*, *Suaeda altissima*, and *Kalidium caspicum* often occupy wet saline areas of eastern Transcaucasia.

Species of *Typha* (especially *Typha angustifolia* and others) are more commonly found alongside the ponds and ports (Shabran port). *Nelumbium caspicum*, *Nymphaea alba*, *Nymphoides peltatum*, *Utricularia vulgaris*, *Salvinia natans*, and others are characteristic for the lower lakes of Kur river. Typically, lotus forms clean dense groups with the presence of very few other plants and creates beautiful sight during flowering time at the beginning of June. Lotus cover is a relict association surviving from Triassic.

The marshes are also widespread in the Talysh botanical-geographical plains. These are represented by *Potamogeton pectinatus*, *Myriophyllum spicatum*, *Trapa hyrcana*, *Ceratophyllum demersum*, all widespread here. *Iris pseudacorus* is another species of swamps spread over Talysh together with *Sparganium erectum* and *S. polydrum*. Main elements of this association are *Ranunculus ophioglossifolius*, *Buschia lateriflora*, *Lippia nodiflora* var. *canescens*, *L. nodiflora* var. *reptans*, *L. nodiflora* var. *rosea*, *Mentha aquatica*, *Polygonum minus* = *Persicaria minor*, and *Alisma plantago-aquatica.*

Water-mash vegetation is found around wetlands, mainly in the low, middle, and higher mountainous, alpine, and subalpine zones. Representatives of these plants

Table 17.3 Species composition and structure of formations of shrub vegetation type

Tamarisk-strawberry-blackberry – Oleaster formations (by *Elaeagnus angustifolia* domination, territory of Khachmaz districts, shrubs till psammophyte phytocenosis at the edge of the Caspian Sea in the basin of the Gudyalchay river)					
No	**Biomorph species**	**Ecol. Groups**	**Abundance (by ball)**	**Tiers and height of ground part (sm)**	**Phenology phase**
Bushes					
1	*Elaeagnus angustifolia*	Psammophyte	4	I (300)	Flow.
2	*Elaeagnus caspica*	Psammophyte	3–4	I (250)	Flow.
3	*Rubus anatolicus*	Xerophyte	2–3	I (120)	Flow.
4	*Tamarix ramosissima*	Mesoxerophyte	2	I (100)	Flow.
5	*Crataegus pentgyana*	Xerophyte	1–2	I (180)	Flow.
6	*Caragana arborescens*	Mesoxerophyte	1–2	III (60)	Veget.
7	*Prunus divaricata* ssp. *caspica*	Xerophyte	1	II (150)	Fruit
Perennial grasses					
8	*Phragmites australis*	Hydrophyte	1–2	I (110)	Veget.
9	*Iris carthalinal*	Hydrophyte	1–2	II (70)	Flow.
10	*Alhagi pseudalhagi*	Mesoxerophyte	1–2	II (40)	Veget.
11	*Cynodon dactylon*	Mesophyte	1–2	III (30)	Flow.
12	*Medicago corelea*	Mesophyte	1–2	III (20)	Flow.
13	*Trifolium vulgare*	Hydrophyte	1	III (15)	Flow.
14	*Plantago lanceolata*	Mesoxerophyte	1	III (10)	Flow.
15	*Aeluropus reflexiaristata*	Mesophyte	1	III (5)	Veget.
Annual grasses					
16	*Galium verticillatum*	Mesoxerophyte	1–2	III (20)	Flow.
17	*Calendula persica*	Xerophyte	1–2	III (15)	Flow.
18	*Torilis heterophylla*	Mesophyte	1–2	III (10)	Veget.
Projective cover – 70–80%					

are described for more than 100 marshes: Goygol, Alagol, Maralgol, and Zelligol massifes in Lesser Caucasus; Halagol in the Greater Caucasus; and Batabat, Ganligol and Goygol (Ordubad), Salvartigol, and others in the Nakhchivan Autonomous Republic. This vegetation type is divided into two subtypes: (1) water plants and (2) marsh plants.

Formation classes: Overwater, floating on the water and drowning in the water, real water vegetation
Formation: *Typhetea laxmannii*
Association:

1. *Typha laxmannii* + *Typha minima* + *T. latifolia*
2. *Typha laxmannii* + *Phragmites australis*
3. *Typha laxmannii* + *Poa trivialis*

Formation: *Lemnetea minor*
Association: *Lemna minor* + *L. trisulcata*

Formation: *Persicarieta hydropiper*
Association: *Persicaria hydropiper*

Formation: *Potamogeton nodosu*s
Association:

1. *Potamogeton nodosu*s
2. *Potamogeton crispus*

Formation classes: Water-marsh vegetation that lives both on land and in water
Formation: *Bolboshoeneta maritimus*
Association: *Bolboschoenus maritimus* + *Typha laxmannii* + *Phragmites australis*

Formation: *Eleocharetea palustris*
Association: *Eleocharis palustris*

Formation: *Cyperetea longus*
Association: *Cyperus longus*

Formation classes: Coastal water-marsh vegetation
Formation: *Juncetea effusus*
Association: *Juncus effusus* + *J. bufonius*

Formation: *Phragmitetea australis*
Association: *Phragmites australis* + *Carex vesicaria*

Formation classes: Subalpine and alpine vegetation
Formation: *Senecietea racemosus*
Association: *Senecio racemosus*

Formation: *Luzuletea spicatae*
Association: *Luzula spicata* + *Carex canescens* + *Elitrigia caespitosa*
Formation: *Saginetea procumbens*

Association: *Sagina procumbens*
Formation: *Calthetea polypetalae*
Association: *Caltha polypetala*

Wormwood and *Gypsophila* semi-deserts cover large areas of Kur-Araz, Near Caspian sea, Nakhchivan AR, and other plains. Low bush deserts are typical for low-seaweed sandy beaches and wet saline soils. Chenopodiacae species are typically dominant for these *Gypsophila* deserts. Desert vegetation type includes 16 formation groups and 19 associations. Main formations are *Salsoleta-Petrosimonietum*, *Salicornia europaea*, *Ephemereta-Petrosimonietum*, and *Artemisieta-Petrosimonietum*. *Salsola* formation is an edificator of different saline vegetation, but sometimes *Artemisia* develops more in some areas. Both spread in small or heavily saline gray soils. *Halocnemetum* is characteristic for *Gypsophila* deserts and develops more on saline areas. *Halocnemum strobilaceum* shrub creates large hills on saline soils of much coincidence in Lokbatan lowland and the steppe zone of Mugam. The small bushes of *Kalidium caspicum* develop in the *Kalidium* desert and are also found in smaller spots on the Caspian coast. Large bushes of *Halostachys caspica* form *Halostachysetum*-type deserts on lowland areas. Unlike the two desert formations mentioned above, this phytocenosis contains five to six species of ephemerals and ephemeroids. This formation is a characteristic for Eastern Transcaucasia. *Suaeda microphylla* and *S. dendroides* bushes form the deserts in the Kur-Araz lowland and on strong saline slopes of mountain and low hills. *Salsola ericoides* spreads on saline areas in the western (Jeyranchol, Acinohur) and eastern (Shirvan, Mil, Mughan plains) regions (Gasimzade 2015; Akhmedova 2011).

Mountain *Salsoletum* formations (*Salsoletum nodulosae*) are formed by small bushes of *Salsola nodulosa*. This plant is adapted to saline mountain slopes and is widespread, especially in the Gobustan foothills, in the Ceyranchol and Acinohur steppes. *Salsoletum dendroides* covers a wider area, being adapted to the degraded soils and landscapes. The composition of Karagan group is usually enriched by ephemerals. In addition, this plant forms mixed groups with wormwood, snuff, as well as species of *Alhagi* sp.; *Glycyrrhiza glabra* species joins the species of *Petrosimonia* genus and *Salsola crassa* (*Climacoptera crassa*), which are more characteristic for lowlands. *Seidlitzia florida* is found on pastures of Shaki district plateau.

Artemisium is the most common type of semi-desert plantation. It develops on saline gray soils forming pure wormwood semi-deserts and sometimes mixed with diffuse and complex transitional forms of *Gypsophila* semi-deserts. *Artemisieto-Salsoletum dendroides* is a mixed variant of desert, and *Artemisieto-Salsoletum ericoides* and *Artemisieto-Salsoletum noduloseta* associations are distributed in Kur-Araz lowlands (Nabiyeva and Ibadullayeva 2012a, b). Mixed species of *Artemisieto-Stipetum lessingiana* and *Artemisieto-Botriochloa ischaemum* are found in the foothills of Gobustan, Jeyranchol, and Nakhchivan Autonomous Republic. Ephemerals and efemeroids – *Poa bulbosa*, *Eremopyrum orientale*, *E. triticeum*, *Anisantha rubens* (*Zerna rubens*), *Erodium cicutarium*, *Bromus japonicus*, *Torularia contortuplicata*, *Medicago minima*, and *M. sativa* var. *coerulea* – occur in all wormwood formations and also form natural semi-desert landscape. This formation develops on brown, light brown, and gray soils and surrounding sand dunes of Caspian sea. It is possible to observe on all stages, from soft toughness to sandboxes. *Convolvulus persicus*, *Tournefortia sibirica*, *Astragalus hyrcanus*, *A. igniarius*, endemic species *Astragalus bakuensis*, *Convolvulus persicus*, *Tournefortia sibirica*, *Astragalus hyrcanus*, *A. igniarius*, and *A. bakuensis* are found on such hills. At present, most of these areas are used for agricultural purposes.

The semi-desert vegetation is mixed with the steppe vegetation on Jeyranchol and Bozgir plateaus and forms semi-steppe (dry steppe). Semi-steppe groups are formed by perennial herbs (Ibadullayeva and Babakishiyeva 2013). The perennial motley grass, *Medicago transcaucasica*, *Centaurea reflexa*, *Gypsophila stevenii*, and *Teucrium polium* ssp. *polium*, and from annuals – *Sideritis montana*, *Minuartia montana*, and *Meniocus linifolius* – all found here besides other plants as main edificators of semi-steppe. These groups are mixed with *Festuca rupicola*, *F. sulcata*, and *Stipa* species (*Stipa caspia*, *S. szovitsiana*), from annuals – *Festuca rupicola*, *F. sulcata*, and *Stipa* species (*Stipa caspia*, *S. szovitsiana*) on slightly higher territories.

The tall bushes of *Chrysopogon gryllus* change the floristic composition depending on the slopes of the mountain on the plateaus of Sheki districts. These bushes are mixed up with perennial grasses on the southern slopes (*Stipa caspica*, *S. szovitsiana*) and a little above with *Agropyron cristatum*, *Botriochloa ischaemum*, and steppe formation. *Potentilla recta*, *Cruciata glabra*, *Stipa capillata*, *Galium verum*, *Filipendula vulgaris*, *F. hexapetala*, *Astragalus multijugus*, *A. stevenianus*, *Medicago transcaucasica*, *Kochia prostrata*, *Salvia nemorosa*, *Onobrychis cyri*, and *O. vaginalis* are the components of motley grass forming semi-steppe in the north. Steppe vegetation is also found in the middle (mat grass) and upper (andropogon) mountain zone. Grassy meadows are found in the upper mountain ranges. Major edificators of the high mountain here are *Festuca rupicola*, *F. sulcata*, *F. supina*, *F. kotschyi-F. ovina*, and *F. varia*. Latter species forms the steppe grass. *Koeleria macrantha* (*K. gracilis*), *Artemisia princeps* var. *orientalis*, *Thymus vulgaris*, *Pimpinella rhodantha*, *Plantago lanceolata*, *Phleum phleoides*, *Cruciata glabra*, and *Onobrychis* sp. are included in steppe vegetation in all variants.

Lichens and tragachanthic types are in the in phrygana type mountain-xerophyte vegetation, which develops in the hot dry areas of the Republic (Nakhchivan, Zuvand). Asian types of tragachanths have developed in the Republic. The small thorn bushes are characteristic for this cenosis, often associated with sainfoin and *Astragalus*. Grossheim (1939) refers *Acantholimon* sp. to the tragachant group. The joint development forms a specific grouping. *Astragalus aureus* is particularly important in the formations of large-sized bushes in the upper mountain ranges. *Astragalus microcephalus* is spread in patches on the middle and lower mountain slopes. *Astragalus andreji* and some other species are not important in the formation of groups, because they have not large areas. *Festuca rupicola* (*F. sulcata*) and species of *Thymus* genus are typical entering the gaps between the tragachanthic bushes of phrygana steppe. *Hedysarum cornutum* is found in lowland like Daridag (near Julfa, Nakhchivan) and Daglig Karabakh (Nagorno-Karabakh). It typically forms a characteristic group on rocky or stony habitats and little mown slopes.

The larger areas of mountain xerophytes in the Nakhchivan Autonomous Republic are overwhelmingly fragmented, diverse as for the varieties of phrygana. There are following species found here: *Halimiphyllum atriplicoides* + *Zygophyllum atriplicoides* + *Adenia glauca* + *Salsola glauca* + *Salvia dracocephaloides* + *Astragalus szovitsii*, clay-rock slopes *Amblyopogon xanthocephalus* + *Hedysarum formosum* + *H. atropatanum* + *Hypericum scabrum* + *Stachys fruticulosa*, stone and rocky areas *Stachys inflata* + *Onobrychis transcaucasica*, and finally the dominants like *Thymus kotschyanus* and *Satureja macrantha*. Besides these dominants in all variants, *Pyrethrum marrubium* + *Lactuca* sp. + *Achillea* sp. + *Phlomis* sp. + *Cousinia* sp., and other species are widely distributed.

Shiblak type occupies small areas as compared to the phrygana in the Republic because these are generally cut by vinegrowers. Their representatives in Nakhchivan Autonomous Republic are *Amygdalus fenzliana*, *Rhamnus pallasii*, *Atraphaxis spinosa*, *Cotoneaster racemiflora*, *Spiraea crenata*, *Caragana grandiflora*, and *Colutea komarovii* all in the low mountain zones of Greater and Lesser Caucasus.

17.9 Conclusions

There is a significant change in the formation and associations occurring in the present-day plant diversity of Azerbaijan when compared with the data covering the last 100 years. It seems that the perennial, annual, and biennials found in different vegetation types play an important role in the formation of vegetation in the country. Significant changes in the formations and associations of present-day vegetation of Azerbaijan have been enlightened during the revision of vegetation when compared with the studies conducted 100 years ago.

Appendices

Appendix 17.1: Caucasus and Near-Border Terrestrial Endemics of Azerbaijan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
	Alliaceae		
1	*Allium dictyoprasum*	2, 4, 5 – Stony-rocky areas	Atropatan
2	*A. egorovae*	5 – Motley grass	Atropatan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
3	*A. kunthianum*	1–3, 5 – Mountain meadow, rocks	Caucasus
4	*A. lenkoranicum*	4 – Stony slopes	Hirkan
5	*A. leucanthum*	1–5 – Dry slopes	East Mediterranean Sea
6	*A. mariae*	2, 5 – Dry, rocky places	Atropatan
7	*A. materculae*	5 – Sandy-clay slopes	Atropatan
8	*A. saxatile*	1 – Dry grassy slopes	Caucasus – Lesser Asia
9	*A. szovitsii*	1, 2, 5 – High mountain meadow and steppey	Caucasus – Lesser Asia
	Amaryllidaceae		
10	*Sternbergia alexandrae*	1, 3 – Dry slopes	Albania
	Anacardiaceae		
11	*Pistacia mutica*	1–3, 5 – Dry slopes	Medit. Sea – Iran
	Apiaceae		
12	*Angelica sachokiana*	1 – Rock cracks	Eastern Caucasus
13	*Aphanopleura trachysperma*	5 – Clay soils	Atropatan
14	*A. zangelanica*	2 – River valley	South Transcauc.
15	*Cachrys caspica*	1, 3 – Coastal plants	Eastern Caucasus
16	*C. microcarpa*	1–5 – Arid clay-stony slopes	Caucasus – Lesser Asia
17	*Carum komarovii*	2 – Subalpine and alpine plant	Caucasus
18	*Dorema glabrum*	5 – Stone-rocky places	Atropatan
19	*Ferula caucasica*	1 –dry slopes	Atropatan
20	*F. oopoda*	5 – Gypsum-stony slopes	Iran – Turan – Caucasus
21	*F. szowitsiana*	5 – Stone-rocky places	Atropatan
22	*Malabaila sulcata*	1, 2, 5 – Clay-limestone slopes	Caucasus – Lesser Asia
23	*Peucedanum pauciradiatum*	2, 5 – Stone-rocky slopes	Atropatan
24	*Pimpinella aromatica*	1, 2, 5 – Clay-stony slope	Eastern Caucasus
25	*P. grossheimii*	4 – Stone-rocky slopes	Atropatan
26	*Symphyoloma graveolens*	1 – Stone mounds	Caucasus
	Aquifoliaceae		
27	*Ilex hyrcana*	2, 4 – In forest	Hirkan
	Araliaceae		
28	*Hedera pastuchowii*	1,4 – Woodlands	Caucasus – Hirkan
	Asparagaceae		
29	*Asparagus ledebourii*	1 – Coastal plants	Albania
	Aspidiaceae		
30	*Dryopteris caucasica*	1, 3, 4 – Woodlands	Caucasus
31	*D. raddeana*	5 – In shady forests	Hirkan
32	*Polystichum kadyrovii*	4 – Hirkan forest	Hirkan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
	Asteraceae		
33	*Amberboa nana*	1, 3, 5 – Dry gravel, clay soaking soil	Caucasus – Front Asia
34	*A. sosnovskyi*	3, 5 – Gravel saline places	Atropatan
35	*Amblyocarpum inuloides*	1, 4 – Places of the forest	Hirkan – Eastern Caucasus
36	*Anthemis fruticulosa*	1 – Clay-roofed, rocky places	Caucasus
37	*Bellis hyrcanica*	4 – coastal phytocenosis	Atropatan
38	*Calendula persica*	1–4 dry gravel and sowing areas	Caucasus – Front Asia
39	*Carduus beckerianus*	4 – In the forests	Hirkan
40	*C. hystrix*	4 – Arid stones-rocky places	Iran – Turan
41	*Carthamus oxyacanthus*	1–3, 5 – Arid clay places, gardens, and arable land	Iran – Turan
42	*Centaurea rhizantha*	4, 5 – Stone rocky places	Turan – Caucasus
43	*Cirsium aduncum*	1, 2, 4, 5 – Gravel, bushes	Turan – Caucasus
44	*C. argillosum*	1 – Lime livestock plant	Eastern Caucasus
45	*C. elodes*	1, 2, 4, 5 – Damp places	Turan – Caucasus
46	*C. lappaceum*	1 – Grassy slopes, mountain meadows	Turan – Caucasus
47	*C. macrocephalum*	1 – Rocky places, stony slopes	Eastern Caucasus
48	*C. rhizocephalum*	1–5 – High mountain meadows	Turan – Caucasus
49	*C. sorocephalum*	4, 5 – Grassy slopes	Iran – Turan
50	*C. strigosum*	1– Rocks, arid slopes, wormwood	Caucasus
51	*C. szovitsii*	1–5 – Grassy slopes, riverbanks bushes	Turan – Caucasus
52	*Cladochaeta candissima*	1 – River valley and coastal sand dunes	Caucasus
53	*Cousinia araxena*	5 – Stone-rock places	Atropatan
54	*C. chlorocephala*	5 – Mountain steppe, meadows	Atropatan – Caucasus
55	*C. cynaroides*	1, 2, 4, 5 – Arid clay-stone slope	Caucasus – Iran – Turan
56	*C. erivanensis*	5 – Arid slope	Atropatan
57	*C. hohenackeri*	4 – Arid slope	Atropatan
58	*C. iljinii*	5 – Gypsum, clay soil	Atropatan
59	*C. macrocephala*	1, 2, 4, 5 – Arid clay and stone slope	Atropatan
60	*C. macroptera*	5 – Stone slope, wormwood	Atropatan
61	*C. pterocaulos*	4 – Arid slope, river valley	Hirkan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
62	*C. purpurea*	5 – Arid rock and stone slope	Atropatan
63	*Echinops bipinnatus*	4 – Arid places	Atropatan
64	*E. opacifolius*	5 – Arid stone slope	Atropatan
65	*Erigeron talyschensis*	4 – Arid slope	Atropatan
66	*Garhadiolus papposus*	5 – Plain, arid places	Turan – Caucasus
67	*Helichrysum araxinum*	4, 5 – Arid stone slope	Atropatan
68	*H. armenium*	2, 4, 5 – Arid gravelly slope	Atropatan
69	*H. plicatum*	4, 5 – Arid clay, gravelly, and rock slope	Atropatan
70	*Heteracia szovitsii*	5 – Arid stone, sandy places	Atropatan
71	*Hieracium cincinnatum* (*H. syreistschikovii*)	2, 4, 5 – Rock cracks	Atropatan
72	*H. macroradium*	4 – Forest	Hirkan
73	*H. rubrobauhini*	2,4 – Bushes	Caucasus – Lesser Asia
74	*H. sericicaule*	2 – Arid places	Caucasus
75	*H. subrubellum*	2 – Arid places	Northern Atropatan
76	*Jurinea spectabilis* (*J. grossheimii*)	2, 5 – Rock slope	Caucasus
77	*Kemulariella rosea*	1 – Rock cracks	Eastern Caucasus
78	*Lactuca wilhelmsiana*	5- forest, bush, juniper woodlands	Caucasus – Iran
79	*Onopordum cinereum*	1, 4 – Arid mountain slope	Atropatan
80	*O. heteracanthum*	1–5 – Roadside, sandy beaches	Caucasus – Iran
81	*Picris strigosa*	2, 4, 5 – Arid clay, stone, rock	Caucasus – Turan
82	*Podospermum canum*	1–3, 5 – Clay-stone slope	Caucasus – Avropa
83	*Psephellus karabaghensis*	2 – Forest, mountain meadows	Caucasus – Iran
84	*P. zuvandicus*	4 – Stone-rock places	Atropatan
85	*Pyrethrum komarovii*	2, 5 – On the rock	Southern Transcauc.
86	*P. meyerianum*	1 – Stone places	Albania
87	*P. ordubadensie*	2, 5 – Rocky places	Southern Transcauc.
88	*Senecio grandidentatus*	1–5 – Forest and bushes, garden and river valleys	Caucasus – Avrasiya
89	*S. kubensis*	1 – Rock slope	Caucasus
90	*S. lipskyi*	5 – Gravelly slope, stone mounds	Atropatan
91	*Serratula caucasica*	1 – Arid slope	Eastern Caucasus
92	*S. coriacea*	5 – Arid gravelly slope	Atropatan
93	*Stemmacantha pulchra*	1, 2, 4 – Stone slope, mounds	Caucasus – Iran
94	*Tanacetum leptophyllum*	1 – Subalpine meadow	Caucasus

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
95	*Taraxacum desertorum*	1, 3–5 – Roadside, arched spaces	Turan – Caucasus
96	*Tomanthea spectabilis*	5 – Arid gravelly grassy slope	Caucasus – Turan
97	*Tragopogon collinus*	1, 4 – Coastal sandy	Caucasus – Turan
98	*T. coloratus*	2, 4, 5 – Arid slope	Caucasus – Turan
99	*T. marginatus*	5 – Arid places	Atropatan
100	*T. nachitschevanicus*	5 – Stone-gravelly mounds	Southern Transcauc.
101	*T. pusillus*	1, 3, 5 – Arid slope	Caucasus – Eurasia
	Betulaceae		
102	*Alnus barbata*	1, 3, 4 – Forest	Hirkan – Evksin
103	*A. subcordata*	4 – Hirkan forest	Hirkan
	Boraginaceae		
104	*Echium amoenum*	4 – Bushes, meadow	Hirkan
105	*Heliotropium szovitsii*	2, 5 – Arid slope	Atropatan
106	*Nonea alpestris*	1 – Meadow and stone places	Eastern Caucasus
107	*N. decurrens*	4 – Mountain meadows	Atropatan
108	*N. flavescens*	1–4 – Saline places	Caucasus – Turan
109	*Onosma gracilis*	5 stone-rock places	Atropatan
110	*O. levinii*	1 – River valley	Eastern Caucasus
111	*Solenanthus brachystemon*	4 – Forest	Hirkan
112	*Suchtelenia calycina*	1, 3 – Arid, clay, saline places	Turan
113	*Symphytum peregrinum*	2–5 – Bushes	Hirkan
114	*Trigonocaryum involucratum*	1 – Stone slope	Eastern Caucasus
	Brassicaceae		
115	*Aethionema edentulum*	5 – Arid stone-rock places	Atropatan
116	*Cardamine tenera*	2, 4 – Riverbank moist places	Hirkan – Evksin
117	*Crambe armena*	5 – Clay -gypsum soil	Southern Trasncauc.
118	*C. gibberosa*	1 – Arid slope	Eastern Caucasus
119	*Draba incompta*	1 – On the rock	Eastern Caucasus
120	*D. mollissima*	1 – Rock and stone places	Eastern Caucasus
121	*Erophila minima*	1, 3 – Wormwood phytocenosis	Iran – Turan
122	*E. praecox*	1, 3, 4 – Wormwood phytocenosis	Iran – Turan
123	*Erysimum babadagense*	1 – Stone-rock places	Eastern Caucasus
124	*Isatis karjaginii*	5 – Rock places	Atropatan
125	*I. latisiliqua*	1, 4, 5 – Arid, clay, stone slope	Eastern Caucasus –Atropatan
126	*I. ornithorhynchus*	5 – Arid sandy – Stone places	Atropatan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
127	*Pseudovesicaria digitata*	1 – Gravelly slope	Caucasus
128	*Raphanus rostratus*	4 – Coastal places	Hirkan
129	*Sameraria glastifolia*	1–3, 5 – Stone-clay soils	Atropatan
130	*Sterigmostemum acanthocarpum*	5 – Clay – Stone slope	Atropatan
131	*Strigosella intermedia*	1, 3, 5 – Arid clay-stone places	Turan – Caucasus
132	*Moricandia meyeri*	2, 4, 5 – Arid clay-gravelly places	Atropatan
	Campanulaceae		
133	*Asyneuma pulchellum*	2, 4, 5 – Phrygana	Turan – Caucasus
134	*Campanula armena*	2, 4, 5 – Rock cracks	Atropatan
135	*C. bayerniana*	2, 5 – Alpine	Atropatan
136	*C. caucasica*	1, 3, 4 – Subalpine meadow	Caucasus
137	*C. ciliata*	1 – Highland meadow	Caucasus
138	*C. kolenatiana*	1 – Rock cracks	Eastern Caucasus
139	*C. meyeriana*	1 – Limestone rock	Eastern Caucasus
140	*C. minsteriana*	5 – Limestone rock	Southern Transcauc.
141	*C. schelkownikowii*	2 – Arid slope	Caucasus
142	*C. stevenii*	1–4 – Arid meadow	Turan – Caucasus
	Caprifoliaceae		
143	*Lonicera bracteolaris*	2, 5 – Stone-rock places	Iran – Turan
	Caryophyllacea		
144	*Acanthophyllum mucronatum*	2, 4, 5 – Stone-gravelly places	Iran – Turan
145	*Allochrusa versicolor*	5 – Stone-gravelly places	Atropatan
146	*Arenaria graminea*	4, 5 – Stone–gravelly places	Atropatan
147	*Dichodon schischkinii*	5 – Highland pastures	Atropatan
148	*Cerastium szowitsii*	2, 5 – Stone-gravelly places	Atropatan
149	*Dianthus cyri*	3, 5 – Sandy places	Caucasus – Front Asia
150	*D. raddeanus*	2, 5 – Meadow	Caucasus – Atropatan
151	*D. schemachensis*	1 – Clay-stone places	Albania
152	*Gypsophila capitata*	1, 5 – Arid-claystone	Eastern Caucasus
153	*G. lipskyi*	2, 5 – On the rock	Atropatan
154	*G. szovitsii*	2, 3, 5 – Sandy-clay slope	Atropatan
155	*Holosteum marginatum*	1–3, 5 – Arid stone slope	Iran – Caucasus
156	*Lepyrodiclis holosteoides*	4, 5 – River coastal	Atropatan – Caucasus
157	*Minuartia lineata*	2, 4, 5 – On the rock	Atropatan
158	*M. sclerantha*	1, 3–5 – Stone-sandy places	Iran – Turan
159	*Paronychia splendens*	4, 5 – Stone-rock places	Caucasus – Front Asia
160	*Saponaria cerastoides*	4 – Bushes	Hirkan – Evksin

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
161	*S. viscosa*	2, 4, 5 – Stone places	Atropatan
162	*Silene caucasica*	1, 5 – Stone-rock places	Eastern Caucasus
163	*S. lacera*	1, 2 – Clay slope	Caucasus
164	*S. marschallii* (*S. praestans, S. propinqua*)	1, 2, 4, 5 – Arid-stone slope	Atropatan
165	*S. meyeri*	4, 5 – Rock cracks	Atropatan
166	*S. schafta*	4 – Forest, rock cracks	Hirkan
167	*S. tatjanae*	1,5 – Limestone slope	Atropatan
168	*S. tenella*	4 – Stone slope	Southern Transcauc. – Iran
	Celastraceae		
169	*Euonymus velutina*	2–4 – Forest and bushes	Iran – Turan
	Chenopodiaceae		
170	*Anabasis eugeniae*	5 – Clay soils	Atropatan
171	*Anthochlamys polygaloides*	4 – Arid–stone slope	Iran – Turan
172	*Beta lomatogona*	4 – Stone slope	Atropatan
173	*B. macrorhiza*	1 – Bushes	Caucasus – Atropatan
174	*Panderia pilosa*	4, 5 – Dumpy places	Caucasus – Front Asia
175	*Salsola camphorosma*	5 – Stone slope	Atropatan
176	*S. nodulosa*	1, 3, 5 – Winter pastures	Caucasus
	Corylaceae		
177	*Carpinus schuschaensis* (*C. geoktschaica*)	1, 2, 4 – Deciduous forests	Hirkan – Eastern Caucasus
	Crassulaceae		
178	*Sedum lenkoranicum*	4 – Forest	Hirkan
179	*S. obtusifolium*	1, 4 – Rock-gravelly places	Iran – Caucasus
180	*S. stevenianum*	1 – Gravelly, rock cracks	Caucasus
181	*S. subulatum*	1, 2, 4, 5 – Stone – Rock slope	Caucasus– Lesser Asia
	Cyperaceae		
182	*Carex acrifolia*	1 – Meadow	Caucasus
183	*C. caucasica*	1, 2 – Subalpine meadows	Caucasus – Front Asia
184	*C. phyllostachys*	1, 4 – Shady forest	Caucasus – Hirkan
185	*Schoenoplectus grossheimii*	4 – Marsh	Hirkan
	Dipsacaceae		
186	*Cephalaria grossheimii*	4 - arable land	Atropatan
187	*Scabiosa hyrcanica*	4 – Mountain xerophyte plantation	Hirkan
	Euphorbiaceae		
188	*Andrachne buschiana*	5 – Arid-stone slope	Atropatan
189	*A. filiformis*	5 – Carbonate stone slope	Atropatan
190	*Euphorbia azerbajdzhanica*	5 – Arid-stone places	Atropatan
191	*E. grossheimii*	5 – Arid slope	Atropatan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
192	*E. iberica*	1, 2, 3, 5 – Forest and bushes	Caucasus
193	*E. ledebourii*	2 – Stone – Rock places	Caucasus
194	*E. marschalliana*	4, 5 – Arid slope	Atropatan
	Fabaceae		
195	*Albizia julibrissin*	4 – Hirkan forest	Hirkan
196	*Astragalus achundovii*	5 – Arid – Stone place	Atropatan
197	*A. argyroides*	5 – Arid – Stone place	Atropatan
198	*A. aznabjurticus*	5 – Limestone rock	Southern Transcaucas.
199	*A. barnassari*	4 – Damp rocky places	Atropatan
200	*A. brachypetalus*	2 – Bushes	Turan – Caucasus
201	*A. brachytropis*	1 – Meadow	Caucasus
202	*A. caraganae*	4, 5 – Clay-stone places	Atropatan
203	*A. caspicus* (*A. theodorianus*)	1–4 – Clay-stone places	Atropatan – Caucasus
204	*A. chalilovii*	5 – Lime rocks	Atropatan
205	*A. cuscutae*	1 – Stone-gravelly slope	Albania
206	*A. declinatus*	2, 5 – Stone-gravelly slope	Atropatan
207	*A. denudatus*	1 – Stone-gravelly slope	Caucasus – Lesser Asia
208	*A. eugenii*	1 – Stone-gravelly slope	Eastern Caucasus
209	*A. euoplus*	2, 5 – Stone-gravelly slope	Atropatan
210	*A. finitimus*	2, 5 – Stone-gravelly slope	Atropatan
211	*A. hohenackeri*	4 – Stone-gravelly slope	Atropatan
212	*A. humilis* ssp. *thedodori*	1 – Stone-gravelly slope	Albania
213	*A. igniarius*	1, 3 – Coastal sandy	Eastern Transcaucas.
214	*A. kabristanicus*	1 – Arid stone slope	Albania
215	*A. karabaghensis* (*A. jucundus*)	2, 4, 5 – Stone-clay places	Atropatan
216	*A. karjaginii* (*A. barba-caprina*)	5 – Arid stone places	Atropatan
217	*A. macrosephalus* (*A. johannis*)	1 – Arid grassy slope	Turan – Caucasus
218	*A. macrourus*	4 – Arid grassy slope	Atropatan
219	*A. megalotropis*	4 – Arid – Stone slope	Atropatan
220	*A. mesites*	2, 5 – Stone-gravelly arid places	Atropatan
221	*A. meyeri*	2, 4 – Rock places	Atropatan
222	*A. montis-aquilis*	5 – Lime rock cracks	Atropatan
223	*A. multijugus*	4 – Clay-gravelly place	Atropatan
224	*A. onobrychioides*	1 – Arid slope	Eastern Caucasus
225	*A. ordubadensis*	2, 5 – Limestone places	Atropatan
226	*A. persicus*	4, 5 – Rock cracks	Atropatan
227	*A. podocarpus*	4 - arable land	Atropatan
228	*A. polyphyllus*	1, 5 – Bushes	Albania
229	*A. prilipkoanus*	2, 5 – Stone-gravelly places	Atropatan
230	*A. refractus*	4 - stone – Gravelly places	Atropatan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
231	*A. rostratus*	4 – Arid slope	Atropatan
232	*A. rzaevii*	2 – Clay-stone slope	Atropatan
233	*A. sachokianus*	1 – Clay-stone slope	Alban
234	*A. sanguinolentus*	1, 2 – Clay-stone slope	Eastern Caucasus
235	*A. schemachensis*	1 – Clay-stone slope	Albania
236	*A. szovitsii*	5 – Gravelly-stone slope	Atropatan
237	*A. theodorii*	1 – Clay-stone slope	Eastern Transcaucas.
238	*A. torrentum*	5 – Stone slope, rock cracks	Atropatan
239	*A. xiphidium* (*A. husseinovii*)	1,2, 4 – Arid-stone slope	Eastern Transcaucas.
240	*Colutea komarovii*	5 – Stone-gravelly slope	Atropatan
241	*Medicago caucasica*	1–5 – Arid-stone slope	Caucasus – Atropatan
242	*M. glutinosa*	1, 5 – Clay-stone slope	Caucasus
243	*Onobrychis atropatana*	2, 5 – Arid-stone slope	Atropatan
244	*O. hohenackeriana*	2, 4 – Arid-stone slope	Atropatan
245	*O. komarovii*	1, 2 – Arid-stone slope	Eastern Transcaucas.
246	*O. vaginalis*	1, 3 – Arid-stone slope	Albania
247	*Trifolium echinatum*	1–4 – Meadow, damp places	–
248	*Vavilovia formosa*	1 – Gravelly mounds	Caucasus
249	*Vicia ciceroidea*	5 – Stone south slope	Atropatan
250	*V. hololasia*	1, 2 – Among weed plants	Eastern –Mediterranean Sea
251	*V. loiseleurii*	1, 4 – Snowblow bushes	Caucasus
	Fagaceae		
252	*Quercus castaneifolia*	1, 4 – Forest	Caucasus – Hirkan
253	*Q. macranthera*	1, 2, 4, 5 – Forest	Caucasus – Lesser Asia
	Gentianaceae		
254	*Gentianella umbellata*	1, 4 – Mountain meadow	Caucasus– Lesser Asia
	Geraniaceae		
255	*Erodium fumaroides*	1 – Meadow	Eastern Caucasus
	Hamamelidaceae		
256	*Parrotia persica*	2, 4 – Deciduous forests	Hirkan
	Hyacinthaceae		
257	*Bellevalia fominii*	1–4 – Clay slope	Atropatan
258	*B. longistyla*	5 – Stone slope	Atropatan
259	*Hyacinthella atropatana*	5 – Gravelly slope	Atropatan
260	*Muscari caucasicum*	1, 2, 4, 5 – Xerophyte, gravelly	Atropatan
261	*Ornithogalum schelkovnikovii*	5 – Forest-meadows	Atropatan
262	*O. sintenisii* (=*O. esxcarpum* = *O. sibthorpir* = *O. schischkinii*)	1, 2, 4 – Forest-bushes	Hirkan
263	*Scilla caucasica*	1, 2, 4, 5 – Forest and bushes	Caucasus – Hirkan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
264	*S. hohenackeri*	3, 4 – Forest and bushes	Caucasus – Hirkan
265	*S. mischtschenkoana*	5 – Rock cracks	Atropatan
	Iridaceae		
266	*Crocus caspius*	4 – Stone-rock places	Hirkan
267	*Iris acutiloba*	1, 3 – Sandy-clay places	Eastern Caucasus
268	*I. alexeenkoi*	2 – Bushes	Caucasus
269	*I. atropatana*	5 – Stone slope	Atropatan
270	*I. grossheimii*	5 – Grassy slope	Atropatan
271	*I. helena*	2, 3, 4, 5 – Wormwood semi-deserts	Turan – Caucasus
272	*I. lycotis*	5 – Wormwood semi-deserts	Atropatan
273	*I. prilipkoana*	5 – Mountain meadow	Southern Transcaucas.
274	*I. pseudocaucasica*	5 – Gravelly slope	Atropatan
	Lamiaceae		
275	*Betonica nivea*	1 – On the rock	Caucasus
276	*Dracocephalum botryoides*	1, 5 – Stone-rock places	Eastern Caucasus
277	*Lamium hyrcanicum*	4 – Hirkan forest	Hirkan
278	*L. transcacucasicum*	5 – Rock shadow	Atropatan
279	*Marrubium parviflorum*	2, 4, 5 – Stone-rock places	Atropatan
280	*M. propinquum*	2, 3, 4 – Clay-stone places	Atropatan
281	*Nepeta betonicifolia*	4, 5 – Gravelly-stone slope	Atropatan
282	*N. cyanea*	1, 5 – Stone mounds	Eastern Caucasus
283	*N. stricifolia*	5 – Stone slope, mountain meadow	Southern Transcaucas.
284	*N. supina*	1 – Alpine rock	Caucasus
285	*Salvia limbata*	2, 4, 5 – Stone-rock places	Atropatan
286	*S. nachiczevanica*	5 – River valley	Atropatan
287	*S. transcaucasica*	5 – Meadow and grassy slope	Atropatan
288	*S. verbascifolia*	2 – Forest and bushes	Caucasus– Lesser Asia
289	*Satureja intermedia*	4 – Gravelly-stone slope	Atropatan
290	*Scutellaria oreophila*	1 – Mountain meadow	Caucasus
291	*Stachys persica*	4 – Forest and bushes	Hirkan
292	*S. setifera*	4, 5 – River valley	Caucasus – Front Asia
293	*Thymus fedtschenkoi*	2 –lime rock	Northern Atropatan
294	*T. hadzhievii*	1 – Stone place	Eastern Transcaucas.
295	*T. karamarjanicus*	1, 3 – Stone place	Eastern Caucasus
296	*T. kjapazi*	2 –lime rock	Northern Atropatan
297	*T. trautvetteri*	4 – Gravelly rock	Atropatan
298	*Ziziphora serpyllacea*	1, 2 – Arid-stone slope	Caucasus – Front Asia
	Liliaceae		
299	*Fritillaria grandiflora* (*F. kotschyana*)	4 – On the rock places in forest	Atropatan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
300	*Gagea alexeenkoana*	1, 2, 4, 5 – Arid-clay slope	Caucasus
301	*Lilium ledebourii*	4 – Forest thickets	Hirkan
302	*Tulipa eichleri*	1, 3, 5 – Grassy slope	Caucasus
	Linaceae		
303	*Linum subbiflorum*	5 – Alpine meadows	Atropatan
	Malvaceae		
304	*Alcea kusariensis*	1 – Bushes, forest glade	Albania
	Melanthiaceae		
305	*Merendera candidissima*	4 – Arid slope	Atropatan
306	*M. eichleri*	1 – Arid-clay slope	Albania
	Oleaceae		
307	*Fraxinus coriariifolia*	1, 4 – Forest	Eastern Mediterranean
	Orchidaceae		
308	*Cephalanthera caucasica*	1, 2, 4	Caucasus – Hirkan
309	*Dactylorhiza incarnata* ssp. *baumgartneriana*	1 – Mountain meadow	Caucasus
	Orobanchaceae		
310	*Cistanche flava*	3 – Sandy places	Eastern Transcaucas.
	Paeoniaceae		
311	*Paeonia tomentosa*	4 – Forest glade-bushes	Hirkan
	Papaveraceae		
312	*Papaver schelkownikowii*	1–3 – Arid slope, wormwood semi-desert	Eastern Transcaucas.
	Pinaceae		
313	*Pinus eldarica*	2 – Stone-rock places	Caucasus
	Plumbaginaceae		
314	*Acantholimon fominii*	1, 2 – Clay-stone slope	Eastern Caucasus
315	*A. tenuiflorum*	1, 2 – Arid, clay, gravelly slope	Northern Atropatan
	Poaceae		
316	*Achnatherum ordubadense*	5 – Rock cracks	
317	*Aegilops strangulata*	1–5 –grassy arid places	Turan – Caucasus
318	*Avena bruhnsiana*	1 – Coastal sandy	Turan – Caucasus
319	*Bromopsis aristata*	1 – Forest and bushes	Caucasus
320	*B. nachiczevanika*	4, 5 – Stone slope	Atropatan
321	*B. woronowii*	4, 5 – Stone – Gravelly slope	Caucasus – Front Asia
322	*Rostraria cristata* ssp. *glabriflora*	4 – Stone slope	Eastern Mediterranean Sea – Iran – Turan
323	*R. cristata* ssp. *subcapitata*	3 – Sea coastal sandy	Eastern Transcaucas.
324	*Stipa transcaucasica*	4, 5 – Stone-rock places	Atropatan
	Polygalaceae		
325	*Polygala hohenackeriana*	1, 3, 5 – Arid clay-stone places	Iran – Turan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
	Ranunculaceaes		
326	*Anemone kuznetzowii*	2 – Arid slope	Northern Atropatan
327	*Delphinium foetidum*	2, 5 – Stone mounds	Atropatan
328	*D. nachiczevanicum*	5 – Stone slope	Atropatan
329	*D. szowitsianum*	2, 4, 5 – Bushes, rock	Atropatan
330	*D. talyschense*	3–5 – Grassy slope	Atropatan
331	*D. tomentellum*	1 – Forest glade	Eastern Caucasus
332	*Pulsatilla albana*	1 – Alpine meadow	Caucasus
333	*Ranunculus crassifolius*	3, 4 – Damp places	Caucasus Mediterranean Sea
	Rosaceae		
334	*Alchemilla raddeana*	2, 5 – Rock places	Northern Atropatan
335	*Cotoneaster meyeri*	1, 2, 4 – Forest and bushes	Caucasus
336	*C. morulus*	1 –forest and bushes	Caucasus
337	*C. saxatilis*	1,2,5–bushes, stone places	Southern Transcaucas.
338	*Crataegus eriantha*	1, 2 – Bushes, stone places	Atropatan
339	*C. szovitsii*	2, 5 – Bushes, stone places	Atropatan
340	*Pyrus acutiserrata*	5 – Forest and bushes	Southern Transcaucas.
341	*P. eldarica*	3 – Juniperus-arid slope	İberiya
342	*P. grossheimii*	4 – Mountains deciduous forests	Hirkan – Southern Transcaucas.
343	*P. hyrcana*	4 – Forest glade	Hirkan – Southern Transcaucas.
344	*P. medvedevii*	5 – Rock places	Southern Transcaucas.
345	*P. vsevolodi*	1 – Deciduous forests	Eastern Caucasus
346	*Sorbus caucasica*	1, 2, 4 – Forest and bushes	Caucasus
347	*S. shemachensis*	1 – Limestone rock and bushes	Eastern Transcaucas.
348	*Rosa alexeenkoi*	1 – Forest glade	Eastern Caucasus
349	*R. azerbaijanica*	1, 2, 4, 5 – Stone slope	Northern Atropatan
350	*R. gadzhieviii*	2 – Deciduous forests	Caucasus
351	*R. glanduloso-setosa*	4 - deciduous forests	Caucasus
352	*R. iljinii*	1 –bushes	Eastern Caucasus
353	*R. karjagini*	5 – Gravelly-stone slope	Atropatan
354	*R. komarovii*	1, 2 – Stone mountain slope	Eastern Caucasus
355	*R. nizami*	2, 5 – Mountain forest	Caucasus
356	*R. prilipkoana*	1, 2, 4 – River coastal	Caucasus – Hirkan
357	*R. sachokiana*	1. 2, 5 – Between the bushes	Caucasus – Iran
358	*R. sosnovskyi*	1 – Hooked jungle	Eastern Transcaucas.
359	*Rubus persicus*	4 – Forest and bushes	Hirkan
360	*R. raddeanus*	4 –bushes	Hirkan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
	Rubiaceae		
361	*Crucianella chlorostachys*	2, 3, 5 – Arid stone slope	Turan – Caucasus
362	*C. exasperata*	4, 5 – Arid stone slope	Atropatan
363	*C. suaveolens*	4, 5 – Arid stone slope	Atropatan
364	*Galium apsheronicum*	1 – Coastal sandy	East Transcaucas.
365	*G. brachyphyllum*	1 – Rock cracks	Caucasus
366	*G. czerepanovii*	5 – Rock cracks	Atropatan
367	*G. eldaricum*	1 – Stone-gravelly slope	Eastern Transcaucas.
368	*G. hyrcanicum*	2, 4, 5 – Stone-gravelly slope	Hirkan – South Transcaucas.
369	*Karamyschewia hedyotoides*	1, 3, 4 – Dump places	Iran – Turan
370	*Neogaillonia szowitzii*	2, 5 – Arid slope	Atropatan
371	*Rubia rigidifolia*	5 – Stone slope	Southern Transcaucas.
	Rutaceae		
372	*Haplophyllum kowalenskyi*	5 – Sandy – Stone places	Atropatan
373	*H. schelkovnikovii*	5 – Clay slope	Atropatan
374	*H. villosum*	1–5 – Arid stone and bushes	Caucasus – Front Asia
	Salicaceae		
375	*Populus hyrcana*	4 – River valley	Hirkan – Evksin
376	*Salix caucasica*	1 – Dump places	Caucasus
377	*S. kuznetzowii*	1 –dump places	Caucasus
	Santalaceae		
378	*Thesiun procumbens*	1, 2, 4 – Clay slope	Turan – Caucasus
379	*T. szowitsii*	1–3, 5 – Stone – Clay slope	Atropatan
	Saxifragaceae		
380	*Saxifraga pseudolaevis*	1 – On the rock	Eastern Caucasus
	Scrophulariaceae		
381	*Digitalis nervosa*	1, 2, 4 – Forest	Caucasus – Hirkan
382	*Linaria schirvanica*	1, 3 – Clay-soil slope	Albania
383	*L. zangezura*	2, 5 – Bushes	Atropatan
384	*Melampyrum chlorostachyum*	2, 5 – Rock cracks	Caucasus
385	*Scrophularia atropatana*	5 – River valley	Atropatan
386	*S. grosseimii*	1, 2, 4, 5 – Stone-rock places	Atropatan
387	*S. thesioides*	5 – Arid slope	Atropatan
388	*S. variegata*	1, 2, 4, 5 – Stone-rock places	Caucasus – Front Asia
389	*S. zuvandica*	4 – Rock cracks	Hirkan
390	*Verbascum paniculatum*	5 – Arid, stone slope	Atropatan
391	*V. stachydiforme*	4 – Between weeds	Hirkan
392	*V. szovitsianum*	2, 5 – Stone-rock places	Atropatan
393	*Veronica crista-galli*	1, 2, 4 – Forest and bushes	Caucasus – Hirkan

No	Family – Taxa	Distribution in Azerbaijan and ecology of biotope	Geographical type
394	*V. minuta*	1, 2 – Rock cracks	Caucasus
395	*V. peduncularis*	1, 2 – Forest and bushes	Evksin – Caucasus
396	*V. petraea*	1 – On the rock	Eastern Caucasus
	Solanaceae		
397	*Solanum kieseritzkii*	4 – Shadow forest	Hirkan
	Valerianaceae		
398	*Valeriana cardamines*	1 – Forest, bushes, subalpine meadows	Caucasus
399	*Valerianella amblyotis*	1, 4, 5 –limestone slope	Caucasus
400	*V. corniculata*	1, 3 – Clay-stone places	Eastern Transcaucas.
401	*V. cymbocarpa*	4, 5 – Clay-stone places	Caucasus– Iran – Turan
402	*V. oxyrrhyncha*	4, 5 – Clay-stone places	Turan – Caucasus
403	*V. plagiostephana*	4, 5 – Clay-stone places	Atropatan
404	*V. sclerocarpa*	1, 2, 4, 5 – Clay-stone places	Turan – Caucasus
	Violaceae		
405	*Viola caucasica*	1, 2 – Rock cracks	Caucasus

Note: (**1**) Great Caucasus, (**2**) Lesser Caucasus, (**3**) Kur-Araz plain, (**4**) Talysh, (**5**) Nakhchivan

Appendix 17.2: Taxonomic Content of Rare and Endangered Endemic in Azerbaijan

Family	Genus	Species
Alliaceae	*Allium*	*A. akaka*, *A. dictyoprasum* (*A. viride*), *A. egorovae*, *A. kunthianum*, *A. lenkoranicum*, *A. leonidis*, *A. leucanthum*, *A. mariae*, *A. materculae*, *A. saxatile*, *A. szovitsii*, *A. talyschense*, *A. ursinum*, *A. woronowii*
Anacardiaceae	*Pistacia*	*P. mutica*
	Rhus	*R. coriaria*
Apiaceae	*Angelica*	*A. sachokiana*
	Astrantia	*A. maxima*
	Carum	*C. caucasicum*
	Pimpinella	*P. aromatica*, *P. grossheimii*
	Bupleurum	*B. wittamannii*
	Ferula	*F. caspica*
Amaryllidaceae	*Sternbergia*	*S. fischeriana*
	Galanthus	*G. caucasicus*
Asparagaceae	*Asparagus*	*A. ledebourii*, *A. persicus*

Family	Genus	Species
Asteraceae	*Calendula*	*C. persica*
	Carthamus	*C. oxyacanthus*
	Lactuca	*L. wilhelmsiana*
	Cousinia	*C. hohenackeri*, *C. orientalis*
	Jurinella	*J. subacaulis*
	Pyrethrum	*P. komarovii*, *P. carneum*, *P. coccineum*
	Telekia	*T. speciosa*
	Tragopogon	*T. karjaginii*
Aceraceae	*Acer*	*A. trautvtteri*
Brassicaceae	*Raphanus*	*R. rostratus*
	Arabis	*A. gerardii*
	Dichasianthus	*D. eldarica*
Boraginaceae	*Buglossoides*	*B. tenuiflora*
Campanulaceae	*Asyneuma*	*A. campanuloides*
Caryophyllaceae	*Gypsophila*	*G. muralis*, *G. robusta*
	Dianthus	*D. capitatus*
	Paronychia	*P. azerbaijanica*
Celtidaceae	*Celtis*	*C. caucasica*
Chenopodiaceae	*Beta*	*Beta lomatogona*, *B. macrorhiza*
	Atriplex	*A. cana*
	Camphorosma	*C. lessinqi*
Cupressaceae	*Juniperus*	*J. foetidissima*
Cyperceae	*Eriophorum*	*E. latifolium*
Corylaceae	*Corylus*	*C. colurna*
Euphorbiaceae	*Euphorbia*	*E. ledebourii*
Ebenaceae	*Diospyros*	*D. lotus*

Family	Genus	Species
Fabaceae	*Astragalus*	*A. achundovii*, *A. argyroides*, *A. aznabjurticus*, *A. alexandri*, *A. badamliensis*, *A. bakuensis*, *A. barnassari*, *A. biebersteinii*, *A. brachypetalus*, *A. brachytropis*, *A. caraganae*, *A. caspicus* (*A. theodorianus*), *A. chalilovii*, *A. conspicuus*, *A. cuscutae*, *A. declinatus*, *A. denudatus*, *A. dzhebrailicus*, *A. schuschensis*, *A. eugenii*, *A. euoplus*, *A. finitimus*, *A. glochideus*, *A. hohenackeri*, *A. humilis*, *A. igniarius*, *A. kabristanicus*, *A. karabaghensis* (*A. jucundus*), *A. karakuschensis*, *A. karjaginii* (*A. barba-caprina*), *A. kazbeki*, *A. kubensis*, *A. lunatus*, *A. macrosephalus* (*A. johannis*), *A. macrourus* (*A. schachbuzensis*), *A. maraziensis*, *A. megalotropis*, *A. mesites*, *A. meyeri*, *A. montis-aquilis*, *A. multijugus* (*A. ornithopodioides*), *A. nachitschevanicus*, *A. neoalbanicus*, *A. onobrychioides*, *A. ordubadensis*, *A. oreades*, *A. paradoxus*, *A. persicus*, *A. podocarpus*, *A. polyphyllus*, *A. prilipkoanus*, *A. refractus*, *A. rostratus*, *A. rzaevii*, *A. sachokianus*, *A. sanguinolentus*, *A. schemachensis*, *A. szovitsii*, *A. theodorii*, *A. torrentum*, *A. xiphidium* (*A. husseinovii*), *A. zangelanus*, *A. zuvanticus*, *A. dzhebrailicus*, *A. gjunaicus*
	Lathyrus	*L. atropatanus* (*Orobus atropatanus*)
	Medicago	*M. caucasica*, *M. glutinosa*
	Onobrychis	*O. atropatana*, *O. biebersteinii*, *O. iberica*, *O. heterophylla*, *O. hohenackeriana*, *O. komarovii*, *O. petraea*, *O. schuschajensis*, *O. vaginalis*
	Securigera	*S. hyrcana* (*Coronilla hyrcana*), *S. orientalis*
	Trifolium	*T. biebersteinii*, *T. caucasicum* ssp. *topczibashovii*, *T. echinatum*, *T. isaevii*, *T. grossheimii*, *T. leucanthum* (*T. sachokianum*), *T. lenkoranicum*
	Vicia	*V. ciceroidea*, *V. hololasia*, *V. loiseleurii*
	Scorpiurus	*S. minimus*
Fagaceae	*Castanea*	*C. sativa*
Fumariaceae	*Corydalis*	*C. alpestris*
İridaceae	*Iris*	*I. camillae*, *I. annae*, *I. iberica*, *I. caucasica*, *I. pumila*, *I. alexeenkoi*, *I. schelkownikowii*, *I. pseudacorus*, *I. reticulatum*
Juncaceae	*Juncus*	*J. alpinoarticulatus*

Family	Genus	Species
Liliaceae	*Tulipa*	*T. eichleri*, *T. biebersteiniana*
	Fritillaria	*F. caucasica*
Lamiaceae	*Salvia*	*S. golneviana*, *S. limbata* (*S. prilipkoana*, *S. fominii*), *S. reuteriana* (*S. nachiczevanica*), *S. suffruticosa* (*S. alexandri*), *S. transcaucasica*, *S. verbascifolia*, *S. karabachensi*, *S. vergeduzica*
	Thymus	*T. fedtschenkoi*, *T. hadzhievii*, *T. karamarjanicus*, *T. karjaginii*, *T. kjapazi*, *T. migricus*, *T. trautvetteri*
Malvaceae	*Alcea*	*A. hyrcana*, *A. kusariansis*, *A. lenkoranica*, *A. sachsachanica*
Moraceae	*Ficus*	*F. hyrcana*
Papaveraceae	*Papaver*	*P. schelkownikowii*, *P. talyschense*
Poaceae	*Aegilops*	*A. strangulata*
	Avena	*A. bruhnsiana*, *A.ventricosa*
	Dactylis	*D. hyrcana*
	Elytrigia	*E. attenuatiglumis* (*Agropyron divaricatum*), *E. heidemaniae*
Punicaceae	*Punica*	*P. granatum*
Plumbaginaceae = Limoniaceae	*Acantholimon*	*A. fominii*, *A. tenuiflorum*
Hemerocallidaceae	*Hemerocallis*	*H. fulva*
Hyacinthaceae	*Scilla*	*S. caucasica*
Orchidaceae	*Himantoglossum*	*H. formosum*
Rosaceae	*Corallorhiza*	*C. trifida*
	Dactylorhiza	*D. flavescens*
	Epipactis	*E. palustris*
	Ophrys	*O. caucasica*, *O. oestrifera*, *O. purpurea*
	Cotoneaster	*C. saxatilis*
	Crataegus	*C. eriantha*
	Pyrus	*P. acutiserrata*, *P. boissieriana*, *P. eldarica*, *P. grossheimii*, *P. hyrcana*, *P. medvedevii*, *P. salicifolia*, *P. vsevolodi*
	Rosa	*R. abutalybovii*, *R. alexeenkoi*, *R. azerbaidzhanica*, *R. gadzhievii*, *R. glandulosa-setosa*, *R. iljinii*, *R. isaevii*, *R. jaroschenkoi*, *R. karjagini*, *R. komarovii*, *R. mandenovae*, *R. nizami*, *R. prilipkoana*, *R. sachokiana*, *R. sosnowskyana*, *R. zakatalensis*, *R. zuvandica*
	Rubus	*R. hyrcanus*, *R. persicus*, *R. raddeanus*
	Sorbus	*S. aucuparia*
	Padus	*P. avium*
	Pyracantha	*P. coccinea*
Celtidaceae	*Celtis*	*C. caucasica*

Family	Genus	Species
Solanaceae	*Solanum*	*S. kieseritzkii*
	Atropa	*A. caucasica*
Scrophulariaceae	*Veronica*	*V. arceuthobia*
	Verbascum	*V. phoeniceum*
	Leptorhabdos	*L. parviflora*
	Linaria	*L. schivanica*, *L. zangeaura*
Staplyleaceae	*Staphylea*	*S. colchica*
Taxaceae	*Taxus*	*T. baccata*
Valeriaceae	*Valerianella*	*V. lipskyi*
Violaceae	*Viola*	*V. caucasica*
Vitaceae	*Vitis*	*V. sylvestris*

References

Akhmedova SZ (2011) Vegetation of winter pastures of Jeyranchol-Ajinour of Azerbaijan and its bioecological and agrophytocenotic features. Dr. thesis, Baku
Alizade VM (2012) Regional strategy of protection: development and perspectives. Proceeding of the Institute of Botany of ANAS (Azerbaijan National Academy of Sciences), Baku-Azerbaijan, "EİM-Tehsil", XXXII, pp 3–7
Anonymous (2003) Conspect of the flora of the Caucasus, vol 1. St. Petersburg University Press, 201 p
Anonymous (2006) Conspect of the flora of the Caucasus, vol 2. St. Petersburg University Press, 500 p
Anonymous (2014) National Atlas of the Republic of Azerbaijan, Baku, 444 p
Askerov AM (2001) The ferns of the Caucasus. Elm, Baku, 244 p
Askerov AM (2016) The plant world of Azerbaijan. TEAS press, Baku, 444 p
Askerova RG (1977) New look of Gageae (*Liliaceae*) in Azerbaijan. Bot J L Nauka 82(11):84–85
Braun-Blanguet J (1964) Pflanzensociologie. Ground-squirrel vegetation in skin. 3 Auflage. Springer Verlag, Wien/New York, 830 p
Davis PH (1965–1985) Flora of Turkey. Vols. 1–9, Edinburgh at the University Press
Engler A (1872) Geograpischen Verhaltnsse, Breslau, 292 p
Gagnidze RI (1974) Botanical – geographical analysis of the floristic complex of the subalpic high Caucasian cave, Tbilisi, 226 p
Ganbarov DS (2014) Spreading of Astracantha and Astragalus species on the highland zones of the Nakhchivan Autonomous Republic. Eur Acad Res:4153–4159
Gasimzade TE (2015) Flora and vegetation of Shirvan. "Elm" Baku, 496 p
Grossheim AM (1939) Analysis of the Caucasus. AzPAN USSR, 230 p
Grossheim AM (1939–1967) Flora of the Caucasus: In the 7th Ann. VV. 1–7, AzPAN USSR, Baku
Gurbanov EM (2004) Flora and Rappiness in the Atropaten Province (in the limits of the Azerbaijan Republic): Authoref of dissert Dr Sc, Baku
Hajiyev VJ (1970) The high-tale rusticeness of the Greater Caucasus and its economical value. Baku: "Elm", 281 p
Hajiyev VJ (2004) Ecosystem of highland vegetation of Azerbaijan. Elm, Baku, 97 p
Ibadli OV (2004) Geophytes of Caucasus and their intrusion. Avtroref of dessert, Baki

Ibadullaeva SJ, Ibragimov AS, Shiralieva GS, Talibova FZ (2008) Subalpine high speed of Nakhchivan AR. Bot J St Petersburg Nauka 93(2):737–744
Ibadullaeva SJ, Qasumov HZ, Seidov MM (2012) *Viscum album* – a new species for the flora of the Nakhchivan Autonomous Republic of Azerbaijan. Bot J 97(10):120–121
Ibadullaeva SJ, Alakbarov R, Qasimov H (2014) *Thymus hyemalis* Lange (Lamiaceae) - a new species for the flora of Azerbaijan. Bot J 7:825–827
Ibadullayeva SJ (2004) Apiaceae family of Azerbaijan flora. Elm, Baku, 321 p
Ibadullayeva SJ, Babakishiyeva T (2013) Current state of the plant cover plate of Azerbaijan. Internship symposium “Caucasian Forestry”, Artvin-Turkey, pp 111–123
Ibadullayeva SJ, Mammadli TB (2011) Current state of summer and winter vegetation cover of Günnüt-Gapichug region. In: Proceeding of the Institute of Botany of Azerbaijan National Academy of Sciences “Elm” Baku, pp 83–91
Ibadullayeva SJ, Mustafayev AB (2014) Classification of vegetation of high mountainous areas of the Greater Caucasus. J. “Xeberler” (News) of ANAS, Biology series N-3:58–65
Ibragimov AS (2005) Vegetation of the Nakhchivan Autonomous Republic and its national economic value. Elm, Baku, 230 p
Ismayilov AH (2007) Study of flora and vegetation of Gilanchay basin. “Xeberler” (News) of Nakhchivan Division of ANAS 2:112–118
Kuznetsov NI (1909) Principles of the Caucasus division into botanical and geographical provinces. SPb Zap Imp Acad Sci 8(24):164
Meusel H, Jager EJ (1989) Ecogeographical differentiation of the forest deciduous forest flora. Plant Syst Evol 162:315–329
Musaev SH (1991) Cereals of Azerbaijan. Elm, Baku, 420 p
Nabiyeva FX, Ibadullayeva SJ (2012a) Development of appropriate informances of deserting processes in the KAL and the PAAR. Glob Adv Res J Geogr Reg Plann 1(5):234–239
Nabiyeva FX, Ibadullayeva SJ (2012b) Water-marsh ecosystems of arid territory. Rep ANAS 5:23–31
Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018a) A comparative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343
Ozturk M, Altay V, Altundağ E et al (2018b) Chapter 6: Herbals in Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1. Springer, Cham, pp 197–266
Portenier NN (2012) Flora and botanical geography of the North Caucasus. M. Partnership of scientific publications KMK
Prilipko LI (1970) Vegetative cover of Azerbaijan. Baku, “Elm”, 170 p
Raunkiaer C (1934) The life forms of plants and statistical plant geography, Oxford, pp 48–154
Red Book of Azerbaijan (2013) Rare and endangered plant and mushroom species. Baku: II edition, 673 p
Red Book of the Azerbaijan (1989) Rare and endangered animal and plant species. Baku, 544 p
Serebryakov IG (1955) The main directions of the evolution of life forms in angiosperm plants. Bull Mosk About Test 60(3):71–91
Serebryakov IG (1962) Life forms of higher plants and their study. Field geobotany, vol 3, 181 p
Seyidov MM, Ibadullayeva S, Qasımov H, Salayeva Z (2014) Flora and vegetation of Shakhbuz State Nature Reserve. Nakhchivan, 400 p
Shennikov AP (1950) Ecology of plants. M Owls Science, 375 p
Talibov TH, İbrahimov AS (2008) Taxonomic spectrum of Nakhchivan Autonomous Republic flora (Higher spore plants, Gymnosperm, Angiosperm). Ajami, Nakhchivan, 350 p
Talibov TH, İbrahimov A (2010) Red book of Nakhchivan Autonomous Republic (Higher spore plants, gymnosperm, angiosperm). Nakhchivan, Ajami, 677 p
The Wood and shrubs of Azerbaijan (1964–1970) vol 3, Publish house of AAS, Baku
Yurtsev BA, Kamelin RV (1991) Basic concepts and the term floristics. Perm, 80 p

Chapter 18
Agrodiversity in Azerbaijan

Zeynal Akparov, Aydin Asgerov, and Afig Mammadov

18.1 Introduction

Agrodiversity covers plants, animals, fungi, and bacteria which affect the biological productivity process in agroecosystems and constitute a significant part of the biodiversity. It plays a great role in the provision of food safety, struggle against hunger and poverty, and creation of high productive and quality new varieties with the ability to adapt to the intensifying global climate changes and which are resistant to biotic and abiotic factors (Yarcı et al. 2007; Yarcı and Altay 2016; Ozturk et al. 2018a, b; Mercimek et al. 2019; Raza et al. 2019; Taşpınar et al. 2019; Ayub et al. 2020; Mushtaq et al. 2020; Rehman et al. 2020; Ruqia et al. 2020; ur Rehman et al. 2020). Suitable climate and soil conditions in the Republic of Azerbaijan have resulted in the occurrence and cultivation of rich agrodiversity. The geneticist Vavilov was therefore keen and has stressed on the reason for inclusion Azerbaijan biodiversity as an important genofond sources in the Southern Caucasus and Western Asia as a whole (Vavilov 1967), the reason being the diversity of climate and soil conditions in the country. Food, fodder, and medicines have been procured from the rich diversity of the country (Ozturk et al. 2018a, b). Important plant species in Azerbaijan have been planted and cultivated from ancient times, and culture has been passed on from generation to generation as a legacy. Nearly more than half of the higher plants in the global flora are of food value and also of agricultural importance. Nearly 2.8% of these have been cultivated as crops. Totally, 5% of 4961 higher plant species belonging to 1117 genera have been reported in the flora of Azerbaijan (Asgarov 2005–2008, 2016), and most of these are in the cultivated form (Anonymous 2018). The wild relatives of crops under in situ conditions have not been investigated much.

Z. Akparov (✉) · A. Asgerov · A. Mammadov
Genetic Resources Institute of Azerbaijan NAS, Baku, Azerbaijan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_18

The Law of the Republic of Azerbaijan “on conservation and sustainable use of crop genetic resources” was adopted by the decree of the President of the Republic of Azerbaijan on 13 December 2011. The law presents the main principles and legal grounds of conservation and effective use for protection of social-cultural and historical heritage taking into account the production of plant genetic resources for food and agricultural production, including the wild ancestors, scientific research, selection and enlightenment activities, as well as interests for future generations in the republic.

Cereals, grain legumes, vegetable-melon crops, leguminous-forage crops, fruits, grape, and industrial crops have been cultivated historically to meet the demand of the population for foodstuff and other products, and these crops are still considered major agricultural crops in Azerbaijan (Anonymous 2006). Archaeological excavations related to Neolithic (e.g., Shengavit point area), Eneolithic (Kultapa, etc.), and Bronze Age periods (Seyfali, Khojali etc.) as well as rock paintings in Gobustan completely confirm the cultivation culture in this area as being at least 6000–8000 years old. These are the initial centers of many plants, especially grains, food plants, and fruits of Azerbaijan.

The richness of the ecological conditions of the country has allowed the cultivation of different cultural crops. This is fully reflected in the country’s agrodiversity. Citrus species crops and tea and early vegetable crops grown in Lankaran-Astara region; dry subtropical crops, cotton, cereals, and grape in Kur-Araz Lowland; grape, potato, and cereals in Ganja-Gazakh region; nuts and cereals in Shaki-Zagatala region; late season vegetable, pome fruits, and cereals in Guba-Khachmaz region; dry subtropical crops in Absheron; and stone fruits, grape, cereals, and forage crops grown in Nakhchivan occupy an important place in the agricultural system. These contribute significantly to meet the demands of the population for food and other crops and add to the income of farmers (Anonymous 2006; Gasimov et al. 2010; Akparov et al. 2018).

Varieties on 94 species have been officially registered to be cultivated in different regions of Azerbaijan and have been regionalized following the state testing (Table 18.1).

It should be noted that the number of varieties cultivated in reality is more than the official registrations. According to the studies conducted by the Genetic Resources Institute, about 70 varieties of pomegranate are grown in the farms and yard areas of the country, but only 8 have been officially registered. Similar facts can be said about the other priority plants. Grapevine is peculiar due to the number of widely spread varieties.

Several foreign varieties of vegetables and F1 hybrids are cultivated in the country. Among the fruit plants, local especially folk-selected varieties prevail. The biggest diversity is among the fruit varieties. Both local and introduced varieties of cereals and legumes are widely used. Most of the wheat varieties grown in Azerbaijan were established in the Research Institute of Crop Husbandry of the Ministry of Agriculture of the Republic of Azerbaijan with guidance of the famous Azerbaijani scientist and academician Jalal Aliyev.

Table 18.1 Plant groups, plants, and number of varieties included in the State Register on selection achievements

Genus/species	Name of genera/species in English	Number of varieties
Cereals		
Triticum	Wheat	59
Triticosecale	Triticale	2
Secale cereale	Rye	1
Hordeum vulgare	Barley	15
Avena sativa	Oat	1
Zea mays	Maize	30
Oryza sativa	Rice	6
Faqopyrum esculentum	Buckwheat	1
Panicum miliaceum	Millet	1
Grain legumes		
Phaseolus vulgaris	Bean	5
Lens (*Lens culinaris*)	Lentil	4
Cicer arietinum	Chickpea	7
Pisum sativum	Green pea	1
Lathyrus sativus	Grass pea	1
Oil crops		
Arachis hypogaea	Groundnut	2
Helianthus annuus	Sunflower	3
Glycine hispida	Soybean	4
Forage crops		
Medicago	Alfalfa	12
Onobrychis viciifolia	Sainfoin	4
Brassica napus	Rape	1
Sorghum bicolor	Sorghum	1
Sorghum sudanense	Sudan grass	1
Dactylis glomerata	Orchard grass	1
Kochia prostrata	Summer cypress	1
Arrhenatherum elatius	False oat-grass	1
Lathyrus sativus	Grass pea	1
Industrial crops		
Beta vulgaris ssp. *vulgaris* var. *saccharifera*	Sugar beet	4
Nicotiana tabacum	Tobacco	7
Gossypium (*Gossypium hirsutum*)	Cotton	27
Vegetables		
Brassica capitata var. alba	Common head cabbage	24
Brassica oleracea var. *oleracea*	Red cabbage	1
Brassica oleracea botrytis	Cauliflower	8
Lycopersicum esculentum	Tomato	76

(continued)

Table 18.1 (continued)

Genus/species	Name of genera/species in English	Number of varieties
Solanum melongena	Eggplant	9
Cucumis sativus	Cucumber	40
Allium cepa	Onion	15
Allium sativum	Garlic	3
Beta vulgaris ssp. *vulgaris* var. *conditiva*	Table beet	5
Daucus carota	Carrot	6
Capsicum annuum var. *grossum*	Pepper	13
Capsicum annuum var. *fasciculatum*	Hot pepper	5
Raphanus sativus	Radish	1
Raphanus sativus var. *rubescens*	Garden radish	6
Phaseolus vulgaris	Common bean	6
Pisum sativum ssp. *sativum*	Pea	5
Lactuca sativa	Lettuce	10
Spinacia oleracea	Spinach	1
Anethum graveolens	Dill	3
Ocimum basilicum	Basil	1
Rumex acetosa	Sorrel	1
Pastinaca sativa	Parsnip	1
Apium	Celery	2
Petroselinum sativum	Parsley	1
Foeniculum vulgare	Fennel	1
Fungi	Mushroom	2
Melon crops		
Citrullus vulgaris	Watermelon	8
Cucumis melo	Muskmelon	5
Cucurbita maxima	Pumpkin	3
Cucurbita pepo	Green pumpkin (fodder pumpkin)	1
Cucurbita pepo var. *patisson*	Squash	1
Cucurbita	Fodder squash	2
Root crops		
Solanum tuberosum	Potato	41
Beta vulgaris ssp. *vulgaris* var. *alba*	Fodder beet	2
Mulberry		
Morus	Mulberry	9
Morus	Mulberry	3
Silkworm		
Bombyx mori	Silkworm	33
Pome fruits		
Malus (*M. domestica*)	Apple	39
Pyrus (*Pyrus communis*)	Pear	17

(continued)

Table 18.1 (continued)

Genus/species	Name of genera/species in English	Number of varieties
Cydonia	Quince	5
Mespilus	Medlar	3
Stone fruits		
Persica	Peach	17
Prunus persica var. *nucipersica*	Nectarine	3
Prunus domestica	Plum	12
Cerasus avium	Sweet cherry	14
Armeniaca vulgaris	Apricot	8
Cerasus vulgaris	Cherry	5
Prunus cerasifera	Myrobalan plum	8
Cornus mas	Cornel	2
Hippophae	Sea buckthorn	3
Walnut family		
Juglans regia	Walnut	4
Corylus avellana	Hazelnut	5
Amygdalus communis	Almond	7
Subtropical crops		
Diospyros (*Diospyros kaki*)	Persimmon	2
Punica granatum	Pomegranate	8
Ficus carica	Fig	9
Olea europaea	Olive	3
Feijoa sellowiana	Feijoa	7
Actinidia (*Actinidia deliciosa*)	Kiwifruit	1
Ziziphus jujuba	Unabi	6
Berries		
Fragaria grandiflora	Strawberry	4
Rubus	Raspberry	1
Eubatus	Blackberry	2
Vitis	Grape	44

18.2 Grain Cereals

One hundred twenty genera and 454 species of meadow grasses (Poaceae) are found in Azerbaijan, out of which 25 species are cultivated in the country. Azerbaijan is considered one of the centers of origin of meadow grasses. Sixteen species of the genus *Triticum* are available (Fig. 18.1). Durum wheat (*T. durum*) represents 43 varieties in the country. Some of these such as; *apulicum*, *hordeiforme*, *leucurum*, and *melanopus* are widely grown all over the lowlands, foothills, and mountainous regions. Bread wheat (*T. aestivum*) represents 87 cultivars, in which *erythrospermum*, *ferrugineum*, *sezium*, *barbarossa*, *lutescens*, *milturum*, and *albidum* are more widespread (Anonymous 2006). Wild species of wheat in Azerbaijan are spread in the lowlands, foothills, and the mountainous regions (*T. boeoticum*, *T. araraticum*, *T. urartu*).

Fig. 18.1 Wheat diversity from the national gene pool

Ten species of *Hordeum* are found in Azerbaijan, two of which, ordinary, multi-rowed, and six-rowed barley (*H. vulgare*) and two-rowed barley (*H. disticun*), are cultivated in the country (Anonymous 2006). Six Eight types of wild barley are grown: wild barley (*Hordeum spontaneum*, *H. glaucum*, *H. bulbosum*, *H. violaceum*, *H. secalinum*, and *H. leporinum*).

Five species of rye (*Secale*) are also found in the country. Only one (*Secale cereal*) is a cultural crop. Wild species are segetale rye (*S. segetale*), vavilovi rye (*S. vavilovi*), anatolicum rye (*S. anatolicum*), and sylvestre rye (*S. sylvestre*).

Only one species of maize (*Zea*), namely, yellow-grained varieties (*Zea mays*), is widespread in the country. Only one species (*Oryza sativa*) of paddy (*Oryza*) is cultivated in Sheki-Zagatala region, in Kur-Araz lowland, and in Talysh. In addition, triticale (326 accessions in gene pool), sorghum (*Sorghum*), millet (*Panicum*), and other crops are naturally widespread in the territory (Anonymous 2006).

18.3 Legumes

In Azerbaijan, 60 genera and 449 species of leguminous crops belonging to Fabaceae are mainly used as food (208 species) and as forage (241 species) and for other purposes. These are widespread in Azerbaijan. Species of chickpea (*Cicer*), lentil (*Lens*), faba bean (*Vicia faba*), bean (*Phaseolus*), pigeon pea (*Pisum*), groundnut (*Arachis*), vetch (*Lathyrus*), and other genera have been cultivated all through the history of Azerbaijan, and their wild species are also widespread in the country (Anonymous 2006).

Forage crops are especially notable among these but are under a threat of extinction in the flora. The basis of forage is grains in the phytocenosis of pastures, hay fields, and common pastures. Out of these, barley, rye, Poaceae, stipe, *Phleum phleoides*, and *Agropyron* are typical examples. Cultivated and wild species of alfalfa (*Medicago*) are widely used among leguminous and forage crops; shamrock (*Trifolium*), sweet clover (*Melilotus*), trefoil (*Lotus* with 17 accessions), sainfoin (*Onobrychis*), faba (*Vicia*), and others occupy a special place in the flora. Plants belonging to cereals and legume families are widespread in natural pastures and meadows (Anonymous 2006).

18.4 Vegetables and Melons

Most of the vegetables and melons are used by the population. About 265 species of vegetable-melon crops grow in the country and majority are consumed. The species belonging to Solanaceae, Brassicaceae, Liliaceae, Chenopodiaceae, Cucurbitaceae, Asteraceae, Portulacaceae, Lamiaceae, Malvaceae, Amaranthaceae, and other families are especially worth noting here due to the area of their distribution, number of species and varieties, as well as utilization as food and for medicinal and industrial purposes (Anonymous 2006).

From vegetables, tomato (*Lycopersicum esculentum*), eggplant (*Solanum melongena*), potato (*Solanum tuberosum*), pepper (*Capsicum annuum*), cabbage (*Brassica capitata*), onion (*Allium cepa*), garlic (*Allium sativum*), and carrot (*Daucus*) and, from melons, watermelon (*Citrullus*), melon (*Cucumis melo*), cucumber (*Cucumis sativus*), and pumpkin (*Cucurbita*) are more cultivated. Among their wild ancestors and relatives *Physalis* (2 wild species), *Allium* (6 species are endemic plants of Azerbaijan from 41 wild species), *Amaranthus* (6 wild species), *Rumex* (17 species), *Polygonum* (27 species), *Calligonum* (4 species), *Malva* (10 species), *Alcea* (8 species), and *Mentha* (5 species in Azerbaijan, 4 species are wild) are widespread. The data on important wild vegetables are given in Table 18.2.

The table reveals that important wild vegetables comprise of 264 species from 27 families and 79 genera, with perspective uses. Important spice plants are saffron (*Crocus*), *Rumex*, *Rheum*, sumac (*Rhus*), tarator (*Chaerophyllum*), *Prangos*, *Apium*, parsley (*Petroselinum*), *Pimpinella*, *Carum*, *Foeniculum*, *Pastinaca*, *Satureja*, marjoram (*Majorana*), thyme (*Thymus*), mint (*Mentha*), *Achillea*, and *Tussilago*. A major percentage of the wild consumable vegetables and spice plants belong to the families Asteraceae, Liliaceae, and Apiales. The genus *Polygonum* and grains are also included here. Dicotyledons in the wild vegetable plants are more than monocotyledons. Ninety-five species of the wild vegetable plants are annuals, 55 are biennials, and 350 are perennial herbaceous plants.

More than 90% of wild vegetable plants can be found in the areas of Nakhchivan AR, Talysh, Greater Caucasus, and Lesser Caucasus of Azerbaijan. Most of these plants are consumed as vegetable, cereals and bread as well as starch, natural coffee, proteins, and sugars, fragrance stuff, and pleasant taste. The composition of the wild

Table 18.2 Important wild vegetables and spice plants

Family	Genus	Number of species with use, perspective
Alismataceae	*Sagittaria*	1
	Alismata	1
Alliaceae	*Allium*	27
Amaranthaceae	*Amaranthus*	4
Apiaceae	*Prangos*	4
	Falcaria	1
	Foeniculum	1
	Chaerophyllum	6
	Heracleum	7
	Apium	1
	Anthriscus	3
	Bifora	2
	Sium	1
	Coriandrum	1
	Daucus	1
	Aegopodium	1
	Carum	3
	Anisum	1
	Pastinaca	4
	Chamaesciadium	1
	Pimpinella	8
Asparagaceae	*Asparagus*	5
Asphodelaceae	*Eremurus*	1
Asteraceae	*Arctium*	3
	Tussilago	1
	Tragopogon	14
	Scorzonera	2
	Lactuca	3
	Cichorium	2
	Cirsium	1
	Taraxacum	4
	Helianthus	1
	Cynara	2
Brassicaceae	*Nasturtium*	1
	Crambe	2
	Lepidium	1
	Capsella	1
	Barbarea	1
	Brassica	1
	Raphanus	1
Campanulaceae	*Campanula*	6

(continued)

Table 18.2 (continued)

Family	Genus	Number of species with use, perspective
Caryophyllaceae	*Stellaria*	5
	Myosoton	1
	Silene	2
Capparidaceae	*Capparis*	1
Chenopodiaceae	*Chenopodium*	13
	Spinacia	1
	Atriplex	8
	Beta	3
Convallariaceae	*Polygonatum*	3
Fabaceae	*Medicago*	2
	Melilotus	5
	Lathyrus	7
	Pisum	1
Hyacinthaceae	*Ornithogalum*	9
Lamiaceae	*Satureja*	5
	Mentha	2
	Stachys	2
	Origanum	1
	Salvia	4
	Melissa	1
	Thymus	1
	Lamium	3
Liliaceae	*Lilium*	3
Malvaceae	*Malva*	5
	Althaea	4
Oxalidaceae	*Oxalis*	1
Plantaginaceae	*Plantago*	2
Poaceae	*Phragmites*	1
	Triticum	2
Polygonaceae	*Polygonum*	5
	Rumex	14
	Rheum	2
Portulacaceae	*Portulaca*	1
Primulaceae	*Primula*	7
Solanaceae	*Solanum*	1
	Physalis	1
Trapaceae	*Trapa*	1
Urticaceae	*Urtica*	2
Totally: 27	**79**	**264**

vegetable plants shows biologically rich active substances such as vitamins, microelements, pectin, proteins, carotenoids, cellulose, etc. for humans.

Farmers are highly interested in the genetic diversity of cultivated plants. Most of these are widespread and used as wild vegetables and several are important as food plants. Leaves and offshoots of mallow (*Malva neglecta*) are used in the preparation of different meals. The core of the *Heracleum* essential oil plant (*Heracleum asperum*) is peeled, eaten, and pickled with salt. Porridge, flat pie with greens, pilaf, and dovga are cooked, dried, and stored from the fresh offshoots and leaves of *Polygonum* with therapeutic significance (*Polygonum alpestre*). Fresh offshoots and leaves of common nettle (*Urtica dioica*) are crumbled with salt and eaten, and they are used in the preparation of different meals. Fresh offshoots and leaves of perennial, lemon-flavored plant lemon balm (*Melissa officinalis*) are gathered and used in perfumery and medicine. Wild fennel (*Foeniculum vulgare*), purple-flowered garlic (*Allium rotundum*), asparagus (*Asparagus officinalis*), common sorrel (*Rumex acetosa*), catchfly (*Silene*), rhubarb (*Rheum undulatum*), winter savory (*Satureja montana*), mint (*Mentha piperita*), French parsley (*Anthriscus cerefolium*), hill coriander (*Bifora radians*), *Tragopogon*, and many others are used as vegetables by the population in Azerbaijan.

18.5 Fruits and Berries

Azerbaijan is also famous for its species richness of trees. There are 435 tree species and 70 are endemic to the country. The tree areas are rich in plant species having food and agricultural significance, especially fruits and berries. Important ones belong to the tree and bush life forms with a total of 150 species belonging to 15 families and 36 genera (Anonymous 2006).

Specifically, the followings can be noted here: the quince, *Cydonia oblonga*; many *Crataegus* species, *C. orientalis*, *C. szovitsii*, *C. meyeri*, *C. eriantha*, *C. caucasica*, *C. curvisepala*, *C. pentagyna*, and *C. pseudoheterophylla*; many species of pears (*Pyrus*), *P. nutans*, *P. eldarica*, *P. medvedevii*, *P. georgica*, *P. syriaca*, *P. grossheimii*, *P. boissieriana*, *P. hyrcana*, *P. vsevolodii*, *P. salicifolia*, and *P. caucasica*; ordinary medlar, *Mespilus germanica*; apple, *Malus orientalis*; main species of cherry (*Cerasus*), *C. avium*, *C. mahaleb*, *C. microcarpa*, *C. araxina*, and *C. incana*; *Prunus padus*; Cornelian cherry, *Cornus mas*; *Elaeagnus angustifolia*; main species of plum (*Prunus*), *P. spinosa*, and *P. divaricata*; main species of barberry (*Berberis*), *B. vulgaris*, *B. crataegina*, and *B. integerrima*; main species of *Eubatus* (*Rubus*), *R. buschii* and *R. anatolicus*; main species of *Ribes* genus (*Ribes*), *R. orientale* and *R. biebersteinii*; *Grossularia reclinata*; *H. rhamnoides* from *Hippophae* genus (*Hippophae*); *F. orientalis* from *Beech* genus (*Fagus*); chestnut, *Castanea sativa*; walnut, *Juglans regia*; main species of nut (*Corylus*), *C. colurna* and *C. avellana*; main species of almond (*Amygdalus*), *A. fenzliana* and *A. nairica*; pomegranate (*Punica granatum*); fig, *Ficus carica*; and persimmon, *Diospyros lotus*. *Juglans regia*, *Corylus avellana*, *Castanea sativa*, *Diospyros kaki*, *D. lotus*, *Cornus mas*, *Prunus divaricata*, and several other species are available on the southern slopes of Major Caucasus and in Guba-Khachmaz region. These are used by people as food. Folk selection varieties of these species are available at farmer holdings located in this region. A large diversity of apple, pear, mulberry, medlar, dogwood, and other crops is widespread in this territory (Anonymous 2006).

At one time, wild and cultivated *Mespilus germanica*, *Punica granatum*, *Cerasus avium*, *Cerasus vulgaris*, and *Vitis* covered large areas within the riverbank woodlands together with oak, hornbeam, and other forest species. However, their area is decreasing due to anthropogenic disturbances. Talysh region contains valuable varieties of blackberry, fig, pomegranate, bush cherry plum, dog rose, and citrus plants, whereas Absheron region is rich in the varieties of grape fig, pistachio (*Pistacia vera*), almond (*Amygdalus fenzliana*), oleaster (*Elaeagnus angustifolia*, *E. caspica*), mulberry (*Morus alba*, *M. nigra*), quince, and pomegranate. These crops grow here naturally or are cultivated by farmers in their holdings and orchards. Distribution of wild grape, strawberry, raspberry, and other berries over the territory of the republic is known. At one time, a number of fruit crops like cornel, sweet cherry, cherry, pomegranate, quince (*Cydonia oblonga*), fig (*Ficus carica*, *F. hyrcana*), pear (*Pyrus*), grape (*Vitis vinifera* and *V. labrusca*), and other fruits are widespread in the territory occupied by Armenia, which were used by local people (Anonymous 2006).

18.6 Wild Relatives of Crops (CWR) in Azerbaijan

The rich intraspecies diversity of the country provides examples of the same species to be cultivated successfully in the regions actually differing from each other both in climate and soils, as well as other ecological factors. It is very important to preserve the "gene pool" of Azerbaijan as fully as possible. One cannot predict in advance if some plants will assist selectors and biotechnicians who are struggling with new problems in the environment which is changing every day, while diseases and vermins are rapidly modified. Today, the research materials which were rejected and considered unnecessary or endangering wild ancestor species and populations can be useful as a valuable genetic donor and can be used effectively by the scientists, especially selectors whose work principles depend on studying hundreds of examples in the future. Food, fodder, and medicinal plants are important and should be planted and cultivated for use of people from the ancient times and pass on to the future generations (Ozturk et al. 2018a, b). The species (subspecies, intraspecies diversity) considered as crop wild relatives (CWR) are of special importance in terms of evolution and genetics. These will be useful for gene transfer in order to cultivate and obtain new forms. Specialists working in this direction always think of these issues such as resistant to the stress factors and diseases/vermins and provide better quality products. The main success of selectors in this work depends on using in situ materials. Therefore, it is very important to study, store, and discover new forms of wild relatives of cultivated plants (WRCP).

Azerbaijan can be considered one of the richest regions in the South Caucasus Group of Asian countries as a center of cultivated plants. It is considered as a formation center of most of the wild relatives of the cultivated plants say wheat (*Triticum boeoticum*, *T. spontaneum*, *T. urartu*, *T. araraticum*, etc.), barley (especially *Hordeum spontaneum*, *H. bulbosum*, *H. geniculatum*, *H. violaceum*, etc.), nine *Aegilops* (*Aegilops kotschyi*, *A. tauschii*, *A. umbellulata*, etc.), and five rye species (*Secale vavilovii*, *S. anatolicum*, *S. segetale*, etc.).

The flora of Azerbaijan is distributed under different climatic and soil conditions. It is situated in an area where various floral elements of the world meet and natural plant species distributed here widely and show high endurance against cold, heat, drought, salinity, disease, and vermins. These features can also be successfully used as a valuable source in the selection and hybridization. The International Treaty on Plant Genetic Resources for Food and Agriculture, adopted by the Food and Agriculture Organization (FAO) of the UN, lists priority genera from Central Asia and Caucasus (CAC) region. The information from the Central Database of Genetic Resources Institute are used in the determination of priority genera of crop wild relatives. All 311 species of CWR belonging to 98 genera and 55 families are found in the flora of Azerbaijan (except decorative plants). These have been identified and determined as belonging to the three groups of gene pool.

According to the classification of wild relatives of cultivated plants adopted in Azerbaijan, these plants are pooled up under three groups of gene pool:

GP-1 – This group includes wild species which are closest to the cultivated plant species from the phylogenetic point of view and are used as a gene source for hybridization and selection. These species have been mentioned both in the International Database (Crop Wild Relatives, Jack Harlan and Jan de Wet 1971) and in the article about the CWR of Azerbaijan (Anonymous 2014; Asgarov et al. 2017).

GP-2 – This group includes normal species which are close to the cultivated plant species on the phylogenetic point of view and registered in the International Database (Anonymous 2014) and in the article about the CWR of Azerbaijan (Anonymous 2014; Asgarov et al. 2017).

These species could be perspective for future selection studies and may pass to the first group.

GP-3 – This group includes the species close to the phylogenetic view with species in culture (belonging to the same subgenus, same selection, and series) and other species not represented in GP-1 and GP-2 gene pool groups but having unique gene pool source (endemic, rarely used for grafting purposes in folk selection, etc.).

Azerbaijan can be considered as one of the richest regions in the Transcaucasian group as a source of cultivated plants in Southwest Asia. Among very valuable ancestor species, we come across cereal grains (wheat, barley, oats, wheatgrass, rye, etc.), grain legumes (heath pea, peas, etc.), fruits (apples, almonds, grapes, medlar, walnuts, etc.), and wild vegetables (onions, beets, carrots, strawberries, etc.), and among feed plants, legumes, fodder plants (*Trigonella*, shamrock clover, alfalfa, melilot, sainfoin, etc.), forage grasses (couch grass, *Poa trivialis*, etc.), numerous oil, spice, herbal, vitamin plants can also be mentioned. There are 124 principal crop wild relatives in the country, included in gene pools 1, 2, and 3 – 38 genera from 15 families (Table 18.3).

Table 18.3 List of global priority crop wild relatives of Azerbaijan

Cereals	
Wheat	*Triticum timopheevii*
	T. urartu
	Aegilops biuncialis
	A. columnaris
	A. crassa
	A. cylindrica
	A. geniculata
	A. kotschyi
	A. neglecta
	A. tauschii subsp. *tauschii*
	A. triuncialis
	A. umbellata
Crest. wheatgrass	*Agropyron cristatum*
	A. desertorum
	A. fragile
Oat	*Avena barbata*
	A. eriantha
	A. fatua
	A. sterilis
	A. ventricosa
Finger millet	*Eleusine indica*
	E. tristachya
Int. wheatgrass	*Elymus elongatus*
	E. hispidus
Barley	*Hordeum brevisubulatum*
	H. bulbosum
	H. spontaneum
Broom millet	*Panicum miliaceum*
Pearl millet	*Pennisetum orientale*
Rye	*Secale segetale*
	S. sylvestre
	S. vavilovii
Foxtail millet	*Setaria italica*
	S. verticillata
	S. viridis
Sorghum	*Sorghum halepense*
Fruit crops	
Apple	*Malus orientalis*
Pear	*Cydonia oblonga*
	Pyrus boissieriana
	P. caucasica
	P. pyrifolia

(continued)

Table 18.3 (continued)

	P. salicifolia
	P. syriaca
Sweet cherry	*Prunus avium*
	P. cerasus
Apricot	*P.* × *dasycarpa*
	P. armeniaca
Myrobalan plum	*P. cerasifera*
Plum	*P. domestica*
	P. spinosa
Sour cherry	*P. mahaleb*
	P. padus
Peach	*P. persica*
Strawberry	*Fragaria* × *ananassa*
Fig	*Ficus carica*
Blackcurrant	*Ribes petraeum*
	R. uva-crispa
Almond	*Prunus dulcis*
	P. fenzliana
Legumes	
Sweet pea	*Lathyrus annuus*
	L. chloranthus
	L. cicera
	L. hirsutus
	L. sylvestris
	L. tuberosus
Lentil	*Lens culinaris* subsp. *orientalis*
	L. ervoides
Alfalfa	*Medicago littoralis*
	M. papillosa
	M. rigidula
	M. sativa subsp. *varia*
	M. truncatula
Pea	*Pisum sativum* subsp. *elatius*
Vetch	*Vicia ciliatula*
	V. ervilia
	V. grandiflora
	V. hybrida
	V. hyrcanica
	V. johannis
	V. lutea
	V. narbonensis
	V. pannonica
	V. sativa subsp. *amphicarpa*

(continued)

Table 18.3 (continued)

	V. sativa subsp. *nigra*
	V. serratifolia
Vegetables	
Garlic	*Allium ampeloprasum*
	A. atroviolaceum
	A. saxatile
	A. scabriscapum
	A. schoenoprasum
Sugar beet	*Beta lomatogona*
	B. macrorhiza
	B. vulgaris subsp. *maritima*
Carrot	*Daucus carota*
Asparagus	*Asparagus officinalis*
	A. verticillatus
Lettuce	*Lactuca azerbaijanica*
	L. georgica
	L. saligna
	L. serriola
Rape	*Brassica elongate*
	B. nigra
	B. oleracea
	B. rapa
	B. tournefortii
Radish	*Raphanus raphanistrum*
Quinoa	*Chenopodium album*
	C. murale
	C. opulifolium
	C. polyspermum
	C. strictum
	C. urbicum
	C. vulvaria
Spinach	*Spinacia tetrandra*
Safflower	*Carthamus glaucus*
	C. gypsicola
	C. lanatus
	C. oxyacantha
Aubergine	*Solanum sisymbriifolium*
Nut crops	
Hazelnut	*Corylus avellana*
	C. colurna
Walnut	*Juglans regia*
Pistachio	*Pistacia atlantica*

Some CWR have been included in the list from the crops not cultivated in Azerbaijan such as *Eleusine coracana* and *Chenopodium quinoa*. Azerbaijan appears as a formation center of many of these plants. For example, among the wild relatives of plant, we have wheat types (*Triticum boeoticum*, *T. spontaneum*, *T. urartu*, *T. araraticum*, and others); their species diversity is more than a hundred; barley (*Hordeum bulbosum*, *H. geniculatum*, *H. violaceum*); and wheat grass (*Aegilops kotschyi*, *A. tauschii*, *A. umbellulata*, and others), and rye (*Secale vavilovii*, *S. anatolicum*, *S. segetale*), in addition to many other genera like *Medicago*, *Onobrychis*, *Vicia*, *Pisum*, as well as fruits, vegetables, and melons, are worth noting.

Wheat species are important as a source of wild relatives in the world (*Triticum boeoticum*, *T. spontaneum*, *T. urartu*, *T. araraticum*, etc.), and their species diversities are more than one hundred. Similarly barley species, especially *Hordeum bulbosum*, *H. geniculatum*, *H. violaceum*, etc., *Aegilops* species (*Aegilops kotschyi*, *A. tauschii*, *A. umbellulata*, etc.), and rye species (*Secale vavilovii*, *S. anatolicum*, *S. segetale*, etc.), together with many fodder plants (*Medicago*, *Onobrychis*, *Vicia*, *Pisum*, etc.), fruits, vegetables, and garden plants, are important.

18.7 Preservation and Documentation of Plant Genetic Resources (PGR)

Wide use of an important part of the plant genetic diversity of Azerbaijan has been possible in the direction of purposeful gatherings from all over the country. In these studies, modern methods have been followed using the directions for reliable protection and increase of resistance to biotic and abiotic stress factors on the basis of models and strategies to be followed. The Genetic Resources Institute of ANAS followed the project, and collections are deposited in the national genebank which was established in 2003. The work was started for collecting seeds for the seed genebank of the national gene pool following field collections (Figs. 18.2 and 18.3). Information system on the core collection, registration, analysis, and study of data through the National Network on PGR and Central Database (CD), the "mirror" of all country's collections, was established in order to provide information support for activities on solving strategic issues directed toward the conservation and effective use of PGR in Azerbaijan. About 14,000 accessions belonging to 395 genera and 1130 species of mostly local genetic diversity are found in the national genebank and gene pool gardens, including valuable accessions of more than 2400 belonging to CWR, and these belong to the varieties and forms of the folk selections (landraces). All these have been collected, restored, and preserved via local and international expeditions. There are 34 national collections of the cultivated plants and their wild relatives in a total of nine scientific research (Genetic Resources Institute, Central Botanical Garden, Institute of Bioresources of Nakhchivan, Research Institute of Crop Husbandry, Research Institute of Fruit and Tea Growing, Research Institute of Viticulture and Wine, "Araz" Scientific Production Association, Research

Fig. 18.2 Genetic Resources Institute and national genebank

Fig. 18.3 Wheat field collection of the Research Institute of Crop Husbandry

Institute of Technical Plants and Plant Protection, Research Institute of Vegetable Growing, etc.) and educational institution (Azerbaijan State Agrarian University) in Azerbaijan.

It should be noted that the importance of improving the country's legislation in the field of PGR is the constant focus of the country. By the order of the President of the Republic of Azerbaijan, the Law of Azerbaijan No. 273-IVQ, dated December 13, 2011, "On Protection and rational use of the crop genetic resources," has been adopted. The law covers the main principles and legal grounds for the production of agricultural crops and food resources and their genetic resources including cultivated plants, their wild relatives in the republic, scientific research, selection and enlightenment activity, as well as conservation and rational use for social, cultural, and historical heritage protection, taking into account the interests of present and future generations.

The management system on PGR was defined by decision No. 259, dated November 13, 2012, adopted by the Cabinet of Ministers under this law. The "Scientific and Technical Council" includes the management system on genetic resources of the cultivated plants, expert councils on the activity directions of PGR within the Scientific and Technical Council, employee teams on individual plants and plant groups, all established in order to keep the collections natural resources of PGR under the control in the republic, organize and provide highest level of coordination in the activities and regions on PGR. For this purpose relevant scientific research and educational institutions, scientists and specialists, with the participation of responsible persons, scientists and specialists of National Academy of Sciences, Ministry of Agriculture, Ministry of Ecology and Natural Resources of the Republic of Azerbaijan and several other organizations. The National Coordinating Institute in the management system on PGR of Genetic Resources Institute of Azerbaijan National Academy of Sciences was formed with this decision. Coordinating activity of the institute is implemented by the Scientific Technical Council, as well as expert councils and employee teams.

It is known that one of the main factors in the protection of agrobiodiversity is properly documented national collections, including the national genebank. The "Information System on PGR of Azerbaijan" was developed which provides the data on gatherings, systemization, storage, spread, exchange, and optimal management of data on plant genetic resources. The Central Database is an integral part of the information system and other databases cover the data space on such resources in different directions. The National Information Exchange Mechanism on agrobiodiversity was established which provides coordination of movement dynamics and management of PGR and the database that helps decision-making mechanisms on regular monitoring of the condition of gene pool and its sustainable use.

Original crops, CWR, and traditional and modern varieties are widely represented in the Central Database of which the principal part which constitutes the data on cereals, legumes, fruits, industrial plants and and berries of high priority. There are more than 14.000 plant accessions included in the database and conserved in the main ex situ collections of Azerbaijan till now. These accessions refer to 113 families, 443 genera, 871 species, and 304 varieties. According to the biological status of the registered samples from the Central Database, 4861 can be classified as modern scientific varieties, 2365 folk selections, 3652 constant research materials, 2205 CWR, and few others. The families Poaceae, Malvaceae, Fabaceae, Rosaceae, Vitaceae, Solanaceae, Lythraceae, Apiaceae, Cucurbitaceae, Betulaceae, and Moraceae are represented by more accessions in the Central Database of the ex situ collections of the republic. The species *Gossypium hirsutum*, *Triticum aestivum*, *Zea mays*, *Vitis vinifera*, *Pyrus communis*, *Triticum status*, *Malus domestica*, *Hordeum vulgare*, *Phaseolus vulgaris*, *Punica granatum*, *Corylus avellana*, *Gossypium barbadense*, *Medicago sativa*, *Ficus carica*, and *Cicer arietinum* differ

Table 18.4 List of available families in the Central Database and total number of accessions belonging to them[a]

Family	Number of accessions	Family	Number of samples	Family	Number of samples
Poaceae	5367	Oleaceae	29	Grossulariaceae	4
Malvaceae	1535	Myrtaceae	24	Scrophulariaceae	4
Fabaceae	2091	Rutaceae	19	Araceae	3
Rosaceae	1074	Cornaceae	17	Orchidaceae	3
Vitaceae	610	Anacardiaceae	17	Caprifoliaceae	2
Solanaceae	245	Amaranthaceae	14	Crassulaceae	2
Cucurbitaceae	198	Theaceae	12	Iridaceae	2
Betulaceae	173	Elaeagnaceae	12	Oxalidaceae	2
Chenopodiaceae	150	Primulaceae	11	Phytolaccaceae	2
Moraceae	147	Papaveraceae	10	Portulacaceae	2
Apiaceae	109	Linaceae	9	Valerianaceae	2
Brassicaceae	86	Caryophyllaceae	8	Celastraceae	2
Lamiaceae	73	Apocynaceae	8	Amaryllidaceae	1
Juglandaceae	59	Asparagaceae	8	Cannabaceae	1
Polygonaceae	57	Berberidaceae	6	Convallariaceae	1
Liliaceae	54	Rubiaceae	6	Hyacinthaceae	1
Asteraceae	51	Ericaceae	5	Lauraceae	1
Rhamnaceae	46	Euphorbiaceae	4	Meliaceae	1
Ebenaceae	36				

[a]Sequence of families is given due to the number of accessions which they have, regardless of their position in the phylogenetic system

much as these are represented with more accessions. Cultivated plants and wild relatives represented in ex situ collections and registered in the database belong to 55 families. Their lists are given in Table 18.4.

18.8 Farm Management of Agrodiversity

The native population of Azerbaijan has cultivated the traditional aboriginal varieties (landraces) and forms of many plants, tried for their protection, breeding, and sustainable use since the ancient times. Today, all farmers and amateur gardeners use these for food and economic needs. They protect them by widely cultivating the ancient landraces and forms which are valuable and more appropriate to local conditions. There are farmer groups in the regions who even bring together collections of many plants in their fields and increase and spread (sell) their seedlings (young plants) and seeds. Some examples from these farmers are as follows. A farmer in Astara region cultivates and keeps more than 20 varieties of rice in his own farm. A farmer in Goygol region has collected 80 grape varieties. There are enough valuable gene pool collections consisting of local varieties and forms of peach, raspberry, and berry plants in the farm of Shamkir region. The farmers of Guba have established important gardens by engrafting wild forms growing on the edges of the forests with cultivated ones. A farmer in this place has created a collection consisting of fruits and other plants of the region by scientists support in his own garden. Many species of leguminous plants are widely grown in order to meet the needs of the population for food products in Lankaran region. Exotic plants which were used for different agricultural purposes by farmers and not found at anywhere else were cultivated, used, and stored in many regions. As a result of regular communication and collaboration with farmers, an important part of the valuable folk selection varieties is being maintained in the country. However, some farmers reject the ancient traditional varieties and forms due to different reasons; they prefer to use widely the modern selection criteria and genetically modified plants. As a result, the valuable ancient varieties and forms well adapted to the local conditions, with high resistance to diseases and vermins have been removed due to their relatively less productivity. Considering this, a significant part of these has not been adequately maintained in time and is not involved in the selection works; thus, their situation is therefore severe.

18.9 Conclusions

Azerbaijan also is very rich in genetic resources. Gene pool of plants and animals from different groups are used in the production of different agricultural and livestock products. Rich plant cover of pastures and hayfields, mountain meadows, and forest glades are highly effective in the development of livestock and crop production. However, conservation, development, and sustainable use of agrodiversity should be and is one of the main directions of the economic policy in the country so as to feed its future generations. Citrus crops and tea and early vegetables are grown in Lankaran-Astara region as dry subtropical crops; cotton is cultivated in the Kur-Araz lowland; grapes, potato, and cereals occur in Ganja-Gazakh; nuts and cereals are cultivated in Shaki-Zagatala; late season vegetables and pome fruits are found in the Guba-Khachmaz; dry subtropical crops are cultured in Absheron; and stone fruits and cereals are also grown in Nakhchivan and occupy an important place in the agricultural system of the country. These contribute significantly to meet the demand of population and fulfill the economic development of farmers as well as the nation as a whole. There are national genebanks and databases (integrated with the global system) on plant and animal genetic resources. National legislation on agrodiversity is constantly improving. The scientific and technical personnel are trained at a large scale to overcome these deficiencies.

References

Anonymous (2006) National Report on the State of plant genetic resources for food and agriculture in Azerbaijan. Baku

Anonymous (2014) Crop wild relatives and climate change. http://www.cwrdiversity.org. Accessed 16 Dec 2014

Anonymous (2018) State registry of selection achievements allowed for the production of agicultural products in the territory of the Republic of Azerbaijan and protected. Baku, 148 p

Akparov ZI, Mammadov AT, Amikishiyev VQ (2018) In popular language on biological diversity. Baku,Zardabi-Publication LLC, 252 p

Asgarov AM (2005–2008) Higher plants of Azerbaijan. Concept of the flora of Azerbaijan, vols. 1–3. Baku

Asgarov A (2016) The world of plants of Azerbaijan. Teas Press, Baku, p 444

Asgarov AM, Akperov ZI, Javadzade TY (2017) Classification and ecobotanical study of crop wild relatives: a case-study in Azerbaijan. Proc ANAS Biol Med Sci 72(3):128–132

Ayub M, Ashraf MY, Kausar A et al (2020) Growth and physio-biochemical responses of maize (*Zea mays* L.) to drought and heat stresses. Plant Biosyst Int J Deal Aspect Plant Biol:1–13

Gasimov MA, Khalilov VS, Gasımova TA (2010) Wild vegetable plants of Azerbaijan and their use perspectives. Scientific works of Azerbaijan Sciety of Botanists, vol, I, pp 371–396

Mercimek HV, Altay V, Ozturk M et al (2019) An overutilised industrial crop tobacco – *Nicotiana tabacum* L. Case study from Turkey. In: Ozturk M et al (eds) Crop production technologies for sustainable use and conservation (Chapter 15). Apple Academic Press, pp 365–394

Mushtaq W, Mehdizade M, Siddiqui MB et al (2020) Phytotoxicity of above - ground weed residue against some crops and weeds. Pak J Bot 52(3):851–860

Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018a) A comparative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343

Ozturk M, Altay V, Altundağ E et al (2018b) Herbals in Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 1 (Chapter 6). Springer, Cham, pp 197–266

Raza MM, Ullah S, Tariq A et al (2019) Alleviation of salinity stress in maize using silicon nutrition. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 47(4):1340–1347

Rehman R, Tarıq A, Haq N et al (2020) Mutations leading to a better tomorrow in the production of improved crop varieties. In: Cambridge Scholar, Chapter 5 (in press)

Ruqia S, Haq SN, Ilyas M et al (2020) Plant metabolomics: role in crop improvement. In: Cambridge Scholar, Chapter 9 (in press)

Taşpınar K, Ozturk M, Altay V, Polat H (2019) Sugar beet - an overutilised ancient crop. In: Ozturk M et al (eds) Crop production technologies for sustainable use and conservation (Chapter 14). Apple Academic Press, pp 321–363

ur Rehman T, Khan MA, Khan H et al (2020) Tillage, nutrients and weed control affects yield of sugar beet. Fresenius Environ Bull 29(5):3380–3387

Vavilov NI (1967) Center of origin. L Sci 1:88–203

Yarcı C, Altay V (2016) Kocaeli ve çevresindeki tarım alanlarının yabani ot florası. Erzincan Univ J Sci Technol 9(2):148–171

Yarcı C, Serin M, Altay V (2007) The segetal vegetation of Kocaeli Province (Turkey). Ekoloji 16(63):23–33

Chapter 19
Faunal Diversity of Azerbaijan

Elman Yusifov and Elshad Ahmadov

19.1 Introduction

The Republic of Azerbaijan is located in the east of South Caucasus, on the west coast of the world's largest inland body of water, also written as the world's largest lake, an endorheic basin the Caspian Sea, differing sharply from other Caucasian nations due to its impressive nature. The country is one of the richest regions in the Caucasus in terms of both natural resources and biodiversity (Ozturk et al. 2018a, b). The diversity of relief, climate, soil, and vegetation has led to the formation of its unique fauna.

Studies on the fauna of Azerbaijan started 200 years back. The species composition of free-living and parasitic protozoans, helminths parasitizing humans, animals and plants, vertebrates and invertebrates in the hydrofauna, insects, arachnida, amphibians, reptiles, birds, and mammals are studied in the animal world of Azerbaijan. The helminths have been a topic of research since years, and investigations have been carried out at the Institute of Zoology and are still going on. Some of the species belonging to the vertebrates fauna of Azerbaijan have the status of rare and endangered species. Ichthyofauna has a rich species composition. Bird migration routes, parking lots, and wintering grounds are of international importance throughout the country.

Arthropod makes up 85% of all animal species found in Azerbaijan, and hundreds of species from this group are described from the country every year, which are new to the fauna. Taking into account their importance in nature, their species composition, biology, ecology, and distribution have been studied intensively by the researchers from the Institute of Zoology of ANAS.

The long-term investigations by the scientists of Azerbaijan have revealed that Cyclostomata is represented by one species in the fauna of Azerbaijan. Distribution

E. Yusifov (✉) · E. Ahmadov
Institute of Zoology of Azerbaijan National Academy of Sciences, Baku, Azerbaijan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_19

of 104 species and a number of subspecies belonging to 12 families of fishes have been recorded in the Azerbaijani sector of the Caspian Sea and in the inland water basins. The amphibian fauna includes 2 groups, 6 families, and 9 genera with 11 species. The reptiles include 63 species from 2 groups (lizards and snakes). Recent work shows that 405 bird species belonging to 19 groups and 65 genera and 115 species of mammals belonging to 7 groups are distributed in the territory of Azerbaijan. The role of arthropods in nature is great as they are an important component of all ecosystems, belonging to the primitive ringed worms in the Precambrian period.

Class of Crustaceans (Crustacea) There are more than 30,000 species grouped under 16 orders and 5 subtypes from the world. In all 450 species from 12 orders have been recorded from the waters of Azerbaijan. Representatives of the class live in the thicknesses (among planktons) and at the bottom (benthos) of the seas and freshwaters (Kasimov 1972, 1987, 2004; Kasimov and Bagirov 1983; Musaev et al. 2004). Some like genus *Balanus* lead a fixed life. There are terrestrial (Isopoda) and parasitic forms. Some like Copepoda are intermediate hosts of pathogenic parasites.

Crustaceans (Fig. 19.1) have distinctive features compared to the other representatives of arthropods. They have two pairs of antennae and limbs with forked structure, and they mostly breathe with gills, which are special outgrowths of limbs. The body of crustaceans consists of three parts – the head, chest, and abdomen. The segments of the head and chest are joined by a common shield and form the cephalothorax. The head consists of 5 segments, the breast in the higher crustaceans consists of 8, and in the lower crustaceans, numbers differ (up to 50) of the segments. In each segment of the crustaceans (with some exceptions), there is a pair of limbs, but in lower crustaceans abdominal segments have no limbs. In many parasitic forms, limbs, as a rule, are reduced. The base of the limb of the body (protopodit) is divided into two parts (exit and enzit), which is considered a primitive feature. In the head part of the body (according to the number of segments), there are five pairs of limbs. Their first pair forms antennas. Usually these antennas are single-branched (sometimes have three-branched ones), two pairs of antennas are located in the front section of the head, and at the level of oral opening, antennas generally play a sensitive role and other head antennas play the role of jaws (mandibula). All limbs of the chest are legs which serve in swimming. However, in some representatives, the first three pairs of terminal extremities are transformed into the maxilla (maxillopods). The jaws have the function of catching and holding food. In most cases, the thoracic limbs are double-stranded. In crustaceans, the abdomen ends in various formations, which are called differently in different representatives. In coniferous crustaceans, they are called caudas (tail), in copepods, furca, and in higher crustaceans, telson (limb). Their body is covered outside with a cuticle of chitinous origin, which forms their external skeleton. In the lower forms, the cover is soft, and in the higher ones, the cover is strong. Along with the implementation of the protective cover, the skeleton plays a supporting function; the growth is accompanied by molting. They have two types of eyes, one called larval (nauplii); it is simple in structure and characteristic of the larval stages of all crustaceans. In some groups of lower crustaceans (e.g., in copepods), the nauplii eyes also function in adults. The second type of

Fig. 19.1 **Crustaceans**: (1) Artemia salina, (2) *Pontastacus* (*Astacus*) *leptodactylus*; **Aranei**: (3) Trachyzelotes jaxartensis, (4) Lycosa tarantula, (5) Mesobuthus eupeus, (6) Galeodes araneoides

crustacean eyes is characteristic of all arthropods and is called complex or faceted. Faceted eyes consist of a set of simple eyes (each facet eye has up to 3.000 simple eyes). Only in few groups, there are two types of eyes found together (order Branchiopoda). The copepods are characterized by nauplii eyes and for decapod crayfish by faceted eyes. The class of crustaceans consists of 11 units. Their classification and main species distributed in Azerbaijan are given below (Tables 19.1 and 19.2).

Table 19.1 Taxonomic classification of Arthropods

Subtype	Class
Branchiata	Crustacea
Chelicerata	Arachnoida
Tracheata	**Subclass Myriapoda:** Diplopoda; Chilopoda; Symphyla; Pauropoda
	Tardigrada; Insecta

Table 19.2 The main species distributed in Azerbaijan

Orders	Species
Anostraca	*Artemia salina*, *Branchinectella media*, *Branchinecta ferox*, *Chirocephalus skorikovi* (endemic), *C. weisigi* (endemic)
Phyllopoda There are 134 species in freshwaters and 57 species in the Caspian Sea	**In freshwaters:** *Triops cancriformis*, *T. cancriformis transcaucasicus*, *Diaphanosoma brachyurum*, *D. leuchtenbergianum*, *D. sarsi*, *Daphnia magna*, *D. pulex*, *D. longispina hyalina*, *Simocephalus vetulus*, *S. elizabethae*, *Moina macrocopa*, *M. brachiata*
	In the Caspian Sea: *Polyphemus exiguus*, *Cercopagis longiventris*, *C. prolongata*, *C. anonix*, *Apagis cylindrata*, *A. beklemishevi*, *Evadne anonyx typica*, *E. prolongata*, *Podonoevadne trigona typica*
Copepoda There are 41 species in the Caspian Sea and 60 species in freshwaters	**In freshwaters:** *Calanipeda aquaedulcis*, *Sinodiaptomus sarsi*, *Hemidiaptomus rylovi*, *Arctodiaptomus acutilobatus*, *Macrocyclops fuscus*, *M. albidus*, *Eucyclops serrulatus*, *Cyclops strenuus*, *C. vicinus*, *Microcyclops gracilis*, *Thermocyclops dybowskii*
	In the Caspian Sea: *Eurytemora grimmi*, *E. minor* (endemic), *Heterocope caspia*, *Halicyclops sarsi*, *Mesochra lilljeborgi*, *Limnocalanus grimaldii*
Branchiura	*Argulus coregoni*, *A. foliaceus*
Cirripedia	*Balanus improvisus*, *B. eburneus*
Ostracoda There are 19 species in inland waters and 88 species in the Caspian Sea	**In inland waters:** *Eucypris lutaria*, *Ilyocypris gibba*, *Cypris bispinosa*, *C. pubera*, *Herpetocypris reptans*, *Cyclocypris ovum*, *Physocypria kraepelini*, *Herpetocypris reptans*, *Candona candida*, *Ilycypris lacustris*, *I. biplicata*, *I. divisa*
	In the Caspian Sea: *Cytherissa inormis*, *Leptocythere bacuana*, *L. mathra*, *L. bacuana longa*, *L. bosqueta artemica*, *L. laevis*, *L. minuta*, *L. laetifica*
Mysidacea There are 20 species in the Caspian Sea. Thirteen species of them are Caspian endemics	*Limnomysis benedeni*, *Katamysis warpachowskyi*, *Paramysis ullskyi*, *P. intermedia*, *P. lacustris*, *P. baeri*, *P. lexolepis, P. grimmi*, *P. kessleri*, *Mysis caspia*, *Diamysis pusilla*, *Mysis microphthalma*, *M. macrolepis*, *M. amblyops*
	In freshwaters: Two species (*Limnomysis benedeni* and *Paramysis lacustris*)
Cumacea There are 18 species in the Caspian Sea	**Endemic species:** *Schizozhynchus bilamellatus*, *S. knipowitchi*, *Pterocuma grandis*, *Stenocuma diastyloides*, *St. gracilis*, *Hircanocuma sarsi*, *Carinocuma birsteini*, *Volgocuma telmatophora*, *Pseudocuma cercaroides*, *P. laevis*, *Caspiocuma campylaspoides*

(continued)

Table 19.2 (continued)

Orders	Species
Isopoda There are two sub-species in the Caspian Sea.	**Endemic species:** *Saduria entomon caspia*, *Jaera sarsi caspica*
	There is one species in freshwaters – *Asellus aquaticus*
	Terrestrial isopods: *Porcellio pruinosus*, *Protracheoniscus orientalis*, *Armadillidium vulgare*, *Hemilepistus klugii*, *H. ruderalis*, *Desertillia elongatus*, *Cylisticus murovdaghiensis*
Amphipoda There are 74 species in the Caspian Sea and 32 species in inland waters.	**In the Caspian Sea:** *Amathillina cristata*, *A. spinosa*, *A. pusilla*, *A. maximovitschi*, *A. affinis*, *Dikerogammarus haemobaphes*, *D. caspius*, *D. oscari*, *Niphargoides* (*Pontogammarus*) *maeoticus*, *N.(P.) robustoides*, *N.(P.) paradoxus*, *Niphargoides compactus*, *N. caspius*, *N. grimmi*, *N. compressus*, *Niphargus caspius*
	In inland waters: *Gammarus matienus*, *G. balcanicus alarodius*, *G. lacustris*, *G. komareki araxenus*, *G. balcanicus talyschensis*, *Pontogammarus aralensis setosus*, *P. sarsi*, *P. robustoides*, *Niphargus galenae*, *N. kurdus*, *Lyurella hyrcana*
Decapoda There are six species in the Caspian Sea and five species in inland waters	*Palaemon elegans*, *P. adspersus*, *Pontastacus* (*Astacus*) *leptodactylus*, *P.(A) eichwaldi*, *Caspiastacus pachypus*
	In inland waters: *A. pilzowii*, *A. leptodactylus*, *Potamon magnum*, *P. albanicum*, *P. ibericum*

Class Arachnids (Arachnida) (Table 19.3) Covers all terrestrial Chelicerata, sizes range from 100 microns to several centimeters, typical sizes 2–3 cm, in some cases – up to 20 cm or more. More than 114,000 species from 13 orders are described globally.

Order Spiders (Aranei) Dimensions vary in the range of 0.8 mm–11 cm; spiders with different colors and patterns are predatory animals, distributed throughout the world, from Africa to the deserts of America, on the glaciers of Greenland, at altitudes of 7000 meters above sea level. The body consists of a cephalothorax and abdomen four pairs of ultimate stems. Single spiders pursue a victim; jumping spiders jump at the victim from a distance 75–80 times their size, which requires careful calculation of distance to the victim. This function is provided by six to eight eyes located in the anterior part of the cephalothorax.

Unlike other arthropods, spider eyes are not faceted, but lens type. Two medium (main) eyes are larger than the rest. Lateral eyes serve to fix any movement. Using these eyes, the spider in the brain produces a picture of the shape and size of the object. In the abdomen are spider warts. Spider fluid consists of protein which gets polymerized in the air. Spiders use a web for various purposes: a grasping net, a net for a cocoon, etc. Sedentary spiders build complex web systems and kill food with poison.

Arachnids are different types of insects, with water spiders feeding on insect larvae, small crustaceans, fish fry. Huge tropical spiders feed on small birds after killing with poison, the power digestive juice on them. The size of the males is smaller than females. In some cases, this difference is more than 1000 times. Some

Table 19.3 Species of arachnids common in Azerbaijan

Orders	Species
Scorpiones 4 species	*Mesobuthus eupeus*, *Mesobuthus caucasicus*, *Androctonus crassicauda*, *Euscorpius mingrelicus*
Pseudoscorpiones 52 species: 5 species are Caucasian endemics	*Atemnus politus*, *Chernes horvathii*, *Chthonius shelkovnikovi*, *Chthonius azerbaidzhanus*, *Dactylochelifer kussariensis*, *Minniza babylonica*, *Neobisium anatolicum*, *N. alticola*
Solifugae 11species	*Daesia schelkovnikovi*, *Galeodes araneoides*, *G. caspius*, *Gluviopsis nigrocinctus*, *Gylippus caucasicus*, *Karschia caucasica*, *Paragaleodes melanopygus*, *Rhagodes caucaicus*
Opiliones 40 species	*Opilio absheronicus*, *O. afghanus*, *O. dinaricus*, *O. lederi*, *O. redicorzevi*, *Paranemostoma filipes*, *Phalangium punctipes*, *Rilaena pusilla*
Aranei 678 species	*Araniella cucurbitina*, *Dysdera azerbajdzhanica*, *Drassodes lapidosus*, *Tenuiphantes tenuis*, *Pardosa italica*, *Cyrba algerina*, *Enoplagnatha macrochelis*, *Xysticus tristrami*
Acariformes 880 species: 47 national endemics	*Paraforcellinia saljanica*, *Bakerdania flabellifolia*, *Imparipes cavernophilis*, *Lorryia opimus*, *Tydeus praeditus*, *Miyatrombicula caucasica*, *Neotrombicula alizadei*, *Riedlinia assadovi*
Parasitiformes 272 species: 12 national and 12 Caucasian endemics	*Amblyseius musaevi*, *A. bregetovae*, *A. pseudaequipilus*, *A. azerbaijanicus*, *A. muganicus*, *A. wainsteini Abbasova*, *A. subalgericus*, *Euseius apsheronica*

species of females eat males after fertilization. For them, custody of offspring is characteristic. Eggs are laid in a cocoon net. The female either carries the cocoon with her or fastens to sturdy objects (plant, wood, stone). After hatching in 30–40 days, the spiders set up their own webs. Many spiders live for a year, and the bird-eating spiders live for 7–8 years. The poison of most spiders is completely safe for humans. Only the bite of some species like *Latrodectus tredecimguttatus* leads to serious diseases. Arachnids are one of the most widely distributed orders in the animal world, with about 42,000 species belonging to 109 families. Nearly 700 species from 44 families distributed in Azerbaijan (Fauna of Azerbaijan 2004). Spiders occupy a unique and irreplaceable status in biological diversity. They play the role of regulators of number of many insects in nature and are prey for some animals, especially for the family Pompilidae, and important in increasing their populations. *Lycosa tarantula* spiders from the family Lycosidae play a special role in agriculture and in natural ecosystems by controlling the numbers of many insects, especially pests. All members of the family have eight eyes located in three rows. In the first (lower) row, there are 4four small eyes. In the second middle row, there are two large eyes. The eyes of the third (upper) row are paired and located on the sides. Vision plays a special role for spiders. Tarantula, like other arachnids, builds a cocoon, laying eggs. The female carries cubs in the abdomen (40–100 individuals) before inoculating them with independent food-producing abilities.

Scorpions (**Scorpiones**) are terrestrial animals, distributed only in warm climatic zones. There are no scorpions in the forests, swamps, subalpine areas, and in the alpine meadows. Of the 1400 species of scorpions, nearly 50 are poisonous and dangerous for humans. The scorpions are the oldest detachment. The largest scorpion is an imperial scorpion (*Pandinus imperator*) up to 20 cm long. The head is covered with a shield with three to six pairs of eyes on it. The cephalothorax consists of small seeds, a large leg with a claw, a sense organ, and four pairs of legs. The frontal part of the segmented abdomen consists of seven segments, and the back part has five segments. On the last segment of the abdomen is the venom gland, opening at the end of the sharp sting. Despite the painful bite of a scorpion, the pain goes away without any consequences in 2–3 days. The black scorpion venom is more toxic and requires hospital treatment. The poison of tropical scorpions is very dangerous for humans. *Mesobuthus eupeus* with 14 subspecies is most common in Azerbaijan. In some territories of Absheron, there are 120 per/ha of land and in Nakhichevan – 250 individuals of scorpions. *Androctonus crassicauda* in the territory of Azerbaijan is widespread in Nakhichevan, settling in minks of gerbils with high fecundity, and breeds 35–70 cubs.

Class Diplopoda These are characterized by a cylindrical body shape and two pairs of limbs on each segment. Only paired four rings of a trunk are deprived of it. The body is covered with a shield rich in calcium carbonate; on the sides there are glands secreting a defensive fluid. There are about 10,000 species of diplopods from 2.200 genera, 170 families and 16 orders in the world. Experts estimate their species diversity in the range of 80,000 species. So far only 10–15% of species of this class have been noted. About 100 species are described from the Caucasus, and 37 species of diplopods from the detachments Glomerida, Polydesmida, and Julida have been described from Azerbaijan. The species are *Hyleoglomeris lenkorana*, *Brachydesmus bidentatus*, *Amblyiulus continentalis*, *Ommatoiulus caspius*, *Megaphyllum brachyurum*, *Brachyiulus lusitanus*, and the main splitters of plant residues *Anuroleptophyllum caucasicum*, etc.

Diplopods play a special role in the ecosystems. They carry out the primary fragmentation of plant remains, are actively involved in the soil formation and circulation of elements. Many diplopods play the role of indicators in determining soils. Their ability to accumulate calcium leads to an increase in water-retaining ability. During monitoring processes they are used to determine soil contamination with heavy metals and radioactive elements. In general all diplopods are regulators of the numbers and terrestrial invertebrates in the soil. They are also the food of predatory insects, reptiles, birds, and some mammals.

Class Chilopoda These are predators with 15–23 pairs of legs, feeding on various invertebrates, and live mainly in the soil, under stones and stumps, on the forest floor, within wooden bark. Their body is tightened, and the eyebrows are lined up; poison in some of them is dangerous for humans and causes fever and paralysis. About 3000 reported from the world, about 60 species belonging to 4 orders Geophilomorpha, Scolopendromorpha, Lithobiomorpha, and Scutigeromorpha have been described from Azerbaijan. There are *Geophilus caucasicus*, *G. transmontanus*, *Pleurogeophilus caucasicus*, *Pachymerium ferriginium*, *Clinopodes* *escherichii*, *Brachygeophilus sukacevi*, *Scolopendra aralocaspica*, *S. cingulata*, *Scutigera coleoptrata*, *Cryptops punctatus*, and other species. The order Lithobiomorpha is widely represented in the *Chilopoda* fauna of Azerbaijan. Most of them belong to the genuses *Lithobius* (14 species) and *Monotarsobus* (18 species). There are *Harpolithobius perplexus*, *Lithobius portschinskii*, *L. viridis*, *L. kessleri*, *L. pusillus*, *L. asper*, *L. antipai*, *L. oblongus*, *Monotarsobius cutipes*, and *M. curtipes*, etc.

Class Tardigrada These are barrel-shaped microscopic organisms, 0.1–0.2 mm body length, and live mainly in freshwater environments – in the water drops among the mammaries, lichens, and waterfowls. The tardigrades have four pairs of short and heavy legs, four to eight long jaws. There are more than 900 species found globally, the 2 species (*Macrobiotus hufeland* and *Milnesium tardigradum*) have been described from Azerbaijan.

Class Insecta This is the largest class in the fauna of Azerbaijan. Their body is divided into three parts which differ sharply from each other – the head, the breast, and the abdomen. The head consists of six segments. The breast part is divided into 3, and the abdomen is divided into 10 to 12 sections. In the head, there are three different eyes (supplement, derivative, facet), mustaches or necklaces, upper jaws (mandibulars), lower jaws (maxillary), and lower lip. All these organs are double in number. There are also non-pairing elements, three simple eyes (ocular), upper lip on the mouthpiece; mouthpieces show different forms. The abdominal section of the breast segment is composed of three pairs of legs consisting of five parts. Depending on the function, the legs are in different forms. Insects are very different also in the trophic relations. Collembola, Homoptera, Phasmoptera, Isoptera, and Orthoptera mainly feed on wood, plants, pollen, juices, and root systems. Plecoptera, Embioptera, Thysanura, and Dermaptera feed mainly on detritus, plant, and animal leftovers. Diplura, Mantoptera, Odonata, and some Diptera species (robber fly) are predatory insects. Trichodectidae are parasitic for animals and birds. Anoplura and Siphonaptera are parasite organisms and feed on the blood of their hosts. Strepsiptera and Diptera are endoparasites in other insects, entering the host's body. The real number of insects is about 1.4–1.8 million, nearly 20% of all species found on earth. More than 10.000 insects have been described from Azerbaijan.

The insects also have a strong anthropogenic impact. Seventy seven are included in the second edition of the Red Book of Azerbaijan, mainly representatives of Lepidoptera (52 species), Odonata (2 species), Coleoptera (19 species), and Hymenoptera (4 species) (Table 19.4 and Fig. 19.2). Main reason for this is the use of biotopes of non-systematic grass seeds for various purposes (non-systematic planting areas etc.), collections without any rules, and others (Aliev 1984, 1997; Rzayeva 2002; Musaev et al. 2004; Snegovaya and Starega 2011).

Phylum Chordata It is considered as the main group of the animal kingdom, including up to 42.000 species. A number of peculiar features for chordates are characteristic (Table 19.5). The basis of their body is a whole or segmented spine column, called chorda. Chorda is an axis of skeleton and consists of vacuolated

Table 19.4 Insect diversity in Azerbaijan

Order	Genus
Anoplura 20 species	*Haematopinus*, *Linognathus*, *Pediculus*, *Phthirius*, *Polyplax*
Apterygota 4 species	*Lepisma*, *Machilis*, *Therobia*
Blattoptera 11 species	*Blatta*, *Blatella*, *Ectobius*, *Periplaneta*, *Phyllodromica*, *Polyphaga*
Collembola more than 100 species	*Anurida*, *Cyphodeus*, *Entomobrya*, *Follosomia*, *Heteromurus*, *Isotoma*, *Isotomiella*, *Orchesella*
Coleoptera 4000 species	*Amara*, *Ampedus*, *Anisoplia*, *Anobium*, *Aphodius*, *Attelabus*, *Carabus*, *Calasoma*, *Cantharis*, *Capnodis*, *Cerambyx*, *Cicindela*, *Coccinella*, *Disirca*, *Dorcadion*, *Haliplus*, *Harpalus*, *Helichus*, *Hydrous*, *Gyrinus*, *Laccophilus*, *Lampyris*, *Limnebius*, *Lucanus*, *Lygistopterus*, *Malachius*, *Mallosia*, *Megasephala*, *Meligetes*, *Mordella*, *Mylacus*, *Oedemera*, *Oryctes*, *Parandra*, *Peltodytes*, *Philonthus*, *Phyllobius*, *Plagionotus*, *Podonta*, *Polyphylla*, *Rhantus*, *Rosalis*, *Scarites*, *Scolysus*, *Sitophilus*, *Sitona*, *Staphylinus*, *Strangalia*, *Tachyporus*, *Thanatophilus*, *Thanasimus*, *Tribolium*, *Xylita*, *Xylotrechus*, *Zabrus*
Dermaptera 7 species	*Anechura*, *Forficula*, *Labia*, *Labiduria*
Diplura 3 species	*Campodea staphylinus*, *C. plusiochaeta*, *Lapyx caucasica*
Diptera 2000 species	*Alluaudomy*, *Bezzia*, *Chironomus*, *Clunio*, *Cnephia*, *Contarinia*, *Corynoneura*, *Cricotopus*, *Culicoides*, *Dasyhelea*, *Diamesa*, *Dilophus*, *Einfeldia*, *Heteropeza*, *Leptoconops*, *Mayetiola*, *Monardia*, *Nephrotoma*, *Odagmia*, *Oestris*, *Palyomyia*, *Procladius*, *Scatopse*, *Simulium*, *Tabanus*, *Tanytarsus*, *Tipula*, *Wasmaniella*, *Wilhelmina*, *Wolfartia*
Embioptera 1 species	*Haploembia solieri*
Ephemeroptera 4 species	*Ameletus*, *Caenis*, *Isonychia*, *Siphlonurus*
Hemiptera 900 species	*Aphelocheirus*, *Capsus*, *Carpocoris*, *Cimex*, *Coptosoma*, *Corixa*, *Deraeocoris*, *Iliocoris*, *Isometopus*, *Lygus*, *Notonecta*, *Nepa*, *Nebrus*, *Megacoelum*, *Myrmedobia*, *Ochterus*, *Phymata*, *Plea*, *Pilophorus*, *Primphyma*, *Pyrrhocoris*, *Ranatra*, *Scantius*, *Spilostethus*, *Stenodema*
Homoptera 900 species	*Adelphocoris*, *Aleurodes*, *Aphelinus*, *Aphis*, *Asiphum*, *Camaro*, *Ceresa*, *Centrotus*, *Chrysis*, *Cynips, Diuleurodes*, *Eriosoma*, *Homotoma*, *Livia*, *Myzocallis*, *Myzodes*, *Myzus*, *Pemphigus*, *Pineus*, *Pomponia*, *Psylla*, *Philaenus*, *Ptyelis*, *Siphoninus*, *Tibicen*, *Thecabius*
Hymenoptera 2700 species	*Abia*, *Ametastegia*, *Ammophila*, *Anachalcis*, *Anagyrus*, *Andrena*, *Apis*, *Arge*, *Athalia*, *Bombus*, *Brachymeria*, *Crematogaster*, *Cephus*, *Cryptocheilus*, *Diospilus*, *Empria*, *Formica*, *Gelis*, *Halictus*, *Hartigia*, *Heterarthrus*, *Hockeria*, *Lasius*, *Macrophya*, *Megalodontes*, *Netelia*, *Nomia*, *Odynerus*, *Pachycephus*, *Pamphilius*, *Pimplini*, *Ponera*, *Pontania*, *Rogas*, *Sceliphron*, *Sphex*, *Stein*, *Tapinoma*, *Triaspis*
Isoptera 2 species	*Kalotermes flavicollis*, *Reticulitermes lucifugus*

(continued)

Table 19.4 (continued)

Order	Genus
Lepidoptera 4500 species	*Agrotis*, *Amorpha*, *Anthocharis*, *Aphantopus*, *Aplasta*, *Aricia*, *Arethusana*, *Argynnis*, *Atychia*, *Axiopoena*, *Biston*, *Bucculatrix*, *Boloria*, *Callimorpha*, *Callophrys*, *Caloptilia*, *Campaea*, *Caradrina*, *Catoca*, *Catocala*, *Celastrina*, *Celerio*, *Cerura*, *Chasara*, *Chilades*, *Coenonympha*, *Colias*, *Cossus*, *Cochlidion*, *Danais*, *Dicranura*, *Deiopea*, *Drepana*, *Earias*, *Erebia*, *Euchloe*, *Euphydryas*, *Eupithecia*, *Euxoa*, *Gortyna*, *Habrosyne*, *Haplotinea*, *Hedya*, *Heodes*, *Hepialus*, *Heterogenea*, *Hipparchia*, *Hyponephele*, *Hyphilare*, *Inachis*, *Incurvaria*, *Iphiclides*, *Lampides*, *Lemonia*, *Libythea*, *Limenitis*, *Lycaena*, *Lyela*, *Malacosoma*, *Marumba*, *Melanargia*, *Melitaea*, *Micropteryx*, *Nemapogon*, *Nepticula*, *Neptis*, *Nola*, *Nymphalis*, *Oenistis*, *Opostega*, *Pandesma*, *Papilio*, *Parnassius*, *Paralasa*, *Phassus*, *Pieris*, *Plebejus*, *Polygonia*, *Polyommatus*, *Procris*, *Pyralis*, *Saturnia*, *Satyrus*, *Segris*, *Sesia*, *Sideridis*, *Smerinthus*, *Spilosoma*, *Thaleropis*, *Theresiminia*, *Thersamonia*, *Tomares*, *Triphaena*, *Thyris*, *Vanessa*, *Zerynthia*, *Zygaena*
Mallophaga 393 species	*Amblycera*, *Anatoecus*, *Aristolochia*, *Colpocephalum*, *Cyclotogaster*, *Goniodes*, *Menacanthus*, *Pseudomenopon*, *Ricinus*, *Trichodectes*, *Trinoton*
Mantoptera 8 species	*Bolivaria*, *Empusa*, *Hierodula*, *Iris*, *Mantis*, *Oxythespis*, *Parameles*
Mecoptera 4 species	*Panorpa caucasica*, *P. communis*, *P. connexa*, *Bittacus tipularis*
Megaloptera 2 species	*Sialis zhiltzovae*, *S. abchasica*
Neuroptera 8 species	*Chrysopa*, *Dilar*, *Hemerobius*, *Hypochrysa*, *Mymecaelurus*, *Nineta*
Odonata 60 species	*Aeschna*, *Agrion*, *Anax*, *Coenagrion*, *Cordulegaster*, *Crocothemis*, *Enallagma*, *Epallage*, *Erythromma*, *Ischnura*, *Lestes*, *Libellula*, *Lindenia*, *Orthretum*, *Platychemis*, *Selysiothemis*, *Sympiena*, *Sympycna*, *Sympetrum*
Orthoptera 92 species	*Chorthippus*, *Dectius*, *Dociostaurus*, *Gryllotalpa*, *Gryllus*, *Isophya*, *Isoimon*, *Locusta*, *Oecanthus*, *Pamphagus*, *Parapholidoptera*, *Poecilimon*, *Tetragryllus*, *Tettigonia*, *Tetrix*
Phasmoptera 1 species	*Ramulus bituberculatus*
Plecoptera 32 species	*Arcynopteryx*, *Capnia*, *Chloroperla*, *Esera*, *Isoperla*, *Leuctra*, *Protonemura*, *Perla*
Protura 1 species	*Eusentomon transitorum*
Psocoptera 6 species	*Lachesilla*, *Lepinotus*, *Trogium*
Raphidioptera 2 species	*Rhaphidia major*, *R. grusinica*
Siphonaptera 89 species	*Amphypsylla*, *Ceratophyllus*, *Ctenocephalides*, *Ctenophthalmus*, *Hystrichopsylla*, *Myxopsylla*, *Paradoxopsyllus*, *Pulex*, *Xenopsylla*
Strepsiptera 4 species	*Andrena*, *Halictus*, *Nespa*, *Polistes*
Trichoptera 45 species	*Glossosoma*, *Leptocerus*, *Lithax*, *Micrasema*, *Rhyacophila*, *Tinodes*
Thysanoptera 56 species and subspecies	*Aeolothrips*, *Aptinothrips*, *Frankliniella*, *Haplothrips*, *Odontothrips*, *Scolothrips*, *Taeniothrips*, *Thrips*

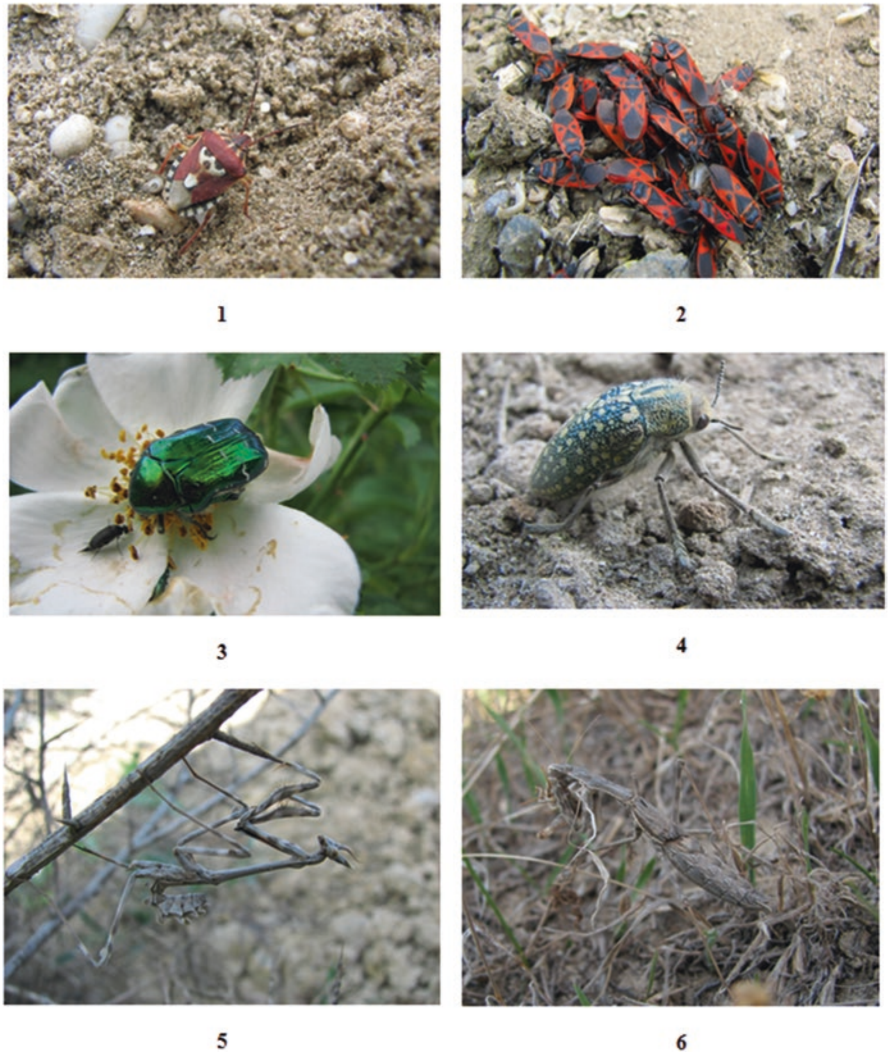


Fig. 19.2 (1) *Cadophila varia*, (2) *Scantius aegyptius* (**Hemiptera**); (3) *Protaetia aeruginosa*, (4) *Julodis faldermanni* (**Coleoptera**); (5) *Empusa pennicornis*, (6) *Bolivaria brachyptera* (**Mantoptera**)

cells. It remains primitive in all organisms throughout the lifetime. In high organized animals, it is replaced by the backbone.

There is no representative of Acrania and Tunicata recorded in the fauna of Azerbaijan.

Table 19.5 Classification of Chordates

Sub-phylum	Class
Acrania	Cephalochordata
Tunicates (Tunicata)	Ascidians (Ascidiae), salpas (Salpae), larvaceans (Appendicularia)
Vertebrates (*Vertebrata*)	**Superclass Agnathans** (**Agnatha**): Pteraspidomorphs (Pteraspidomorphi), cephalaspidomorphs (Cephalaspidomorphi), cyclostomes (Cyclostomata)
	Superclass Gnathostomes (**Gnathostoma**): Cartilaginous fishes (Chondrichthyes), bony fishes (Osteichthyes), amphibians (Amphibia), reptilians (Reptilia), birds (Aves), mammals (Mammalia)

Sub-phylum *Vertebrata* has a higher structure of integuments, consisting of two layers – multilayer epidermis and corium. Scales, feathers, hair, and claws are its derivatives. In vertebrates, the chorda occurs only in the period of embryonic development. The sub-phylum has a high structure and functional diversity which poses difficulties in its classification. According to the most common classification, the vertebrate sub-phylum is subdivided into the classes of cyclostomata (Cyclostomata), cartilaginous fishes (Chonrichthyes), bony fishes (Osteichthyes), amphibians (Amphibia), reptiles (Reptilia), birds (Aves), and mammals (Mammalia).

Class Cyclostomata Representatives are primitive animals, inhabitants of the seas and freshwaters. Of the two subclasses of these jawless fish – the lamprey (Petromyzones) and mixin (Myxini) – have more than 40 species. These are the most common members of this class, but most typical representative is the lamprey (*Lampetra fluviatilis*), used in the food industry. The absence of jaws and limbs in the lampreys and mixin indicates that they belong to the lowest rank of vertebrates. Modern cyclostomes are formed from ancient vertebrates – uncranials. Their body is bare, serpentine, and covered with slime; the mouth part locks jaw in the form of a funnel. In the world fauna, each subclass is represented by one detachment. Mixins are not found in the fauna of Azerbaijan. Lampreys are represented by 1 family, 7 genera, and up to 25 species. In the waters of the territories from Yalama to Astara, there is only one species – Caspian lamprey (*Caspiomyzon wagneri*). This is a migratory species and lives in the seas, only during the breeding season enters the rivers. Due to the sharp decline of this endemic Caspian species, it was included in the first edition of the Red Book of Azerbaijan. An important reason for this was a sharp decrease in their biotopes due to the construction of hydroelectric stations and dams. However, as a result of the high productivity of the species (14,000–40,000 eggs) and the ability to adapt to new conditions, its numbers recovered and even increased.

Class Chondrichthyes Members of this class mostly live in the seas and oceans. The cartilaginous fishes from this class include 730 species. The class is divided into two subclasses – plastinated (Elasmobranchii) and whole-headed (*Holocephali*) (Table 19.6). The most common representatives are the shark and the stingrays. There are no species of this class in the ichthyofauna of Azerbaijan.

Table 19.6 Classification class of cartilaginous fish (Chondrichthyes)

Subclass	Superorder	Order
Plastinated (Elasmobranchii)	Sharks (Selachii)	Carcharhiniformes, Heterodontiformes, Hexanchiformes, Lamniformes, Orectolobiformes, Pristiophoriformes, Squaliformes, Squatiniformes
	Stingrays (Batoidea)	Myliobatiformes, Rajiformes, Torpediniformes, Pristiformes
Whole-headed (Holocephali)		Chimaeras (Chimaeriformes)

Class Osteichthyes This class of bony fishes includes up to 1500 species. They live in the seas and in freshwaters. Their body consists of head, torso, and tail. Their length ranges from a few millimeters to several meters. The muscles show a segmental structure.

Bony fish are divided into subclasses of lobe-finned fishes (**Sarcopterygii**) and ray-finned fishes (**Actinopterygii**). The lobe-finned fish cover orders Coelacanthiformes, Ceratodontiformes, and Lepidosirenidae. Modern ray-finned fishes consist of 35 units. Ninety five percent of modern fish belong to ray-finned fishes.

The ichthyofauna of Azerbaijan consists of 13 orders, 101 taxa, and 9 species which are included in the second edition of the Red Book of Azerbaijan (Table 19.7 and Fig. 19.3). On the basis of their habitats, these fishes are divided into four ecological groups (marine, freshwater, migratory, and semi-migratory). Most of herrings (*Alosa* sp.), sprats (*Clupeonella* sp.), sea pikeperch (*Sander marinus*), gobies (*Neogobius* sp.), etc. are marine species. In turn, they are subdivided into open space fish (herring, sprat) and bottom fish (goby).

Freshwater fishes are subdivided into rheophilic or flowing water fishes (trout, gudgeon, squirrelfish) and limnophilic or stagnant water fishes (rudd, dace, perch, pike). At certain periods, some fishes (carp, cattle, bream) are related to both types. Sturgeon, salmon, bleak, and white eye belong to the group of migratory fish. Before sexual maturity, these fishes live in the seas and then migrate into rivers for spawning, swimming long distances, and migrating to the mouth of rivers. Migratory fishes have a number of characteristics; they can bear the drastic changes in salinity. Migration provides benefits to passing fish: it helps in the development of young individuals and provides adults with a rich food base. However, during migration, the obstacles encountered (currents, dams, waterfalls) contribute to their great loss. During migration, changes in the degree of salinity contribute toward the extermination of skin parasites. Many fish (salmon, herring) die after spawning.

Semi-migratory fishes (carp, bream, roach, pike perch) mostly live at certain depths of Caspian Sea; for spawning they move into rivers and spawn near the source of the river. Other migratory fishes spawn several times. The migratory fishes have industrial importance; therefore during hydropower building, special fish passages are built.

Table 19.7 The ichthyofauna of Azerbaijan

Order	Species
Acipenseriformes	*Acipenser nudiventris*, *A. gueldenstaedtii*, *A. ruthenus*, *A. stellatus*, *Huso huso*
Anguilliformes	*Anguilla anguilla*
Atheriniformes	*Atherina mochon*
Clupeiformes	*Alosa caspia*, *A. saposhnikovi, A. brashnikovi*, *A. brashnikovi brashnikovi*, *A. brashnikovi agrachanica*, *A. brashnikovi sarensis*, *A. brashnikovi autumnalis*, *A. brashnikovi kisselevitschi*, *A. brashnikovi grimmi*, *A. curensis*, *A. kessleri*, *A. kessleri volgensis*, *A. kessleri grimm*, *Clupeonella delicatula*, *C. engrauliformes*, *C. grimmi*
Cypriniformes	*Abramis brama*, *A. sapa*, *Acanthalburnus microlepis*, *Alburnus charusini*, *A. hohenakeri*, *Alburnoides bipunctatus*, *Alfilippi kessler*, *Aspius aspius*, *A. taeniatus*, *Barbus ciscaucasicus*, *B. cyri*, *B. brachycephalus*, *B. capito*, *B. mursa*, *Blicca bjoercna*, *Chalcalburnus chalcoides*, *C. chlongissimus*, *Chondrostoma oxyrhynchym*, *C. cyri*, *Cyprinus carpio*, *Gobio ciscaucasus*, *G. persa*, *Cobitis taenia*, *C. aurata*, *C. caspia*, *Nemacheilus angorae*, *N. lenkoranensis*, *N. negra*, *N. brandti*, *Pelecus cultratus*, *Rhodeus sericeus*, *Rutilus rutilus*, *R. sojuchbulagi*, *R. atropatenus*, *R. frisii*, *Leuciscus cephalus*, *L. orientalis*, *Scardinius erytrophthalmus*, *Tinca tinca*, *Varicorhinus capoeta*, *V. sevangi*, *V. gracilis*, *Vimba vimba persa*
Esociformes	*Esox lucius*
Gasterosteiformes	*Pungitius platygaster*, *Gasterosteus aculeatus*
Mugiliformes	*Liza auratus*, *L. saliens*
Perciformes	*Anatirostrum profundorum*, *Bentlhophiloides brauneri*, *Benthophilus macrocephalus*, *B. magistri*, *B. ctenolepidus*, *B. leptocephalus*, *B. stellatus*, *B. spinosus*, *B. baeri*, *B. granulosus*, *B. leptorhynchus*, *B. grimmi*, *Caspiosoma caspium*, *Knipowitschia longicaudata*, *K. iljini*, *Mesogobius nonultimus*, *Neogobius melanostomus*, *N. caspius*, *N. fluviatilis*, *N. bathybius*, *N. syrman*, *N. kessleri*, *N. platyrostris*, *N. ratan*, *N. gimnotrachelus*, *N. nonultimus*, *Perca fluviatilis*, *Proterorhinus marmoratus*, *P. caucasicus*, *Stizostedion lucioperca*, *S. volgensis*, *S. marinus*
Salmoniformes	*Salmo trutta*, *S. caspius*, *S. fario*, *Stenodus leucichthys gueldenstaedtii*
Siluriformes	*Silurus glanis*
Syngnathiformes	*Syngnathus nigrolineatus*

Fishes play an important role in biological diversity, especially in the nutrition of humans as well as some animals (mink, samur, desman, bear, wetlands birds, and birds of prey); an adult cormorant (*Phalacrocorax* sp.) eats up to 700 fish per day.

Class Amphibia It has up to 4000 species reported globally. They take an intermediate position between aquatic and terrestrial animals, spending their whole lives or the larval stages in a reservoir or in moist soils near the reservoirs. In comparison with terrestrial animals, the structure of internal organs and their functioning is most primitive. The body surface is covered with skin and mucus. In the frontal bone, there are remains of cartilage characteristics of Crossopterygians. Amphibians have no chest and ribs; there are five-fingered fore and hind limbs. The muscular system consists of well-developed specifically moving muscles. Amphibians are hetero-

Fig. 19.3 Rare and endangered fishes of Azerbaijan. [(1) Caspian salmon (*Salmo trutta caspius*); (2) barbel (*Barbus capito*); (3) chekhon-ziege (*Pelecus cultratus*); (4) trout (*Salmo trutta fario*); (5) sea pike perch (*Sander marinus*); (6) bream (*Abramis sapa*); (7) Caspian barbel (*Barbus brachycephalus*); (8) Azerbaijani spring roach (*Rutilus atropatenus*); (9) carp (*Acipenser nudiventris*)]

sexual animals. Males have a pair of seed bags, and females have a pair of ovaries. The development takes place with metamorphosis. In the water from the eggs hatch larvae, which after development turn into tadpoles. Studies on the taxonomy of amphibians and reptiles are still going on in Azerbaijan. The notable workers are (Ganiev and Gasimova 2012; Akhmadov et al. 2013, 2015; Talibov and Mammadov

Table 19.8 Amphibians of Azerbaijan (11 species)

Order	Family	Genus	Species
Anura	Pelobatidae	*Pelobates*	*P. syriacus*
	Pelodytidae	*Pelodytes*	*P. caucasicus*
	Bufonidae	*Pseudepidalea*	*P. variabilis*
		Bufo	*B. verrucosissimus*, *B. eichwaldi*
	Hylidae	*Hyla*	*H. orientalis*, *H. savignyi*
	Ranidae	*Pelophylax*	*P. ridibundus*
		Rana	*Rana macrocnemus*
Caudata	Salamandridae	*Lissotriton*	*Lissotriton vulgaris*
		Triturus	*Triturus karelinii*

2016; Talibov et al. 2018). Their findings are summarized below (Tables 19.8 and 19.9; Figs. 19.4 and 19.5).

Class Reptilia These are the first terrestrial vertebrates, with nearly 7.000 species known in the world continuing their life cycle by laying eggs on land and breathe only with the help of the lungs. The extremities of reptiles are five-fingered. For the first time, representatives of this class have developed the cortex of the brain, skin is covered with horny scales and shell, and mucus is absent. This characteristic of the skin indicates the independence of the osmotic pressure of the body from the environment. This class is divided into several orders: squamates (Squamata), turtles (Chelonia), crocodilians (Crocodylia), and rhynchocephales (Rhynchocephalia). In some sources rhynchocephales are superorder.

Class Aves Birds are flying group and walk on the ground as well. Up to 9.000 species of birds from 40 orders are known in the world, distributed everywhere. According to our ornithologists (Tuayev 2000; Patrikeev 2004; Mustafayev 2004), there are 405 species of birds from 187 genera, 58 families, and 18 orders distributed in Azerbaijan, 33% are monotypic, and 201 species are represented by 1 subspecies, 31 by 2 subspecies, and 9 by 3 subspecies. The common starling (*Sturnus vulgaris*) is represented by four, and common reed bunting (*Emberiza shoeniclus*) is represented by seven subspecies. The ornithologist who spent many years studying the avifauna of Azerbaijan has noted that this fauna of Azerbaijan is common with polytypic birds (424 species and subspecies); of these 302 subspecies from 243 species are polytypic.

The richest among the orders are Passeridae (146 species), Charadriiformes (64 species), Anseriformes (31 species), and Falconiformes (29 species). Table 19.10 shows the list of birds of Azerbaijan. The species included in the Red Book of Azerbaijan are marked in red (Table 19.10; Fig. 19.6).

Class Mammalia is the highest class of vertebrates with about 3.200 species in the world. They feed their babies with milk. Body temperatures are stable and do not depend on the surrounding temperature. As a result, they are active in all climates. Their bodies are covered with hair; weight is about 2 grams to 150 tons. The

Table 19.9 The reptiles of Azerbaijan (57 species)

Order	Family	Genus	Species
Testudines	Testudinidae	*Testudo*	*T. graeca*
	Emydidae	*Mauremus*	*M. caspica*
		Emys	*E. orbicularis*
Sauria	Gekkonidae	*Cyrtopodion*	*C. caspius*
	Agamidae	*Trapelus*	*T. ruderatus*
		Laudakia	*L. caucasica*
		Phynocephalus	*P. helioscopus*
	Anguidae	*Pseudopus*	*P. apodus*
		Angius	*A. fragilis*
	Scincidae	*Trachylepis*	*T. septemtaeniata*
		Eumeces	*E. schneideri*
		Ablepharus	*A. bivittatus*, *A. pannonicus*
	Lacertidae	*Eremia*	*E. velox*, *E. strauchi*, *E. arguta*, *E. pleskei*
		Ophisops	*O. elegans*
		Lacerta	*L. parva*, *L. media*, *L. strigata*
		Darevskia	*D. chlorogaster*, *D. rudis*, *D. caucasica*, *D. raddei*, *D. portschinskii*, *D. valentini*, *D. armeniaca*, *D. rostombekovi*, *D. praticola*
Serpentes	Typhlopidae	*Typhlops*	*T. vermicularis*
	Boidae	*Eryx*	*Eryx jaculus*
	Colubridae	*Natrix*	*N. natrix*, *N. tessellata*, *N. megalocephala*
		Rhynchocalamus	*R. melanocephalus*
		Eineris	*E. collaris*, *E. punctatolineatus*, *E. modestus*
		Coronella	*C. austriaca*
		Hemerrhois	*H. ravergieri*, *H. nummifer*
		Dolichophis	*D. caspius, D. schmidti*
		Platyceps	*P. najadum*
		Elaphe	*E. dione*, *E. sauromates*
		Zamenis	*Z. hohenakeri*, *Z. persica*
		Malpolon	*M. monspessulanus*
		Psammophis	*P. lineolatus*
		Telescopus	*T. fallax*
	Viperidae	*Gloydius*	*G. halys*
		Macrovipera	*M. lebetina*
		Montivipera	*M. raddei*
		Pellas	*P. shemakhensis*, *P. eriwanensis*, *P. renardi*

species composition, systematic status, distribution characteristics, and main aspects of ecology of mammals in Azerbaijan are being studies at length currently (Tables 19.11 and 19.12; Fig. 19.7) (Musaev et al. 2004; Rakhmatulina 2005, 2006; Kuliev 2002, 2016, 2019; Talibov and Mammadov 2016; Guliyev et al. 2017).

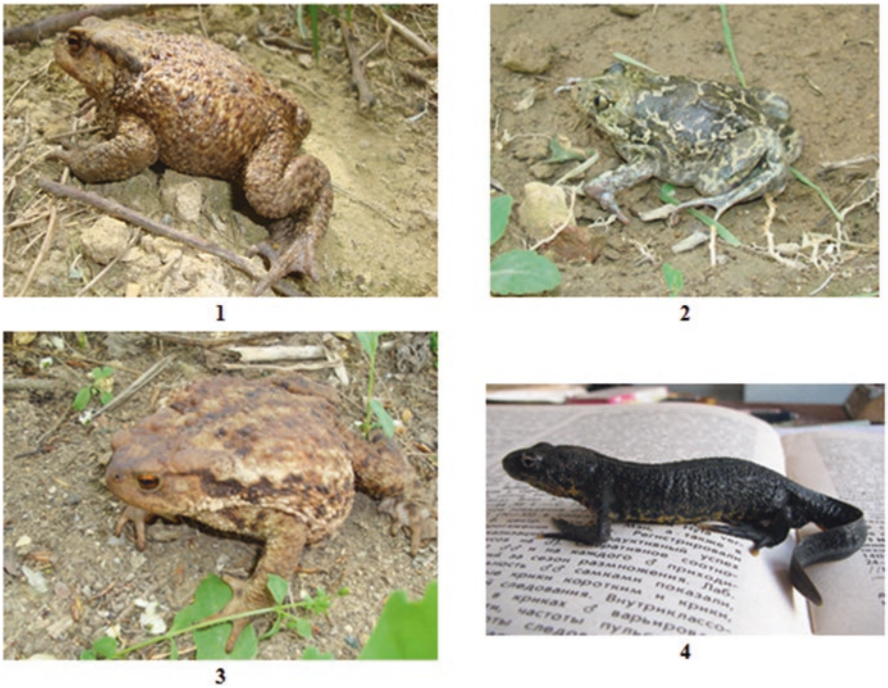


Fig. 19.4 Rare and endangered species of Amphibians of Azerbaijan. [(**1**) Caucasian toad (*Bufo verrucosissimus*); (**2**) Eastern spadefoot or Syrian spadefoot (*Pelobates syriacus*); (**3**) Eichwald's toad or Talysh toad (*Bufo eichwaldi*); (**4**) Southern crested newt (*Triturus karelinii*)]

Fig. 19.5 Rare and endangered species of reptiles of Azerbaijan. [(**1**) *Montivipera raddei*, (**2**) *Pelias renardi*, (**3**) *Rhynchocalamus melanocephalus*, (**4**) *Elaphe sauromates*, (**5**) *Ablepharus pannonicus*, (**6**) *Trachylepis septemtaeniata*, (**7**) *Phrynocephalus helioscopus*, (**8**) *Testudo graeca*]

Table 19.10 The taxonomic structure of birds of Azerbaijan (405 species and subspecies)

Order	Species
Anseriformes	*Anser erythropus*, *Aythya nyroca*, *Branta ruficollis*, *Cygnus olor*, *C. bewickii*, *Marmaronetta angustirostris*, *Melanitta fusca*, *Oxyura leucocephala*
Apodiformes	*Apus apus*, *A. melba*
Caprimulgiformes	*Caprimulgus europaeus*
Charadriiformes	*Burchinus oedicnemus*, *Charadrius leschenaultii*, *Chettusia gregaria*, *C. leucura*, *Glareola nordmanni*, *Larus canis*, *L. melanocephalus*, *Numenius tenuirostris*, *Recurvirostra avosetta*, *Tringa glareola*, *other*
Ciconiiformes	*Ardea purpurea*, *A. cinerea*, *Ardeola ralloides*, *Bubulcus ibis*, *Botaurus stellaris*, *Ciconia ciconia*, *C. nigra*, *Egretta garzetta*, *Nycticorax nycticorax*, *Platalea leucorodia*, *Plegadis falcinellus*, *other*
Columbiformes	*Columba livia*, *Pterocles orientalis*, *Streptopelia turtur*, *other*
Coraciiformes	*Coracias garrulus*, *Alcedo atthis*, *Halcyon smyrnensis*, *Merops apiaster*, *M. supercilliosus*, *Upupa epops*, *other*
Cuculiformes	*Cuculus canorus*
Falconiformes	*Aegypius monachus*, *Aquila nipalensis*, *A. clanga*, *A. heliaca*, *A. chrysaetos*, *Accipiter gentilis*, *A. brevipes*, *A. badius*, *Buteo rufinus*, *Circaetus gallicus*, *Circus macrourus*, *Falco peregrinus*, *F. biarmicus*, *F. cherrug*, *F. columbaris*, *F. naumanni*, *F. subbuteo*, *F. vespertinus*, *Gypaetus barbatus*, *Gyps fulvus*, *Haliaeetus albicus*, *Hieraaetus pennatus*, *Milvus migrans*, *M. milvus*, *Neopron percnopterus*, *Pandion haliaetus*, *Pernis apivorus*, *other*
Galliformes	*Alectoris chukar*, *Ammoperdix griseogularis*, *Coturnix coturnix*, *Francolinus francolinus*, *Lyrurus mlokosiewiczi*, *Phasianus colchicus*, *Perdix perdix*, *Tetraogallus caspius*, *T. caucasicus*, *other*
Gaviiformes	*Gavia stellata*, *G. arctica*, *other*
Gruiformes	*Anthropoides virgo*, *Grus grus*, *G. leucogeranus*, *Chlamydotis undulata*, *Crex crex*, *Fulica atra*, *Otis tarda*, *O. tetrax*, *Porphyrio porphyrio*, *Rallus aquaticus*, *other*
Passeriformes	*Anthus campestris*, *Bucanetes mongolicus*, *Calandrella rufescens*, *Corax corax*, *Corvus monedula*, *C. cornix*, *Delichon urbica*, *Emberiza calandra*, *E. buchanani*, *Hirundo rustica*, *Irania gutturalis*, *Lanius cristatus*, *Melanocorypha yeltoniensis*, *M. bimaculata*, *Motacilla flava*, *Oenanthe xanthoprymna*, *Oriolus oriolus*, *Parus cristatus*, *Passer domesticus*, *Regulus regulus*, *Rhodopechys githagineus*, *R. sanguinea*, *Riparia riparia*, *Sitta europaea*, *S. tephronota*, *Sturnus vulgaris*, *Turdus viscivorus*, *other*
Pelecaniformes	*Pelecanus onocrotalus*, *P. crispus*, *Phalacrocorax carbo*, *other*
Phoenicopteriformes	*Phoenicopterus ruber*
Podicipediformes	*Podiceps ruficollis*, *P. cristatus*, *P. auritus*, *other*
Piciformes	*Jynx torquilla*, *Picus viridis*, *P. canus*, *Dendrocopos major*, *other*
Strigiformes	*Bubo bubo*, *Asio otus*, *Athene noctua*, *other*

Fig. 19.6 (1) *Athene noctua* (**Strigiformes**); (2) *Merops superciliosus* (*Merops superciliosus*) (**Coraciiformes**); (3) *Arenaria interpres* (**Charadriiformes**); (4) *Lanius minor* (**Passeriformes**); (5) Suncus etruscus (Insectivora); (6) Phoca caspica (Pinnipedia)

Table 19.11 Class Mammalia

N	Ordo	Described taxons: *Species/genus/family* Planet	Country
Subclass Theria			
1	Macroscelidea	15/4/1	–
2	Cetacea	88/40/14	–
3	Tubulidentata	1/1/1	–
4	*Insectivora*	424/67/6	13/7/3
5	Artiodactyla	196/82/10	8/7/3
6	Hyracoidea	11/3/1	–
7	Sirenia	4/2/2	–
8	Lagomorpha	87/12/2	2/2/2
9	Rodentia	1999/431/28	37/19/7
10	Xenarthra	29/13/4	–
11	Pholidota	7/1/1	–
12	Pinnipedia	33/21/3	1/1/1
13	Primates	256/64/13	–
14	Scandentia	18/6/1	–
15	Perissodactyla	16/6/3	–
16	Proboscidea	2/2/1	–
17	Chiroptera	977/174/18	33/11/4
18	Dermoptera	2/1/1	–
19	Carnivora	231/95/9	20/14/6
Infra-class Metathera			
20	Didelphimorphia	63/13/1	–
21	Paucituberculata	5/3/1	–
22	Microbiotheria	1/1/1	–
23	Dasyuromorphia	72/17/2	–
24	*Notoryctemorphia*	2/1/1	–
25	Peramelemorphia	18/7/2	–
26	*Diprotodontia*	128/39/10	–
Subclass Prototheria			
27	Monotremata	3/3/2	–
Total		**4688/1109/139**	114/61/26

Table 19.12 The mammals of Azerbaijan (115 species)

Ordo	Species
Insectivora 13 species	*Crocidura suaveolens*, *C. leucodon*, *C. gueldenstaedtii*, *C. persica*, *C. zarudnyi*, *Erinaceus concolor*, *Hemiechinus auritus*, *Neomys schelkovnikovi*, *Suncus etruscus*, *Sorex raddei*, *S. caucasica*, *S. minutus*, *Talpa levantis*
Chiroptera 33 *species*	*Barbastella barbastellus*, *B. leucomelas*, *Eptesicus bottae*, *Hypsugo savii*, ***Myotis bechsteinii***, ***M. emarginatus***, ***M. blythi****i*, *M. nattereri*, *M. emarginatus*, *M. mystacinus*, *Miniopterus schreibersii*, *Nyctalus noctula*, *N. leisleri*, *Pipistrellus pipistrellus*, *P. nathusii*, *Plecotus auritus*, *P. austriacus*, *P. kuhlii*, *Rhinolophus hipposideros*, *R. blasti*, *R. euryale*, *R. mehelyi*, *R. ferrumequinum*, *Vespertilio murinus*, *Tadarida teniotis*, *and others*
Rodentia 37 *species*	*Allactaga elater*, *A. williamsi*, *Apodemus agrarius*, *Arvicola terrestris*, ***Calomyscus urartensis***, ***Chionomys gud***, ***Chionomys roberti***, ***Chionomys nivalis***, *Cricetulus migratorius*, *Dryomys nitedula*, ***Ellobius lutescens***, *Glis glis caspicus*, *Glis g. orientalis*, ***Hystrix hystrix***, *Meriones persicus*, ***Micromys minutes***, ***Mesocricetus brandti***, ***Microtus schelkovnikovi***, *Mus musculus*, *Rattus norvegicus*, *R. rattus*, *Sciurus anomalus*, *S. vulgaris*, ***Sylvaemus hyrcanicus***, *and others*
Lagomorpha 2 species	*Lepus europaea*, *Oryctolagus cuniculus*
Carnivora 18 *species*	*Canis aurea*, *C. lupus*, ***Hyaena hyaena***, *Lutra lutra*, ***Martes martes***, *M. foina*, *Meles meles*, ***Mustela erminea***, *M. nivalis*, ***Lutra lutra***, ***Felis silvestris***, ***Felis chaus***, ***Lynx lynx***, ***Otocolobus manul***, ***Panthera pardus***, ***Ursus arctos***, ***Vormela peregusna***, *Vulpes vulpes*
Pinnipedia 1 species	***Phoca caspica***
Artiodactyla 8 species	***Capra aegagrus***, *C. cylindricornis*, ***Capreolus capreolus***, ***Cervus elaphus***, ***Gazella subgutturosa***, ***Ovis orientalis***, ***Rupicapra rupicapra***, *Sus scrofa*

Rare species marked in bold

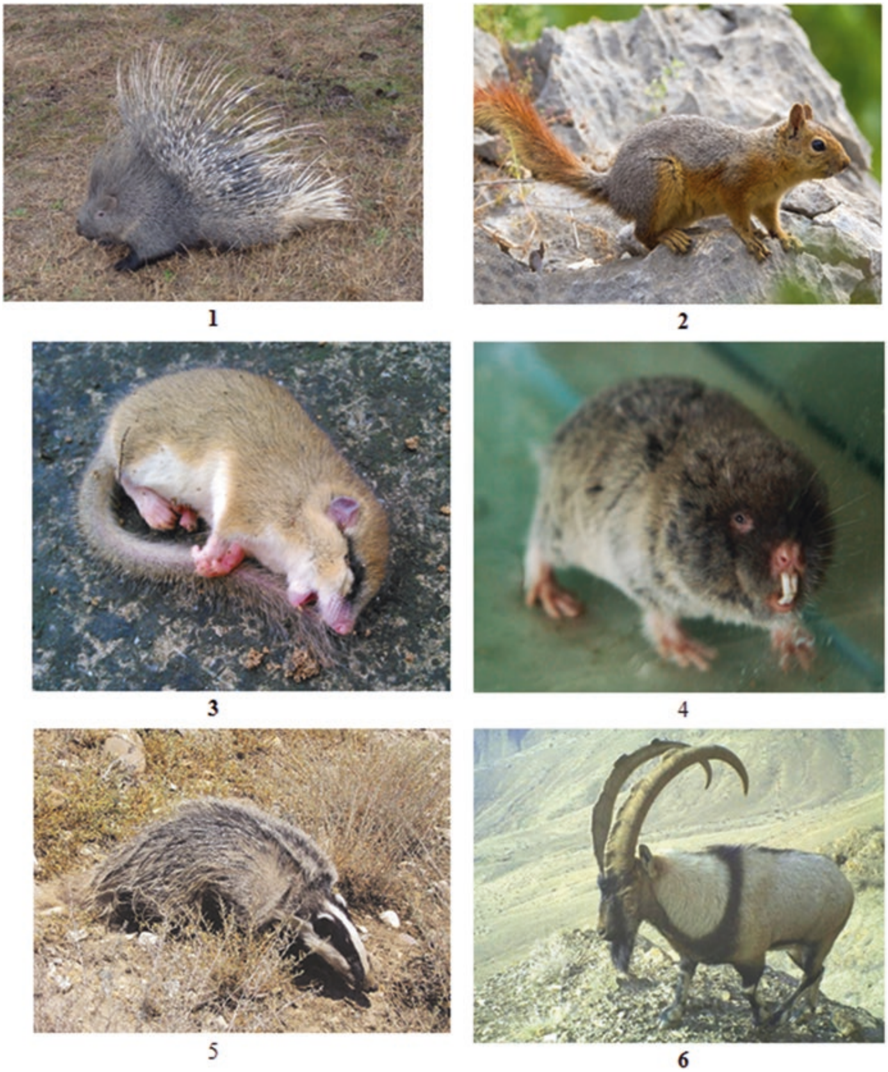


Fig. 19.7 (**1**) *Hystrix hystrix*, (2) *Sciurus anomalus*, (3) *Dryomys nitedula*, (4) *Ellobius lutescens* (**Rodentia**); (5) *Meles meles* (**Carnivora**); (6) *Capra aegagrus* (**Artiodactyla**)

References

Akhmadov SB, Isgandarov TM, Gasimova GH (2013) Taxonomic spectra of amphibian (Amphibia) and reptile (Reptilia) fauna of Azerbaijan. Proc Inst Zool ANAS 31(1):45–55

Akhmadov SB, Novruzov NE, Bunyatova SN, Gasymova GK (2015) The study of herpetofauna (Amphibia: Anura; Reptilia: Testudines, Sauria, Serpentes) of biocenoses of the Divichi estuary of the Caspian Sea. Vestnik MGOU Ser: Nat Sci 4:6–15

Aliev SV (1984) Scoops (Lepidoptera, Noctuidae) of Azerbaijan. Elm, Baku, 227 s

Aliev AA (1997) Ichneumonids (Hymenoptera, Ichneumonidae) of Azerbaijan. Elm, Baku, 303 p

Ganiev FR, Gasimova GKh (2012) The modern species composition of the batrachofauna of Azerbaijan and the distribution of amphibians by biotopes. In: Materials of the XIV International Scientific Conference "Biological Diversity of the Caucasus and the South of Russia", Makhachkala, November 5–7, 2012, pp 129–131

Guliyev QN, Guliyev SM, Ibrahimli AS et al (2017) Taxonomic spectrum of mammalian species (Mammalia L., 1758) in the fauna of Azerbaijan. Proc Azerbaijan Soc Zool 9(1):58–74

Kasimov AG (1972) Freshwater fauna of the Caucasus. Elm, Baku, 288 p

Kasimov AG (1987) Fauna of Caspian Sea. Elm, Baku, 156 p

Kasimov AG (2004) Ecology of plankton of the Caspian Sea. Adiloğlu, Baku, 545 p

Kasimov AG, Bagirov RM (1983) Biology of the Caspian. Azerneshr, Baku, 156 p

Kuliev ZM (2002) Carp and marine fish of the southern and central Caspian. Araz Publishing House, Baku, 254 p

Kuliev S (2016) Deer of the Azerbaijan (Artiodactyla: Cervidae). LAP LAMBERT Academic Publishing RU, 209p

Kuliev S (2019) Chamois of Azerbaijan (Artiodactula: Rupicapra). LAP LAMBERT Academic Publishing RU, 225p

Musaev MA, Aliev SV, Kasimov AH et al (2004) Fauna of Azerbaijan. Vol. II and III. Arthropods and vertebrates. Elm, Baku

Mustafayev QT (2004) Taxonomic spectrum of Azerbaijani ornithofauna. Baku University Publishing House, Baku, 35 p

Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018a) A comparative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343

Ozturk M, Altay V, Altundağ E (2018b) Herbals in Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health. Vol. 1. Springer, Cham, pp 197–266

Patrikeev M (2004) Birds of Azerbaijan. Publisher: Pensoft Pub (1807), 380 p

Rakhmatulina IK (2005) Bats of Azerbaijan (Fauna, ecology, zoogeography). Baku, 480 p

Rakhmatulina IK (2006) Biological diversity: flying mammals of Azerbaijan. Baku, 99 p

Rzayeva LM (2002) Chalcides (Hymenoptera, Chalcidoidea) of eastern Transcaucasia and their economic importance. Elm, Baku, 354 p

Snegovaya NY, Starega W (2011) Harvestmen (Arachnida, Opiliones) from Talysh, with description of a new genus and other taxonomical changes. Fragmenta Faunistica 54(1):47–58

Talibov TH, Mammadov AF (2016) Taxonomic spectrum of vertebrate fauna of the Nakhchivan Autonomous Republic. Teacher's Publishing House, Baku, 76 p

Talibov TH, Bayramov AB, Maharramov MM et al (2018) Fauna of the Nakhchivan Autonomous Republic: fish and amphibians. Ajami, Nakhchivan, 180 p

Tuayev DQ (2000) Catalog of Azerbaijani birds. Baku, 228 p

Chapter 20
Genus *Crataegus* (Rosaceae) in the Flora of Nakhchivan Autonomous Republic of Azerbaijan

Anvar Ibrahimov

20.1 Introduction

Nakhchivan Autonomous Republic is a part of Azerbaijan. It is located in the south-western part of the Lesser Caucasus Mountains. The total length of its border is 398 km. The region covers 5363 km^2 and borders Armenia (221 km) to the east and north, Iran (179 km) to the south and west, and Turkey (15 km) to the north-west. Its highest peak is Gapudzhik (3906 m) and the lowest is 600 m, situated on the left bank of Aras River, at the foot of the steep slope of Soyugdag ridge. The climate is of extreme continental type, with hot summers and severe winters, and the average annual temperature is 10–14 °C; but the areas located above 2300–2400 m have a mean annual temperature below 4 °C. The maximum temperature in the lower parts of the republic is 18 °C in January and 41–43 °C in July–August. Relative humidity varies in different parts. In the city of Nakhchivan, it is 74–76% in December–February and 39–40% in July–August. In the middle mountain zone, it is 69–78% and 52–55% in December–February and July–August, respectively, which is similar to the foothills of the Lesser Caucasus. The main bulk of precipitation falls in spring (March–May) and the minimum in July–August. In the lowland part the annual rainfall is 210–310 mm, in the mid-mountainous area it is 365–550 mm, and in the alpine area it is 660 mm. Nakhchivan is considered as a separate climatic and physico-geographical region of Azerbaijan (Mirzeyev 1972; Ozturk et al. 2018a, b). Soil formation is divided into the following zones: the lower zone (700–1200 m), mid-foothills zone (1200–1800 m), high foothills (1800–2400 m), and alpine zone (2400–2800 m). In view of vertical zoning, within each soil zone, most widely developed soil types are brown, light brown, grey-brown, grey soils, gray desert,

A. Ibrahimov (✉)
Institute of Bioresources, Nakhchivan Section of the National Academy of Sciences of Azerbaijan, Nakhchivan, Azerbaijan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_20

alluvial meadow-grey desert, meadow alluvial, saline meadow, meadow-swamp carbonate, mountain-meadow-steppe, mountain-forest, brown, black soil, ore-brown, and brown (Aliev and Zeynalov 1988; Seyidova and Huseyn 2012). The territory of Nakhichivan has a rich flora and different vegetation types, the reason being the natural conditions of the area as well as its extremely complex geological and geomorphological features. The territory covers several botanical-geographical regions, including the Caucasian, Central Asian, and Iranian migration flora. There are 2963 species of higher plants in the territory, assembled under 880 genera and 168 families (Talibov and Ibragimov 2008).

The genus *Crataegus* is one of the oldest representatives of the Rosaceae family. Its antiquity is confirmed by the findings from paleobotany. According to Kryshtofovich (1957), representatives of *Crataegus* were found in the Mesozoic era and were widespread in the third period, as has been determined by the traces found in upper oligosene, Miocene, and Pliocene sediments in the former USSR.

The modern area of *Crataegus* genus is considered an area of hot and subtropical provinces located between 30° and 60° of the northern hemisphere (Takhtajan 1978). They are mainly spread in the flora of America and very few in the Eurasian and the Mediterranean basin. Pojarkova (1939) has published information on the distribution of 16 species in 3 sections, namely: C. *pentagyna* Waldst. et Kit., *C. orientalis* Pall. ex Bieb., *C. szovitsii* Pojark., *C. pontica* C.Koch, *C. meyeri* Pojark., *C. eriantha* Pojark., *C. caucasica* C.Koch, *C. atrosanguinea* Pojark., *C. kyrtostyla* Finger, *C. beckeriana* Pojark. (=*C. pallasii* Griseb.), *C. monogyna* Jacq., *C. pseudoheterophylla* Pojark., *C. microphylla* C.Koch, *C. zangezura* Pojark., *C. schraderiana* Ledeb., and *C. armena* Pojark. in the Caucasus part of *Flora of the USSR*. The species *C. zangezura*, *C. schraderiana*, and *C. armena* are of hybridogenic origin as such; Pojarkova has included these in the list of hybrid species.

Poletiko (1954) has changed the systematic composition of the *Crataegus* genus based on known herbarium specimens during his study on the "Trees and Shrubs of the USSR" and has included here 15 species, namely: *C. pentagyna*, *C. zangezura*, *C. orientali*s, *C. szovitsii*, *C. pontica*, *C. meyeri*, *C. eriantha*, *C. caucasica*, *C. atrosanguinea*, *C. kyrtostyla, C. pseudoheterophylla, C. armena*, *C. pallasii*, *C. monogyna*, *C. microphylla*, spread in the Caucasus. He has noted that *C. zangezura* and *C. armena* species are not found in the cultural conditions. *C. schraderiana* (*C. orientalis* x *C. pentagyna?*) hybrid species has been called *C. tournefortii* and has been shown to have spread only in Minsk and Crimea as a cultural species. Grossheim (1952) has pointed out the distribution of 14 hawthorn taxa in the Caucasus in his book Flora of the Caucasus. These are as follows: *Pentagynae* (*C. pentagyna*, *C. colchica*), *Azaroli* (*C. orientalis*, *C. szovitsii*, *C. pontica*), and *Oxyacantha* (*C. meyeri*, *C. eriantha*, *C. caucasica*, *C. atrosanguinea*, *C. kyrtostyla*, *C. pallasii*, *C. monogyna*, *C. pseudoheterophylla*, *C. lagenaria*). The author has noted that as a result of regular hybridization between the species of *Crataegus* genus, there are always new species formed with hybridogen origin. Notable among these are *C. zangezura* (*C. pentagyna x?*), *C. armena* (*C. kyrtostyla* x *C. meyeri*), and *C. schraderiana* (*C. orientalis x C. pentagyna*), all described as hybridogenic species in *Flora of the USSR* (Grossheim 1934).

The studies related with wild species of *Crataegus* genus have also been evaluated by Sargsyan (2011), Gabrielian (Gabrielian and Sargsyan 2009), and others (Browicz 1972; Donmez 2004; Riedl 1969).

In the book *Flora of Azerbaijan* by Prilipko (1954), 9 species have been mentioned: *C. pentagyna*, *C. orientalis*, *C. szovitsii*, *C. meyeri*, *C. eriantha*, *C. caucasica*, *C. kyrtostyla, C. pseudoheterophylla*, and *C. lagenaria*, distributed in the territory of Azerbaijan. *C. zangezura* (*C. pentagyna x?*), *C. armena* (*C. kyrtostyla x C. meyeri*), and *C. schraderiana* (*C. orientalis x C. pentagyna*) are recorded as being of hybridogenic origin in *Flora of the Caucasus* (Grossheim 1952).

Fundamental research on this genus in Azerbaijan was conducted by Kasumova (1981, 1983, 1985). Kasumova has enlightened the systematic situation of the *Crataegus* genus and has shown that there are not 9 but 19 species of the genus (Kasumova 1985, 2004; Kasumova et al. 1991) distributed in the area. Out of these, *C. atrosanguinea*, *C. armena*, *C. zangezura*, *C. pontica*, and *C. tournefortii* species are recorded for Azerbaijan; *C. monogyna* and *C. pallasii* species for South Caucasus (Transcaucasia); and *C. pojarkovae* for Caucasus flora for the first time. She has also published the new *C. cinovskisii* species as well as *C. meyeri* ssp. *eryantha* but the latter subspecies has been changed as *C. eriantha* with species rank and *C. atrofusca* has been added back to the list of species.

Askerov (2006) has reported 17 species of hawthorn from Azerbaijan. He has included *C. atrofusca* together with *C. pentagyna*, mentioned earlier by Kasumova (2004). According to the author, *C. atrofusca* differs from *C. pentagyna* in the features of leaves, sepals, and fruits. All these characters are not sufficient for giving species status to *C. atrofusca,* it could be a species variation. According to Askerov (2006) the species of hawthorn distributed in Azerbaijan are; *C. pentagyna* (incl. *C. atrofusca), C. orientalis (C. laciniata), C. szovitsii, C. meyeri, C. eriantha, C. caucasica, C. curvisepala (C. kyrtostyla), C. microphylla (C. lagenaria), C. pseudoheterophylla, C. atrosanguinea, C. armena, C. zangezura, C. pallasii*, *C. pontica*, *C. monogyna*, *C. pojarkoviae*, and *C. tournefortii*. The wild species like *C. chlorocarpa, C. pedicellata, C. collina, C. canadensis*, and *C. crusgali* are introduced ones.

Asadov et al. (2008) have reported 11 species of hawthorn from Azerbaijan, and further studies have been undertaken by Ufimov (2011, 2013); *Crataegus talyschensis* has been added to the Caucasian flora, thus presenting the distribution of 30 species of *Crataegus* in the Caucasus. These are grouped as follows:

Sect. 1. ***Pentagynae*** (*Crataegus pentagyna*, *C. talyschensis*, *C. atrofusca*, *C. susanykleinae*).

Sect. 2. ***Azaroli*** (*C. orientalis*, *C. pojarkoviae*, *C. gabrielianae*, *C. szovitsii*, *C. pontica*).

Sect. 3. ***Crataegus*** (*C. meyeri*, *C. eriantha*, *C. taurica*, *C. ambigua*, *C. atrosanguinea*, *C. caucasica*, *C. x razdanica*, *C. pallasii*, *C. stevenii*, *C. microphylla*, *C. rhipidophylla*, *C. x kyrtostyla*, *C. monogyna*, *C. pseudoheterophylla*, *C. x armena*, *C. x daghestanica*).

Hybrid species (*C. x tournefortii*, *C. x cinovskisii*, *C. x zangezura*, C. *x rubrinervis*, *C. x ulotricha*).

Data on the distribution from Nakhchivan has been evaluated by Prilipko (1939, 1954), Grossheim (1952), *Trees and Shrubs of Azerbaijan* (1970), Asadov and Asadov (2001), Gurbanov (1996, 2004), Isaev and Kasumova (1976) and Kasumova (1983, 1985), Kasumova et al. 1991), Ibragimov (2005) and Talibov (2001), Talibov and Ibragimov (2008), Talibov and Ibragimov (2010).

In the studies of Prilipko (1939), information has been given on the distribution of four species (*C. orientalis*, *C. pentagyna*, *C. pectinata* (= *C. meyeri*), *C. monogyna*). This information has been given in the *Flora of the Caucasus* by Grossheim (1952), *Flora of Azerbaijan* by Prilipko (1954) and in the book on *Trees and Shrubs of Azerbaijan* (1970). There are six species (*C. orientalis*, *C. szovitsii*, *C. meyeri, C. caucasica*, *C. pseudoheterophylla*, *C. kyrtostyla*) listed for Nakhchivan. Same data has been published by Asadov and Asadov (2001) and Asadov et al. (2014). On the other hand Kasumova (1991) has identified 13 species (*C. atrosanguinea*, *C. armena*, *C. caucasica*, *C. cinovskisii*, *C. curvisepala* (= *C. kyrtostyla*), *C. meyeri*, *C. pojarkovae*, *C. pontica*, *C. pseudoheterophylla*, *C. szovitsii*, *C. tournefortii*, *C. zangezura*) from Nakhchivan. These are ones out of 19 total species included in the flora of Azerbaijan.

The latest systematics of species belonging to the *Crataegus* genus has been given in the book Taxonomic Spectra of the Flora of Nakhchivan Autonomous Republic, published by Talibov and Ibragimov (2008). They have recorded 20 species in the area, out of which 15 species: *C. armena*, *C. caucasica*, *C. cinovskisii*, *C. curvisepala*, *C. eriantha*, *C. meyeri*, *C. monogyna*, *C. orientalis*, *C. pallasii*, *C. pentagyna*, *C. pojarkoviae*, *C. pontica*, *C. pseudoheterophylla*, *C. szovitsii*, and *C. zangezura*, are found in wildlife and 5 species: *C. chlorocarpa*, *C. ferganensis*, *C. sanguinea*, *C. songarica*, and *C. turkestanica*, are cultivated.*C. atrosanguinea* and *C. tournefortii* were recorded by Kasumova (2004) from the area. These have not been presented in the book for doubtful taxonomical status. However, detailed information has been included on the distribution of species in the Autonomous Republic in the book Biodiversity of the Flora of the Nakhchivan Autonomous Republic and Protection of Its Rare Species (Talibov 2001). Sargsyan (2011) also points out that the distribution area of *C. tournefortii* is Nakhchivan Autonomous Republic territory, informing about the wild species of the *Crataegus* genus spread in the South Caucasus.

20.2 Data Analysis

The present situation of *Crataegus* in Nakhchivan flora has been followed from the herbarium specimens of the Herbarium of Botany Institute of Azerbaijan National Academy of Sciences, the Bioresources Institute of Nakhchivan Section of Azerbaijan National Academy of Sciences, and Nakhchivan State University. A comparative analysis of the photographs of herbarium specimens has been followed. The *Crataegus* genus field expeditions during 2004–2018 have also been considered. The situation of *Crataegus* genus by Ufimov (2011, 2013) and systematics of hawthorns from Nakhchivan have been evaluated in detail. The book *Areas of Trees and Shrubs of the USSR* (1980) was followed for species areal data.

20.3 Results

In all, 17 species of the genus *Crataegus* have been noted from Nakhchivan. These are grouped under *Crataegus*, Pentagynae, and Azaroli sections.

Genus *Crataegus* L. 1753, Sp. Pl. 1: 475, p.p.

Type: *Crataegus rhipidophylla* Gandoger (= *Crataegus oxyacantha* L., nom.rejic.)

Sect. 1. *Crataegus* – sect. *Oxyacantha* Loud. 1838, Arbor Fruit. Brit. 2: 829; Poyakova 1939, Fl. USSR 9: 436. – sect. *Oxyacanthae* Zabel ex C.K. Schneider 1906, III. Handb. Laubholzk 1:768.

The *Crataegus* species are shrubs or small trees, 5–15 m tall, with small pome fruits and (usually) thorny branches. The fruit, sometimes known as a "haw," is berry-like but structurally a pome containing 1 to 5 pyrenes that resemble the "stones" of plums, peaches, etc., which are drupaceous fruits in the same subfamily.

Type: *C. rhipidophylla* Gand.

1. ***C. atrosanguinea* Pojark.** 1939, *Fl. USSR* 9, Addenda 8:504; Grossheym 1952, *Flora of the Caucasus*, 5:43; Poletiko 1954, *Trees and Shrubs of the USSR* 3:549; Fedorov 1958, *Flora of Armenia* 3:299; Riedl 1969, *Fl. Iran*. 66:59; Browicz 1972, *Fl. Turk*. 4:142; Khatamsaz 1992, *Fl. of Iran* 6:256; *C. ambigua* subsp. *ambigua* (auct. non Meyer ex Becker) Christensen 1992, Syst. Bot. Monogr. 35:73, p. min. p., excl. typ. It is 8–10 (12) m tall, flowering in May–June, fruits ripen in September–October, with a diameter of 1.2–1.8 cm, round, dark red colored, pulped, and juicy. The number of seeds in the fruit are 2. 2n (3x) = 51.

Type: "Armenia, Nork village near Jerevan, 14.10.1937, n 380, A. Pojarkova," holotype: LE., isotype: LE.

Common distribution: South Caucasus, Eastern Turkey, Central and Northern Iran.

Distribution: Found in Chalkhangala village of Kangarli region, among the vineyards, Jahri village of Babak region, in the area of Nusnus village of Ordubad region, in the low and middle zones at the height of 800–1800 m from the sea level on the slopes of mountains, at the banks of rivers and in the valleys, among the shrubs.

Christensen (1992) has recorded *C. atrosanguinea* as a synonym of *C. ambigua* ssp. *ambigua* Meyer ex Becker. However, analysis has revealed that these are different species and differ from each other in apparent features. The leaves are large, greenish, with smooth edges, but only slightly larger denticle plaques on the top of the leaf of *C. atrosanguinea* species, the fruits have 2 seeds. The leaves are dark green colored, with denticle plaques and dents continuing from the middle of the leaf to the peak of the *C. ambigua* species, number of seeds in the fruit of *C. ambigua* are noted as 1–2 (3) in the herbarium samples stored in Sanct-Petersburg (Christensen 1992).

2. ***C. armena* Pojark.** 1939, *Flora of the USSR*, 9, Addenda 8:509 (*Crataegus meyeri. Crataegus rhipidophylla*); Fedorov 1958, *Flora of Armenia* 3:300; Poletiko 1954, *Trees and sShrubs of the USSR* 3:552; Riedl 1969, *Fl. Iran* 66:62; Khatamsaz 1992, *Fl. of Iran* 6:266; Christensen 1992, Syst. Bot. Monogr. 35:138.

A small tree or a bush 2–2.5 m tall, flowering in June, fruits ripen in September–October, diameter of fruits 1.0–1.2 cm, long ellipsoid, light red colored, and juicy. Fruit pulp is yellow, usually one, sometimes 2 seeds. 2n (3x) = 51.

Type: USSR, Armenia, distr. Megri, prope opp. Lishk, 01.10.1936, Pojarkova n 754 (holotype: LE; isotype: LE!).

Common distribution: South Caucasus, Northern Iran, in scrub and on rocky mountain slopes; 1300–2500 m.

Distribution: Plants are found on gravel-stony slopes of Gizilgishlag village of Shahbuz region, in the low, medium and high mountain zones of Bichenek forest between 800 and 2000 m (2200 m) above sea level, in arid woodlands and between the bushes.

C. armena species has been included in the flora of Azerbaijan by Kasumova (1983) according to the samples collected from Bichenek forest (20.X.1980) and Gizilgishlag village (10.X.1980, stony-gravel slopes) of Shahbuz region. According to Pojarkova (1939), this species is of hybridogenic origin formed by the cross-breeding of *C. kyrtostyla* and *C. meyeri*. Grossheim (1952) did not regard *C. armena* as an independent species and included it in the hybrid species. Fedorov (1958) did not agree with Grossheim, as "the *C. armena* species has not been fully proven to be a hybrid"; therefore, it was considered more acceptable to regard this species as an independent one. Christensen (1992) mentions that this species was derived from the hybridization of *C. criteris* and *C. monogyna* species. The lower leaf slices of the flowering twig of *C. armena* are 1–5 dental, like *C. monogyna*. The number of dentals of *C. monogyna* species varies between 6 and 16. There are also many similarities in the perianths in *C. armena*, *C. monogyna*, and *C. meyeri*. The perianths of the flowering twigs of *C. armena* species is pyrene, resembling *C. meyeri*. Sargsyan (2011) notes that C. *monogyna* has not been found in Armenia, and there has not been any introduction in the area so far. The author is also skeptical about the spread of *C. monogyna* in Nakhchivan and Iran, so *C. monogyna* cannot have crossed with *C. meyeri*. As regards the number of dentals of the leaf slices and similarity with perianths, the hybrid origin of *C. armena* should be accepted normal. Sargsyan (2011) agrees with Pojarkova (1939) that *C. meyeri* and *C. rhipidophylla* (*C. kyrtostyla*) species are hybrids.

3. ***C. caucasica* C.Koch** 1853, Verh. Ver. Beford. Gartenb. Konigl. Preuss. Staaten, N.R. 1:286; idem 1854, Crat. et Mespilus: 66; Pojarkova 1939, *Flora of the USSR* 9:447; Grossheim 1952, *Flora of the Caucasus* 2, 5:42; Prilipko 1954, *Flora of Azerbaijan* 5:73; Poletiko 1954, *Trees and Shrubs of the USSR* 3:549; Fedorov 1958, *Flora of Armenia* 3:299; Riedl 1969, *Fl. Iran.* 66:59; Christensen 1992, Syst. Bot. Monogr. 35:69, *C. oxyacantha* L. var. *caucassica* (K.Koch) Boiss. 1872, *Fl. Or.* 2:664; Lipskiy 1899, *Flora of the Caucasus*: 297; Medvedev 1919, *Trees and Shrubs of the Caucasus*: 112, *C. oxyacantha* auct. non L.: Ledeb. 1843, *Fl. Ross.* 2:89. Medvedev

Tree or shrub 5 to 7 m tall, flowering in May, fruits ripen in September–October, with 1.0–1.3 cm diameter, egg-shaped-round, at ripening becomes dark purple colored and looks like an open spot on top, fruit pulp is yellow, usually 2 seeds. 2n (3x) = 51.

Type: USSR, Caucasus, Wilhelms s.n. (holotype: B, destroyed).

Neotype, here designated, following suggestion by Riedl in Rechinger, 1969, *Fl. Iran*. 66: 59: U.S.S.R., Azerbaijan, Kirovabad (Ganja), 27.09.1937, leg. et det. Pojarkova, n 288 (LE).

Common distribution: South Caucasus, Talysh, Easternmost parts of Turkey, Iran, Georgia, Nakhichevan, Armenia and Azerbaijan; on rocky mountain slopes and along the roadsides.

Distribution: The samples stored in the Herbarium of the Botany Institute of Azerbaijan National Academy of Sciences have been collected from Bist village of Ordubad district and the surroundings of Bichanak village of Shahbuz district. During these investigations, this species has been found from Nasirvaz and Nürgüt villages of Ordubad region, in the lower and middle zones at 800 to 1800 m above sea level, in the arid rare forests, on dry stony slopes of rivers, among the shrubs near the forest as singly or in groups.

4. ***C. eriantha* Pojark.** 1939, *Flora of the USSR* 9, Addenda 8:500; Grossheim 1952, *Flora of the Caucasus* 2, 5:42; Prilipko 1954, *Flora of Azerbaijan* 5:73; Poletiko 1954, *Trees and Shrubs of the USSR* 3:546; *C. pectinata* auct. Non Bosc.: C.A. Mey. ex Hohen. 1838, Enum. Pl. Talysch: 330, p.p.; Ledeb.1843, *Fl. Ross*. 2:91, p.p., *C. melanocarpa* β *heterophylla* Boiss. 1872, *Fl. Or.* 2:662, p.p.; Lipskiy 1899, *Flora of the Caucasus*: 297, *C. meyeri* Pojark. Christensen 1992, Syst. Bot. Monogr. 35:59 (p. min. p.)

Height is 3–5 m, trees or shrubs, flowering in May–June, fruits ripens in September–October, 2 seeded, rarely one.

Type: "In declvibus prope fluvium Gandscha, disrictus Airum, 01.05.1844. n 1399 Flora Transcauc. Legit. Dr. Koilenati", holotype: LE; isotype: LE!.

Common distribution: Caucasia, South Caucasus endemic.

Distribution: Bichenek, Kuku, and Ayrinj village of Shahbuz region; Nurgut, Nasirvaz, and Bist villages of Ordubad region; in the low and middle mountain zones, at 800–1800 m high altitudes above sea level; on the stony slopes of the mountains; in bushes and in arid rare forests. *C. eriantha* is closer to *C. cultivar*, but differs from fewer fragmented, rarely fuzzy leaves, relatively large, sparse, dense fuzzy flowering groups. There is a need for a comprehensive study on this species.

5. ***C. meyeri* Pojark.** 1939, *Flora of the USSR* 9, Addenda 8:500; Grossheim 1952, *Flora of the Caucasus*. 2, 5:42; Prilipko 1954, *Flora of Azerbaijan* 5:72; Poletiko 1954, *Trees and Shrubs of the USSR* 3:546; Fedorov 1958, *Flora of Armenia*. 3:299; Prilipko 1965, Dendroflora of the Caucasus 4:148; Riedl 1969, *Fl. Iran.* 66:58; Browicz 1972, *Fl. Turk.* 4: 140; Khatamsaz 992, *Fl. of Iran* 6:253; Christensen 1992, Syst. Bot. Monogr. 35:59 p. max p., incl. typ., *C. pectinata* auct. non Bosc.: C.A.Mey. ex Hohen. 1838, Enum. Pl. Talysch: 130, nom. nud., p.p.; Ledeb. 1843, *Fl. Ross*. 2, 1:91, p.p.; Boiss.1872, *Fl. Or*. 2:663, p.p.; Grossheim 1934, *Flora of the Caucasus*. 4:291. *C. pectinata* Bosc. Lipskiy 1899, *Flora of the Caucasus*: 297, *C. oxyacantha* var. *pectinata* Schmalh. 895, *Flora of Central and Southern Russia* 1:350, p.p., *C. tournefortii* auct. non Griseb.: C.Koch 1854, Crat. et Mesp.: 47., *C. ambigua* var. *hohenackeri* C.K. Schneider, 1906, Illustr. Handb. Laubh. 1:785, p.p.

The height is 2–6 (8) m, trees or shrubs, flowering in May–June and fruits ripen in September–November, fruits are oval, round, length is 1.2–1.8 cm, dark red, with 2 seeds, but in some cases one seed. 2n (4x) = 68; 2n (3x) = 51.

Type: USSR, Armenia, in vicinitate urbis Jerevan, in faucibus fl. Gjarni-czai, prope monasterium Gehart, 11.10.1936, Pojarkova n 792 (holotype: LE).

Common distribution: South Caucasus, Talish, Ukraine, Crimea, Anatolia, North Iraq, Armenia, Azerbaijan, Iran; dry meadows and woodlands; 1200–2800 m.

Distribution: It has been recorded from Chalkhanqala village of Kangarli region, Kulus, Kuku, Kolany, South Gishlag, Bichanak suburb of the villages of Shahbuz region by Kasumova and Akhundov (2004). Investigations have revealed that the *C. meyeri* species is found individually or in groups on stony slopes, among the arid sparse forests and bushes at altitudes of 800–2000 m (2200 m) in the low, middle and high altitudes around Havush village of Sharur district, Bichanek village of Shahbuz region, sometimes found in the woodland of the Autonomous Republic, at 2200 m altitudes in the woods and on the edges of roads. It is widespread in the South Caucasus and described as *C. pectinata* C.A.Mey, following Grossheim's (1952) *Flora of the Caucasus*. According to Pojarkova (1939), some authors have reported *C. meyeri* species with 2–3 seeded fruits like *C. caucasica*, and some have mixed it up with *C. orientalis* species due to dense fuzzy leaves.

6. ***C. monogyna* Jacq.** 1775, *Fl. Austr*. 3:50; Wild. Sp. pl. II, 1799, 2:1006; Ldb. *Fl. Ross.*, II, 1, 89 (ex parte). – *Mespilus monogyna* Willd. Enum. Pl. berol. I (1809) 524, *Mespilus oxycantha* var. *monogyna* Schmalhausen (1895), *Flora of Central and Southern Russia, Crimea and the North Caucasus*, 350 (ex parte); 1:89; Pojarkova 1939, *Flora of the USSR*, 9:454; Poletiko 1954, *Trees and Shrubs of the USSR*, 3:554; Browicz 1972, *Fl. Turk*. 4:145; Christensen 1992, Syst. Bot. Monogr. 35:100; Grossheim 1952, *Flora of the Caucasus* 5:41.

A tree or shrub, flowering in June, fruits ripen in September, brown-red, egg or elliptic shaped. 2n = 34.

Type: Austria, Jacquin s. n. (lectotype, here designated: BM!; isolectotype: TO).

Common distribution: From southern Scandinavia to northern Africa, Caucasus, Crimea, Turkey, Middle East, northern Iraq, and northwestern Iran; on calcareous rocks, mica-schists, volcanic rocks, as well as granite and other siliceous rocks; in openings in forests with *Fagus*, *Quercus*, *Pinus*, *Cedrus* in macchies, meadows, along rivers, in rocky places, on field edges, in hedges, and along roadsides.

Distribution: Found in the arid sparse forests, on stony slopes and forest fronts at 1200–2000 m altitude in middle and high mountainous zones, suburban areas of Bichanek village of Shahbuz region, Nasirvaz and Nurgut villages of Ordubad district. A polymorphic species, as per Pojarkova (1939), Russian and European authors mention that they did not differentiate between *C. kyrtostyla* species and one slot hawthorn. However, *C. kyrtostyla* species differs sharply from *C. monogyna* by the fragmentation of the smallest, wide, darker green leaf and the shape of the sepals and stigma. We feel *C. monogyna* has a narrower range, adapted to the European part of former Soviet Union (southern and especially eastern regions) and cannot spread in the South Caucasus in comparison to *C. kyrtostyla* species. However, there are species formed by hybridization of *C. kyrtostyla x C. monogyna* in the South Caucasus. Despite the fact that the distribution area of *C. monogyna* has been shown as Ganja, Lankaran, and Garabagh by Grossheim (1934), herbarium samples collected later have been designated as *C. curvisepala* (*C. kyrtostyla*). The information given by Sargsyan (2011) shows that *C. pentagyna* species are not distributed in Nakhchivan Autonomous Republic.

7. ***C. pallasii* Griseb.** 1843, Spicil. Fl. Rumel. et Bithyn. 1:89; Trautvetter 1882, Fl. Ross. 1:279; Poletiko 1954, *Trees and Shrubs of the USSR* 3:553; Christensen 1992, Syst. Bot. Monogr. 35:80, *C. monogyna* var. *nigra* Pall. 1784, *Fl. Ross.* 1, 1:26, tab. XII. – *C. beckeriana* Pojark. 1939, *Flora of the USSR* 9:505, 453, nom. Superfl.

The height is 1.5–3 m of shrub. It flourishes in May and fruit ripens in September–October. The length of the fruit is 0.8–1.0 cm, is round, dark red colored, and it has 1–2 seeds.

Type: USSR, Sarepta [Krasnoarmeiski Gorod], Pallas s.n. (holotype: LE!).

Common distribution: Southeastern Europe, Caucasus, Turkey, Checheno-Ingushskaya ASSR, Dagestan, mouth of Kuban River, and near Volgograd (Krasnoarmeiski Gorod); on mountain slopes, along rivers, and in scrub.

Distribution: Plant is distributed on rocky slopes and among the sparse woods in the villages of Akhura, Havush, Sadarak of Sharur region. During our investigations, the species has been found around Bichanek, Kuku village of the Shahbuz region, Nasirvaz and Nurgut villages of Ordubad region between 1200 and 1800 m altitude in the middle mountain zones, on dry rocky slopes, on the edges of forest, among shrubs and bushes, and at the bottom of rocks individually.

8. ***C. pseudoheterophylla* Pojark.** 1939, *Flora of the USSR* 9, Addenda 8:506; Grossheim 1952, *Flora of the Caucasus* 5:43; Prilipko 1954, *Flora of Azerbaijan* 5:74; Poletiko 1954, *Trees and Shrubs of the USSR* 3:556; Fedorov 1958, *Flora of Armenia*. 3:303; Browicz 1972, *Fl. Turk*. 4:145; Christensen 1992, Syst. Bot. Monogr. 35:96.

The height is 3–6 m, trees or bushes, flowering in May, fruits ripen in September, length is 0.7–1.0 cm, broad, oval or ellipsoid shaped, brown-red colored and one seeded. 2n (4x) = 68.

Type: USSR, Armenia, distr. Jerevan, prope monas terium Gehart, in faucibus fl. Gjarni-czai, 11.10.1936, Pojarkova n 793 (holotype: LE; isotype: LE!).

Common distribution: Eastern Europe, Caucasus, Anatolia, Caucasus, Crimea, Dagestan, Iran, Turkmenistan, Uzbekistan, Kazakhstan, Kirgizstan, Tadzhikistan, Afghanistan, Pakistan?, northern India, and Tibet; in scrub, rocky mountainous tracts, gorges, along rivers, and at field edges.

Distribution: One of the least spread species in the Autonomous Republic, mainly found in Ayrinj, Bichenek, South and Gold Gishlag of Shahbuz region, Chalkhangala village of Kangarli region, and foothills near Ordubad city as per the report of Kasumova and Akhundov (2004). During this study, samples have been found from Bichanek village of Shahbuz region; Akhura, Havush, and Sadarak village of Sharur district; in the middle and high mountain zones, between 1200 and 2000 m altitudes on steep slopes of mountains, among the bushes, on the banks of rivers, on the slopes of broad-leaved forests.

The specimens collected around Ganja despite the description as *C. pseudoheterophylla* by Hokonaker (Pojarkova 1939), as Poletiko (1954) noticed, sometimes dendrological reports refer mistakenly to it as *C. monogyna* or *C. heterophylla*. However, *C. heterophylla* is distributed in Spain as wild species and is not found in the former Soviet Union. Pojarkova (1939) notes that both *C. kyrtostyla* and *C. pseudoheterophylla* have been shown as *C. monogyna* found in the literature sources by the researchers of Caucasian flora; the plant has been found in Tuapse and the Front Caucasus of Krasnodar region (Fedorov 1958). According to Sargsyan (2011), the hawthorn hybridizes as *C. pseudoheterophylla x C. atrosanguinea = C.* x *C. razdanica*; *C. pentagyna* x *C. pseudoheterophylla = C. x C. zangezura* species.

9. ***C. rhipidophylla* Gand.** (=*C. curvisepala* Lindm.; *C. kyrtostyla* Pojark.) 1871, Bull. Soc. Bot. France 18:447; Christensen 1992, Syst. Bot. Monogr. 35:88; Tsvelev 2000, Manual of the vascular plants of North-West Russia: 457. *C. oxyacantha* L. 1753, Sp. Pl.: 477, nom. rej. *C. curvisepala* Lindm. 1918, Svensk Fanerogamfl.: 307 – idem, 1926:332; *C. monogyna* var. *rubra* Pall. 1784, *Fl. Ross.* 1, 1:26. *C. laciniata* Steven ex Besser 1822, Enum. Pl. Volhyn.: 56, non *C. laciniata* Ucria, 1793. *C. monogyna* var. *laciniata* (Besser) Ledeb. 1844, *Fl. Ross.* 2, 1:89, non *C. monogyna* var. *laciniata* K. Koch 1853. *C. kyrtostyla* Fingerh. 1829, Linnaea 4:372; Rupr. 1860, *Fl. Ingrica*: 349; Pojarkova 1939, *Flora of the USSR* 9:450; Poletiko 1954, *Trees and Shrubs of the USSR* 3:350; Fedorov 1958, *Flora of Armenia*. 3:300. *C. Kyrtostyla* auct. non Fingerh.: Schmidt 1859, Arch. Naturk. Liv., Ehst.- u. Kurlands, ser. 2, 1:210.

Type: France, Rhone, Liergues, a la Combe, 2 Oct. 1870, Gandoger, holo.: LY.

Neotype: Luxembourg, a 50 m de la frontiere belge, en face du pont de Romeldange surla Sure, 11 Aug 1960, Lawalree 11,088 (BR). It is 3–8 m tall, tree or bush, flowering in May–June, fruit ripens in September–October. Fruits are red, long ellipsoid, length is 1.2–1.4 cm, one seeded. 2n (2x) = 34; 2n (3x) = 51.

Common distribution: From southern Scandinavia and the Baltic region to France, the Balkan Peninsula, Anatolia, Caucasia, Crimea, Ukraine, rarely planted as an ornamental within its natural range; on limestone, granite, volcanic rocks; in open woodlands with *Platanus*, *Fagus*, *Fraxinus*, *Pinus*, *Acer*, *Sambucus*, *Salix*, and *Sorbus*.

Distribution: Literature data show its distribution only from Kuku village of Shahbuz region; this species was also collected by Kasumova (2004) in the village of Bichanak. During the expeditions, this species was found on the rocky slopes around Nasirvaz and Nurgut villages of Ordubad district, Khazinedere of Julfa region, and Garagush mountain range of Sharur region, at 800–2000 m altitudes, as individually or in small groups, in forests, on glades, in bright oak forests, and arid sparse woods. Sometimes, along with other species of hawthorns, they form brushwoods on riverbeds and on dry slopes of the mountains.

In contemporary literature (Tzvelev 2001; Christensen and Zielinski 2008; Donmez 2004), although *C. curvisepala* (*C. kyrtostylae*) is mentioned as *C. rhipidophylla*, it has not been mentioned in the work of Cherepanov (1995). In the studies of Sargsyan (2011), *C. curvisepala* (*C. kyritostyla*) species was accepted as *C. rhipidophylla*.

10. ***C. zangezura*** **Pojark.** 1939, *Flora of the USSR* 9 Addenda 8:508 (*Crataegus pentagyna x C. pseudoheterophylla*); Fedorov 1958, *Flora of Armenia*. 3:300; *C. zangezura* Pojark. nothosubsp. *zangezura* Christensen 1992, Syst. Bot. Monogr. 35:134.

The height is 1.5–2.5 m, a bush or tree, flowering in May, fruits ripen in September–October. The length fruit is 0.6–0.9 cm, darker cherry colored, pulp is juicy, usually two seeded, very rarely 3 seeds, 2n (4x) = 68.

Type: USSR, Armenia, Zangezur, prope opp. Goris (Genjuri), in parte inferiore faucium Goris-czaj, 21.09.1936, Pojarkova n 540 (holotype: LE; isotype: LE).

Common distribution: Kopet-Dagh in Turkmenistan, Iran, and Caucasus; on rocky mountain slopes and in scrub.

Distribution: It is found on stony slopes and among sparse forests of the surrounding areas of Nusnus village of Ordubad district and Chalkhangala village of Babak region as individually. During the investigations, the species was found around Bichanak village of Shahbuz region and Nusnus village of Sharur region at altitude of 800–2000 m, on the rocks, in sparse forests, among bushes and in the valleys.

This species was added to the flora of Azerbaijan as a new species in 1983 by Kasumova (1983) based on the specimens collected from Chalkhangala village of Kengerli region and Nusnus village of Ordubad district. Pojarkova (1939) believes that *C. zangezura* is of hybrid origin, (*Crataegus pentagyna x C. pseudoheterophylla*) close to *C. pallasia* species. Therefore, it would be better to consider *C. zangezur* as a substitute for *C. pallasia* in South Caucasus. Grossheim (1952) argues that *C. zangazur* is an ordinary hybrid genus for Caucasus, derived from *Crataegus pentagyna* and other hawthorns. However, based on Pojarkova's (1939) studies, it is unacceptable to give *C. zangezura* an independent species status. Both Grossheim (1952) and Prilipko (1954) suggest that this species is distributed in Small Caucasus in the book *Flora of Azerbaijan* (Prilipko 1954). Poletiko (1954) has proposed to include *C. zangazur* in the *Pentagynae* section in the book *Flora of Azerbaijan* (Prilipko 1954). However, author has noted that it would be more correct to add *C. zangezura* to *Crataegus* branch when considering the fruits of blackberries; fruit pulp is yellowish (no red) and 2 seeded (not 3–5). The same information has been recorded in the works of Fedorov (1958) and Isaev and Kasumova (1976). But, Christensen (1992) offers two subspecies, showing that *C. zangezura* is of hybrid origin derived from the cross between *C. pentagyna* and *C. pseudoheterophylla*: *C. zangezura* nothosubsp. *zangezura* (*C. pentagyna* subsp. *pentagyna x C. pseudoheterophylla* subsp. *pseudoheterophylla*) for the territory of Armenia and *C. zangezura* nothosubsp *pseudoambigua* (Pojarkova) (*C. pentagyna* subsp. *pseudomelanocarpa* x *C. pseudoheterophylla* subsp. *turkestanica*) for the territory of Turkmenistan.

Sect. 2. *Pentagynae* C.K. Schneid. 1906, Ill. Handb. Laubh.1:768. *Pentagynae* Zabel Pojarkova 1939, *Flora of the USSR* 9:430; *Melanocarpae* Zabel 1903, Beissn., Schelle and Zabel Handb. Laubh. Benenn.: 178, nom. nud.

The branches of these trees are covered with short thorns, leaves are egg shaped or oval-rhomboid, nude or lower surface is fussy. The flower group is bare or hairy; black fruits have slightly red pulp. Seeds are 2–5, front side is smoother, back side has scarce furrow, belly side is slightly lower.

Type: *C. pentagyna* Waldst. et Kit. ex Willd.

11. ***C. pentagyna* Waldst. et Kit.** ex Willd. 1800, Sp. Pl. 2, 2:1006; Regel 1871, Acta Horti Petropol. I:113; Trautvetter 1882, *Fl. Ross*., 1:279; Grossheim 1934, *Flora of the Caucasus*. 4:290; Pojarkova 1939, *Flora of the USSR* 9:430; Grossheim 1952, *Flora of the Caucasus* 5:40; Prilipko 1954, *Flora of Azerbaijan* 5:71; Poletiko 1954, *Trees and Shrubs of the USSR* 3:537; Fedorov 1958, *Flora of Armenia*. 3:296; Browicz 1972, *Fl. Turk*. 4:135; *C. pentagyna* subsp. *pentagyna* Christensen 1992, Syst. Bot. Monogr. 35:53. *C. melanocarpa* M. Bieb. 1808, *Fl. Taur.-Cauc*. 1:386; Hohenacker 1836, Enum. Pl. Talysh: 130; Ledebour 1844, *Fl. Ross*. 2, 1:89; Boissier 1872, *Fl. Or*. 2: 661 p.p. (excl. var. *heterophylla* et var. *atrofusca*); Lipskiy 1899, *Flora of the Caucasus*: 297; Medvedev 1919, *Trees and Shrubs of the Caucasus*: 110; Riedl 1969, *Fl. Iran*. 66:53; *C. oliveriana* Bosc. 1825, in DC., Prodr. 2:630; Hohen. 1838, Enum. Pl. Talysh: 130. *C. oxyacantha* L. var. *oliveriana* (Bosc.) Lindl. 1837, Bot. Reg. 23 tab. 1933. *C. elbursensis* Rech. f. 1942, Ann. Naturhist. Mus. Wien 53:343. *C. melanocarpa* subsp. *elbursensis* (Rech. f.) Riedl 1969, *Flora Iran*. 66:54. *Mespilus pentagyna* K. Koch in Schmalh. 1895, *Flora of Central and Southern Russia* 1:350. *C. colchica* Grossh. 1934, *Flora of the Caucasus*. 4:290.

It is tree or bush, 3–8 (12) m tall, flowering in May–June, fruits ripen in October, are spherical shaped, black colored, with blue spots, 3–5 seeded. The pulp part is red. 2n (2x) = 34.

Type: “Hungary/Yugoslavia. In Dunato et Syrmio (Danube and Serbia), Kitaibel s.n.”, holotype: B-W 9718.

Common distribution: From Hungary and Yugoslavia through Romania and Bulgaria to Ukraine, Crimea, Moldavia, northeastern Greece, Turkey, Caucasus, Iran, Kopet Dagh, and northeastern Iraq; on limestones, serpentine rocks, rocky mountain slopes, among scrub with *Rosa*, *Quercus*, etc., along rivers.

Distribution: Plant is found in the surrounding forests and mountain slopes of Bichanak village of Shahbuz region, Nasirvaz and Nurgut villages of Ordubad district, low and middle mountain zones, at 800–1800 m altitude, in the brushwoods, in the forest glades, rare oak and open places of mixed forests.

Grossheim (1934) has distinguished this species from other species in the lower surface of leaves, and flower axis is grayish-felt fussy; he called it *C. colchica*. *C. pentagyna* mainly hybridizes with other types of hawthorns, forming dark-red-colored pulped fruits (*C.* x *zangezura* = *C. pentagyna x C. pseudoheterophylla*).

Sect. 3. *Azaroli* Loud. 1838, Arbor. frutic. Brit. 2:826. Sect. *Orientales* Zabel 1903 in Beissn., Schelle and Zabel, Hand. Laubh.-Benenn.: 179, nom. nud; Schneid. 1906, III. Handbuch der Laubh. 1:781, in clavem.

It is not a big tree or a bush; thorns are short or lacking; leaves are egg shaped, oblongate egg like, hairy, and fragmentary; base is narrowed to the wedge or rhomboidal; flower group is felted fussy; anthers are white; large fruits are yellowish, pink, red-pink, round, smooth, and have slight furrow on it.

Type: *C. azarolus* L.

12. ***C. cinovskisii* Kassumova** Bot. Zurn. 1985, (Moscow, Leningrad) 70, 2:266. *C. pseudoazarolus* Popov 1929, Bulletın of applied botany, of genetics and plant breeding 22:442, fig. 101 (*Crataegus azarolus* var. *pontica, Crataegus pentagyna*); Christensen 1992, Syst. Bot. Monogr., 35:123.

The tree is 5–6 m tall, flowering in May, fruits ripen in September, fruits are dark red, sphere shaped, 0.6–1.5 cm long, 0.5–1.3 cm wide, and 4–5 seeded.

Type: Azerbaijan. Nakhichevan, Babek district, Aznaberd (Chalkhangala) village, along the roads, among vineyards, 11.10.1973, Kassumova s. n. (holotype: BAK; isotype: LE).

According to Kasumova (2004), *C. cinovskisii* Kassumova are close to *C. pontica* and differ from those by dark-colored fruits (not yellowish) and 4–5 (2–3) seeds.

Common distribution: Nakhichevan and Kopet-Dagh in Turkmenistan; on mountain slopes, in scrubs with *Cerasus*, *Cotoneaster*, *Rhamnus*, in vineyards, and on roadsides.

Distribution: Found in Çalkhanqala village of Kangarli region at 1000–1200 m altitude, along the roadsides and among the vineyards. This species is an endemic of Nakhchivan.

There is a need for additional research in the future.

13. ***C. orientalis* Pall. ex Bieb.** 1808, *Fl. Taur. Caucas*. 1:387. Ibid., 1819, 3:332; Medvedev 1919, *Trees and Shrubs of the Caucasus*: 112; Lipskiy 1899, *Flora of the Caucasus*.: 297; Grossheim 1934, *Flora of the Caucasus*. 4:290; Pojarkova 1939, *Flora of the USSR* 9:433; Grossheim 1952, *Flora of the Caucasus*. 2, 5:41; Prilipko 1954, *Flora of Azerbaijan* 5:71; Poletiko 1954, *Trees and Shrubs of the USSR* 3:538; Fedorov 1958, *Flora of Armenia*. 3:296; Riedl 1969, *Fl. Iran*. 66:55; Browicz 1972, *Fl. Turk*. 4:136; *C. orientalis* Pall. 1796, Ind. Taur.:107, nom. nud. *C. orientalis* subsp. *orientalis* Christensen 1992, Syst. Bot. Monogr. 35:41. *C. laciniata* Ucria 1793, Nuovo Rocc. opusc. Aut. Sic. 6:251; Ledeb. 1843, *Fl. Ross*. 2, 1:90; Steven 1856, Bull. Soc. Nat. Moscou 29, 1:248. *C. tanacetifolia* var. *orientalis* Regel 1871, Acta Horti Petropol. 1:114; Schmalh. 1895, *Flora of Central and Southern Russia* 1:350.

Its height is 1.5–3 (5) m, trees or bushes, flowering in June, fruits ripen in September–October, are spherical in shape and black, with blue spots on them, 3–5 seeded. The pulp is red. 2n (4x) = 68.

Type: "…frequens in Tauria meridionalis collibus Ponto euxino adjacentibus, U.S.S.R., Crimea, Marshall von Bieberstein s. n.", holotype: BM.

Common distribution: The Mediterranean region, Turkey, Caucasus, Crimea, and western Iran; on calcareous rocks, quartzite and other siliceous rocks; in steppes, meadows, along rivers, and in open forests of *Quercus*, *Fagus*, *Pyrus*, *Carpinus*, *Cornus*, *Abies*, *Pinus*, *Cedrus*, *Juniperus*.

Distribution: The samples at the Herbarium of Botany Institute of Azerbaijan National Academy of Sciences have been collected from the surroundings of Anagut (8.V.1947, Rzazade) village of Ordubad district, Khoshkeshin village of Julfa region (13.VIII.1938, Novruzova). According to Kasumova (2004) information, it is mentioned that plant occurs in Kuku, Kechili, Kolani, Southern Gishlag, Yukhary Gishlag, Bichanek village of Shahbuz region, Chalkhangala village of Kengerli region, Nusnus villages of Ordubad district, Arafsa village of Julfa region at 800–2000 m above sea level as individually or in small groups, edges of forests, glades, open oak forests, and arid sparse forests. Sometimes, along with other species of hawthorn, they form brushwoods on dry slopes of the mountains.

In Caucasus, the fruits of *C. orientalis* are collected from the field and sold in the markets, usually eaten raw, but occasionally they are ground and mixed with flour for the preparation of a sweet bread. The wood is used for preparing tool handles.

14. ***C. pojarkoviae*** **Kossych,** 1964, Novitates systematicae plantarum non vascularium: 147. *C. laciniata* Ucria subsp. *pojarkovae* (Kossych) Franco 1968, Feddes Repert. 79:37. *C. orientalis* Pall. subsp. *pojarkovae* (Kossych) Byatt 1977, Contrib. Crataeg. Eur.: 89; Christensen 1992, Syst. Bot. Monogr. 35:43.

The trees are 3–6 m tall, flowering in June, fruits ripen in September, sphereovary or pear shaped, diameter is 1.5–2.5 cm, ribs yellow colored and 5 seeded. 2n (3x) = 51.

Type: USSR, Crimea, Karadag, in parte inferiore declitatis australis jugi Sjurju-Kaja, 14.06.1960, 22.09.1960, Kossych s.n. (holotype: YALT; isotype: LE!).

Common distribution: Caucasus, Crimea.

Distribution: It is found on stony-gravel slopes of Yukhari Gishlag village of Shahbuz region, in the middle and high mountain zones between 1200 and 2000 m altitude as individually in arid sparse forests.

C. pojarkoviae Kossych. species was included in the flora of Azerbaijan in accordance with the samples collected from Gizil Gishlag village of Shahbuz region by Kasumova (1981) (dried stones-gravel slopes, 20.X.1980). It was included in the Armenian flora by Sargsyan (2011). Christensen (1992) has accepted *C. pojarkoviae* Kossych. as a subspecies of *C. orientalis* subsp. *pojarkoviae* (Kossych) Byatt. It should be noted that *C. pojarkoviae* Kossych. differs from *C. orientalis* in the rough-thorny branches and yellow fruits (not orange), round-oval or pear shaped (not crushed from poles or ribbed). For this reason, it is advisable to consider it as an independent species taking into account its specific features.

15. ***C. pontica*** **C.Koch** 1853, Verh. Ver. Beford. Gartend. Konigl. Preuss. N.R. 1:269. ejusd. 1854, Weissdorn: 49, Grossheim 1934, *Flora of the Caucasus*. 4:290; Pojarkova 1939, *Flora of the USSR* 9:435; Grossheim 1952, *Flora of the Caucasus* 5:41; Poletiko 1954, *Trees and Shrubs of the USSR* 3:541; Riedl 1969, *Fl. Iran*. 66:57; Browicz 1972, *Fl. Turk*. 4:138; *C. azarolus* var. *pontica* (C.Koch) Christensen 1992, Syst. Bot. Monogr. 35:38.

The plant is 4–8 m tall, flowering in June, fruits ripen in September–October, are yellowish or orange-yellowish, with a diameter of 3.0 cm, 2–3 seeded. The fruit is fragrant. 2n (4x) = 68.

Type: Turkey. Prov. Coruh, in der Niihe von Ardanuc, 28.08.1843, Koch n 187 (holotype: B, destroyed).

Neotype, here designated: drawing of holotype, in Pojarkova, 1939.

Common distribution: Jordan, Turkey, Caucasus, Georgia, Iraq, Iran, Turkmenistan (Kopet-Dagh), southern Kazakhstan, Uzbekistan, Tadzhikistan, Kirgizstan, and Israel.

Distribution: According to Kasumova (2004), the distribution of plants has been shown to lie around Yukhary Gishlag of Shahbuz region. The field study revealed that the plant is also distributed around Chalkhangala village of Babak region, around Ashagi Gishlag, South Gishlag, Kolani village of Shahbuz region, and in the Lizbirt zone. The information on the distribution of plants also from Nursu and Gecazur (Agbulag) villages of Shahbuz region, lower and middle mountain zones, at altitudes of 800–1800 m above sea level, on dry slopes of mountain rivers and in the arid forests as individually are as per "*Biodiversity of the Flora of Nakhchivan AR and Protection of Its Rare Species* (*Cormobionta*)" (Talibov 2001).

C. pontica is a new species, included in the flora of Azerbaijan by Kasumova (1981) after samples collected by her from the Autonomous Republic.

16. ***C. szovitsii* Pojark.** 1939, *Flora of the USSR*, 9, Addenda 8:499. Grossheim 1952, *Flora of the Caucasus* 5:41; Poletiko 1954, *Trees and Shrubs of the USSR* 3:540; Prilipko 1954, *Flora of Azerbaijan* 5:72; Fedorov 1958, *Flora of Armeni*a. 3:297; Riedl 1969, *Fl. Iran*. 66:55; Browicz 1972, *Fl. Turk*. 4: 138; *C. orientalis* Pall. subsp. *szovitsii* (Pojark.) Christensen 1992, Syst. Bot. Monogr. 35:47. *C. orientalis* var. *connecta* Diapulis 1934, Feddes Repert. 34:56. *Mespilus monogyna* var. *armeniaca* Wenzig 1874, Linnaea 38:157.

Small tree or a bush with a height of 2 to 3 m, flowering in June, fruits ripen in September–October, color is dark red, 3–4, and in some cases 2 seeds.

Type: USSR, Azerbaijan: Nagorno-Karabagh, in collibus prope Shusha, Hohenacker n 3423 (holotype: LE; isotypes: BM! G! W!).

Common distribution: Caucasus, Turkey, western Iran.

Distribution: According to Isaev and Kasumova (1976), it is distributed on the dry stony slopes between the Payiz and Buzgov villages of Babek region and Kolani village of Shahbuz region. It has also been found that these plants are distributed around Arafsa village of Julfa region, Kuku and Ayrinj villages of Shahbuz region, in the middle mountainous zones, at 1200–1800 m above sea level, on stony slopes of mountains, rocky habitats, among brushwoods, arid sparse forests, and edges of forests.

It was added to the Nakhchivan Autonomous Republic flora as a new species during the analysis of materials collected from Kolani (dry-stony slopes) village of Shahbuz region and Payiz and Buzgov villages of Babek region by Isaev and Kasumova (1976). According to the authors, the collected herbariums differ from the typical examples of 3–5 seeds (not 2–4).

C. szovitsii species has been regarded as *C. orientalis* subsp. *szovitsi*i (Pojark.) by Christensen (1992). However, during an analysis of both species, it has been found that *C. szovitsii* differs from *C. orientalis* by more fragmented leaves, reddish-yellow fruits and seed numbers of 3 (2) to 4 (5). Generally, *C. szovitsii* can be regarded as an independent species, as per the obvious selection of other hawthorn species for many features.

17. ***C. tournefortii* Griseb.** 1843, Spicil. Fl. Rumel. Et Bithyn. 1:90. Pojarkova 1950, Pojarkova 1950, Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk SSSR 12:108; Poletiko 1954, *Trees and Shrubs of the USSR* 3:539; *C. sanguinea* auct. Schrad. 1834, Index Sem. Hort. Gotting.: 2, non *C. sanguinea* Pall. *C. orientalis* auct. non Pall.: Lindl. 1836, Bot. Reg. 22: t. 1852. *C. orientalis* var. *sanguinea* (Schrad.) Loud. 1838, Arb. Brit. 2:828. *C. orientalis* var. *tournefortii* (Griseb.) Schneider 1906, III. Handb. Laubholzk. 1:787. *C. schraderiana* Ledeb. 1844, *Fl. Ross.* 2, 1:91; Pojarkova 1939, *Flora of the USSR* 9:464; Fedorov 1958, *Flora of Armenia*. 3:299; *C. orientalis* Pall. subsp. *orientalis* Christensen 1992, Syst. Bot. Monogr., 35:41.

A small thorned tree or bush, with a height of 2–2.5 m, leaves are dark green with upper surface covered with short hairs, flowers are located in multiflowered cymes, flowering in June, fruits ripen in September–October, are light or dark cherry colored, diameter is 1.0–1.6 cm, 3–5 seeds. 2n (3x) = 51; 2n (4x) = 68.

Type: Tab. 1852 in Lindley, Bot. Reg. 22.1836 (lectotype, here designated).

Common distribution: Europe, Caucasus, Sicily (Nebrodi Mts), Albania, southern Yugoslavia, Greece, Bulgaria, Turkey, Ukraine (near Odessa), and Crimea.

Distribution: Plants have been collected from Chalkhangala village of Kengerli region and Bichanek forest of Shahbuz region by Kasumova (2004). The plants are found in the Khanbulagi areas of Sharur region, in the middle and upper mountain zones, at 1300–1400 m altitude, on the edges of forests, on stony slopes as individually or in groups as per "The flora biodiversity and preservation of its rare species of Nakhchivan Autonomous Republic" (Talibov 2001). Sargsyan (2011) has also reported on dissemination of this species in the Nakhchivan Autonomous Republic.

According to Pojarkova (1939), distribution of this species is shown in Crimea and South Caucasus. In *Flora of Azerbaijan* (Prilipko 1954), it has been included as *C. tournefortii* under *C. schraderiana* and distribution recorded as Nakhchivan Autonomous Republic. Christensen (1992) has adopted *C. tournefortii* as a synonym of *C. orientalis*, which included *C. orientalis* subsp. *orientalis*. However, the analysis has shown that both species differ from each other sharply in the floral shapes, shape of leaves, fussy, size, shape, color of fruits, and number of seeds. It is possible to assume that *C. tournefortii* is a completely different species, and there is need for additional studies.

Letukhova and Potapenko (2011) report that *C. tournefortii* is of hybrid origin resulting from the hybridization of *C. orientalis* and *C. pentagyna* species.

20.4 Conclusions

According to the collected herbarium materials covering the period of expeditions undertaken from 2004 to 2018, together with the published data, we conclude that there are 22 species of the *Crataegus* genus in the Nakhichevan Autonomous region.

Seventeen species are found in the wild. Five species, namely, *C. chlorocarpa, C. ferganensis, C. sanguinea, C. songarica, C. turkestanica*, are introduced and used in the greenery of parks and gardens under cultural conditions (Ibrahimov 2012, 2016; Talibov and Ibrahimov 2013). Out of these, *C. pojarkoviae* and *C. tournefortii* have been included in the former *Red Book of USSR* (1984), *C. pontica* species has been included in the book *Plants and Plant Formations*, recommended for the "Red" and "Green" Books of "Azerbaijan" by Hajiyev and Musayev (1996). In recent years, as a result of effects of climatic and anthropogenic factors on the territory of Autonomous Republic, these species are threatened with destruction. In fact, a number of precious species of hawthorns constitute the wildlife gene pool in nature. For this reason, as a result of studies conducted by Talibov and Ibragimov (2008), this fact has been taken into account so as to underline the rare and endangered species of *C. orientalis* and *C. pontica*, which have been included in the *Red Book of Nakhchivan Autonomous Republic* and ways of protection of these species outlined.

References

Aliev GA, Zeynalov AK (1988) Soils of the Nakhchivan ASSR. Azerneshr, Baku

Areas of trees and shrubs of the USSR (1980) Leningrad 2:68–77

Asadaov KS, Asadaov AK (2001) Wild fruit plants of Azerbaijan. Azerbaijan Milli Encyclopediasi, Baku, pp 17–26

Asadov KS, Mamedov FM, Sadigova SA (2008) Dendroflora and forests of the northeastern part of the Greater Caucasus. Baku, pp 142–144

Asadov KS, Mirzoev OH, Mamedov FM (2014) Dendrology. Baku, pp 308–312

Askerov AM (2006) Higher plants of Azerbaijan (Abstract of flora of Azerbaijan). Baku 2:71–73

Browicz K (1972) *Crataegus* L. (Rosaceae). Flora of Turkey and the East Aegean Islands. Edinburgh 4:133–147

Cherepanov SK (1995) Vascular plants of Russia and adjacent states (of the former USSR). Mir i Sem'ya, Saint Petersburg, pp 855–857

Christensen KI (1992) Revision of *Crataegu*s Sect. *Crataegus* and Nothosect. *Crataeguineae* (*Rosaceae-Maloideae*) in the old world. Syst Bot Monogr 35:1–199

Christensen KI, Zielinski J (2008) Notes on the genus *Crataegus* (*Rosaceae-Pyreae*) in southern Europe, the Crimea and western Asia. Nord J Bot 26:344–360

Donmez AA (2004) The genus *Crataegus* L. (Rosaceae) with special reference to hibridisation and biodiversity in Turkey. Turk J Bot 28(1–2):29–37

Fedorov AA (1958) The genus *Crataegus.* Flora of Armenia. Yerevan 3:291–303

Gabrielian ETZ, Sargsyan MV (2009) New to science endemic species *Crataegus susanykleinae* (Rosaceae) from Armenia. Flora, Veget Plant Resour Armenia 17:10–11

Grossheim AA (1934) Flora of the Caucasus. Baku 4:290–291

Grossheim AA (1952) Flora of the Caucasus. Moscow-Leningrad: Acad Sci USSR 5:39–44

Gurbanov EM (1996) Plant world of Nakhichevanchay river basin. Baku State University, Baku, pp 1–248

Gurbanov EM (2004) Flora and vegetation of Atropatena province (within Azerbaijan Republic). Autoreferat of dissertation for the degree of doctor of biological sciences. Baku, pp 1–59

Hajiyev VS, Musayev SG (1996) Plants and plant formations recommended for the "Red" and "Green" Books of Azerbaijan. Baku, pp 1–40

Ibragimov ASh (2005) Vegetation of the Nakhchivan Autonomous Republic and its national economic importance. Baku, pp 1–236

Ibrahimov AM (2012) State studies of trees and shrubs, common in the territory of the Nakhchivan Autonomous Republic (Wild, cultural, introduced). News of Nakhchivan Section of Azerbaijan National Academy of Sciences. Ser Nat Techn Sci 8(4):89–104

Ibrahimov AM (2016) Taxonomic analysis of trees and shrubs, distributed in forest ecosystem of the Nakhchivan Autonomous Republic. News of Nakhchivan Section of Azerbaijan National Academy of Sciences. Ser Nat Techn Sci 12(4):100–109

Isaev YM, Kasumova TA (1976) Hawthorn Shovitsa (*Crataegus szovitsii* Pojark.)- a new species of the flora of the Nakhichevan ASSR. Rep Acad Sci Azerbaijan SSR 32(3):61–62

Kasumova TA (1981) New species of hawthorn for the flora of Azerbaijan. Rep Acad Sci Azerbaijan SSR 37(1):69–71

Kasumova TA (1983) New species of hawthorn for flora of Azerbaijan II. Rep Acad Sci Azerbaijan SSR 39(7):73–75

Kasumova TA (1985) A new species of the genus *Crataegus* (*Rosaceae*) from Azerbaijan. Bot J 70:266–267

Kasumova TA (1991) On the forgotten form of the genus *Crataegus* (*Rosaceae*). Bot J 76(7):985–986

Kasumova TA (2004) The key for determining the species of the genus *Crataegus* in the flora of Azerbaijan. Proc Inst Bot Natl Acad Sci Azerbaijan 25:101–103

Kasumova TA, Akhundov GF (2004) Hawthorns of the Nakhchivan ASSR. Rep Acad Sci Azerbaijan SSR 41(4):54–57

Kasumova TA, Amirov GA, Ibragimov AS (1991) Reserves of fruits of *Crataegus* L. species in the Nakhchivan ASSR. Rastitelnye Resursy 27(2):24–26

Kryshtofovich AN (1957) Paleobotany. Leningrad, 650 p

Letukhova VJ, Potapenko IL (2011) Modern state of *Crataegus tournefortii* Grieseb population at Stary Krym (Ukraine, Krimea). Nat Almanac Ser: Biol Sci 15:83–89

Mirzeyev PS (1972) Agroclimatic characteristic of Nakhchivan ASSR. Azerneshr, Baku

Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018a) A comparative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343

Ozturk M, Altay V, Altundağ E et al (2018b) Herbals in Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health. Vol. 1. Springer, Cham, pp 197–266

Pojarkova AI (1939) Genus *Crataegus* L. Flora of the USSR. Moscow-Leningrad Acad Sci USSR 9:416–510

Poletiko OM (1954) Genus *Crataegus* L. trees and shrubs of the USSR. Moscow-Leningrad. Acad Sci USSR 3:514–577

Prilipko LI (1939) Vegetation references in the Nakhchivan ASSR. Baku 7:1–196

Prilipko LI (1954) Genus *Crataegus* L. Flora of Azerbaijan. Baku 5:67–78

Red Book of USSR (1984) Rare and endangered species of animals and plants. Forest Industry, Moscow, pp 354–357

Riedl H (1969) Crataegus (Rosaceae). Flora Iranica. Graz-Austria: Akademische Druck und Verlagsanstalt 66:49–65

Sargsyan MV (2011) The genus *Crataegus* (*Rosaceae*) in Southern Transcaucasia. Takhtajania 1:110–117

Seyidova H, Huseyn E (2012) Macrofungi of Nakhchivan Autonomous Republic (Azerbaijan). Turk J Bot 36(36):761–768

Takhtajan FK (1978) The floristic regions of the World. Leningrad, pp 1–248

Talibov TG (2001) Biodiversity of the flora of the Nakhchivan AR and protection of its rare species (*Cormobionta*). Baku, pp 71–72

Talibov TH, Ibragimov ASh (2008) Taxonomic spectre of the flora of Nakhchivan Autonomous Republic. Nakhchivan, pp 128–130

Talibov TH, Ibragimov ASh (2010) Red book of Nakhchivan Autonomous Republic. Nakhchivan, pp 356–361

Talibov TH, Ibrahimov AM (2013) The dendrofloras of Nakhchivan Autonomous Republic. News of Nakhchivan Section of Azerbaijan National Academy of Sciences. Ser Nat Techn Sci 9(4):69–77

Trees and shrubs of Azerbaijan (1970) Baku 3, p 284

Tzvelev NN (2001) *Crataegus* L. Flora of East Europe. St Petersburg 10:557–586

Ufimov RA (2011) A new species of the genus *Crataegus* (*Rosaceae*) from Talysh. Bot J 96(9):1254–1257

Ufimov RA (2013) The genus hawthorn *(Crataegus* L., Rosaceae*)* in the flora of Eastern Europe and the Caucasus. Doctor's Dissertation, St Petersburg, pp 1–22

Chapter 21
Herbals Used in Western Iran as Food and for Health Treatments

Mehdi Younessi-Hamzekhanlu, Moslem Abdipour, Ata Dejahang, Mohsen Sabzi-Nojadeh, and Mina Amani

21.1 Introduction

Iran is situated in west Asia, with an area of more than 1.6 million km^2, 16th largest country in the world (Heshmati 2012). Its neighboring countries are Armenia, Azerbaijan, Turkmenistan, and Caspian Sea on the north, Afghanistan and Pakistan on the east, Oman Sea and Persian Gulf on the south, and Iraq and Turkey on the west. The Alborz and Zagros mountains ranging between 500 and 2500 m stretch in northwest-northeast, northwest- southeast direction and play an important role in determining the distribution of precipitation in the country. The area among these mountains is high plateau, but it gradually slopes down to become desert in the southern part of Afghanistan and near Pakistan border. Damavand peak in the Alborz reaches 5600 m asl, while the Caspian coastal area is below sea level (−28 m) (Heshmati 2013).

The climate is extremely continental with hot and dry summer and very cold winters particularly in inland areas. The temperature annually ranges between 22 and 26 °C; rainy period is mainly during November to May and dry period between May and October, average annual rainfall being about 240 mm, with maximum in

M. Younessi-Hamzekhanlu (✉) · M. Sabzi-Nojadeh
Molecular Genetics and Genetic Engineering Department, Ahar Faculty of Agriculture and Natural Resources, University of Tabriz, Ahar, Iran
e-mail: myounessi@tabrizu.ac.ir

M. Abdipour
Biometrical Genetic, Kohgiluyeh and Boyerahmad Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Yasuj, Iran

A. Dejahang · M. Amani
Department of Horticultural Sciences, Faculty of Agriculture, University of Tabriz, Tabriz, Iran
e-mail: adejahang@ut.ac.ir

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_21

the Caspian Sea plains, Alborz (1800 mm), and Zagros slopes (480 mm) (Heshmati 2013). The plant diversity includes 8000–9500 species of flowering plants from 167 to 190 families and 1600 genera, 2000 being endemics (Bazyar et al. 2013; Eftekhari and Ramezani 2004; Younessi-Hamzekhanlu et al. 2020). The Hyrcanian, Zagros, Irano-Turanian, and Khalij-o-Ommanian are the four Ecological Zones, differing physiographically and climatically. In addition, Arasbaran region, which is located in northwestern Iran, is of special importance in terms of plant species diversity, as many species related to the pre-glacial period, as well as wild relatives of important crops including grains and forages and local land races, grow in this area (Parsa et al. 2016; Younessi-Hamzekhanlu et al. 2020). The Zagros ecological zone extends over a large area of about 4.749,000 ha with semi-arid climate and temperate winter. The highest peaks exceed 4.000 m covered permanently with snow. Many large rivers originate from here, draining into the Persian Gulf or the Caspian Sea (Heshmati 2013).

The climate is semi-arid temperate in the forest and steppe forest areas of Zagros Mountains, annual precipitation between 400 and 800 mm, mostly in winter and spring. Winters are severe, often below −25 degrees ^{0}C, and extreme summer aridity also recorded (Anderson 1999; Frey and Probst 1986). The steppe forest consists mainly of deciduous, broad-leaved trees or shrubs with a dense ground cover of steppe vegetation, dominated by *Quercus* spp., *Pistacia* spp., and others (Heshmati 2013). In the North reaches of this range, between 400 and 500 m dominating plants are the species of *Astragalus*, *Salvia*, and few others. Between 700 and 800 m, we find forests or forest remnants of *Quercus brantii* and/or *Q. boissieri*. These are found up to an altitude of nearly 1.700 m. Between 1 and 2.000 m, i.e., above timber line a relatively wide zone of sub-alpine vegetation is distributed (Zohary 1973). Further south forests become poor and a rich steppe flora develops among the trees. The forest remnants mainly include *Quercus persica* together with xerophilous forest of *Quercus* spp., *Crataegus* spp., *Prunus amygdalus*, *Celtis* spp., and *Pyrus* spp. up to an elevation of 2400 m; the vegetation is steppe dominated by shrubs below 1400 m (Heshmati 2013).

A significant portion of plant diversity in the country is related to medicinal plants (about 2300 species). Iran has a wide range of medicinal experiences because of long historical precedent and human diversity, ethnicity, language, and climate. The herbal medicines are considered to be of great importance especially, for tribes and residents settled in the impassable parts (Asadbeigi et al. 2014; Ozturk and Hakeem 2018, 2019a, b; Ozturk et al. 2018a, b; Younessi-Hamzekhanlu et al. 2020). West parts of Iran show a vast diversity of humans, majority inhabiting the areas around Zagros Mountains. Traditional medicine is a part of folkloric culture in here, and traditional herbal drugs are used at a large scale (Bahraminejad et al. 2012; Azizi and Keshavarzi 2015; Akbari et al. 2018). Due to the ancient culture in this region, a great historical interest is seen among people in the studied region related to the use of herbals. The public knowledge about medicinal plant use in this region is relatively high, and a number of scarcely used medicinal plants with promising phytotherapeutical applications have been reported (Afshari et al. 2013; Naghibi et al. 2014; Younessi-Hamzekhanlu et al. 2020). The botanical research and data collected by a large number of researches can provide better recognition of this great treasure for current and future generations (Asadbeigi et al. 2014). Historically Egyptians and Chinese are among the pioneering nations who have used plants as medication since 2700 years back. Most of these plants are still being used (Baharvand Ahmadi et al. 2015). The importance of valuable indigenous information on traditional treatments in Iran can play a great role for world society if special attention is given to the traditional treatments and the drugs extracted from medicinal plants (Delfan et al. 2014c). Numerous ethnobotanical studies have been carried out to identify the therapeutic properties of medicinal plants and how to use them in Iran. The data has been recorded with a wide range of herbal traditional medicines to relieve pain and treat various diseases.

In Lorestan province, 18 medicinal plants from 11 plant families is used for treating and healing skin lesions (Delfan et al. 2014a); 15 herbs traditionally used to treat headaches (Delfan et al. 2014b); 14 plants used to relieve toothache (Delfan et al. 2014c); 17 plants from 12 families used to control and treat kidney stone pain; 15 species from 11 families used for the treatment of stomach disorders, including gastritis and peptic ulcers (Delfan et al. 2015a); and 23 medicinal plants used for treating cold and its symptoms (cough, sore throat, sneezing, runny nose) (Delfan et al. 2015b). In the west Azerbaijan province, 20 plants from 10 families are used to treat respiratory disorders (Asadbeigi et al. 2014); 22 plants from 10 families used for psychiatric and neurological disorders (Saki et al. 2014); 30 medicinal plants from 17 families for the treatment of diabetes (Bahmani et al. 2014); 22 plants from 17 families used for skin healthcare (Baharvand Ahmadi et al. 2015); and 123 plants from 46 families used to cure various ailments (Younessi-Hamzekhanlu et al. 2020). In Ilam province 22 medicinal plants from 16 families used to treat diseases and syndromes of herd dog (Bahmani and Eftekhari 2013) and 16 different families used for cancer therapy (Bahmani et al. 2017). In Chaharmahal-o-Bakhtiari province, 16 native plants are used for antimicrobial activity (Pirbalouti et al. 2012). In Kohgiluyeh-va-Boyerahmad province, some medicine plants in particular *Dorema aucheri* have been evaluated for cytotoxic activity (Mosaddegh et al. 2012). In Kermanshah province, species from Asteraceae and Apiaceae families are used to treat chronic gastrointestinal diseases and skin disorders (Eftekharinasab et al. 2012). In Khuzestan province, 60 plant species from 23 families are used to treat respiratory and gastrointestinal diseases (Razmjoue et al. 2018). In Kurdistan province, 56 medicinal plant species belonging to 48 genera and 24 families are used for treating different diseases (Tabad and Jalilian 2015). In Hamadan province, 45 traditionally used plant species, from 23 families, are used for treating some pain and diseases (Naghibi et al. 2014).

21.2 Plant Diversity

A total of 331 important herbs belonging to 65 different families have been identified during this study, which have been applied for the treatment of various ailments in the Western regions of Iran. Some of these are evaluated as edible plants in this region. The detailed information on these is presented in Appendix 21.1. The data in the appendix reveals the fact that among the families, Asteraceae, Lamiaceae, Apiaceae, and Rosaceae top the list with 48, 43, 30, and 26 species, respectively, as the most dominant families (Fig. 21.1).

These families also have been reported as popular families in the earlier studies done in other regions of Iran such as south of Kerman (Sadat-Hosseini et al. 2017) and Saravan region, Baluchistan (Sadeghi et al. 2018). In spite of big cultural and regional divergences, our results indicate that Apiaceae, Lamiaceae, Asteraceae, and Rosaceae are the most popular families not only in West but also cited mostly in other regions of the country. In fact there are hundreds of taxa in different families. Data show the existing of hundreds taxa in each mentioned families. An evaluation of major previous ethnopharmological reports have enlightened the frequently used medicinal plants. Figure 21.2 shows the plant species with the highest relative frequency citation from different provinces of Western region of Iran. The Fig. 21.2 shows that *Lawsonia inermis* ranks first as the most cited herb, followed by *Hypericum perforatum, Mentha spicata,* and *Artemisia dracunculus. Mentha spicata* is used for treatment of different ailments including toothache, abdominal and ear pain, as skin cleaner, as antiseptic, anti-flatulence, in diarrhea, improving blood flow, and stomach problems. These ailments can be categorized into five main groups: general, digestive, blood, ear, and skin problems. Similar effects have been reported by Avicenna in *The Canon of Medicine* book (e.g., headache, ear pains, anti-bleeding, breast inflammation, stomach reinforcement, hiccup, blood vomiting, jaundice, diarrhea, abdominal bleeding). On the other hand, mint has been used as

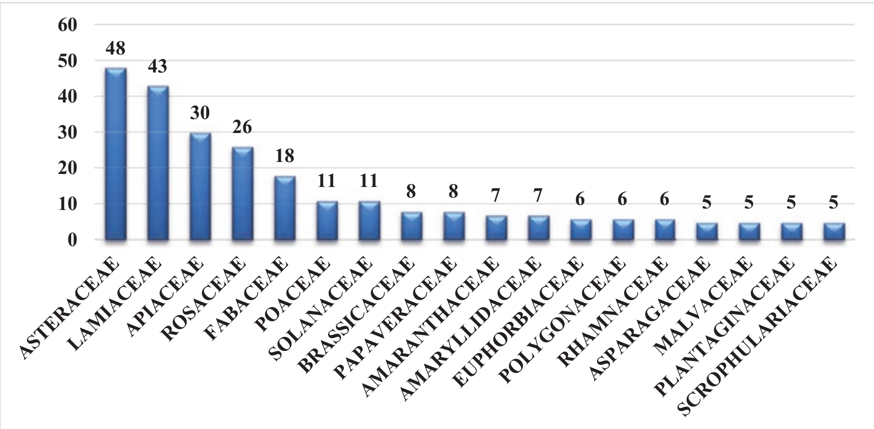


Fig. 21.1 Well-known plant families and their related taxa numbers

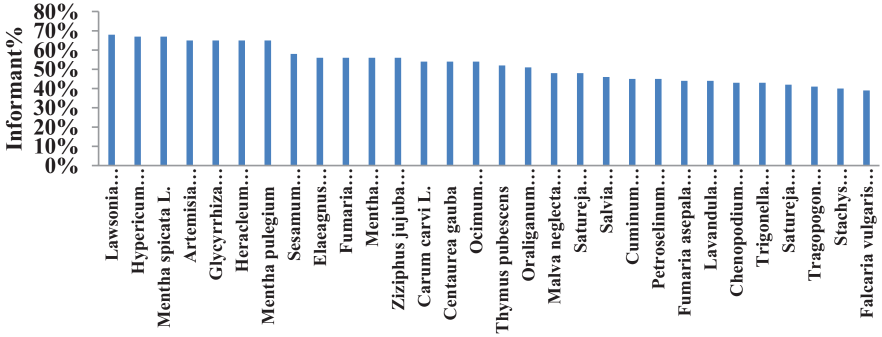


Fig. 21.2 Medicinal plants highly cited by the informants (%)

an edible plant along with many foods in different regions of Iran. *Asafoetida* dried latex (oleo-gum resin) exuding from the roots of *Ferula assa-foetida* possesses different pharmaceutical properties, such as antimicrobial, antibacterial, antispasmodic, and anti-inflammatory; even muscle relaxant activities have been reported for *Ferula assa-foetida* (Samadi et al. 2016; Hassanabadi et al. 2019). In Turkmen Sahra, north of Iran, *Glycyrrhiza glabra* has been given as decoction for curing gastric ulcers, hemorrhoids, liver disorders, and muscle spasm problems (Ghorbani 2005). The roots are frequently used by other people living in the south of Kerman for alleviating stomach-related ailments (i.e., stomach pain, ulcers, and acidification) (Sadat-Hosseini et al. 2017). The liquorice in fact is regarded as an important herbal drug all over the world (Altay et al. 2016; Ozturk et al. 2017a, b; Pleskanovskaya et al. 2019).

21.3 Plant Parts Used

Plant parts used by local people to treat different disorders include leaves, aerial parts, stems, roots, bark, resin, seeds, bulbs, whole plant, tubercules, flowers, and fruits (Fig. 21.3). In this regard, the leaves rank first (18%), followed by aerial parts (16%), flower (15%), fruit (12%), and branch (10%). In addition to these, the whole plant (2%), bulbs (2%), and tubercules (1%) are also preferred parts for diseases therapy but with least frequency. Several factors influence consumers preference for a particular plant part including concentrations of bioactive compounds, difficulty of the related plant part harvesting, and its seasonal accessibility (Mosaddegh et al. 2012; Younessi-Hamzekhanlu et al. 2020). Unlike flowers and fruits that appear only during the reproductive stage of the plants, the leaves are available throughout the growing season. On the other hand, due to their high photosynthetic activity, they can be rich in various metabolites and can be easily harvested, which makes them an easy target compared to underground parts such as roots, bulbs, and tubercules (Sadat-Hosseini et al. 2017; Hassanabadi et al. 2019). It has been documented

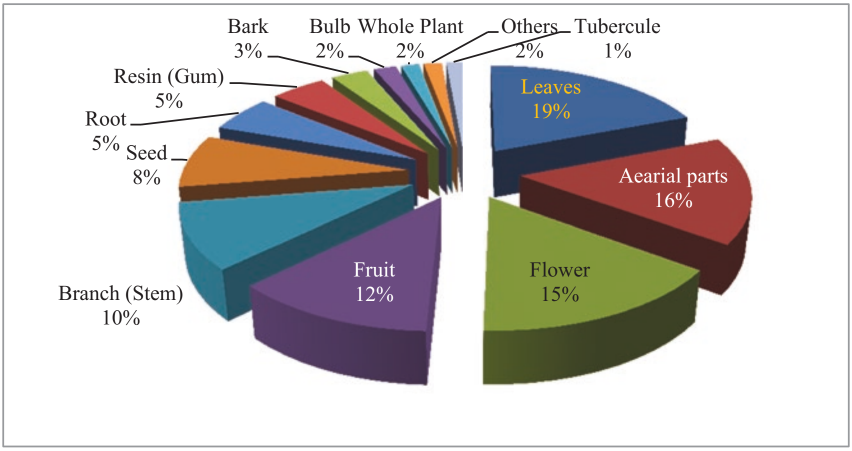


Fig. 21.3 Different plant parts used by people with percentage used in west of Iran

that in families like Apiaceae, Lamiaceae, Rosaceae, Asteraceae, Fabaceae, and Solanaceae (as the richest families of Iran flora), usually leaves and aerial parts are preferred by local people in different provinces of Iran (Ghorbani 2005; Sadat-Hosseini et al. 2017; Maleki and Akhani 2018). Other facts for harvesting time are that people mainly harvest medicinal plants in early spring in the west of Iran, i.e., during their vegetative phase, therefore no flower or seed may be formed.

21.4 Plants Used as a Food

Some of plant species are used as edible or medicinal plants in west of Iran. These plants are consumed fresh, or prepared as local foods and breads. For example, *Allium tripedale* and *A. ampeloprasum* are used by Kurdish people in the west of Iran for making delicious and appetizing bread called "Kalaneh" and local soup called "Dokhwa." *Rheum ribes* is a hardy perennial used for several purposes since ancient times. Its fresh stems and petioles are consumed as vegetable, and stems are also used for fresh consumption as digestive and appetizer, while the roots are used to treat diabetes (Öztürk et al. 2007). Also, in the northwest of Iran, particular bread is baked by combination of different plants called "kata" or "khitab." It is also eaten with butter, which makes it delicious. Various herbs such as *Echium* spp., *Rumex* spp., *Allium ampeloprasum, Petroselinum crispum, Falcaria vulgaris*, and *Urtica dioica* are placed inside the dough and then baked on the pan. Some plants like *F. vulgaris, Malva sylvestris*, and wild spinach are cooked in oil and consumed alone or with other foods. These kinds of foods are a famous dish, especially among the residents of Germi-Madadli tribe (Ardabil province), which is baked in most houses in spring.

Qatikhli Ash and Airan Ashi: The plants used in these foods are collected in spring. But the cooking varies, depending on the region and mainly include *Falcaria vulgaris,* Aghjabashi, *Trachyspermum ammi, Allium sativum, A. ampeloprasum,* Onija, *Nasturtium officinale*, *Mentha longifolia, Eremurus spectabilis, Coriandrum sativum*, and *Rumex* spp.

Omaj Ashi: It is a special type of soup, very useful in treating colds. The thyme (*Thymus vulgaris*) is the main edible herb in the composition of Omaj ashi. There is another type of soup that is cooked in the same way as Omaj ashi called cold soup, in which the predominant ingredient is *Mentha spicata*. It is also effective in treating colds, chest inflammation, and infections.

Tara Kukusi: The ingredients' of this food are *Alliums* spp. and *Achillea millefolium.* It should be noted that Yarrow is used in very small amounts in this food due to its bitterness. So this plant is used at early stages of growth when it is less bitter.

21.5 Preparations and Application Modes

Different preparation modes of plants can be grouped under 13 main divisions as presented in Fig. 21.4. Most frequent application way is decoction (18%) followed by distillation (15%), consuming directly (14%), and infusion (14%). Almost 9% of the plants are mixed with honey and milk as these two ingredients are major prod-

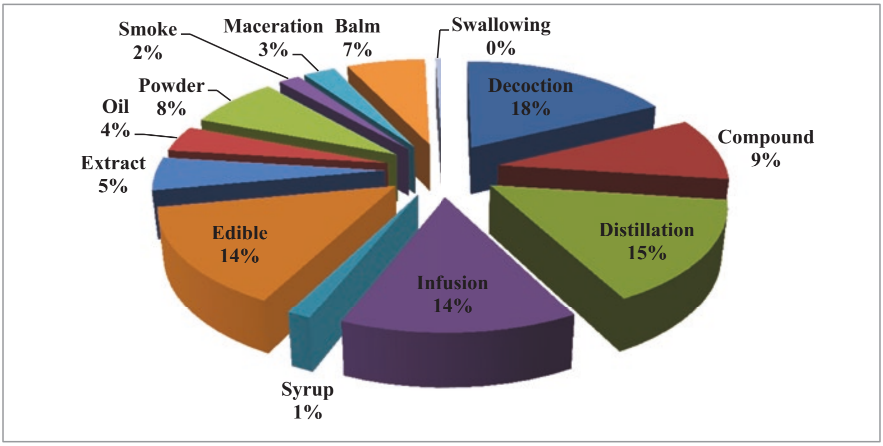


Fig. 21.4 Various preparation methods of the plants and their related percentage used by people living in West Iran

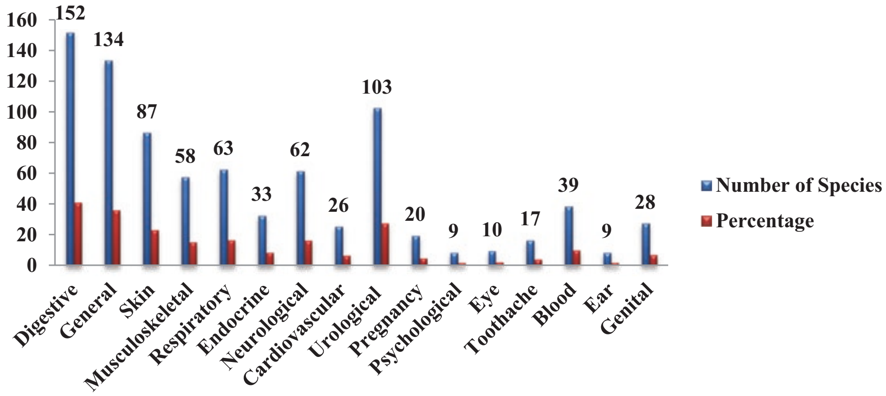


Fig. 21.5 Percentage of species in each medicinal use category

ucts of farmers in the region and easily available for use. It is worth noting that in some plants combination of methods is used for preparation due to the use of different plant parts. For example, in the case of *Allium iranicum,* the bulbs and leaves are prepared in decoction and as infusion, respectively, to treat disorders like bloating and kidney stone. Infusions are prepared to extract the active compounds, whereas for decoction, the plant materials are boiled in the water. Decoction and infusion are mainly used as a dominant method in other regions of Iran including, Taftan and Hazar mountains (Southeast of Iran), Turkmen Sahra (Northeast of Iran), and Kerman (South of Iran) (Ghorbani 2005; Mosaddegh et al. 2012; Sadat-Hosseini et al. 2017; Maleki and Akhani 2018).

A total of 1100 uses for medicinal plants have been recorded. These can be grouped under 16 medicinal use categories. Majority of the plants (41%, 152 species) are applied to cure digestive disorders, followed by general (36%, 134 species), urological (28%, 103 species), and skin (23%, 87 species) diseases (Fig. 21.5). This ranking is due to the occurrence of various diseases in the region. The importance of different diseases among Iranian ethnic groups in general varies in different regions, which makes a difference in the ranking of diseases in terms of number of species used. However, as in our results digestive use category was determined as major category used by locals of Iran, such as Kerman (Sadat-Hosseini et al. 2017), Sirjan (Nasab and Khosravi 2014), Turkmen Sahra (Ghorbani 2005), and Taftan (Maleki and Akhani 2018). In addition, the climatic conditions of the region and cultural trends are also effective in this regard. For example, Taftan (southeastern Iran) region is characterized by high sunlight exposure, and long-term exposure to intense sunlight causes skin and hair disorders. Therefore, in this region skin use category was ranked second after digestive problems in view of the number of species used for curing of various ailments (Maleki and Akhani 2018). However, due to the humid climate of the western region of the country (Iran), skin problems are in the lower ranks in terms of importance.

21.6 Conclusions

Our study has clearly documented the ethnopharmacological knowledge of different cultures living in in the west of Iran. The current study has recognized 331 different medicinal plant species belonging to 65 families which are mainly applied for medicinal purposes under different application methods. However, some species are consumed freshly as a vegetable or cooked as food. The study area is more mountainous, and there is an adequate water for growing trees and plants which makes it a unique center of endemic medicinal plants. Based on our comparisons, many medicinal plants growing in the area are used in other regions of Iran as well and, with similar applications, only more or less small changes in application modes. Although different ethnic groups live in Iran, the common historical memories might be the reason for these similarities in the use of various herbs. Furthermore, based on the current study, Iran has a great potential in medicinal plants, and it should be screened for phytochemicals and analyzed for protection against different diseases as well as pandemics. Medicinal plant species have wide range of therapeutic applications in indigenous societies. They have varied therapeutic effects in indigenous societies. Therefore, research projects should be designed for these areas with priority before the library of wild medicinal plants and their uses is lost.

Appendix 21.1 Medicinal and Aromatic Plants Used in West Iran

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Amaranthaceae						
Chenopodium album	Aerial parts, leaves	Salmka, Shoralan	Distillation, edible	Stomach problems, bladder infection, gallbladder, warts treatment, rheumatic therapy, diarrhea, female genital	Digestive, musculoskeletal, genital, urological	I
Noaea mucronata	Leaves, flowers	Khargo	Edible	Anti-calculus, urolithiasis	Urological, digestive	E, I
Salsola orientalis	Aerial parts	Alafeshor	Distillation, extract, oil	Cancer therapy respiratory	Respiratory, general	I
Salsola rigida	Areal parts	Alafe Shoor	Decoction	Removing intestinal worms	Digestive	I
Salsola vermiculata	Stems, leaves	Shoor Alaf Shoor-Esharghi	Distillation, oil, infusion, edible, moisturized in water	Laxative	Digestive	E, I
Seidlitzia rosmarinus	Aerial parts	Choghan	Distillation	Disinfectant of clothes and insecticide, diuretic, blood purifier, menstruation regulator	General, blood, genital, urological	E, I
Spinacia oleracea	Leaves	Spênakh, Shomoon	Edible	Hema Externaloietic, lung inflammation, intestinal inflammation, diabetes, sedative, rheumatic	Blood, respiratory, digestive, endocrine, neurological, musculoskeletal	I
Amaryllıdaceae						

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Allium affine	Shoot	Piazok, Pivaz	Compound in food	Strengthen the teeth and gums	General	E, I
Allium akaka	Leaves, bulb	Aneshk, Anesh, Valk	Edible	Appetizer, antiseptic, anti-parasitic, and good digestive systems	Digestive, general, musculoskeletal	I
Allium iranicum	Leaves, bulb	Tara	Decoction, infusion	Carminative, hypothermia kidney stone	Digestive, urological	I
Allium rubellum	Bulb	Sir-E Zangulei, Ajujeh	Powder	Hyperlipidemia, ear infections	Endocrine, ear	I
Allium tripedale (syn.: Nectaroscordum tripedale)	Aerial parts	Piyazake, Piaz-E Tabestanie, Lorestani	Edible	Common cold	General	I
Narcissus papyraceus	Roots	Nêrgz, Narges	Decoction	Wound healing	General	E, I
Narcissus tazetta	Flowers, bulb	Gole Narges	Powder	Flowers: Aromatic oral aromatherapy (sedative, headache and cold), anti-parasitic, and abortion	General, Neurological	E, I
Anacardıaceae						
Pistacia atlantica	Barks, gum, stems, fruits, resin	Ghazwan, Wanatagh, Banak, Kalang, Kaleh, Van, Pesteh Koohi, Baneh	Edible, liniment	Mind stranger, anti-hemorrhoid, laxative, stomach stranger and bone pain, joint pains, toothache, wound healing, improving, sexual power, astringent	General, genital, blood, neurological, digestive, musculoskeletal	E, I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Pistacia khinjuk	Leaves, fruits, resin	Koleng Narmeh, Narmeh Van Khenjuk, Khinjuk	Compound in food, distillation, extract, oil	Digestive disorders, diuretic, asthma, stomach stranger and fragrant mouth, hemorrhoid treatment	Blood, musculoskeletal, respiratory, urological, digestive	I
Rhus coriaria	Fruits	Smagh, Sumakh	Edible, compound in food	Hypertension, blood purifier, blood glucose, anti-bleeding, mouth cleaner, blood lipid reduction, anti-nausea, anti-diabetes	Blood, endocrine, digestive	I
Apıaceae						
Carum carvi	Seeds, aerial parts	Kardi, Zireh	Distillation, infusion, edible, compound	Anti-obesity, anti-flatulence, dyspnea, breastfeeding, blood purification, stomach and liver reinforcement, and anti-inflammatory, breast milk increasing, seizure	Endocrine, blood, digestive, pregnancy and childbearing, neurological	I
Coriandrum sativum	Leaves	Kishnish	Edible	Constipation, anti-fever, anti-flatulence, diabetes	General, digestive, endocrine	I
Cuminum cyminum	Seeds	Zire Sabz	Boiled	Asthma	Respiratory	I
Dorema aucheri	Leaves	Bilahar, Manda	Edible	Bone strength, for hot temperament	General, musculoskeletal	I
Echinophora platyloba	Aerial plant	Khosharizeh	Extract, oil	Anti-fungal	General	E
Eryngium amethystinum	Aerial parts	Tusdu Dibi	Distillation	Diabetes, eye pain, intestinal colitis treatment	Endocrine, eye, digestive	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Eryngium billardieri	Roots, stems	Zool, Kharzool	Distillation	Treatment of constipation	Digestive	I
Falcaria vulgaris	Leaves	Ghazyakhe, Ghaz Ayaqi	Liniment. Distillation, compound in food	Vitiligo, liver, lipid disorders	Digestive, endocrine, skin	E, I
Ferula assa-foetida	Gum	Kama, Gane-Bu	Extract	Stomachache	Digestive	I
Ferula behboudiana	Stems, leaves, flowers	Anio, Koma-elorestani	Infusion	Antiseptic (smoking), spice and air fresher	General	E
Ferula gummosa	Fruits	Kama, Angiyun	Powder	Liver cysts	Digestive	I
Ferula haussknechtii	Stems, leaves, flowers, branches	Komeh, Komieh Koma	Infusion	Antiseptic (smoking), disinfectant	General, respiratory	E, I
Ferulago angulata (syn.: Ferula angulata)	Flowers, leaves, stems	Chnoor, Chavir, Chavil-Eshevidi	Liniment, compound in food, decoction	Antiseptic, strengthen hair and air fresher, headache	Skin, general	I
Foeniculum vulgare	Seeds	Sary ot, Raziane	Infusion, decoction	Abscess treatment, kidney disorders, breast milk increasing, hasten menstruation, peptic ulcer	General, genital, urological, pregnancy, and childbearing	I
Haussknechtia elymaitica	Aerial part	Kelos-E Kuhi	Decoction	Diabetes, hypertension	Endocrine, blood	I
Heracleum lasiopetalum	Fruits	Kashme, Goolpar, Kereson	Extract	Antiseptic, spice, and condiment	General	I
Heracleum persicum	Leaves	Solan	Decoction	Anti-fever, sedative, anti-seizure, anti-flatulence	General, neurological, digestive	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Kelussia odoratissima	Leaves	Kelus	Extract	Edible as vegetable, flavoring, indigestion, rheumatism, sedative	Musculoskeletal, general, neurological	I
Lagoecia cuminoides	Aerial part	Alaf-E Kaaji	Infusion	Diarrhea	Digestive	I
Oliveria decumbens	Aerial part	Moshkurak	Decoction	Relieve thirst in children	General	I
Opopanax hispidus	Stems, leaves, flowers	Alaf Shir Koma	Extract	Antiseptic (smoking)	General	E, I
Pastinaca sativa	Roots	Gêzar, Zardak, Qum Keshiri	Edible	Eye disorders, anti-nausea, diarrhea, kidney disorders	Eye, digestive, urological	I
Petroselinum crispum	Aerial parts	Jafari	Distillation, edible	Blood increasing, sedative	Blood, neurological	I
Pimpinella affinis	Flowers, shoot, seeds	Taretizake Baghi	Decoction	Relieving chest pain, sedative	Neurological	I
Pimpinella anisum	Fruits	Raziane, Vaveh Shing, Badian Romi	Edible. Liniment, distillation, powder	Carminative and culinary use	Digestive	I
Prangos ferulacea	Aerial parts	Lo, Chashir	Edible	Body toner, diabetes, toot pain, urinary tract opening, breast milk increasing, stomach pain, anti-flatulence, sedative	General, endocrine, urological, pregnancy and childbearing, digestive, neurological	I
Scandix pecten-veneris	Aerial part	Suzanak	Decoction	Palpitation, blood coagulation, body pains	Cardiovascular, blood, neurological	I
Smyrnium cordifolium	Stems	Bêlahar, Pinomeh, Vangi Avandol	Infusion, powder, compound in food	Indigestion and stomachic	Digestive	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Trachyspermum ammi	Seeds	Zenyan	Infusion, Distillation	Anti-flatulence, anti-drug addiction	Digestive, psychological	I
Turgenia latifolia	Aerial part	Dareh Jouyi	Infusion	Urinary duct problems	Urological	E, I
Apocynaceae						
Nerium oleander (syn.: Nerium indicum)	Leaves, flowers, barks, latex	Horaltil, Jeleh, Gharjalak Kharzahreh, Kish, Zhale, Khar-Zahreh	Compound in food, decoction	External: Burn, wound healing and eczema, internal: diuretic and heart tonic, abortion	Skin, urological, cardiovascular, pregnancy, and childbearing	E, I
Periploca aphylla	Leaves, flowers	Kholf Gishder	Oil, distillation	Anti-inflammatory	Musculoskeletal	E
Araceae						
Zantedeschia aethiopica	Flowers, stems	Livik	Compound in food	Respiratory diseases, asthma	Respiratory	I
Asparagaceae						
Muscari armeniacum	Barks	Sire Mirgane, Iyt Soghalaghi	Decoction	Foot pain	Musculoskeletal	I
Ornithogalum brachystachys	Leaves	Shermorgh	Cooked	Anthelmintic, infection	General	I
Ornithogalum sintenisii	Leaves	Shir Moralgh	Decoction	Sedative	Neurological	I
Scilla siberica	Leaves	Najm Abi	Distillation	Sedative	Neurological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Urginea maritima	Bulb	Gaav Piazi	Heated bulb is put on aching tooth, fresh bulb squashed and put around aching organ	Toothache, kidney stones, rheumatism, joint pains	Musculoskeletal, general, urological	I
Asteraceae						
Achillea santolinoides ssp. *wilhelmsii*	Flowers	Bozhane, Sanjigolo	Distillation, infusion, powder	Heart disorders, antispasmodic, anti-parasitic, diuretic, digestive pain, kidney pain, psychosis, blood purifier	Cardiovascular, musculoskeletal, digestive, urological, psychological, blood	I
Artemisia annua	Flowers, stems	Khers Dari, Dermaneh	Infusion	Headache, ulcers and warts healing, treatment of warts	Skin, neurological	E, I
Artemisia aucheri	Leaves	Gole chawisha, Dermana Kevi	Distillation, oil	Anti-cough	General	I
Artemisia dracunculus	Leaves	Talkhoon	Compound in food	Useful for the stomach, anti-worth, teeth pain, anti-flatulence	Digestive	I
Artemisia herba-alba	Aerial parts	Doukhoshgele	Distillation, decoction, smoke	Anthelmintic	General	E, I
Artemisia scoparia	Flowers	Salmaneh, Jaroy-E-Mashhadi	Edible	Indigestion, emollient and sore throat	General, digestive, neurological	I
Artemisia sieberi	Stems, leaves	Bookhoshkere, Dermaneh-E-Zagrosi	Moisturized in water	Anti-parasitic, anti-diarrhea, and stomachache	Digestive	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Calendula arvensis (syn.: Calendula persica)	Capitula, flowers, leaves	Gole-Zarde, Golzardeh Hamisheh Bahar-E-Irani	Distillation, decoction, infusion, edible	Wounds, eczema, and other dermal disorders	Skin	E, I
Carthamus oxyacantha	Flowers Capitula	Drke zarde, Zardeh Siri, Zarde-Dereg	Infusion, edible. Compound in food	Treatment of menorrhagia and other menstrual disorders in women	Genital	I
Carthamus tinctorius	Aerial parts	Ghakhli, Saritikan	Powder	Vulnerary	General	E
Centaurea gaubae	Flowers	Shawbo, Shab Bo	Decoction	Heal wounds	Skin	E, I
Centaurea iberica	Flowers	Asan Darag, Gole Gandome- Chaman Zar	Edible, compound in food	Gastric pain, stomachache	Digestive	I
Centaurea intricata	Flowers, aerial parts	Benjek Dargi, Gole Gandome- Darham Barham	Compound in food	Indigestion and gastric pain	Digestive	I
Centaurea ovina	Flowers, Capitola	Tilage, Gole Gandom	Compound in food	Indigestion and gastric pain	Digestive	I
Centaurea pseudoscabiosa	Aerial parts	Gole Gandome	Extract	Skin ailments	Skin	I
Chamaemelum nobile	Flowers	Gola Hajiana	Distillation	Menstrual pain	Female genital	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Cichorium intybus	Aerial parts	Chatdan Goosh	Distillation	Liver disorders, jaundice and skin itching treatment, nervous disorders, constipation, lipid disorders, diabetes, stomach pain, heart pain, facilitating delivery, blood purifier	Digestive, skin, neurological, endocrine, cardiovascular, pregnancy, blood	I
Cirsium dracocephalum	Stems	Drke karane, Kangare-Dereg	Edible	Gastric infections	Digestive	I
Cirsium sorocephalum (syn.: C. congestum)	Stems	Kangar Darag, Kagar-E-Anboh	Distillation, infusion, powder	Antiseptic for gastric, laxative, diuretic, stomach pain, and skin disorders	Skin, digestive, urological	I
Cirsium vulgare	Stems	Galgan	Edible	Intestinal tract, stomach disorders, frequent urination, hemorrhoid	Digestive, urological	I
Cnicus benedictus	Leaves	Karkol, Kharmoghadas, Kharshotor	Edible	Treatment of kidney stones and bladder	Digestive	I
Cota altissima (*Anthemis altissima*)	Leaves, flowers	Babineh, Babooneh	Edible	Dyspepsia, indigestion, and skin whitening	Digestive, skin	E, I
Cynara scolymus	Leaves	Drke kare, Kenger	Decoction	Strengthen the digestive systems	Digestive	I
Echinops ritrodes	Stems	Kartashi, Shekar Tighal	Boiled	Treat skin and gastrointestinal diseases, chronic cough sore throat	Digestive, skin, general, respiratory	E, I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Echinops viscidulus	Bulb	Tosi, Ghane Shakrook Shekar Tighal	Edible	Cough, cold, sore throat, and edible as vegetable	General, respiratory	I
Glebionis coronaria (syn.: Chrysanthemum coranarium)	Aerial parts	Babuney-E Sheytani	Decoction	Headache, migraine	Neurological	I
Gundelia tournefortii	Leaves, stems, roots, seeds	Ghnar, Kenyer, Kangar	Compound	Edible as vegetable, indigestion, tonic, laxative, anti-calculus, diabetes, and culinary	General, digestive, Endocrine	I
Helianthus tuberosus	Roots	Shalgam	Compound in food	Hypoglycemia	Endocrine	I
Helichrysum oligocephalum	Aerial part	Derameh Karimkhani	Infusion	Cold	General	I
Inula oculus-christi	Flowers, shoot	Mosaffaye Cheshme Masih	Decoction	Rheumatism, myalgia, bone pain	Musculoskeletal	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Matricaria chamomilla (syn.: M. recutita)	Flowers, petal, branches	Gole hajiane, Babanak, Chawishe, Bayboon, Gole Bayeneh, Baboone Darooi	Infusion, Boil liquid	Anti-seizure, sleep disturbance, sedative, skin brightening, breast milk increasing, anti-flatulence, menstruation regulator, migraine, abdominal pains, teeth pain, blood purifier, diuretic, foot pain, menstruation pain, teeth infection, reinforce fertility of females, headache, joint pains, common cold, prevent hair loss	Neurological, skin, pregnancy, genital, digestive, blood, endocrine, musculoskeletal, urological, general, psychological	I
Picnomon acarna	Leaves, flowers	Gemal Diom Zard Khar, Khare Zard	Edible, moisturized in water, distillation, extract	Indigestion, gastric disorders and stomachic, the melancholy of wound healing, removing blemishes, treatment of freckles and acne	Digestive respiratory, endocrine, cardiovascular, cardiovascular, skin	E, I
Rhaponticum repens	Leaves	Kakra, Kakireh	Distillation	Asthma	Respiratory	I
Scorzonera cinerea	Roots	Sheng	Boiled	Cough	General	E, I
Senecio vulgaris	Whole plant	Pergeiah	Decoction	Drug dependency	Psychological	I
Silybum marianum	Seeds, stems	Drki mryem, Kharkhangeloo, Kharoozeh	Powder	Sedative, stomach reflux	Digestive, neurological	E, I
Tanacetum balsamita	Seeds	Shasparim	Distillation	Abdominal pains	Digestive	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Tanacetum parthenium	Leaves, flowers	Babouneyeh Kabir	Decoction	Anti-headaches	General	E, I
Tanacetum polycephalum	Leaves	Samsa Minay-Eporalkopeh	Powder, infusion, edible, moisturized in water	Anti-hemorrhoid, anti-inflammatory, and sting	Digestive, general	E, I
Taraxacum campylodes	Leaves	Talishk, Panpangulu	Edible	Rheumatic therapy, laxative, blood purifier, jaundice, hepatitis, lipid disorders, hypertension, eye reinforcement	Musculoskeletal, digestive, blood, endocrine, eye	I
Tragopogon buphthalmoides	Leaves, latex	Shamshireh	Edible	Constipation, warts	Digestive, skin	E, I
Tragopogon caricifolius	Leaves	Sheng	Boiled	Chronic cough	General	I
Tragopogon dubius	Leaves	Yemlik	Compound in food	For hot temperament, stomach bleeding, rheumatic treatment	General, digestive, musculoskeletal	I
Tragopogon graminifolius	Roots, flowers, leaves	Haplook Shang	Moisturizad in water, powder, distillation, infusion	Emollient, sore throat, and wound healing	Respiratory, digestive, general	E, I
Tragopogon rechingeri	Leaves	Bizn rishi, Rishboz, sheng	Powder	Anemia	Blood	I
Tripleurospermum disciforme	Aerial parts	Babune Kazeb, Mamasur Suri, Babooneh	Decoction, distillation	Strengthen of stomach, antiseptic, seasoning of yogurt, kidney stone, antispasmodic, anti-inflammatory, acne, and itching	Digestive, general, urological, musculoskeletal, skin	E, I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Xanthium spinosum	Leaves, fruits	Chazanak Zardineh	Edible, moisturized in water, powder	Dermal disorders, diuretic	Urological, skin	E, I
Xanthium strumarium	Leaves, fruits	Chazanak Zardineh	Oil, distillation, edible	Laxative, stomach, tonic	Digestive, general	E, I
Boraginaceae						
Rindera lanata	Seeds	Zabun Gueri	Decoction, liniment	Joint pains	Musculoskeletal	E, I
Brassicaceae						
Fibigia macrocarpa	Aerial parts	Pulak	Distillation	Treatment of migraine headaches and sinus infections	Neurological	I
Isatis raphanifolia	Roots, leaves, seeds	Vasmeh	Liniment	Coloring for hair	Skin	E, I
Lepidium sativum	Leaves	Taratizah	Extract, oil	Arthritis pain reliever	Musculoskeletal	E, I
Lepidium draba	Aerial part	Sozeh, Macheh	Decoction	Cold and fever	General	I
Nasturtium officinale	Whole plants	Koozala, Bargami, Bulaq Oti	Edible, compound	For hot temperament, body pains, foot pains, goiter treatment, diuretic, antispasmodic, rheumatic, stomach reinforcement, blood purifier, bone reinforcement, anti-flatulence	General, musculoskeletal, endocrine urological, digestive, blood	I
Raphanus raphanistrum ssp. *sativus*	Roots	Qara Toop	Compound	Dry cough treatment, bile disorders, gallstone, stomach reinforcement, bladder stones	Digestive, respiratory, general, urological	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Sinapis arvensis	Stems, flowers	Khartal, Terpeki Khardal-e zagrosi	Infusion, distillation, compound in food	Laxative and stomachache	Digestive	E, I
Sisymbrium brassiciforme	Seeds	Khakshir, Shovaran	Maceration	Fever, hyperthermia	General	I
Caprifoliaceae						
Lonicera nummulariifolia	Leaves, flowers	Pelakhoral, Shan Pelakhoral	Liniment, infusion, powder, edible	Anti-fever, anti-diarrhea, sedative, and cough	General, digestive, neurological, respiratory	I
Valeriana officinalis	Roots	Pishik Oti	Powder	Sedative, anti-seizure, anti-depression, stress treatment, sleep disturbance	Neurological, psychological	I
Caryophyllaceae						
Silene ampullata	Aerial parts, roots	Silene	Extract	Insect repellent	General	E
Vaccaria oxyodonta	Flowers	Sabounak-E Dane Zard	Boiled	Skin allergy and constipation	Skin, digestive	I
Colchicaceae						
Colchicum kotschyi	Flowers	Gole chaw ishe, Kirgeh Keh ran, Gol-E-Hasrat	Infusion, compound in food	Rheumatism	Musculoskeletal	E
Crassulaceae						
Echeveria elegans	Seeds	Pinome, Sagh	Infusion	Headache	General	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Umbilicus intermedius	Leaves	Gol-E Arus	Fresh leaves with leaves of *Rumex* and *Ocimum* are put on the burnt place	Skin disorders	Skin	E
Cucurbitaceae						
Cucurbita pepo	Fruits	Bal Qabakh	Edible	Prostate treatment, dry cough treatment, anti-pneumonia, foot pain, anti-ulcer, wound treatment	Genital, digestive, respiratory, musculoskeletal, general	I
Ecballium elaterium	Fruits	Dagh Khiari	Extract	Sinusitis treatment	Respiratory	E, I
Cupressaceae						
Juniperus excelsa	Branches	Kamar-Os, Persian Juniper	Syrup is poured onto the tooth	Toothache	General	I
Elaeagnaceae						
Elaeagnus angustifolia	Fruits	Iyda	Edible	Bone reinforcement, diarrhea, stomach acidity, arthritis, osteoporosis	Digestive, musculoskeletal	I
Ephedraceae						
Ephedra foliata (syn.: E. ciliata)	Roots, stems	Armak, Rish Boz, Korali Feri Oralmac, Oralmak	Decoction, compound, distillation, oil, infusion, edible, compound in food	Antibacterial, anti-fever, antimicrobial, and antipyretic	General	E, I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Equisetaceae						
Equisetum arvense	Aerial parts	Dom-E Asb	Boiled	Hair loss, nails strengthening	Skin	E, I
Euphorbiaceae						
Euphorbia amygdaloides	Aerial parts	Sootbayan	Distillation	Diarrhea, infectious wounds, skin infectious, diuretic, scorpion poison	Digestive, urological, skin, general, urological	I
Euphorbia graminifolia	Areal parts	Shir Kosh	Decoction	Removing intestinal worms	Digestive	I
Euphorbia helioscopia	Shoot	Khozhilk, Gia kala	Oil	Anti-arthritic and rheumatic	Musculoskeletal	E, I
Euphorbia macroclada	Latex	Shirghoteghan, Farfiun	Distillation, oil, infusion	Anti-wart	Skin	E
Euphorbia macrocarpa	Leaves, stems	Ferfeion	Decoction	Excretion of parasites and intestinal worm elimination	Digestive	E, I
Ricinus communis	Seeds	Geychah	Oil	Laxative, constipation, intestinal tract cleaning, arthritis	Digestive musculoskeletal	I
Fabaceae						
Astragalus ovinus	Fruits	Gondkhoralosi	Edible	Stomachache	Digestive	I
Cercis siliquastrum	Whole plant	Arghavan	Decoction	Wash infected wounds	Skin	E
Cicer anatolicum	Whole plant, fruits	Nokhod	Maceration, decoction	Kidney stones, constipation, diarrhea	Digestive, urological	I
Glycyrrhiza glabra	Roots, gum	Balak, Shirin Bayan	Distillation, powder	Stomach problems, lung pains, opening heart arteries	Digestive respiratory, cardiovascular	I
Lens culinaris	Fruits	Adas, Adase Germez	Compound in food	Wound healing	Skin	E

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Lotus corniculatus	Aerial parts	Younje Kifila, Yonje Zard	Infusion	Laxative, increasing blood	Blood, digestive	I
Medicago sativa	Leaves, aerial parts	Yonja	Edible, liniment	Blood coagulation, intestinal problems, anemia, abdominal pains, infant length increasing, blood sugar, obesity, diuretic	Blood, digestive, endocrine, urological	E, I
Melilotus officinalis	Flowers	Qizil Yonja	Distillation	Anemia	Blood	I
Onobrychis elymaitiaca	Leaves, flowers	Pieh Kol Speres-E-Elami	Extract, edible	Anti-calculus, kidney problems	Respiratory, digestive	I
Ononis spinosa	Roots	Khar Khar	Decoction, extract	Diuretic, stomachache, skin, pains	Digestive, skin, urological, general	E, I
Phaseolus vulgaris	Fruits	Lubia	Compound in food	Strengthening the heart	Cardiovascular	I
Prosopis farcta	Fruits	Belaveri, Broweri, Khosh, Khah Shak, Kahoorak	Liniment, edible, distillation	Blood thinner and anti-diabetic (reduction of blood glucose)	Blood, Endocrine	E, I
Secugeria varia (syn.: Coronilla varia)	Leaves	Yonja Baghi	Edible, decoction	Sedative	Neurological	I
Trifolium purpureum	Flowers	Shabdar Argavani	Decoction, Brewed	Excretion of phlegm and pertussis and abdominal pain and treatment of bronchitis	Digestive, respiratory	I
Trifolium repens	Leaves, flowers	Shapareh Shabdar-Esephid	Edible, moisturized in water	Analgesia and dermal disorders	Skin	E, I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Trifolium stellatum	Flowers	Separa, Shuvar-E Ghermez	Decoction	For inflammation, sedative, expectorant	Neurological, general, respiratory	I
Trigonella foenum-graecum	Aerial parts	Shemli, Shanbalileh	Compound in food	Hyperlipidemia, blood sugar reducing, slimming, anemia, anti-hair loss, foot pain	Blood, endocrine, skin, musculoskeletal	E, I
Vicia sativa ssp. *nigra (syn.: V. angustifolia)*	Fruits	Masheh Maran, Mashak-E-Barg	Swallowing, smoke	Cough	Respiratory	E, I
Fagaceae						
Quercus brantii	Fruits, seeds, barks	Baroo, Bali, Bero Baloot	Distillation, infusion, liniment	Gastric ulcer, stringent, sore throat and anti-diabetes	Digestive, Endocrine, general	E, I
Quercus infectoria	Gal, fruits	Mazoodar, Palit	Liniment, edible	Skin blister, enuresis, skin reinforcement (for carpet weavers), baby's umbilical infection	Skin, urological, pregnancy, and childbirth	E, I
Gentıanaceae						
Gentiana olivieri	Roots	Malandar	Powder	For disinfecting wounds	Skin	E
Hyperıcaceae						
Hypericum perforatum	Flowers, shoot	Alaf chai	Decoction	Menses regulation, dysmenorrhea, vaginal discharge and pruritus, eliminate intestinal worms, treat abdominal pain, relieve headaches	Genital, neurological, urological	I
Hypericum scabrum	Flowers, branches	Siveh ran, Gol-E-Raye	Extract, chewy, liniment	Sedative, headache and nerve systems relaxant	Neurological, general	E, I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Irıdaceae						
Crocus pallasii ssp. *haussknechtii*	Leaves, flowers, tubercule	Pishouk, Pishog, Joo Ghasem	Extract, distillation	Stomach and intestinal antibiotic, antiseptic for gastric	Digestive	E, I
Crocus sativus	Stems	Zafarn	Distillation, infusion	Stomach augmentation, asthma treatment, menstrual regulation, antispasmodic	Digestive, respiratory, genital, musculoskeletal	I
Gladiolus italicus	Roots, fruits	Gol-E Khastegari	Decoction	Heart and lung problems, infections	Cardiovascular, respiratory, general	I
Ixıolırıaceae						
Ixiolirion tataricum	Gland, flowers, shoot	Khiarak	Edible	Washing of skin abscess and disinfection of infectious wounds	Skin	I
Juglandaceae						
Juglans regia	Fruits, leaves	Giwez, Gaviz	Edible	Joint pains, hyperlipidemia, blood sugar, arthritis, brain reinforcement, stomach pain, antispasmodic, skin problems, breast milk finishing	Endocrine musculoskeletal, digestive, skin, pregnancy	I
Lamıaceae						
Eremostachys molucelloides (syn.: E. macrophylla)	Seeds, aerial parts	Sonbole Biyabani, Mer Giyah	Decoction, distillation, infusion	Wounds healing	Skin	E, I
Lallemantia iberica	Grain	Balango, Balangoo	Boiled liquid	Common cold	General	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Lamium album	Aearial parts	Gazne, Gazaneh	Infusion, distillation	Anti-skin swelling	Skin	E
Lavandula angustifolia	Aerial parts	Ostokodoos	Infusion	Nervous reliever, infant cough, menstrual regulation, stomach problems, asthma	Neurological, respiratory, digestive, female genital	I
Mentha longifolia	Leaves	Pooneh, Yarpiz	Infusion, distillation, decoction, compound in food	Antiseptic, cough treatment, angina, abdominal pains, flu, appetizer, uterus cysts, skin allergy, constipation, diarrhea, sedative, blood sugar reducing, menstrual regulation	General, respiratory, skin, digestive, neurological, endocrine, female genital	I
Mentha pulegium	Aerial parts	Poneh	Boiled	Treat tympanites and tomina, antispasmodic and carminative effect, exterminator, causes menstruation	Musculoskeletal, digestive, genital, general	I
Mentha spicata	Aerial parts	Nana	Distillation, oil, infusion	Antiseptic, anti-flatulence, diarrhea, abdominal pains, blood flow improving, stomach problems, ear pains, greasy skin cleaning, teeth pain	General, digestive, blood, ear, skin	I
Nepeta glomerulosa	Aerial part	Petpetaveh	Infusion	Cold	General	I
Nepeta macrosiphon	Flowers, branches, leaves	Poneh	Decoction	Treatment of gonorrhea and anti-flatulence	Digestive, urological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Nepeta persica	Leaves, flowers	Poneh say Poneh say-E-Irani	Distillation, balm, liniment, infusion	Anti-urticarial	General	E, I
Ocimum basilicum	Leaves, seeds	Rêhane, Reyhan	Edible, moisturized in water	Pneumonia, anti-depression, nervous systems boosting, mouth freshener	Respiratory, neurologic, psychological, digestive	I
Origanum vulgare	Flowers, branches, leaves	Marzangosh	Brewed, decoction	Treat heartburn problems, sore throat and shortness of breath treatment, asthma, and rheumatism	General, respiratory, musculoskeletal	I
Phlomis lanceolata	Flowers, branches	Gosh bare Sar Neizei	Decoction	Anti-flatulence and internal and external swelling	Digestive	I
Phlomis olivieri	Leaves, flowers	Labeh Goshak, Giveh Balkeh, Goshbareh, Bareh gosh, Chalmah	Liniment, oil	Carminative and anti-flatulence	Digestive	E, I
Phlomoides adenantha (syn.: Eremostachys adenantha)	Aerial part	Gandal	Decoction, extract	Poisoning, snake bite	General	E, I
Phlomoides laevigata	Roots	Chila Daghi	Compound	Joint pains, rheumatism, arthritis	Musculoskeletal	E
Prunella vulgaris	Flowers, branches	Nana Chamani	Decoction	Internal and external swelling, nasal discharge, hemorrhoids, and bleeding	General, respiratory, digestive, blood	I
Salvia bracteata	Flowers, branches	Maryam Goli	Brewed, decoction	Treat heartburn and expel the dead fetus in the womb	General, pregnancy	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Salvia hydrangea	Aerial parts, flowers	Maryam Goliye, Tamashaei Gol Ovrune, Gole Arone, Mariam Goli	Extract, boiled	Treatment of colds, anti-stress, cough, emollient, sore throat, antibacterial	General, psychological, respiratory	E, I
Salvia multicaulis	Flowers	Gol-E Paeizeh, Mardghoush	Syrup is poured onto the tooth	Toothache, common cold	General	E, I
Salvia officinalis	Flowers	Qara Khot	Infusion	Headache, mouth cleaning, lipid disorders,	Neurological, endocrine, digestive	I
Salvia palaestina	Leaves, flowers	Cherogi Maryam Goli Falestini	Smoking, compound, liniment, moisturized in water	Women fertility and women infections	Genital	E, I
Salvia sclarea	Seeds	Dun Sefid	Seeds directly put in eyes, cooked in combination with other herbs	Cleaning eyes, colds, dry cough	General, respiratory, eye	E, I
Salvia viridis	Aerial part	Seghedous	Decoction	Cold	General	I
Satureja bachtiarica	Aerial parts	Marze Bakhtiyari, Marza Koei	Extract	Seasoning of food and salad, edible as vegetable, flavoring, indigestion, cough, antibacterial	General, respiratory, digestive	I
Satureja hortensis	Flowers, branches	Marze	Decoction	Treatment of jaundice rheumatic pains anti-flatulence, toothache pain	General, digestive, musculoskeletal	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Satureja khuzistanica	Aerial parts, branches, leaves, stems	Jataneh, Jatareh Marzeh	Decoction, dried leaves poured on food and consumed, liniment, infusion, edible, distillation, compound in food	Stomach ache, indigestion, headache, gastric pain, anti-leech	General, digestive, neurological	E, I
Satureja montana	Aerial parts	Daagh Marzasi	Infusion, distillation, compound in food	Gout, female genital boosting, scorch, rheumatic, sedative, stomach reinforcement, flu, uterus cyst, abdominal pains, diarrhea	Skin, musculoskeletal, genital, digestive, pregnancy, general	I
Stachys lavandulifolia	Leaves, flowers	Toklijeh, Tuklooja	Distillation, infusion	Skin infection, menorrhagia, antibacterial, gastrointestinal and respiratory disorder, wound healing, cardiac disorders, fever and malaria, uterus cyst, headache, stomach pains, uretic, skin problems, heart reinforcement, abdominal pains	Skin, digestive, genital, general, cardiovascular, urological, neurological, pregnancy	E, I
Stachys pilifera	Aerial parts	Sonboleye mu Dar, Marze Kuhi	Decoction	Treatment of colds and constipation, menstrual disorders, in particular amenorrhea	General, digestive, genital	I
Stachys schtschegleevii	Aerial parts	Choban Kibriti, Sichan Goolaghi	Compound in food, infusion	Infection treatment, fever, abdominal pains, stomach pains, flu, anti-flatulence, blood sugar, nervous improvement, pneumonia	General, digestive, endocrine, neurological, respiratory, musculoskeletal	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Stachys spectabilis	Flowers, branches	Sonbole Tamashayi	Decoction, brewed	Treat heartburn and eliminate diarrhea	Digestive, general	I
Teucrium polium	Aerial parts, flowers	Maryam Nokhodi	Liniment, decoction	Fever, infectious wound	General	E, I
Thymbra spicata	Leaves, flowers	Azboh, Hazboh Avishan-Ezophaye	Distillation, infusion	Spice, cough, antibacterial, and carminative	Digestive, general	I
Thymus daenensis	Aerial parts	Avishane Denaei, Ovshum	Ethanol extract, essential oil	Treatment of cold and sinusitis, treatment of women infections	General, respiratory, female genital	I
Thymus kotschyanus	Flowers, shoot	Avishan	Brewed, incense	Cough, asthma	General, respiratory	I
Thymus lancifolius	Aerial part leaves, roots	Kahlic Oti, Avishan	Decoction, extraction, infusion, powder	Stomachache, hypothermia, diarrhea, carminative, gastric ulcer, ınflammation	Digestive	I
Thymus pubescens	Aerial parts	Azarbeh	Distillation	Gastrointestinal disorder, herpes, lung infection, and skin problem	Skin, respiratory, digestive	E, I
Thymus vulgaris	Leaves	Hazbê, Kahlik Oti	Infusion, distillation, compound	Cough, flu treatment, abdominal pains, fortifies the stomach, improve vision in eyes, headache, sedative, angina, blood pressure, urinary tract cleaning, hypertension	Musculoskeletal, pregnancy, cardiovascular, digestive, respiratory, neurological, general, eye, urological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Vitex agnus-castus (syn.: V. pseudo-negundo)	Leaves, flowers, seeds	Kerf, Keref, Kerof Bangaro, Pênj panja, Bangeroo	Powder, decoction	Increases breast milk, dysmenorrhea, menstruation disorders, stomachache, stomach ulcers, rheumatism	Pregnancy and childbirth, musculoskeletal, digestive, female genital	I
Zataria multiflora	Arieal parts	Oralishom	Infusion	Cold, headache, stomach reflux	General, neurological, digestive	I
Ziziphora capitata	Leaves, flowers	Kakooti, Moshk, Taramoshk	Liniment, compound in food, edible, powder, decoction, distillation	Spice and culinary	General	E, I
Ziziphora tenuior	Leaves, flowers	Kakouti	Extract	Green tea, spice, culinary, antibacterial, carminative, anti-asthmatic	Respiratory, general	I
Lılıaceae						
Fritillaria imperialis	Bulb, roots, flowers	Halale brme, Sosan Gol, Ashke Maryam, Laleh Vazhgon	Syrup, decoction	Rheumatism and sciatica	Musculoskeletal, neurological	E, I
Lınaceae						
Linum album	Aerial parts	Katan Sefid, Chakamdari	Powder	Salves for bone fracture, warts	Musculoskeletal, skin	E

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Linum usitatissimum	Seeds	Katan, Zarayak	Boiled, liniment	Bedsore, slimming, child birth problems, pneumonia, eye problems, diarrhea, blood increasing, menstrual regulation, anti-hair loss	General, endocrine, pregnancy, eye, digestive, genital, skin	E, I
Lythraceae						
Lawsonia inermis	Leaves	Khana, Hana	Infusion, edible, compound	Urinary tract infections	Urological	E, I
Punica granatum	Fruits	Hanar, Nar	Edible	Liver disease, blood purifier, teeth cleaning, sedative, anemia, blood sugar, heart boosting, anti-bleeding, anti-nausea, skin itching, hemorrhoid	Digestive, blood, endocrine, skin, cardiovascular, neurological	I
Malvaceae						
Abelmoschus esculentis (syn.: Hibiscus esculentus)	Fruits	Bamieh	Edible	Constipation	Digestive	I
Gossypium hirsutum	Flowers	Pamoo, Pamukh	Balm	Backache	Musculoskeletal	E
Hibiscus trionum	Flowers	Gole hêro, Khatmi Serang	Boiled	Cough, inducing mucus	General, respiratory	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Malva neglecta	Leaves	Papa chawre, Aman Komanji	Distillation, infusion	Infectious wound, sinusitis, teeth pain, acne removing, abdominal pains, foot infection, uterus infection, laxative, cough	Pregnancy, respiratory, musculoskeletal, digestive, skin	I
Malva sylvestris	Flowers	Papke, Panirak, noon, Bengeshti	Powder, decoction	Anti-cough, soothing sore throat, hair loss	General, skin	I
Moraceae						
Ficus carica	Fruits	Hanjir, Injir	Edible	Constipation, lung pains, laxative, kidney problems	Digestive, respiratory, urological	I
Ficus johannis	Fruits, latex	Kozir	Moisturized fruits, latex	Constipation, warts	Skin, digestive	E, I
Morus alba	Fruits	Too, Agh toot	Edible	Hypertension, rheumatism, blood sugar	Cardiovascular, musculoskeletal, endocrine	I
Morus nigra	Fruits	Toe rasha, Qara toot	Syrup	Mouth ulcers	Digestive	I
Myrtaceae						
Eucalyptus camaldulensis	Leaves	Okaliptus, Eucalyptus	Boiled liquid	Common cold	General	I
Myrtus communis	Whole plant, leaves	Myrtle, Mord, Moort	Extract, powder, compound in food, edible	Anti-hair loss, antiseptic (smoking), women diseases, wound (antimicrobial), and air freshener	Genital, general, skin	E, I
Nıtrarıaceae						

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Peganum harmala	Seeds	Aspandar, Uzarlik	Swallowing, smoke	Asthma, menstrual regulation, rheumatism, anti- flatulence, diarrhea, blood sugar and lipid, anti-obesity, anti-nausea, snivel, stomach problems, foot pain, sedative, antiseptic	Digestive, respiratory, genital, musculoskeletal, endocrine, neurological, general	I
Oleaceae						
Fraxinus angustifolia (syn.: F. rotundifolia)	Leaves, seeds	Bnawach, Bnaw, Baniyu	Decoction	Coughs, foot pain	Respiratory, musculoskeletal	I
Ligustrum ovalifolium	Flowers, seeds	Barge no	Powder, infusion	Vomiting, diarrhea, hypercholia	Digestive, endocrine	I
Olea europaea	Fruits, fruits	Zeytun	Edible	Coughs, gum infections, dry skins, insect bites	Respiratory, skin	I
Orchidaceae						
Anacamptis palustris (syn.: Orchis palustris)	Leaves	Salme, Salab	Powder	Respiratory systems disorders	Respiratory	I
Dactylorhiza incarnata	Roots	Sahlab Salme Mirgi,	Powder	Anemia, laxative, mucus removing, lung lightening, anti-seizure, sedative	Respiratory, digestive, blood, neurological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Orchis mascula	Underground glands	Salme kawe, Salab Nar	Powder	Emollient, relieves bladder swelling and eliminate irritation and inflammation, oral digestive tract, strengthen sexual power and treat infections and uterine inflammation in women	Digestive, genital, urological	I
Papaveraceae						
Fumaria asepala	Aerial parts	Shahtareh	Boiled	Head and face itching, allergy, face acne	Skin	E
Fumaria officinalis	Aerial parts	Shatara	Distillation	Skin itching, skin allergy, external inflammation, hair reinforcement, liver problems, jaundice, blood purifier	Skin, digestive, neurological, blood	I
Fumaria parviflora	Flowers, stems, leaves	Shatareh, Shahtareh-Eirani	Compound in food, syrup	Dermal disorders, wound, and eczema	Skin	E
Hypecoum pendulum	Flowers, shoot	Shah tare	Boiled	Skin allergy	Skin	E
Papaver argemone	Flowers	Khashkhash	Infusion, decoction	Headache, coughs	General	I
Papaver dubium	Flowers, seeds	Khshkhash	Edible, compound, liniment	Intestinal parasites, sedative	Neurological, digestive	I
Papaver fugax	Aerial parts, seeds	Khash Khash Rizan	Decoction	Relieve insomnia in humans and create tension in livestock	General	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Papaver rhoeas	Sap, syrup, seeds	Khashkhash, Shaghayegh	Sap collection, drying and mixed with water and drink tea, some syrup is put on the tooth	Migraine, an analgesic and hypnotic, toothache, inducing mucus	Neurological, general respiratory	I
Pedalıaceae						
Sesamum indicum	Seeds	Konji, Konjood	Oil	Brain reinforcement, hair boosting, menstrual regulation, scorching	Neurological, skin, female genital	I
Plantagınaceae						
Plantago atrata	Leaves, aerial part	Bale Gushak	Infusion	Rheumatism and joint pains	Musculoskeletal	E, I
Plantago indica (syn.: *P. psyllium*)	Aerial parts, seeds	Qarni Yarihk, Barhang	Infusion, boiled liquid, oral, brewed	Amaurosis, asthma, diarrhea, hemorrhoid, treat cough and respiratory disorders, common cold	Eye, respiratory, digestive	I
Plantago lanceolata	Leaves, seeds	Bagh Yarpaghi,	Liniment, infusion	Cough, acne	Respiratory, skin	E, I
Plantago major	Leaves, seeds	Bizovsha, Khourchang, Barhang	Infusion, boiled	Pneumonia, mouth wounds, constipation, cough, abdominal pains, lung inflammation, throat pains, sedative, acne, healing cuts, wounds and boils, pulmonary infection	General, digestive, respiratory, neurological, skin	E, I
Veronica anagallis-aquatica	Aerial part	Pa Sorkhak, pa Sukhtak	Decoction	Burns	Skin	E
Platanaceae						

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Platanus orientalis	Branches	Chenar	Boiled	Treatment of asthma, hoarseness	Respiratory	I
Poaceae						
Alopecurus pratensis	Aerial parts	Tulku Goyrugu	Infusion	Kidney and stomach problems	Digestive, urological	I
Avena barbata	Fruits	Ganem-Gia	Edible	Stomachache, indigestion, rheumatism and tonic	General, digestive, musculoskeletal	I
Avena sativa	Seeds	Oat	Boiled	Antiseptic	General	E, I
Avena wiestii	Seeds	Ganem Giah, Youlaf	Decoction	Gastric pain, indigestion, rheumatism and tonic	General, neurological, digestive, musculoskeletal	I
Elymus repens	Roots	Chayir Oyi	Distillation, decoction	Heart reinforcement, heart vessel opening, cholesterol reducing, blood sugar, foot pain, kidney problems	Cardiovascular, endocrine, musculoskeletal, urological	I
Hordeum murinum ssp. *glaucum*	Fruits	Jo	Edible	Urinary tract infections	Urological	I
Phleum pratense	Branches	Kalake-Goralbe	Brewed	Stomachache	Digestive	I
Sorghum halepense	Leaves, stems, flowers	Helit Ghiagh, Chaeer	Liniment	Abortion for human and animals	Pregnancy	I
Stipa capensis	Flowers	Golkouh, Bahmah Giah Chaman Sozani	Edible, liniment, distillation, compound in food	Nerve systems problems and gastric disorders	Neurological, digestive	I
Triticum aestivum	Straw	Saman	Smoke	Scorpion bite	General	E

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Zea mays	Corn silk, fruits	Zoralrat	Edible, infusion	Infection of urinary systems, heart tonic	Cardiovascular, urological	I
Polygonaceae						
Polygonum arenastrum	Aerial parts	Girkh Boghoom, at Goyrooghoo	Distillation, decoction	Blood sugar, skin rash, rheumatic, arthritis, abdominal pains	Skin, musculoskeletal, endocrine, digestive	I
Polygonum patulum	Aerial parts	Alaf haft band	Distillation, decoction	Treat burns	Skin	E
Rheum rhabarbarum	Seeds	Rivas, Avalik	Infusion	Kidney stone, uterus cyst, lipid disorders,	Endocrine, pregnancy, urological	I
Rheum ribes	Aerial parts, flowers	Rêwas, Ushgun	Edible, compound in food	Constipation treatment, blood purifier, blood sugar, diarrhea, lipid disorders, abdominal pains, kidney stone, skin itching, hypertension	Blood, urological, digestive, skin, endocrine, cardiovascular	I
Rumex acetosella	Leaves	Tooralshah	Edible	Hypertension, pneumonia, diuretic, laxative, blood purifier	Respiratory, urological, digestive, cardiovascular, blood	I
Rumex thyrsiflorus	Leaves	Tershoka	Compound in food	Strengthen the digestive systems	Digestive	I
Portulacaceae						
Portulaca oleracea	Leaves, aerial parts	Palpine, Parpina	Compound in food	Hypertension, skin itching, migraine, kidney problems stomach problems, scorching, anti-flatulence, prostate, anti-fever	Cardiovascular, skin, neurological, urological, digestive, genital, general	I
Primulaceae						
Anagallis arvensis	Aerial part	Cheshm Khoralusi	Infusion	Cold, sedative	General, neurological	E, I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Primula auriculata	Flowers	Tootia	Extract	Flu and sneezing, eye diseases, anti-infection, cataract, trachoma	Eye, general	I
Pteridaceae						
Adiantum capillus-veneris	Aerial part	Gol-E Siavoshi	Decoction	Asthma, dyspnea	Respiratory	I
Ranunculaceae						
Adonis dentata	Flowers	Gol Zarde, Cheshme, Khoralous, Gol, Khoralousak	Distillation, edible	Digestive disorders and indigestion, jaundice	Digestive, Skin	I
Ceratocephalus falcatus	Aerial parts, spine	Alaleh	Decoction	Kidney stones, kidney disorders	Urological	I
Consolida orientalis	Flowers	Zaban Ghafa, Zaban pas, Ghafa-E-Denae	Distillation, edible	Laxative and anti-parasitic	Digestive, general	I
Nigella sativa	Seeds	Seiahdaneh	Oil	Treat warts, skin disorders	Skin	E
Resedaceae						
Ochradenus baccatus	Aerial part, seeds	Qeleech	Infusion	Asthma, cold	General, respiratory	I
Rhamnaceae						
Paliurus spina-christi	Fruits	Dereg Dar, Siyah Telo	Edible, infusion, distillation	Anti-hypertensive and reduced cholesterol	Endocrine	E, I
Rhamnus cornifolia	Barks	Gerduye Kuhi, Gerdu Koei	Compound	Skin problems	Skin	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Rhamnus pallasii	Fruits	Arjan, Siah Tangress	Edible, compound in food	Cold, wheezy chest, emollient, cough, and sore throat	Respiratory, general	I
Ziziphus jujuba	Fruits	Annab	Edible	Anemia, sedative, cold	Blood, general, neurological	I
Ziziphus nummularia	Leaves, fruits	Darak, Konar Ramlik	Liniment, compound in food, edible	Gastric pain and stomachache	Digestive	E, I
Ziziphus spina-christi	Fruits, leaves	Konar	Decoction, powder	Fruits for chest, insomnia, blood purification, muscle pains, respiratory problems, anemia, leaves for hair fall and dandruff	Blood, musculoskeletal, general, skin, respiratory	I
Rosaceae						
Amygdalus lycioides	Fruits, seeds	Taneges, Tangras	Decoction, smoke, powder	Good hair condition	Skin	E
Cerasus microcarpa	Barks, resin leaves, fruits, roots	Balalook, Malho, Beralik	Powder, decoction	Antiseptic and disinfection of wounds	Musculoskeletal, general	E, I
Cotoneaster luristanicus	Resin	Shir Khesht, Shirkhesht-e lorestani	Liniment, distillation, compound in food, extract	Laxative for babies	Digestive	I
Crataegus azarolus var. *aronia*	Fruits, flowers, leaves	Goizhe zarde, Zalzalake Zard	Brewed, decoction	Reduce stress and relieve depression, reduce blood pressure, and strengthen the general body, laxative	Psychological, blood, digestive	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Crataegus azarolus var. *pontica* *(syn.: C. pontica)*	Fruits, leaves	Goyizh, Goizh, Gich, Zalzalak	Edible, powder	Tonic, edible as wild fruits, heart tonic, antihypertensive, and headache	General, cardiovascular, neurological, blood	I
Crataegus monogyna	Fruits	Goizhe rasha, Girch, common hawthorn	Compound in food, decoction	Anti-blood lipid, toothache	Blood, general	E, I
Crataegus rhipidophylla	Fruits	Goizhe soore, Yemishan	Edible	Heart vessel opening, diuretic, stomach problems, blood sugar, throat pain	Cardiovascular, digestive, endocrine, respiratory	I
Cydonia oblonga	Fruits, seeds	Bai, Heyva	Edible, moisturized in water	Strengthen the heart, pneumonia, skin lightening, blood purifier, blood sugar, hypertension	Respiratory, cardiovascular endocrine	E, I
Malus pumila	Fruits	Qirmizi Alma	Powder	Ear pain, teeth pain, anti-hair loss, lipid problems, stomach disease	Ear, digestive, skin, endocrine	I
Prunus arabica	Fruits, leaves	Bayem	Decoction	Anti-parasitic, strengthen hair, baby earache, bronchitis, digestive disorders	General, skin, ear, respiratory, digestive	I
Prunus armeniaca *(syn.: Armeniaca vulgaris)*	Fruits, gum	Alocheh, Shilane, Qeysi	Powder, moisturized in water	Anthelmintic, pneumonia, anti-flatulence	General, respiratory, digestive	I
Prunus brachypetala *(syn.: Cerasus brachypetala)*	Fruits	Albaloye, Kuhestani Albalo Koei	Orally, powder	Controlling of blood pressure	Blood	I

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Prunus cerasus (syn.: Cerasus vulgaris)	Fruits	Belalok, Gilas	Compound in food, edible	Blood purification, urinary tract problems, heart pains, liver problems	Blood, urological, digestive, cardiovascular	I
Prunus dulcis	Fruits	Chwale, Shirin Badam	Oil	Strengthening the roots of the hair, bone and brain, constipation	Skin, musculoskeletal, neurological, digestive	E
Prunus lycioides	Aerial parts	Tanyers	Edible	Antiseptic for gastric	Digestive	E, I
Prunus mahaleb (syn.: Cerasus mahaleb)	Fruits	Malham, Heloneh, Mahloo, Mahlab, Bralik	Edible, powder, distillation, infusion	Laxative, anti-calculus, culinary and spice, and wild fruits: Stomachache, antimicrobial, appetizer	Digestive, general	I
Prunus microcarpa	Resin, barks	Helonah	Liniment	Urolithiasis, fever	General, urological	E, I
Prunus persica (syn.: Persica vulgaris)	Leaves	Dermaneh	Powder	Hemorrhoids	Digestive	E, I
Prunus scoparia (syn.: Amygdalus scoparia)	Leaves, fruits, stems, barks, branches, seeds	Jargeh, Dagh Badami	Edible, infusion, oil	Snake bites, foot and hand pains, cold	General, musculoskeletal	E, I
Pyrus salicifolia	Fruits	Harme, Golabi	Fresh food	Nerve tonic	Neurological	I
Pyrus syriaca	Seeds	Anjik oral Anjichak	Cooked seeds	Migraine	Neurological	I
Rosa canina	Fruits	Hool, Shilan, Iyt Burnu	Decoction, compound	Kidney stone, intestinal tract cleaning, diarrhea, diuretic, sedative, hypertension, rheumatic, abortion, skin problems	Urological, digestive, neurological cardiovascular, pregnancy, skin	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Rosa damascena	Flowers	Gole soore, Qizil Gul	Distillation, oil, infusion	Sedative, pneumonia, heart problems, skin lightening, anti-menstrual bleeding	Neurological, cardiovascular, respiratory, skin, female genital	E, I
Rosa foetida	Fruits, flowers, seeds	Nastarane Zard	Brewed, decoction	Treatment of herpes and diarrhea	Digestive, general	I
Rubus anatolicus	Fruits	Tootrk, Tiyarak Tameshk Barg	Distillation, oil, infusion	Stomachache, anti-parasite	Digestive, general	I
Sanguisorba minor	Roots, leaves	Toot Rubahi, Gheytarun	Decoction	İnfections and wounds, diarrhea, hemorrhoids, hypothermia	General, digestive	I
Rubıaceae						
Galium verum	Aerial parts	Sherpaner	Powder	Wounds	Skin	E
Rubia tinctorum	Roots	Baghcha Boyaqi	Liniment	Eye disease, bone fracture, joint pains	Eye, musculoskeletal	E
Rutaceae						
Ruta graveolens	Syrup	Jerit, Sodab	Syrup is poured onto the tooth	Toothache	General	I
Salıcaceae						
Salix aegyptiaca	Flowers	Bidmish	Distillation	Blood increasing, sedative, laxative, heart problems	Blood, neurological, digestive, cardiovascular	I
Salix alba	Leaves	Sovood Aghaji	Extract	Sedative, anti-fever, liver problems, anti-allergy	Neurological, skin, digestive, general	E
Santalaceae						

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Viscum album	Leaves, stems, flowers	Darpechanak Darvash	Swallowing, smoke, vaporal, infusion	Body pain, joint pain, and abscess	Musculoskeletal, skin, general,	E, I
Sapındaceae						
Acer monspessulanum	Barks	Kikom, Kêkf	Decoction	Foot pain	Musculoskeletal	I
Scrophularıaceae						
Scrophularia deserti	Stems, leaves	Benjek Mashin, Gol-Emaymoni	Infusion, compound, distillation	Wound and burn healing and antimicrobial	General, skin	I
Scrophularia scopolii	Aerial parts	Sazoyee	Extract	Treat gangrenous wounds	Skin	I
Scrophularia striata	Stems, leaves	Teshneh Dari Gole-maymoni	Compound in food, infusion	Wound and burn healing and antimicrobial	General, skin	E, I
Verbascum speciosum	Leaves, flowers aerial part	Bonje Maari, Gol-E Mahour	Boiled, decoction	Blood coagulation of women after childbirth, wound disinfection, wound microbial infection	Skin, blood, blood forming organs and immune mechanism	I
Verbascum thapsus	Leaves, flowers	Sigir Gurughi	Distillation, balm	Mucus stimulation, sedative	Respiratory, neurological	E, I
Solanaceae						
Datura innoxia	Latex	Tatureh, Datureh-Egoldorosht	Infusion	Anti-wart	Skin	E
Datura stramonium	Seeds	Tatoureh	Decoction	Sedative	Neurological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Hyoscyamus kurdicus	Seeds, leaves	Bazrolbanj Kordi,	Smoking	Treat eye infections and get rid of eye worms	Eye	E, I
Hyoscyamus niger	Leaves	Bat bat	Liniment	Acne, blood sugar, asthma	Skin, endocrine, respiratory	E
Hyoscyamus reticulatus	Seeds	Alaf-E Koladar, Alaf-E Kase, Bangoo	Smoke	Skin problems, toothache	Skin, general	E, I
Lycium depressum	Leaves, fruits	Khoshk, Goralg Tigh	Powder, edible	Kidney problems	Urological	E, I
Nicotiana tabacum	Leaves	Tootoon	Smoke	Ear pain	Ear	E
Physalis divaricata	Fruits	Arosak Postheh Pardeh	Distillation	Kidney disorders	Urological	I
Solanum americanum (syn.: S. nigrum)	Fruits	Goosh Uzumi, Roarazak, Tamate Kivi Leh, sag Angoral, Tajrizi-E-Siyah	Infusion, powder, compound in food, edible	Sedative, anti-bleeding, skin diseases, wound healing, and eczema	Blood, neurological, skin	E, I
Solanum dulcamara	Fruits, seeds	Taj Rizi	Decoction	Sedatives, antidepressant	Psychological	E, I
Solanum tuberosum	Tuber	Sife zamine, Yeralma	Liniment	Treatment of scorching	Skin	E
Tamaricaceae						
Tamarix ramosissima	Leaves, resin	Shoor Gaz Gaz-E-Shahi	Edible	Dermal disorders, wound healing, and sputum	Skin, respiratory	E, I
Typhaceae						

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Typha domingensis	Pollen, rhizome, flowers, resin	Lovan Loei	Edible	Antipyretic	General	E, I
Ulmaceae						
Ulmus glabra	Leaves	Vazam Narvan-Ebarg Riz	Syrup, edible	Heart and fertility disorders	Cardiovascular, pregnancy	I
Urticaceae						
Urtica dioica ssp. *dioica*	Leaves, stems	Gazane do Paye	Decoction	Relieves knee pain and rheumatic pains and treats diabetes	Musculoskeletal, endocrine	I
Urtica andicola	Aerial parts	Gijitikani	Distillation, infusion	Kidney stone, hypertension, blood sugar, foot pain, diarrhea, prostate, anemia, skin problems	Urological, musculoskeletal, cardiovascular, genital, endocrine, blood, skin, digestive	I
Violaceae						
Viola tricolor	Flowers, branches	Gole Banoushe	Infusion	Headache, migraine	General, neurological	I
Vitaceae						
Vitis vinifera	Shoot	Trê, Mêw, Raz, Hangoor	Verjuice is placed in a glass container and then exposed to the sunshine to become red and usable	Kidney infection treatment	Urological	I

(continued)

Family/taxa	Part used	Vernacular name	Preparation	Application	Use categories	Mode of use (I: Internal; E: External)
Zingiberaceae						
Curcuma longa	Roots	Zarde chêw, Zardchoobe, Sarikook	Compound, liniment	Skin lightening, fracture, heart vessel problems, anti-bleeding, teeth pain, stomach pain, blood sugar, brain reinforcement	Musculoskeletal, skin, digestive, blood, endocrine, neurological	E, I
Zingiber officinale	Roots	Zanjafêl, Znajabil	Distillation, infusion, edible	Stomach reinforcement, intestinal cleaning, sexual tonic	Digestive, genital	I
Zygophyllaceae						
Tribulus terrestris	Aerial parts	Paykol, Damir Tikani	Distillation	Kidney stone, liver disease, hemorrhoid, cough	Urological, digestive, respiratory	I

References

Afshari F, Ebrahimi M, Akbari M, Farajpour M (2013) Cytological investigations and new chromosome number reports in yarrow (*Achillea millefolium* Linnaeus, 1753) accessions from Iran. Comp Cytogene 7:271

Akbari M, Farajpour M, Aalifar M, Sadat Hosseini M (2018) Gamma irradiation affects the total phenol, anthocyanin and antioxidant properties in three different persian pistachio nuts. Nat Prod Res 32:322–326

Altay V, Karahan F, Ozturk M et al (2016) Molecular and ecological investigations on the wild populations of *Glycyrrhiza* L. taxa distributed in the East Mediterranean Area of Turkey. J Plant Res 129(6):1021–1032

Anderson S (1999) The lizards of Iran. Society for the Study of Amphibians and Reptiles. Oxford, Ohio 6, 1–442

Asadbeigi M, Mohammadi T, Rafieian-Kopaei M et al (2014) Traditional effects of medicinal plants in the treatment of respiratory diseases and disorders: an ethnobotanical study in the Urmia. Asian Pac J Trop Med 7:S364–S368

Azizi H, Keshavarzi M (2015) Ethnobotanical study of medicinal plants of Sardasht, Western Azerbaijan, Iran. J Herb Drug 6:113–119

Baharvand Ahmadi B, Bahmani M, Naghdi N et al (2015) Medicinal plants used to treat infectious and non-infectious diseases of skin and skin appendages in city of Urmia, Northwest Iran. Der Pharmacia Lettre 7:189–196

Bahmani M, Eftekhari Z (2013) An ethnoveterinary study of medicinal plants in treatment of diseases and syndromes of herd dog in southern regions of Ilam province, Iran. Comp Clin Path 22:403–407

Bahmani M, Zargaran A, Rafieian-Kopaei M, Saki K (2014) Ethnobotanical study of medicinal plants used in the management of diabetes mellitus in the Urmia, Northwest Iran. Asian Pac J Trop Med 7:S348–S354

Bahmani M, Nejad ASM, Shah NA et al (2017) Survey on ethnobotanical uses of anti-cancer herbs in southern region of Ilam, West Iran. J Biol Res-Boll della Soc Ital Biol Sperim 90:1

Bahraminejad S, Abbasi S, Maassoumi S, Tabeen S (2012) Evaluation of inhibitory effects of extracts of plants from western Iran against *Phytophthora drechsleri*. Aust J Crop Sci 6:255

Bazyar M, Bonyad A, Babaie Kafaki S (2013) Study of most element of forest destruction by used the IRS-1C and LANDSAT image in the southern zagros forest (Case study: Kohkeloeye and Boveirahmad province). Int J Adv Biol Biomed Res 1:35–44

Delfan B, Bahmani M, Eftekhari Z et al (2014a) Effective herbs on the wound and skin disorders: a ethnobotanical study in Lorestan province, west of Iran. Asian Pac J Trop Dis 4:S938–S942

Delfan B, Bahmani M, Hassanzadazar H et al (2014b) Identification of medicinal plants affecting on headaches and migraines in Lorestan Province, West of Iran. Asian Pac J Trop Med 7:S376–S379

Delfan B, Bahmani M, Rafieian-Kopaei M et al (2014c) A review study on ethnobotanical study of medicinal plants used in relief of toothache in Lorestan Province, Iran. Asian Pac J Trop Dis 4:S879–S884

Delfan B, Bahmani M, Hassanzadazar H et al (2015a) Ethnobotany study of effective medicinal plants on gastric problems in Lorestan province, West of Iran. J Chem Pharm Res 2:483–492

Delfan B, Kazemeini H, Bahmani M (2015b) Identifying effective medicinal plants for cold in Lorestan province, West of Iran. Evid Based Complement Alternat Med 20:173–179

Eftekhari T, Ramezani M (2004) Introduction to plant biodiversity in Iran. In: Knama PP (ed) Biodiversity and medicinal plant wealth of south Asian countries. National Botanical Research Institute, (Council of Scientific & Industrial Research), Lucknow, pp 39–40

Eftekharinasab N, Zarei D, Paidar S et al (2012) Identification of wild medicinal plant in Dalahoo mountain and their used indigenous knowledge (Kermanshah, Iran). Ann Biol Res 3:3234–3239

Frey W, Probst W (1986) A synopsis of the vegetation of Iran. In: Contributions to the vegetation of Southwest Asia, vol 24. Ludwig Reichert, Wiesbaden, Germany

Ghorbani A (2005) Studies on pharmaceutical ethnobotany in the region of Turkmen Sahra, North of Iran: (part 1): general results. J Ethnopharmacol 102:58–68
Hassanabadi M, Ebrahimi M, Farajpour M, Dejahang A (2019) Variation in essential oil components among Iranian *Ferula assa-foetida* L. accessions. Ind Crop Prod 140:11598
Heshmati G (2012) Vegetation characteristics of four ecological zones of Iran. Int J Plant Prod 1:215–224
Heshmati GA (2013) Indigenous plant species from the drylands of Iran, distribution and potential for habitat maintenance and repair. In: Heshmati GA, Squires VR (eds) Combating desertification in Asia, Africa and the Middle East. Springer, Dordrecht, pp 355–375
Maleki T, Akhani H (2018) Ethnobotanical and ethnomedicinal studies in Baluchi tribes: a case study in Mt. Taftan, southeastern Iran. J Ethnopharmacol 217:163–177
Mosaddegh M, Naghibi F, Moazzeni H et al (2012) Ethnobotanical survey of herbal remedies traditionally used in Kohghiluyeh va Boyer Ahmad province of Iran. J Ethnopharmacol 141:80–95
Naghibi F, Esmaeili S, Malekmohammadi M et al (2014) Ethnobotanical survey of medicinal plants used traditionally in two villages of Hamedan, Iran. Res J Pharmacogn 1:7–14
Nasab FK, Khosravi AR (2014) Ethnobotanical study of medicinal plants of Sirjan in Kerman Province, Iran. J Ethnopharmacol 154:190–197
Ozturk M, Hakeem KR (2018) Plant and human health. In: Ethnobotany and physiology, vol 1. Springer Science+Business Media, New York, 805 p
Ozturk M, Hakeem KR (2019a) Plant and human health. In: Phytochemistry and molecular aspects, vol 2. Springer Science+Business Media, New York, 697 p
Ozturk M, Hakeem KR (2019b) Plant and human health. In: Phytochemistry and therapeutic uses, vol 3. Springer+Business Media, New York, 385 p
Öztürk M, Aydoğmuş-Öztürk F, Duru ME, Topçu G (2007) Antioxidant activity of stem and root extracts of Rhubarb (*Rheum ribes*): an edible medicinal plant. Food Chem 103:623–630
Ozturk M, Altay V, Hakeem KR, Akcicek E (2017a) Liquorice: from botany to Phytochemistry. Springer briefs in plant science. Springer Nature, Basel. 139 p. https://doi.org/10.1007/978-3-319-74240-3
Ozturk M, Altay V, Karahan F (2017b) Studies on trace elements distributed in *Glycyrrhiza* taxa in Hatay-Turkey. Int J Plant Environ 3(2):1–7
Ozturk M, Altay V, Altundağ E et al (2018a) Herbal in Iğdır (Turkey), Nakhcivan (Azerbaijan), and Tabriz (Iran). In: Ozturk M, Hakeem KR (eds) Plant and human health, Vol. 1, Springer International Publishing AG, part of Springer Nature, Berlin/Heidelberg, Germany, 2018, p 197–266
Ozturk M, Altundağ E, Ibadullayeva SJ et al (2018b) A comperative analysis of medicinal and aromatic plants used in the traditional medicine of Iğdır (Turkey), Nakhchivan (Azerbaijan), and Tabriz (Iran). Pak J Bot 50(1):337–343
Parsa VA, Yavari A, Nejadi A (2016) Spatio-temporal analysis of land use/land cover pattern changes in Arasbaran biosphere reserve: Iran. Model Earth Syst Environ 2:1–13
Pirbalouti AG, Malekpoor F, Hamedi B (2012) Ethnobotany and antimicrobial activity of medicinal plants of Bakhtiari Zagross mountains, Iran. J Med Plants Res 6:675–679
Pleskanovskaya SA, Mamedova MA, Ashiraliyeva MA et al (2019) *Glycyrrhiza glabra* (licorice) in Turkmenistan: medicinal and biological aspects. In: Ozturk M, Hakeem KR (eds) Plant and human health, vol 3. Springer, Cham, pp 23–35
Razmjoue D, Zarei Z, Armand R (2018) Ethnobotanical study (identification, medical properties and how to use) of some medicinal plants of Behbahan city of Khuzestan Province, Iran. J Med Plant 4:33–49
Sadat-Hosseini M, Farajpour M, Boroomand N, Solaimani-Sardou F (2017) Ethnopharmacological studies of indigenous medicinal plants in the south of Kerman, Iran. J Ethnopharmacol 199:194–204
Sadeghi Z, Akaberi M, Sobhkhizi A et al (2018) Evaluation the ethno-pharmacological studies in Iran during 2004-2016: a systematic review. J Cell Physiol 233:914–923

Saki K, Bahmani M, Rafieian-Kopaei M et al (2014) The most common native medicinal plants used for psychiatric and neurological disorders in Urmia city, northwest of Iran. Asian Pac J Trop Dis 4:S895–S901

Samadi N, Shahani S, Akbarzadeh H et al (2016) Essential oil analysis and antibacterial activity of *Ferula assa-foetida* L. aerial parts from Neishabour mountains. Res J Pharmacogn 3:35–42

Tabad M, Jalilian N (2015) Ethnobotanical study of medicinal plants in Zarivar region (Marivan), Iran. J Med Plant 2:55–75

Younessi-Hamzekhanlu M, Ozturk M, Altay V et al (2020) Ethnopharmacological study of medicinal plants from Khoy city of West Azerbaijan-Iran. Indian J Tradit Knowl 19:251–267

Zohary M (1973) Geobotanical foundations of the Middle East. Taylor & Francis, Oxfordshire, United Kingdom

Chapter 22
Fish Fauna in the Amur Water System of the Jewish Autonomous Region in Russia

Vitaliy N. Burik

22.1 Introduction

The water system of the Jewish Autonomous Region (JAR) is represented by the south bend of the middle Amur River and the network of its left tributaries. This part of Amur is the most southern one which to a large extent determines the extensive ichthyological use of this water area. The history of the JAR fishery research is closely connected with the study of the Amur fish fauna as a whole. In 1872, Dibouwski and other researchers conducted systematic studies on the species composition of Amur fish. A combined expedition was carried out in the Amur River area under the direction of Nikolsky during which a part of the Amur flood basin from the village Leninskoye to the influx of the Tunguska River was investigated. Later on, the problems of Amur fish fauna were studied by the experts of the Khabarovsk branch of the TINRO-Center (Burik 2008).

22.2 Study Area

From 2001 to 2018, we studied taxonomical features of fish fauna in the river basin of the middle watercourse of Amur in the Far East of Russia, in the Jewish Autonomous Region. Methods included direct supervision of the nature, which included field route surveys, station research activities, and ichthyological control of fishing. The specific structural determinants of freshwater fishes and vertebrates in the fauna of USSR have been used. The analysis of the scientific data published by the Russian scientists on freshwater fish fauna of the Far East of Russia was surveyed. Systematic groups are given according to N.G. Bogutskaya and

V. N. Burik (✉)
Institute for Complex Analysis of Regional Problems Far Eastern Branch of Russian Academy of Sciences, Birobidzhan, Russia

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_22

A.M. Naseka «The catalog Cephalaspidomorphi and fishes of fresh and saltish waters of Russia with nomenclature and taxonomical comments» (Bogutskaya and Naseka 2004).

22.3 Data Evaluation

The fish fauna of the JAR water area has a number of specific ecocenotic and biological characteristics. The life cycles of the main species and ecological specificities have been taken into consideration, mainly restricted to the Amur riverbed (Kryzhanovsky et al. 1951). In warm seasons, the bulk of the Amur fish heads upstream to the system of the tributary reservoirs for spawning and growing period which includes the upper and middle tributaries, of lakes, bays, and oxbows. In autumn, fishes migrate back, bunching into larger shoals for overwintering in the wintering holes of the Amur riverbed and lower reaches of the large tributaries (Nikolsky 1956). The composition of the Amur tributaries fish fauna varies considerably, depending on how far the entrance to the Amur River is and also on the river flow character.

In general ichthyological diversity of the middle Amur River in the JAR includes 66 genera and 92 species from 25 families in the Amur basin. This is 74.2% of the species diversity of fish in the basin of Amur (Burik 2008). Currently, the region is inhabited by the representatives of 12 units of fish and fish-shaped: Petromyzontiformes, 1 family, 1 genus, and 2 species; Acipenseriformes, 1 family, 2 genera, and 2 species; Cypriniformes, 3 families, 41 genera, and 61 species; Siluriformes, 2 families, 3 genera, and 6 species; Esociformes, 1 family, 1 genus, and 1 species; Osmeriformes, 1 family, 1 genus, and 1 species; Salmoniformes, 3 families, 5 genera, and 7 species; Gadiformes, 1 family, 1 genus, and 1 species; Beloniformes, 1 family, 1 genus, and 1 species; Gasterosteiformes, 1 family, 1 genus, and 1 species; Scorpaeniformes, 1 family, 2 genera, and 2 species; and Perciformes, 6 families, 7 genera, and 7 species.

Cephalaspidomorphi (Petromizontes)

Petromyzontiformes

Petromyzontidae:

Lethenteron camtschaticum (Tilesius, 1811), river eight-eye lamprey; *Lethenteron reissneri* (Dybowski, 1869), Far Eastern brook lamprey

Osteichthyes

Acipenseriformes

Acipenseridae:

Acipenser schrenckii (Brandt, 1869), Japanese sturgeon; *Huso dauricus* (Georgi, 1775), Huso sturgeon

Cypriniformes

Cyprinidae:

Acheilognathus asmussii (Dybowski, 1872), spiny bitterling; *Acheilognathus chankaensis* (Dybowski, 1872), Khanka spiny bitterling; *Rhodeus amurensis*

(Vronsky, 1967), amurskiy gorchak; *Rhodeus ocellatus* (Kner, 1866), rosy bitterling; *Rhodeus sericeus* (Pallas, 1776), Amur bitterling; *Ctenopharyngodon idella* (Valenciennes, 1844), white Amur; *Mylopharyngodon piceus* (Richardson, 1846), black carp; *Squaliobarbus curriculus* (Richardson, 1846), Barbel chub; *Chanodichthys erythropterus* (Basilewcky, 1855), predatory carp; *Chanodichthys mongolicus* (Basilewcky, 1855), Mongolian redfin; *Culter alburnus* (Basilewcky, 1855), lookup; *Hemiculter leucisculus* (Basilewcky, 1855), Korean sharpbelly; *Hemiculter lucidus* (Dibouwski, 1872), Ussuri sharpbelly; *Megalobrama skolkovii* (Dibouwski, 1872), black Amur bream; *Parabramis pekinensis* (Basilewcky, 1855), white Amur bream; *Carassius auratus* (Linnaeus, 1758), golden carp; *Carassius gibelio* (Bloch, 1782), Prussian carp; *Cyprinus carpio haematopterus* (Temminck et Schlegel, 1846), Amur wild carp; *Abbottina rivularis* (Basilewcky, 1855), Chinese false gudgeon; *Gnathopogon strigatus* (Regan, 1908), Manchurian gudgeon; *Gobio cynocephalus* (Dibouwski, 1869), Siberian gudgeon; *Gobio soldatova* (Berg, 1914), Soldatov's gudgeon; *Gobiobotia pappenheimi* (Kreyenberg, 1911), eight-whiskered gudgeon; *Hemibarbus labeo* (Pallas, 1776), steed; *Hemibarbus maculatus* (Bleeker, 1871), spotted steed; *Ladislavia taczanowskii* (Dybowski, 1869), Taczanowski's gudgeon; *Microphysogobio tungtingensis* (Nichols, 1926), long-nosed gudgeon; *Pseudorasbora parva* (Temminck et Schlegel, 1846), stone morokos; *Romanogobio tenuicorpus* (Mori, 1934), Amur whitefin gudgeon; *Sarcocheilichthys czerskii* (Berg, 1914), Cherskii's thicklip gudgeon; *Sarcocheilichthys sinensis* (Bleeker, 1871), Chinese lake gudgeon; *Sarcocheilichthys soldatovi* (Berg, 1914), Soldatov's thicklip gudgeon; *Saurogobio dabryi* (Bleeker, 1871), Chinese lizard gudgeon; *Squalidus chankaensis* (Dibouwski, 1872), Khanka gudgeon ; *Elopichthys bambusa* (Richardson, 1845), yellowcheek; *Aristichthys nobilis* (Richardson, 1845), bighead carp; *Hypophthalmichthys molitrix* (Valenciennes, 1844), silver carp; *Leuciscus waleckii* (Dybowski, 1869), Amur ide; *Phoxinus czekanowskii* (Dibouwski, 1820), Czekanowski's minnow; *Phoxinus lagowskii* (Dibouwski, 1869), Lagowski's minnow; *Phoxinus oxycephalus* (Sauvage, Dabry de Thiersant, 1874), Chinese minnow; *Phoxinus percnurus mantschuricus* (Berg, 1907), lake minnow; *Phoxinus phoxinus* (Linnaeus, 1758), common minnow; *Pseudaspius leptocephalus* (Pallas,1776), flathead asp; *Aphyocypris chinensis* (Gunther, 1868), Chinese bleak; *Opsariichthys bidens* (Gunther, 1873), cyprinid; *Plagiognathops microlepis* (Bleeker, 1871), smallscale yellowfin; *Xenocypris macrolepis* (Bleeker, 1871), yellowfin.

Cobitidae:

Cobitis choii (Kim et Son, 1984), Choi's spiny loach; *Cobitis lutheri* (Rendahl, 1935), Luther's spiny loach; *Cobitis melanoleuca* (Nichols, 1925), Siberian spiny loach; *Parabotia mantschurica* (Berg, 1907), Manchurian spiny loach; *Misgurnus anguillicaudatus* (Cantor, 1842), pond loach; *Misgurnus nikolskiy* (Vasil'eva, 2001), Misgurnus nikolskiy; *Misgurnus mohoity* (Cantor, 1842), Oriental weatherloach; *Paramisgurnus dabryanus* (Dabry de Thiersant, 1872), large-scale loach

Balitoridae:

Barbatula toni (Dybowski, 1869), ray-finned fish; *Lefua costata* (Kessler, 1876), eight-whiskered stone loach; *Lefua pleskei* (Herzenstein, 1887), eight-barbel loach

Siluriformes

Bagridae:

Tachysurus argentivittatus (Regan, 1905), dwarf catfish; *Tachysurus fulvidraco* (Richardson, 1846), banded catfish; *Tachysurus brashnikowi* (Berg, 1907), Brazhnikov's catfish; *Pelteobagrus ussuriensis* (Dybowski, 1872), Ussuri catfish

Siluridae:

Silurus asotus (Linnaeus, 1758), Japanese catfish; *Silurus soldatovi* (Nikolsky et Soin, 1948), Soldatov's catfish

Esociformes

Esocidae:

Esox reichertii (Dybowski, 1869) – Amur pike

Osmeriformes

Osmeridae:

Hypomesus olidus (Pallas, 1814) – pond smelt

Salangidae:

Protosalanx hyalocranius (Abbott, 1901) – clearhead icefish

Salmoniformes

Coregonidae:

Coregonus chadary (Dybowski, 1862), Chadary whitefish; *Coregonus ussuriensis* (Berg, 1906), Amur whitefish

Thymallidae:

Thymallus tugarinae (Knizhin, Antonov, Safronov & Weiss, 2007) – Amur grayling

Salmonidae:

Brachymystax lenok (Pallas, 1773), lenok; *Brachymystax tumensis* (Mori, 1930), blunt-snouted lenok; *Hucho taimen* (Pallas, 1773), taimen, Danube salmon; *Oncorhynchus keta* (Walbaum, 1792), calico salmon, chum salmon

Gadiformes

Lotidae

Lota lota (Linnaeus, 1758) – thin-tailed burbot

Beloniformes

Adrianichthyidae

Oryzias sinensis (Chen, Uwa et Chu, 1989) – Chinese rice fish

Gasterosteiformes

Gasterosteidae

Pungitius sinensis (Guichenot, 1869) – Amur stickleback

Scorpaeniformes

Cottidae

Cottus czanaga (Dybowski, 1869), spotted sculpin; *Mesocottus haitej* (Dibowski, 1869), Amur sculpin

Perciformes

Percichthyidae

Siniperca chuatsi (Basilewcky, 1855) – Mandarin fish, Chuatsi bass

Percidae

Stizostedion lucioperca (Linnaeus, 1758) – pikeperch

Odontobutidae

Micropercops cinctus (Dabry de Thiersant, 1872), sleepers; *Perccottus glenii* (Dybowski, 1877), Chinese sleeper

Gobiidae

Rhinogobius lindbergi (Berg, 1933) – gobies

Osphronemidae

Macropodus ocellatus (Cantor, 1842) – round-tailed paradise fish

Channidae

Channa argus (Cantor, 1842) – northern snakehead

The JAR fish fauna represents three groups, depending on the attachment to separate biotopes. The most widespread ones are all the systematic groups of fish in the biotopes of the of the Amur basin lowland rivers, found in the Amur River and in the lower and middle tributary streams. The second group of fish is commonly found in the oblast's rivers and consists of freshwater salmonids inhabiting the mountain rivers. The third group is represented by fish inhabiting the stagnant water reservoirs which hardly ever join the main stream flows of the Amur basin.

Typical channel fish inhabiting the middle reaches of fairly large tributaries of the Amur region can be attributed to several eurybiontic and nanobiotech species. From relatively monobiontic species *Phoxinus lagowskii*, *Mesocottus haitej*, *Lethenteron camtschaticum* live here; eurybiontic fish of this group (in this case easily adapting to changes in the nature of the current, temperature, channel landscape) – several species of minnows, *Leuciscus waleckii*, *Hemibarbus labeo*, *Rhodeus sericeus*. It should be noted that such a division is conditional, as microslaves different sections of the river channel, meanders, stretches, etc. are different.

A group of fish usually found in mountian rivers in a region where the average water flow rate is more than 2 m/s freshwater salmonids e.g., *Brachymystax* sp. and *Thymallus tugarinae*, as well as *Phoxinus phoxinus* and *P. lagowskii* from the carp family. The question of how many *P. lagowskii*, *Cottus czanaga*, *Mesocottus haitej* exist along the rivers is not sufficiently studied at present. In addition to the factor of direct physical influence, the flow rate affects the qualitative composition and the number of representatives of the fish fauna, as an important condition in the formation of the food base. The higher the speed of the current, the lower the bioproductivity of the water body and the poorer the planktonic composition of the bottom flora and fauna. In such conditions, there are species with specific diets and behaviors. Often these are highly ergonomical omnivores (*Coregonus ussuriensis*, *Thymallus tugarinae*, *Leuciscus waleckii*, *Phoxinus lagowskii*) or predatory (*Brachymystax* sp., *Hucho taimen*, *Esox reichertii*) forms having a rugged elongated body, or fish, for the development of eggs that require high aeration of water.

A separate group of fish is in the standing water reservoirs, constantly inhabiting and reproducing there. In marshy lakes, oxbow, and small laced bays of the lower and middle streams of rivers, there are *Perccottus glenii*, *Phoxinus percnurus mantschuricus*, *Misgurnus nikolskiy*, and *Carassius gibelio* (tall lake form). It should be noted that the dynamics of isolated populations of the abovementioned fish is highly dependent on periodic spills of the Amur and its tributaries, thus without replenishing the feed base, and gene pool isolated fish populations of these reservoirs qualitatively and quantitatively degrade.

The freshwater fish fauna of territories of the Russian Far East, representing the basins of the Pacific and Arctic oceans, are connected with the Amur fish fauna. The Amur fish fauna developed in several stages in various geological times at the junction of the boreal and subtropical belts and has therefore Palearctic, boreal, subtropical, and tropical components. The fish fauna of the Amur-Manchurian region has a well-defined transient nature with approximately equal borderline manifestations; on the northern borderline, there are 70% of the northern species and 30% of the southern ones and on the southern borderline, 30% of the northern species and 70% of the southern ones. It is either widespread throughout the Far East related to the number of species in past geological epochs (tertiary fish fauna, boreal ichthyocomplex, etc.) or secondary area of distribution of some species of fish from the basin. As in the rest of the Amur fish fauna, here the Sino-Indian taxa by origin are dominant (Cypriniformes, Siluriformes, etc.) and Palearctic ones (Esociformes, Salmoniformes, etc.). From the Sino-Indian fish fauna taxa, the most numbers of fish are represented by the group of Chinese plain (Chereshnev 1998; Wei-Jen et al. 2014).

The fish fauna are represented by seven groups of fish and fish-shaped Cyclostomatae, which differ historically and in geographical origin. The main group of fishes in the Chinese plain complex includes 43 species, which have representatives of Cyprinidae, Balitoridae, and Cobitidae; these are about 47% of all the species of fish living in JAR. The representatives of the boreal fauna are the second by the quantity of species group (18 species); the ancient tertiary fauna is well represented by 16 species of fish. In addition, there are representatives of South Indo-African fauna (seven species), Northern fresh-Arctic complex (three species), Pacific ichthyocomplex (three species), and marine origin (two species) in the water basins.

The composition of the fish fauna of the Amur tributaries varies considerably, depending on the distance to the confluence of the Amur and also the nature of the flow of these rivers. The greatest biodiversity of fish fauna has been observed in the reservoirs of Amur floodplain, in the lower reaches of its tributaries, which are deep enough and have a flat flow pattern in this area.

For reservoirs of central Amur, it is possible to allocate ten main biotopes differing in structure of fish fauna: (1) channel Amur, (2) inundated Amur (reservoirs of the floodplain and lower reach of large inflows), (3) small flat rivers, (4) inundated large inflows, (5) average course of large inflows, (6) average current of the mountain rivers, (7) mountain upper courses, (8) large forest lakes, (9) small lakes, and (10) anthropogenic reservoirs. A part of biotopes is characterized by the impoverished structure with prevalence or exclusive presence of stenobiontic species (from 67% to 100%). These are biotopes of upper courses of mountain rivers (no more than ten species of fish are noted; the Salmoniformes group is considerably presented) and also a small number in freezing marshy lakes (four to five species of fish, generally representatives of Cypriniformes group). The greatest species variety (all species of fish which are almost living in area) and also the highest density of fish fauna are observed in the biotopes included in spawning and fodder cycles of fishes under migration ways, sites of a mass fodder migration of fishes, Chinese plain complex, and other ichthyocomplex. As a rule, these biotopes are directly connected with the Amur floodplain or belong to the lower watercourse of flat tributaries of Amur River (the rivers of Tunguska, Bira, Small Bira, Bidzhan, Dobraia, Ventselevka, Zabelovka).

For the comparative analysis of the taxonomical data of fish fauna of JAR, we show the data of the neighboring plots of the Amur basin-Zeisky reservoir with the adjoining plot of the river Zeya in the West. Amur River is near the Komsomolsk Nature Reserve in the East (Bondarenko et al. 2004), and the lake Khanka lies in the southern plot of the Amur basin (Barabanshikov et al. 2006; Burik 2013) (Appendix 22.1).

The number of fish species (92) in JAR is more than those in the basic sites of the Amur basin, because on the compacted area of the region, majority of the representatives live, including cold water ones as well as heat-loving groups of the Amur fish fauna.

Taxonomically and depending on the representation of species of Amur fish fauna, it is very close to the fish fauna of rivers of Primorye coast and the North-Western Sakhalin, together with the depleted fish fauna of Amur River and supplemented by some evrigaline species (saltish water species) of the Pacific coast (Ivanov and Ivanova 2001; Shedko 2001; Burik 2013) (Appendix 22.2 and Table 22.1).

Six species of rare fishes are found in the Amur basin in the territory of JAR. All are included in the Red Lists of JAR and the Red Lists of the Russian Federation. These are representatives of Cypriniformes group, a black carp (*Mylopharyngodon*

Table 22.1 Taxa commonality in the fish fauna of the JAR and other regions of the Russian Far East

Taxa	Regions						
	Zeysky reservoir	The lake Khanka	Komsomolsk Nature Reserve	Rivers of the North-West of the Sakhalin	Rivers of the Primorye coast	The Tumen River	Freshwaters of Chukotka
Units	9 (100%)	9 (100%)	10 (100%)	9 (56.3%)	10 (62.5%)	8 (88.9%)	8 (80%)
Family	16 (100%)	18 (100%)	17 (100%)	17 (70.8%)	19 (55.9%)	13 (86.7%)	13 (81.3%)
Genus	36 (100%)	56 (93.3%)	38 (97.4%)	29 (59.2%)	30 (45.5%)	25 (61%)	13 (48.1%)
Species	46 (97.9%)	75 (88.2%)	42 (95.5%)	36 (49.3%)	36 (39.6%)	31 (57.4%)	12 (18.8%)
Index Jacquar, К	49.5%	73.5%	44.2%	27.9%	24.5%	27%	8.3%

piceus (Richardson, 1846)), a black Amur bream (*Megalobrama terminalis* (Richardson, 1846)), smallscale yellowfin (*Plagiognathops microlepis* (Bleeker, 1871)), and yellowcheek (*Elopichthys bambusa* (Richardson, 1845)); Siluriformes group, Soldatov's catfish (*Silurus soldatovi* Nikolskii & Soin, 1948); and Perciformes group, mandarin fish or the Chinese perch (Chuatsi bass) (*Siniperca chuatsi* (Basilewsky, 1855)).

Currently, 17 species of fish are caught in the region. The most important fishing species are *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Chanodichthys erythropterus*, *Esox reichertii*, *Parabramis pekinensis*, *Silurus asotus*, *Carassius gibelio*, *Leuciscus waleckii*, *Coregonus ussuriensis*, *Tachysurus fulvidraco*, and *Hemibarbus maculatus.*

During the last 8 years, fishing in the region has not been intensive enough; it tends to decrease. According to China's fish protection inspection experts, the catch of ordinary fish on the Chinese side on the border section of the Amur is from 200 to 400 tons per year (excluding sturgeons, calico salmon, lamprey).

Many fish of the indigenous Chinese ichthyocomplex inhabit the Amur River, on the northern border of its habitat. Therefore, they are in a zone of ecological oppression, become mature adult, and gain harvested weight and the necessary sizes much later than on the southern border of habitat or in areas of acclimatization.

So far as the age dynamics of many Amur fish populations is concerned, it is characterized by high mortality at an early age due to the flood regime of the Amur and drying and freezing of small floodplain reservoirs. The yearly replenishment of fish shoal is a small percentage of the total, and the number of aging groups increases. For such fish, the decrease in the number at a more mature age is slowly recovering (Nikolsky 1956). Fishing regulation mechanisms are not enough. Overfishing of older fish (usually the largest and most prolific bions) due to poaching menaces reduces the number and ends up with difficulties in the shoal reproduction. At present, there are two factories for the fingerling breeding of Siberian salmon. The lenok and grayling will be replenished with artificially grown fry. In the nearest time, factory farming of sturgeon will start working. However, in addition to these essential species of fish, artificial reproduction (or rather "additional production") of carp populations and a following release of artificially grown juveniles into the environment are possible.

22.4 Conclusions

The fish fauna of JAR are represented by seven groups of fish and fish-shaped Cyclostomatae, which differ in the historical and geographical origin. The main group of fish – the Chinese plain complex – includes 43 species. The representatives of the boreal fauna are the second by the number of species (18); the ancient tertiary fauna is well represented by 16 species of fish. In addition, there are the representatives of South Indo-African fauna (seven species), Northern fresh-Arctic complex (three species), Pacific ichthyocomplex (three species), and marine origin (two species) water basins.

In summary, what environmental factors play a significant role in the composition and density of the fish fauna of theAmur reservoirs, like the rivers of the Jewish Autonomous Region. We note primarily the flow rate of rivers, which is a direct physical factor (pressure, oxygen saturation, temperature) and affects the composition and amount of aquatic vegetation and biota in general. Another important factor is the remoteness of sites or individual reservoirs from the Amur River, which makes it difficult to migrate individual species. Also important are the width of the channel, the stern sections and spawning grounds associated with it, the width of the floodplain, the presence of additional reservoirs (bays, old channels, etc.).

The specificity of the fish fauna of JAR is a zoogeographical diversity which is due to the bordering geographical position of the region and rich taxonomical representation. Comparison of the fish fauna of the southern area of the basin of the middle Amur River with that of the neighboring areas of the Amur basin and other regions by the degree of taxonomic proximity confirms the theoretical views of I. A. Chereshnev (1998). He supposes there has been the settling of Sino-Indian component from the Amur basin in the basins of the southern part of the Far East of Russia.

Appendices

Appendix 22.1: Total Number of Families, Genera, and Species of Cephalaspidomorphi and Fishes of Amur River Reservoirs of JAR and Other Sites of the Basin of the Amur River

		Amur fish fauna of Russia (25 families)		*Jewish Autonomous Region* (22 families)		*Zeysky reservoir* (16 families)		*The lake Khanka* (18 families)		*Komsomolsk Nature Reserve* (17 families)	
No	Family	Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species
1	Petromyzontidae	1	2	1	2	1	2	1	1	1	1
2	Acipenseridae	2	2	2	2	2	2	2	2	2	2
3	Salmonidae	4	11	3	4	2	3	4	5	3	4
4	Coregonidae	1	4	1	2	1	2	1	1	1	1
5	Thymallidae	1	5	1	1	1	1	1	1	1	1
6	Ocmeridae	2	3	1	1	1	1	–	–	–	–
7	Salangidae	2	2	–	–	–	–	1	1	–	–
8	Esocidae	1	1	1	1	1	1	1	1	1	1
9	Cyprinidae	35	55	35	49	16	23	34	53	19	22
10	Balitoridae	2	4	2	3	1	1	2	2	–	–
11	Cobitidae	4	8	4	9	2	3	3	4	2	2
12	Bagridae	2	4	2	4	2	2	2	5	2	3
13	Siluridae	1	2	1	2	1	1	2	2	1	1
14	Lotidae	1	1	1	1	1	1	1	1	1	1

15	Mugilidae	1	1	–	–	–	–	–	–	–	–
16	Adrianichthyidae	1	1	1	1	–	–	–	–	–	–
17	Gasterosteidae	2	5	1	1	–	–	1	2	1	1
18	Cottidae	3	4	2	2	2	2	–	–	1	1
19	Percichthyidae	1	1	1	1	1	1	1	1	1	1
20	Percidae	2	2	1	1	–	–	1	1	1	1
21	Osphronemidae	1	1	1	1	–	–	–	–	–	–
22	Odontobutidae	2	2	2	2	1	1	1	1	1	1
23	Gobiidae	2	4	1	1	–	–	1	1	–	–
24	Channidae	1	1	1	1	–	–	1	1	1	1
25	Pleuronectidae	1	1	–	–	–	–	–	–	–	–
	Total	76	128	66	92	36	47	60	85	40	45

Appendix 22.2: Total Number of Families, Genus and Species Cephalaspidomorphi and Fishes of Fresh Waters of Northwest Sakhalin, Primorye, Chukotka

No	Family	*Rivers of the North-West of the Sakhalin* (24 families)		*Rivers of the Primorye coast* (34 families)		*The Tumen river* (15 families)		*Freshwaters of Chukotka* (16 families)	
		Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species
1	Petromyzontidae	1	3	1	2	1	2	1	3
2	Acipenseridae	–	–	1	1	1	1	1	1
3	Clupeidae	1	1	2	3	–	–	1	1
4	Salmonidae	5	11	4	8	3	5	4	13
5	Coregonidae	1	1	1	1	–	–	3	11
6	Thymallidae	1	1	1	2	–	–	1	3
7	Osmeridae	3	5	3	5	3	3	3	3
8	Salangidae	–	–	1	1	1	1	–	–
9	Esocidae	1	1	1	1	–	–	1	1
10	Dalliidae	–	–	–	–	–	–	1	3
11	Cyprinidae	11	18	14	17	16	20	3	4
12	Catostomidae	–	–	–	–	–	–	1	2
13	Balitoridae	2	2	2	2	2	2	1	1
14	Cobitidae	2	3	2	2	2	4	–	–
15	Bagridae	1	1	2	2	–	–	–	–
16	Siluridae	1	1	1	2	1	1	–	–
17	Gadidae	1	1	1	1	–	–	–	–
18	Lotidae	1	1	–	–	–	–	1	1
19	Belonidae	–	–	1	1	–	–	–	–
20	Hemiramphidae	–	–	1	1	–	–	–	–
21	Mugilidae	1	2	1	2	1	1	–	–
22	Gasterosteidae	2	4	2	4	1	1	2	3
23	Syngnathidae	–	–	1	1	–	–	–	–
24	Sebastidae	–	–	1	1	–	–	–	–
25	Cottidae	4	5	3	6	1	3	1	2
26	Liparidae	–	–	1	1	–	–	–	–
27	Blepsiidae	1	1	–	–	–	–	–	–
28	Percichthyidae	1	1	1	1	–	–	–	–
29	Percidae	–	–	1	1	–	–	2	2
30	Sparidae	–	–	1	1	–	–	–	–
31	Stichaeidae	–	–	1	1	–	–	–	–
32	Cryptacanthodidae	–	–	1	1	–	–	–	–

(continued)

No	Family	*Rivers of the North-West of the Sakhalin* (24 families)		*Rivers of the Primorye coast* (34 families)		*The Tumen river* (15 families)		*Freshwaters of Chukotka* (16 families)	
		Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species	Number of genus	Number of species
33	Pholidae	1	1	2	2	–	–	–	–
34	Odontobutidae	1	1	1	1	1	1	–	–
35	Gobiidae	2	3	6	12	6	8	–	–
36	Zoarcidae	1	1	–	–	–	–	–	–
37	Channidae	–	–	1	1	1	1	–	–
38	Pleuronectidae	2	2	2	2	–	–	–	–
39	Tetraodontidae	–	–	1	1	–	–	–	–
	Total:	49	73	66	79+12[a]	41	54	27	64

[a]In fauna of the rivers of the coast of Primorye, 79 native and 12 introdutsirovanny species of fish are given (Shedko 2001)

References

Barabanshikov EI, Nazarov VA, Svirsky VG (2006) Fauna Cephalaspidomorphi and fishes of the Lake Khanka. TINRO News 146:97–110

Bogutskaya NG, Naseka AM (2004) The catalog Cephalaspidomorphi and fishes of fresh and saltish waters of Russia with nomenclature and taxonomical comments. Association of scientific editions of KMK, Moscow

Bondarenko IV, Yurochkin RK, Kolbina EA (2004) Fishes. Dynamics of the seasonal phenomena and processes in a natural complex of the Komsomolsk reserve: Nature chronicle. Publishing of Komsomolsk Reserve, Komsomolsk-on-Amur

Burik VN (2008) Fish fauna of the Jewish autonomous region. Reg Probl 10:68–75

Burik V (2013) The taxonomic characteristics of the fish fauna of the Middle-Amur in comparison with the freshwater fish fauna of some areas of the Far East of Russia. In: 3rd International Geography Symposium - GEOMED 2013, June 10–13, Kemer, Antalya, Turkey, Symposium Proceedings, ISBN: 978-605-62253-8-3, pp 42–48

Chereshnev IA (1998) Biogeography of fresh-water fishes of the Far East of Russia. Dalnauka, Vladivostok

Ivanov AN, Ivanova LV (2001) About structure and zoogeographical division into districts of a fish fauna of fresh waters of northwest Sakhalin. Readings memory of Vladimir Yakovlevich Levanidov 1:249–263

Kryzhanovsky SG, Smirnov AI, Soin SG (1951) Materials on development of fishes of the Amur River. Works of the Amur icthyological expedition of 1945–1949, vol 2. MOIP Publishing House, Moscow, pp 5–222

Nikolsky GV (1956) Fishes of the basin of Amur. Science, Moscow

Shedko SV (2001) List Cephalaspidomorphi and fishes of fresh waters of the coast of Primorye. Readings memory of Vladimir Yakovlevich Levanidov 1:229–249

Wei-Jen C, Sebastien L, Luciano BB, Richard L (2014) Mayden and Brett Riddle. Historical biogeography of a new antitropical clade of temperate freshwater fishes. J Biogeogr 9:1–13

Chapter 23
Paleogeography of Caspian Sea, Water Level Fluctuations, and Consequences on the Environment and Civilization

Mustafa Ergun

23.1 Introduction

The Caspian Sea is the largest enclosed inland water body of the world. The main water input is the Volga River in the north. It is a closed basin, with its own sea level history. There is a need to understand its paleogeography quite well in accordance with climatic and environmental circumstances. During the Ice Age period (120 to 12 ka), all waters were kept in the polar regions up to 40–45° latitudes. From here down to the equator, all the earth's surface was covered with desert because of little rains. Living things could only survive at the narrow band of equatorial region and the suitable place at the boundaries of 35–40° latitudes. The South Caspian Sea is the ideal location for life. Noah Flood most probably occurred here with lash of water pouring down from the Aral Sea and Uzboy Strait at around 15 ka due to breakage of ice dam in the western Siberia. In the course of the geological history, the impact of the listed factors varied in efficiency from one stage to another.

The Civilization of the world can be summarized as follows; a- after the ice age: Harran (12,000 BC, SW Turkey); Anau (6–8,000 BC, Turkmenistan): Konya (7,000 BC, Central Turkey); Palestine (7,000 BC) and after the development of deltas: Mesopotamia (4,000 BC); Egypt (3,500 BC); Harappa (3,300 BC, India); Troia (4,000 BC, NW Turkey). These early civilizations are closely related with the Caspian Sea region just after the end of the Ice Age. Therefore, the first civilization on earth was probably in the deep basin of the South Caspian Sea. These people probably got dispersed from here eastward and westward after the Big Caspian Floods; the water fluctuations had a great effect on the earliest civilizations in this part of the world.

M. Ergun (✉)
DEU/IMST, INOC Centre, Inciralti, Izmir, Turkey
e-mail: Mustafa.ergun@deu.edu.tr

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7_23

23.2 Location of the Caspian Sea and Its Name

The *Caspian Sea* the largest inland/landlocked body of water, but it is salt water which is the remnants of the larger sea, Tethys Ocean. It is facing evaporation increases and decrease in flow feeder rivers and increase in irrigation/industrial uses. It is surrounded by Russia, Azerbaijan, Iran, Turkmenistan, and Kazakhstan, lying east to the Caucasus Mountains and to the west of the vast steppe of Central Asia. The south of the Caspian Sea is bounded by the Alburz Mountains. The salinity is approximately 1.2% (12 g/l), about a third of the salinity of the world's ocean. It is an endorheic sea.

The name of the Caspian Sea was probably derived from the tribes called Caspiane; however Turkish tribes called this sea as Hazar. The name "Hazar" is somehow related with the fluctuation of sea level in this inland water. It is connected to the Black Sea by the Manych Spillway (Fig. 23.1). The height of the Manych Spillway is about 25 m above sea level. When the water level of the Caspian Sea is above 25 m or so, the Caspian Sea waters flow to the Black Sea.

23.3 Geological Evolution of the Caspian Sea

The southern boundary of the Tethys Ocean is made up of the Eastern Mediterranean and the Middle East, whereas the northern boundary is made up of the Black Sea and the Caspian Sea (Ergün 2016) (Fig. 23.2). The basins of the Eastern Mediterranean, the Black Sea, and the Southern Caspian Sea basis are laid over the oceanic lithosphere. While the Arabian plate has been moving very fast norhward, the Iranian plate has been pushed southeastward between the Arabian plate and

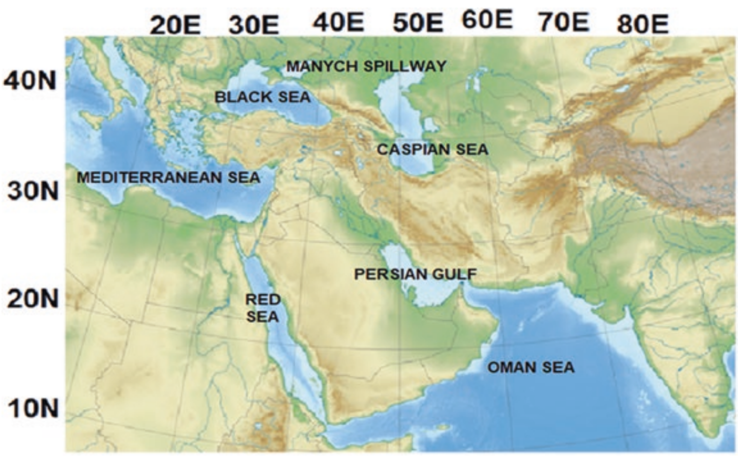


Fig. 23.1 General physical geographic map of the Middle East. (Base map from: It.wikipedia.org)

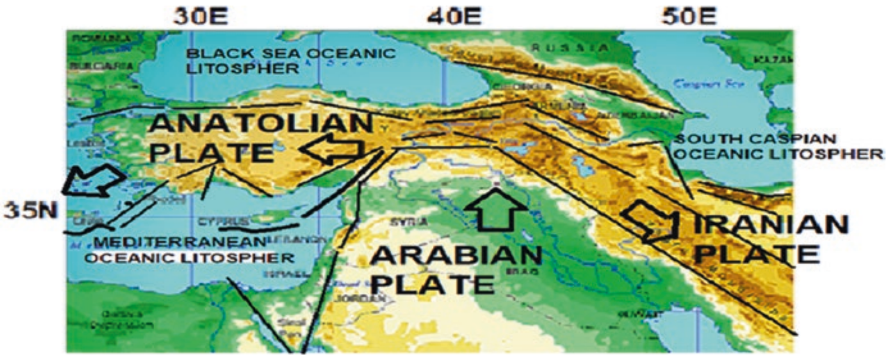


Fig. 23.2 Tectonic zones of the Anatolia and Iranian plateaus [Notes: Anatolian Plate; Iranian Plate; Mediterranean Oceanic Lithosphere; Black Sea Oceanic Lithosphere; South Caspian Oceanic Lithosphere]. (Base map from: It.wikipedia.org)

oceanic lithosphere of the Southern Caspian Sea, squezed between the Alburz Mountains in the north and the Zagros Belt in the southwest. The Anatolian/Iran Plateaus were formed after the disappearance of the Tethyian Ocean for the last 200 ka after the disintegration of the Pangea (Fig. 23.2). The relicts of the old Tethys Ocean crusts are left in the Messenian and Abyssal plains in the Eastern Mediterranean and the Black Sea and the southern Caspian Sea basins. The Black Sea/South Caspian Sea possess 100-milligal lower gravity value than other isostatically compensated oceans, and the two basins with very thick sedimentary cover are actually sinking (Ergün 2016).

The Caspian Sea and the Black Sea were the part of a Mesozoic chain of back-arc basins stretching over a distance of 3,000 km. This chain was located between the continental margins of Eurasia to the north and Mesozoic-Paleocene belts to the south. Neo-Tethys was the south of the island-arc system. Suggested that the basins were formed during three separate tectonic episodes: (i) Middle Jurassic, (ii) Late Jurassic, and (iii) Late Cretaceous times. The combined Caspian Sea-Black Sea paleobasin reached its maximum extent during the Paleocene, occupying an area of 900 km wide and 3000 km long (Fig. 23.2) (Berberian 1983).

23.4 Mediterranean-Marmara Sea-Black Sea-Caspian Sea Water Connections

The old Tethys Ocean connected both to the Atlantic and Indo-Pacific Oceans up to Palocene times. Five million years ago, during the Messenian period (end of Miocene) of long-lasting ice-age of the very dry period, a large landlocked sea had been formed where the Caspian was part of it. The waters became fresher, but then a link to the ocean was again established, and a marine environment returned. About 2 million years ago, that link to the ocean was closed, and inland waters again became much fresher, through rainfall and the melting of glaciers. Eventually the Caspian Sea severed its connection to the Black Sea and became permanently landlocked (Chepalyga 2007b; Yanina 2014). Lake levels in the earlier Late Khazar basin, according to spatial distribution of the deposits, did not exceed −10 m, and its surface area was not much bigger than the modern Caspian Sea. As per Chepalyga (2007a), the early Khvalynian transgression was a catastrophic Great (Bible) Flood, and its transgressive phases were the "waves" of this flood developed at high speed. He even executed a Noah's Ark reconstruction on waves of the Khvalynian Sea. During transgressions, the surface area of the Caspian increased as much as 250% compared to the current sea, and water levels reached +50 m. Caspian Sea levels were as low as −140 m during maximum regressions, resulting in lake level variations of 190 m in the Late Pleistocene. The marine transgressions in the Pontian Basin (Karangat in the Late Pleistocene and Black Sea in the Holocene) occurred in warm interglacial times (Fig. 23.3). Caspian type of lake seas in the Pontian Basin developed during cold climate intervals.

The Manych-Kerch Spıllway connected the Caspian and Black Seas. The spillway bottom gradient was 0.0001 (10 cm/km), and the drop in water level from the Caspian Sea (+50 m) to the Black Sea (−80 to −100 m) reached 150 m at the beginning of the excess water flow; by the end of this flow, the drop was 100 m. In all probability, during the course of the Khvalynian transgression, specific environ-

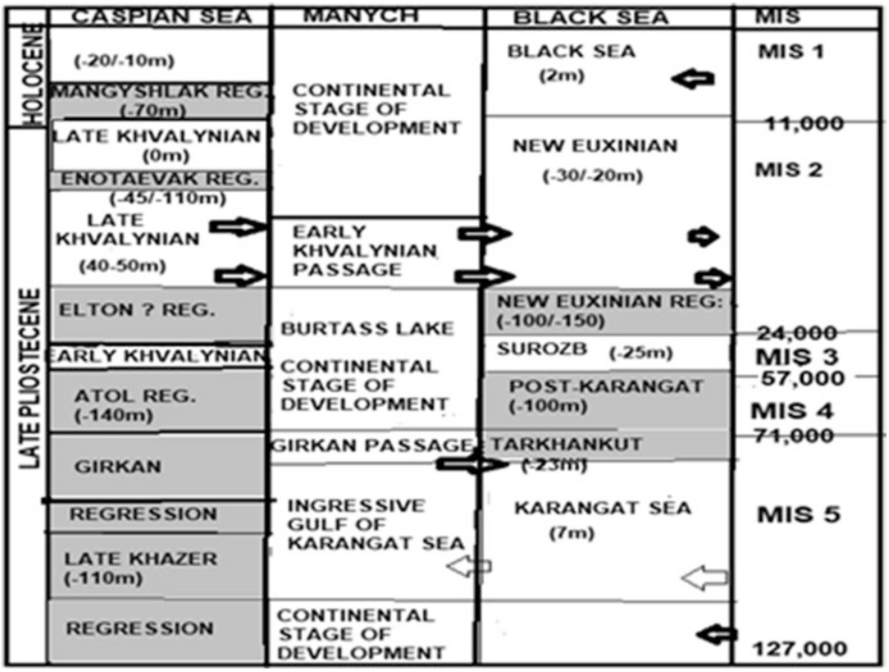


Fig. 23.3 Correlation of paleogeographical events in the Caspian Sea and in the Black Sea during the Late Pleistocene. (Modified from Yanina 2014)

ments arouse in the Caspian basin that favored a survival of Neanderthal populations.

23.5 Climate Change Issues and Climate Zones

All these changes are due to the solar energy reaching to the earth's surface from an angle. Low solar energy means the ice ages in the world. According to the Milankovitch Theory, earth-orbital changes occur over 1000s to 100,000s yrs, ice ages are almost certainly triggered by slow wobbles in the earth's axis and its orbit around the sun which in turn affect the geographic distribution of the solar radiation at different times of the year. Its cycles describe the collective effects of changes in the earth's movements on its climate over thousands of years, and its three periodicities are eccentricity, 95 ka (400 ka); obliquity, 41 ka; and precession, 19–21 ka. The climate is likely to experience a long-lasting (50 k year) interglacial period. However, the amplitude and, to a lesser extent, the timing of future climatic changes depend on the CO_2 scenario.

The Last Glacial Maximum (LGM) was the most recent time when ice sheets were at their greatest extent (Grosswald 1980) (Figs. 23.4 and 23.5). All over the world, climates at the Last Glacial Maximum were cooler and almost everywhere drier. Even in less affected regions, rainforest cover decreased much, especially in West Africa where a few refugia were surrounded by tropical grasslands. Figure 23.5 shows the climatic condition of Eurasia with the brown area being cold and desert or semi-desert, including the mountainous areas between the Black and Caspian

Fig. 23.4 The climatic condition of Eurasia during the Ice Age maximum. (From http://www.innerx.net/personal/tsmith/iceciv.html). [*Brown*, area being cold and desert or semi-desert, with glaciers in the higher altitudes (*black areas*); *green* and *yellow*, show areas favorable for human habitation in wet and dry periods, respectively; *red* shows the extended land area due to low sea levels)]

Fig. 23.5 A generalized scenario of pro-glacial "Great Lakes" at the southern edge of the Eurasian Ice Sheet. (Modified from Grosswald 1980) (Base map from: Google Earth)

Seas, with glaciers in the higher altitudes (black areas). Much of the world was cold, dry, and inhospitable, with frequent storms and a dust-laden atmosphere (Fig. 23.4). During the Quaternary period, large ice-dammed lakes with reversed outlets, e.g., toward the Caspian Sea, formed south of these ice sheets (Mangerud et al. 2004). During the global Last Glacial Maximum (LGM, about 20 ka), the Barents-Kara Ice Sheet was too small to block these eastern rivers. Mangerud et al. (2004) have identified only two periods when drainage was diverted toward the Caspian and Black Seas. The first time, the drainage of the West Siberian Plain was forced toward the Aral, Caspian, and Black Seas by the advancing Barents-Kara Ice Sheet at 90 ka. This led the Caspian Sea to overflow along the Manych Pass at 26 m a.s.l. to the Black Sea. The last overflow from the Caspian Sea lasted from 19 to 13 ka (16–11 ka 14C-years) and was interrupted by a regression at 17–16 ka. The sudden end of this regression occurred at 15 ka. The reason of this interruption was that the ice dam broke down and water flooded down to the Caspian basin through the Aral Sea and Uzboy channel (probably due to the meteor impact to the ice dam?). Water level was raised to +50 m from about −150 m (Fig. 23.5).

In all probability, specific environments arouse in the Caspian basin that possibly favored a survival of Neanderthal populations (Dolukhanov et al. 2000). One of the factors might be a "cascade" of basins, including the Caspian-Black Sea spillway across Manych-Kerch Valley, which effectively isolated the Caucasian-Central Asia area.

23.6 Caspian Sea Region Water Level Variations

Although sea rise after the last glaciations took about 15,000 years, the change would nevertheless have been perceived as a continuous retreat of the shoreline and loss of land which was quite noticeable in one generation. These matters were more devastating for the marginal seas such as the Black Sea and the Caspian Sea as well as the Sea of Marmara because the fall of sea level was much more the open ocean waters. Given the fertility of coastal plains, both for the terrestrial fauna on grasslands and resources in marshes, deltas, and wetlands, the continuous loss of such land must have been an unfortunate aspect of life in the Late Paleolithic and Mesolithic periods.

A rising sea level occasionally inundated an area of low gradient such as the North Caspian seafloor, creating massively extensive new marshlands and new environments which could support coastal and aquatic systems.

The Caspian Sea appears to be the epicenter of the flood and the most sensitive indicator of other events. During flooding, the Caspian Sea expanded over an area of about 1 million km^2 (presently 371,000 km^2), up to 1.1 million km^2 if the Aral-Sarikamysh basin included. All these facts have been discussed by Chepalyga (2007b). It was called the *Khvalynian Transgression* (Fig. 23.6). At the peak of the flood, sea level in the Caspian basin reached 190 to 200 m above the level of the previous basin. Chepalyga (2007b) described that the flood's history may be divided into ten oscillations. Evidence from geology, lithology, paleontology, and geomorphology reflect the Great Eurasian Floods in the Ponto-Caspian basin (Chepalyga

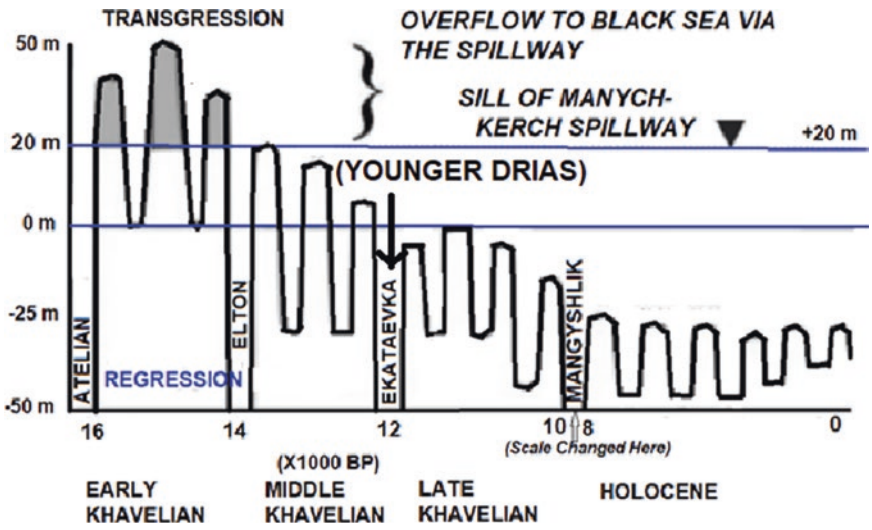


Fig. 23.6 Late glacial flood in the Ponto-Caspian basin (Modified after Chepalyga 2007b). [Notes: Khvalynian Transgression (15,000 years ago); end of the Ice Age, 12,000 years ago; sea-level optimum reached at about 5–6,000 years ago]

2002). At the peak of the flood, sea level in the Caspian basin reached 190 to 200 m above the level of the previous basin. The flood's history may be divided into ten oscillations (each lasting 500–600 years), which may be grouped into three super-food waves that have been identified in river valleys, each lasting as long as 2000 years. These events might have stimulated the beginning of shipping, as well as horse domestication. The paleogeography of the Caspian Sea first of all is the history of fluctuations of its level (Yanina 2014). Historic and paleogeographical data give evidence to considerable level oscillations, whose amplitude was more than 100 m during Pleistocene and Holocene (Fig. 23.6).

23.7 What Is the Noah Flood?

There are very many flood myths in the religions around the world. In this respect, such myths might have originated in real historical floods, possibly in the Caspian region, which lies in the right region for Biblical legends (not too far from the Mount Ararat). Water levels of the Caspian Sea can be shown as Figs. 23.7 and 23.8. We must consider the climate as well as paleogeography during the Ice Age period (from 120 to 12 ka). Since all water was kept at the polar regions during the Ice Age, water levels of the oceans were around 120/130 m below sea level, and these periods are very dry times with almost no rain. Therefore, the wide areas of the world (from 35/40° latitudes up to equator) are subtropical (deserts with no water). Living things could only occur at the boundary of ice-covered regions and the narrow equatorial areas. The southern Caspian Sea and its surroundings were the most possible living environment for the *Homo sapiens* (Neatherthandal people disappeared at around 40 ka due to harsh climate of the Ice Age).

23.7.1 Consequences of the Noah Floods

Living things could only occur at the boundary of ice-covered regions and the narrow equatorial areas. As explained above, the Khvalynian Transgression took place at the Caspian Sea at around 15 ka with the shattering of the ice dam at the north of Aral Sea (possibly due to a meteorite) and water following through the Uzboy Strait filling the Caspian Sea from about −150 m up to +50 m for a short time. Therefore, this is the ideal location to explain the dramatic events of flooding (Chepalyga 2007a). People could not escape to the south because of the Alborz Mountains. At this conjucture, we must consider the effects of gas hydrate accumulations at the tundra areas of the Caspian region. Sudden rise of sea level in the Caspian Sea could had dissolved gas hydrates creating catastrophic conditions in the secluded basin of the Southern Caspian Sea.

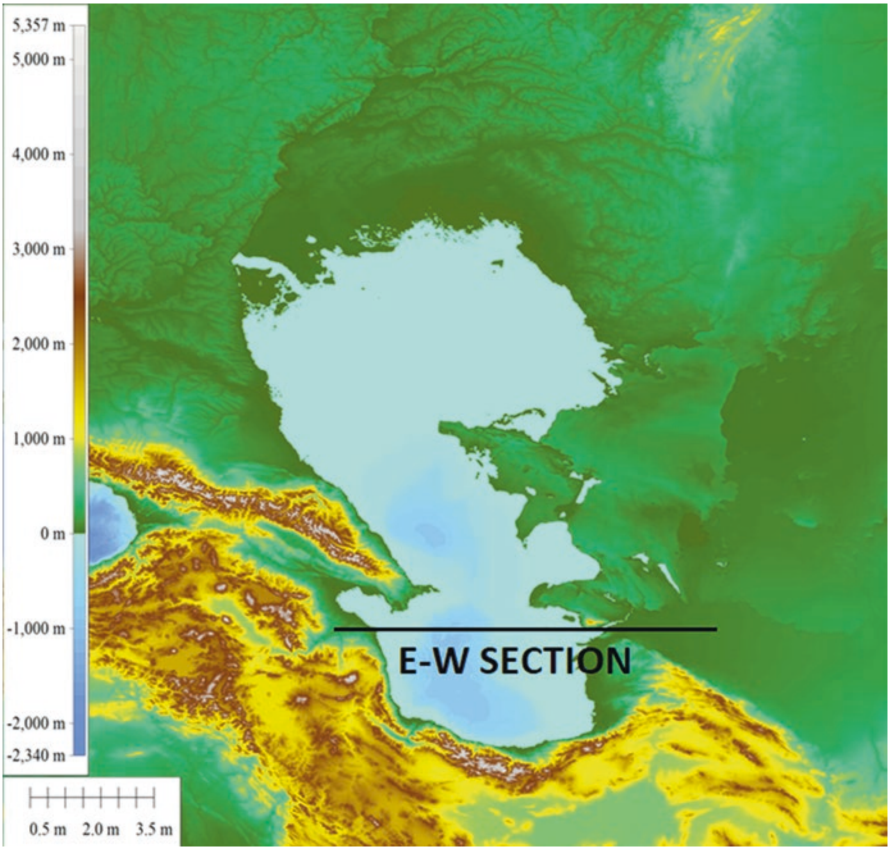


Fig. 23.7 Physiographic map of the Caspian Sea

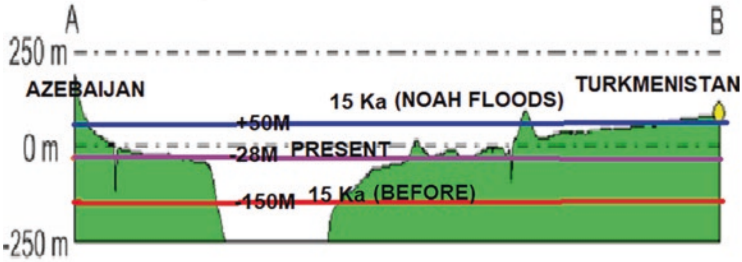


Fig. 23.8 East-west section through the South Caspian Sea (present water level, −28 m; water level at 15 ka, −150 m; water level after floods, +50 m)

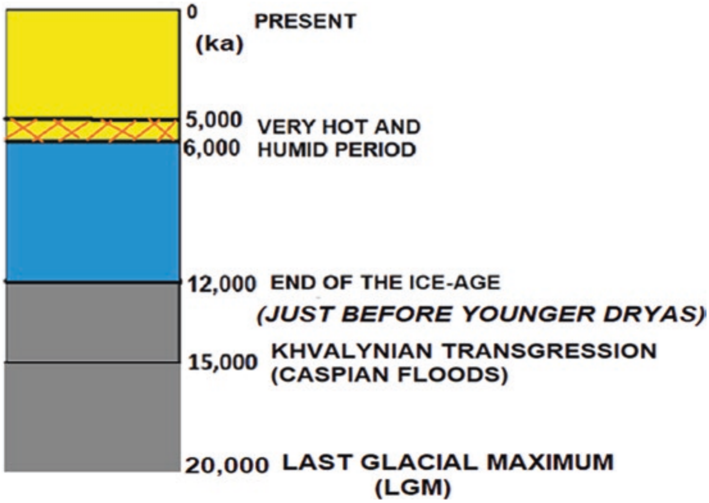


Fig. 23.9 The important events of the Caspian Sea area for the last 15 ka: 15 ka Khvalynian Transgression; 12 ka the end of Ice Age; 5–6 ka optimum sea level for the formation of deltas

Civilization steps can be summarized as follows (Fig. 23.9):

- 15 ka to 12 ka (sea level at 125/130 m) (except the Caspian Sea)
- 12 ka to 5/6 ka (sea level started to be reduced gradually)
- 5–6 ka to the present (optimum sea level) (formation of deltas)

Therefore, life existed in some very restricted areas before 12,000 ka (the end of Ice Age). Between 12,000 ka and 5/6,000 ka, the sea level rose very fast because of the very hot climate during this period. Deltas started to develop, and this led to the rapid development of delta cultures like Mesopotamia. During the Ice Age, the Caspian region was most probably the unique area where the surviving human beings were able to survive, but the sensitivity of this region affected them greatly because people were kept on the move with floods together with the change of climate in this sensitive enclosed area There is a cyclicity of about 5/600 year's periods in the Caspian Sea water level fluctuations. During the LGM, a large part of Eurasia was covered by large ice sheets in the northern parts above 45° N. The south of the latitude of 35° N was covered with harsh desert areas with no habitation in general. The habitable areas were mainly distributed in between 35° N and 40° N (Fig. 23.10). Therefore, human civilizations started from this area after the end of the Ice Age at around 12,000 ka.

The words "Hazar" and "Sefer" in present-day Turkish languange mean settled (living in peace) and on the move (at war), respectively. "Hazar" is also the name of the Caspian Sea used by all Turkish tribes globally. The word of "**BALKAN**" means marshy, bushy and jungle area in Turkish. This is a district name in North Turkmenistan. The people had moved north and westward episodically due to the rise of sea level in the Caspian Sea as the climate had become warmer. These people

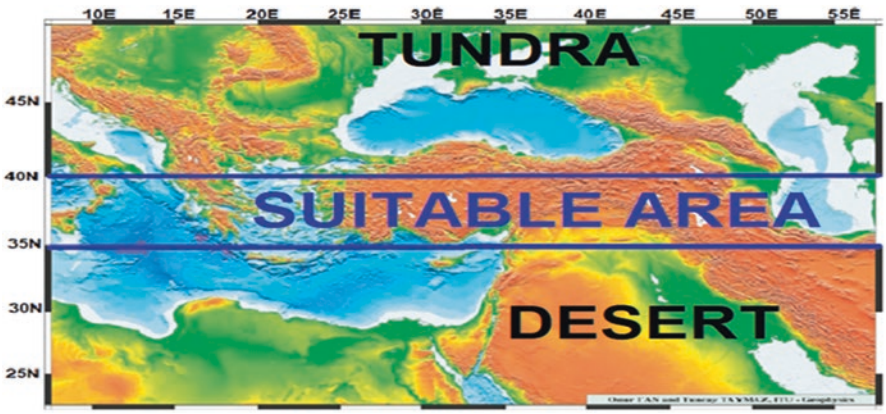


Fig. 23.10 The schematic showing the Eurasia area. It was ice covered, with very cold climate above about 40° N latitudes. A very dry and desert-covered area with no habitation existed below 40° N latitudes down to the equatorial region. There was only a small area around between 35 and 40° N latitudes where life could had been survived during the Ice Age. (Base map from: It.wikipedia.org)

went around the Black Sea and settled in the Balkan Region, and it was named "Balkan." Also the word "Alp" means high and dignified in Turkish (it is the root of the Alp Mountains).

The Noah Flood may appear as a worldwide phenomenon. However, it was mentioned as a local issue in the sacred books. It was only for the people of the tribe of Noah affected by the floods. The story of a global flood occurs as a common myth in many cultures. We have to bear in mind that there are very many folkloric stories about the floods in the countries which are riparian to the Caspian Sea (Azerbaijan, Turkmenistan, and Kazakhstan).

The real history starts with the invention of writing by the Sumerians about 3,500 BC. Therefore, anything before should be considered as the prehistory (Renfrew 2008). The areas where the main Anau culture developed are the mountain streams reaching the plains. Pumpelly put forward the first theory of "oasis fresh water life" from the archeological materials found, including the first agricultural activities of the human beings. It is very clear that a great leap forward was made in the World Civilization after the formation of deltas around 5–6,000 ka. Science and knowledge has progressed in such a way that we could answer the question how the populations of hunters and collectors had become agriculturalists during the Holocene (about 10,000 years ago). It is a reality that a great deal of climate change had occurred in the world globally at the end of the Ice Age. Immersive amount of ice sheets had disappeared in Eurasia. As the sea level had risen by about 120–130 m, the coastlines took completely different appearance. The problem is a bit different in the Caspian and Black Seas' domain. Because the Khvalynian Transgression occurred in the Caspian Sea where the sea level rose to +50 m suddenly, then the excess water was flown to the Black Sea. The end of the

Ice Age was 12,700–10,800 BC; temperatures fell down drastically all over the world, but the Taurus and Zagros mountains ice-blocked barriers between the south and north. The Younger Drayas covered 10,800–9,600 BC; world temperatures came to the level of present day, ice started to melt, and sea level rose.

Considering the sudden climate change during the end of the Ice Age in west Asia, there could be no food shortage, because the large areas had become suitable for plants and animals to survive. After the latest phase of the cold climate, temperatures increased, and areas covered with tundra changed into permanent forest landscapes in Europe and Asia. During this period, the winter rains increased in the Harran area. Water capacities of Euphrates and Tigris rivers increased with the melting of East Anatolian Ice cover in the north. Accordingly, a very rich habitat developed in the Harran plain (Fig. 23.11). This region is important because of right climate, rich water resources (Tigris and Euphrates rivers), rich mining areas, and plenty of obsidian (flint stones) volcanic rocks.

Therefore, the early civilization started in SW Turkey around the Harran plains where the first wheat was cultivated about 12 ka, which then spread to the Central Anatolia (10 ka) and Thrace (8 ka). There is the story of wheat about the disagreement between the sons of Adam, Kabil, and Cain. Kabil gave the bunch of wheat produced by him to God as a gift, whereas Cain had given one sheep. The rage of Kabil whose gift was not accepted by the God had caused the first murder of mankind. The Turkish saying says it is wheat with sheep and the rest is a game. Wheat is the sacred food for people. The cereal which triggered the civilization is wheat (Ozturk and Gul 2020). Neolithic culture started with agriculture around the world with human migrations following the change of climate after the Ice Age. The essential element is protein for the development of brain. Pythic models of America and Asia started with corn/potatoes and rice, respectively, and stayed locally, but wheat was the triggering commodity in the Harran valley at around 10,000 BC. Wheat

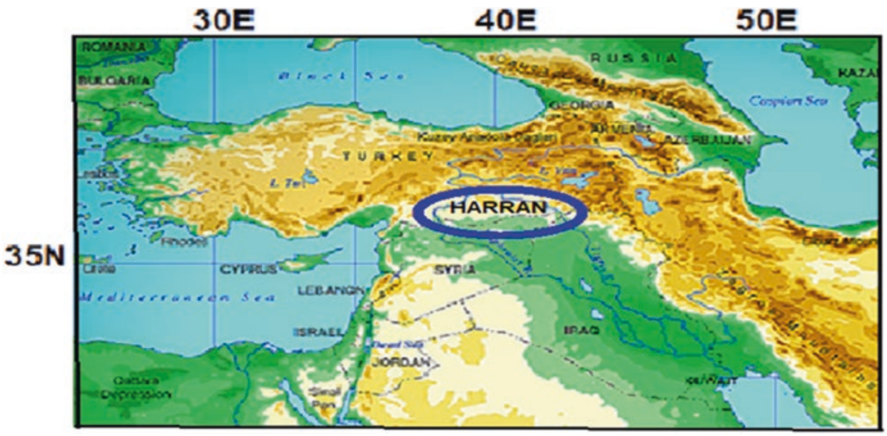


Fig. 23.11 The earliest civilization in the Harran Region (SE Turkey). (Base map from: It.wikipedia.org)

contains both proteins and carbohydrates, in contrast to rice, potatoes, and corn which are not (Fig. 23.12).

Wheat cultivation in SW Turkey (Harran) started around 10,400 BC and spread all over Anatolia, Mesopotamia, and Palestine. With the end of the Ice Age, Anatolia became habitable with the change of paleogeography. The earliest civilization moved northward and westward reaching to Thrace around 8 ka (possibly the Straits of Dardanelles and Bosphorus were not open as yet), and the civilization of Sumerians started around 6 ka (Fig. 23.13).

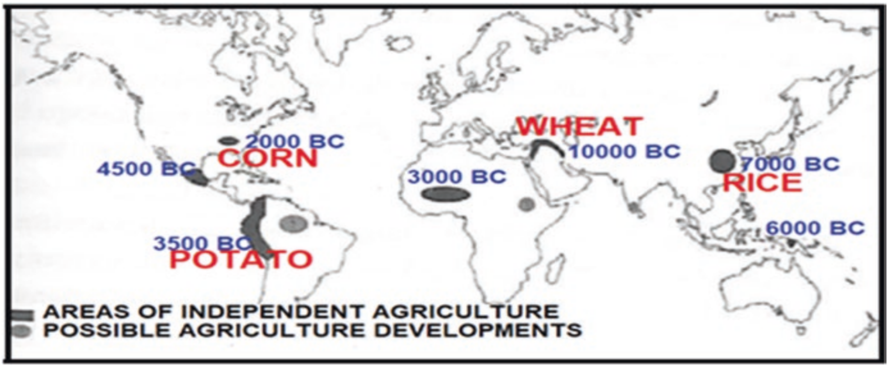


Fig. 23.12 Civilizations around the world. (From the book *Sapiens* of Harari)

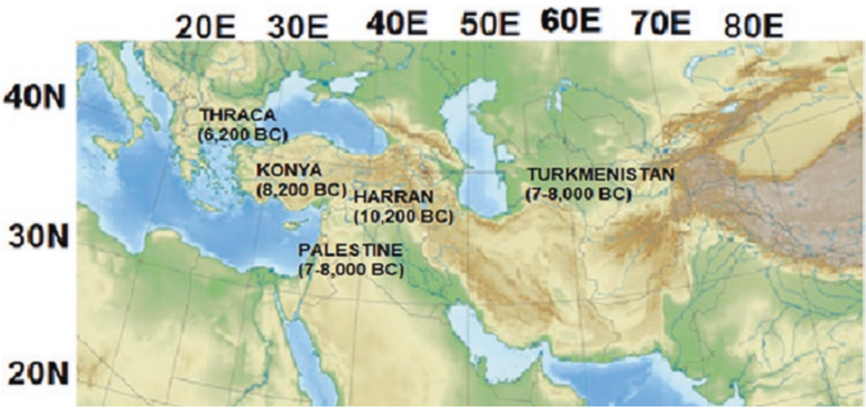


Fig. 23.13 Progression of wheat production from Harran plain (SW Turkey) around 10,200 BC. It reached to Konya region (Central Turkey) by about 8,200 BC and to Thrace by 6,200 BC and eventually to western Europe after 1,000 years later. (Base map from: It.wikipedia.org)

23.8 First Civilization in the World

There is a town and a lake named URMU in SW of Iran. UR means city in the old Turkish language, and it started as MU (People of Sun) which is the name of the lost continent (Churchward 1935). The term "UR" also means city in old Turkish. The first town that was established was called URFA (claimed to be founded by Noah), which again starts with UR. Antique sites of Gobeklitepe, which is about 10 km east of Urfa, have just been discovered, only a decade back, and it would give more insights into the prehistory of this area. The name "Göbekli Tepe" has not changed since its foundation (Schmidt 2012; Luckwert 2015). It means "abdomen hill" in Turkish.

The Harran Plain and the city of Urfa are very important sites for the development of the world civilization. There are Neolithic Age settlements going back to 10,000 BC (Fig. 23.14). Of course there is the civilization in the northern Syria at Abu Hureyra (near Rakka, along the Euphrates River) which was occupied earlier from ~13,000 to 6,000 years ago, before, during, and after the introduction of agriculture in the region. Abu Hureyra is remarkable for its excellent faunal and floral preservation, providing crucial evidence for the economic shifts in diet and food production. It was a permanent, year-round settlement of hunters-gatherers, who gathered over 100 species of edible seeds and fruits from the Euphrates valley and nearby regions. The settlers also had access to an abundance of animals, particularly Persian gazelles. The people grew domestic crops including rye, lentils, and einkorn wheat, but added emmer wheat, barley, chickpeas, and field beans, a switch from reliance on Persian gazelle to domestic sheep and goats.

Urfa, with its wealth of biblical associations, is regarded as a holy site by all faiths. In this connection, we have to understand the meaning of the coincidence of Brahman (India) and Abraham (Middle East). Probably, the meaning of these words is the "son of sacred woman." If we can explain the language connection between

Fig. 23.14 The location of the earliest civilization sites in Harran (SW Turkey). (Compiled from Schmidt 2012) at the Fertile Crescent (9–10,000 BC)

Sanskrit and Sumerian languages, we will get many answers as both have connection with the Caspian Region.

23.9 What Happened in the Western Caspian Sea?

The escape routes to the west Azerbaijan (the ancient name of this country is called Aran) through the Aras River (Ara Su which means pure water in Turkish) to the Ararat Mountain (AK Mountain in Turkish, meaning White "Sacred" Mountain). Aran means plain warm area or wintering place (Fig. 23.15). There is an Azerbaijan town called Nakhcivan (City of Noah) at the east of the Mountain Ararat. There are rock drawings at about 65 km west of Baku called Gobustan, dated 14 ka in Azerbaijan. There is a town and a lake named Urmu in SW of Iran. The word of UR/OR means gathering, trench, and castle wall (later evolved to be used for city). Probably this word was passed in Latin such as Organ, Organization, and Urban. Therefore, any place starting with UR means city like Urmu, Urfa, Ur, Uruk, etc.

Olive trees can grow SW of the Caspian Sea (the South of Azerbaijan and Resht area in the Caspian coast of Iran). Olive is "zirdum" in the Sumerian language. This word is "Zeytin" in modern Turkish. Olive was mentioned in the Noah Floods in the religious books as well as in the Gılgamesh stories in Sumerian writings. Therefore, we should follow the civilization steps from the Caspian Sea through the Aras River and Urmu area (SW Iran (Azerbaijan) between the passages of the Taurus and Zagros Mountains down to the most suitable area of the Harran Plains creating the first civilization of the world (about 12,000 years ago).

After the formation of deltas (5–6 ka), people had moved southeastward to Mesopotamia delta area and established several towns called Ur, Uruk, Lagash, and others creating early Sumerian culture and first writing in the world. Sumerians called themselves Kengers which is a Turkish tribe. Sumerian language is proto-Turkish (Cıg 2008; Gerey 2003). People of Sumerians called themselves as Karabashli (which means superior headed in Turkish). The people called Karaman

Fig. 23.15 West Caspian Sea area and the significant places: Ararat, Nakhcivan, Aras River, Urmu and Urmu Lake, Lake Van, and Gobustan

in Central Anatolia (Konya region) too have early civilization connections which go back to 7,000 BC in Çatalhoyuk. The word Karaman in Turkish means "I am superior."

Civilization of the world can be summarized as follows:

(a) After the Ice Age: Harran (10,000 BC, SW Turkey); Anau (6–8,000 BC, Turkmenistan); Konya (7,000 BC. Central Turkey); Palestine (7,000 BC); and Mehrgarh (7,000 BC, Pakistan)
(b) After the development of deltas: Mesopotamia (4,000 BC); Egypt (3,500 BC); Harappa (3,300 BC, Pakistan); Troia (4,000 BC, NW Turkey); and Harappa (3,300 BC; Pakistan)

These are summarized in Fig. 23.16. It is very clear that these early civilizations are closely related with the Caspian Sea region just after the end of the Ice Age. In the east of the Caspian Sea is Turkmenistan, where the archaeological site Anau was established 9 ka in the east of Ashgabat. The first archaeological site in the Indian subcontinent is in the north of Panjab, the Harappa, established in 5.3 ka which is long after Anau. Civilization most probably moved southeastward toward the Upper Panjab Valley following the outskirts of Afghan mountains. This early civilization Harappa goes back to 3,300 BC. There are very many similarities between the ruins of Anau and Harappa. The language of Sanskrit (which is not spoken now) has affinity with the Caspian region.

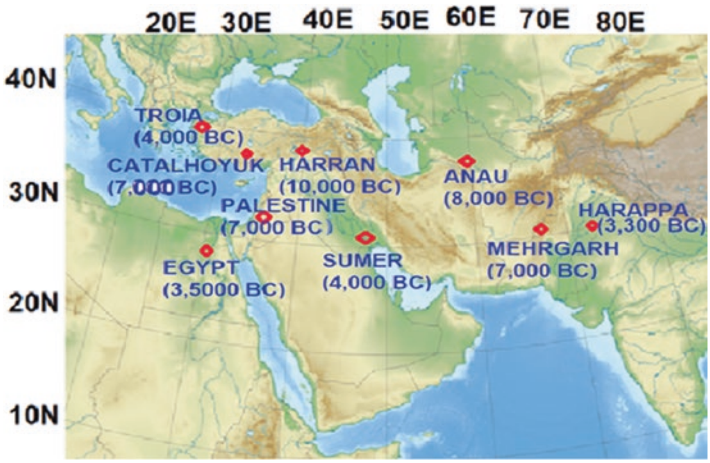


Fig. 23.16 Civilizations developed around the Caspian Sea. (Base map from: It.wikipedia.org)

23.10 What Happened in the Eastern Caspian Sea?

Pumpelly (1837–1923) carried out archaeological excavations near Ashgabat area of Anau (Anav) and Mari (Merv) in Turkmenistan in the early 1900s. He found the earliest civilizations around 9000 BC; cereals were produced, and domestications of sheep and goat in the region were noted (Fig. 23.17). The name ANAU is related with the God of Sky (as in Sumer). The areas where the main Anau culture developed are the mountain streams reaching the plains. At the end of the last Ice Age (120,000 years ago), they were concentrated around great fresh water lakes in order to survive with the wild animals and plants. This civilization moved westward along the Black Sea coast to Europe. We have to consider that the water level of the Caspian Sea fluctuated at almost 5/600 years cyclicity (Chepalyga 2007b).

North Indian Culture Mehrgarh is a Neolithic site (dated 7,000 BC) the west of the Indus River valley. This area was habitable during the Last Glacial Maximum (20 ka) and connected to the Anatolia via Kavir Desert and the Caspian Sea (Fig. 23.18). It may be contemporaneous with the Anau culture of Turkmenistan. The Harappa Culture is the civilization in the North of Panjab (Fig. 23.18); it is long after the cultures of Anau and Mehrgarh. Also the lost language of Sanskrit has roots in the Caspian Region. It is clear that the civilization moved eastward and southward following the mountain streams down to the North Panjab plains with the change of climate at the end of the Ice Age (12 ka).

Fig. 23.17 Archaeological sites in Turkmenistan and the Anau site in the east of Ashgabat. (Base map from: It.wikipedia.org)

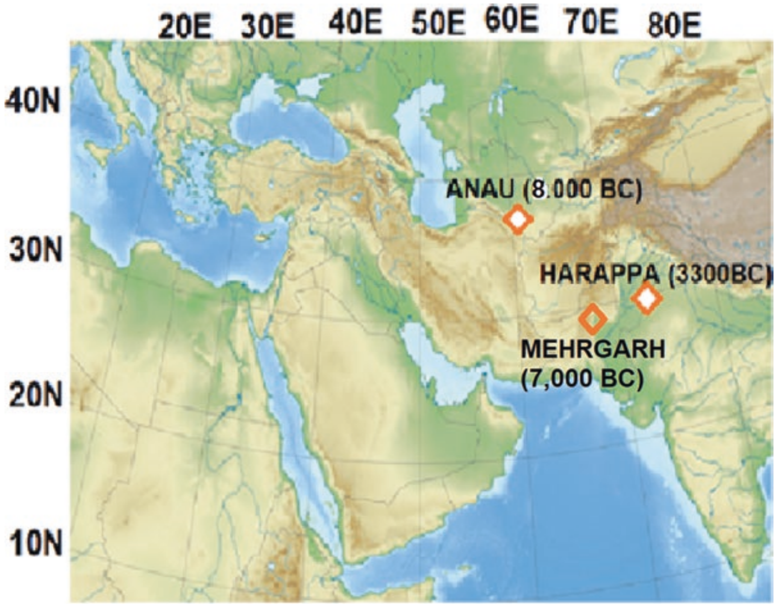


Fig. 23.18 Anau culture (8,000 BC) in Turkmenistan, Mehrgarh (7,000 BC and Harappa (3.300 BC) in the North Panjab (the earliest Indian cultures). (Base map from: It.wikipedia.org)

The LGM (20 ka) was much cooler and almost everywhere drier, even in the less affected regions, rainforest cover greatly diminished, and deserts expanded (Fig. 23.4). Exceptions were in Afghanistan and Iran, where a major lake was formed in the Dasht-e Kavir. Firdausi (eleventh century) mentioned the existence of a lake in this area. The Kavir National Park area is one of the crucial areas to understand the civilization during and after the end of the Ice Age (12 ka). Geographically this is at the very interesting location where the Alborz and Zagros mountain chains intercept (Fig. 23.19). The old towns of Qom (Kum), Kashan, and Rey (now Tehran) are placed at the shores of this lake which has disappeared now (almost). The name of Qom is probably the word "Kume" meaning "grouping, messing" in Turkish. This area was full of springs and watersheds, and shepherds would have come here to water their herds. With the progression of time, they established their tents in the area ending within the establishment of permanent living areas. If you go to the NW direction, you will reach to Urmu area in the Iranian Azerbaijan (the old name of Azerbaijan is Aran). This word Aran could have been changed to Eran and then to Iran eventually.

23.11 Oasis Theory

Pumpelly put forward the first theory of "Oasis, Fresh water Lake" from the archeological materials found with first agricultural activities of humans (Childe 1969). One of the first established cities, URFA in SE Turkey is stated as the city established

Fig. 23.19 Position of the Kavir National Park area in Iran. (Base map from: It.wikipedia.org)

by Noah in the biblical writings. It is around a sacred lake (Balikli Gol; Fish Lake). People in this region consider these fishes as sacred. There are also many caves around the hills in this city for the early dwellings of human beings. Civilization moved to Central Anatolia by 7–8,000 BC toward the lakes around Konya Plain (then it was a lake). The site of Çatalhöyük is dated back as 7,000 BC. The civilization reached to the Aegean coast by 4,000 BC (Fig. 23.20).

There is a saying which goes "Light Comes from the East." The civilization of the west has migrated westward from the near east. At the end of the last Ice Age (12,000 years ago), they were concentrated around great fresh water lakes and shared the area with wild animals and plants. This civilization moved westward along Anatolia and the Black Sea coasts to Europe. We have to consider that the water level of the Caspian Sea fluctuated at almost 5/600 years cyclicity. Çatalhöyük (Konya, Central Turkey) is an archaeological site dated 7,000 BC at about 52 km east of Konya in Central Turkey. It is an important Neolithic and Chalcolithic settlement area just around the Konya plain which was a lake just after the Ice Age (Fig. 23.21).

It is obvious that people moved to Çatalhöyük area about 9,000 years ago with the change of climate after the civilization in Harran at 10,000 BC. Konya region was a Pleistocene lake, and the early settlements were around this lake (Fig. 23.22). The name Konya was Kava (bull) Wana (country) in the Luwian language which

Fig. 23.20 Westward movement of civilization from the Harran Plain (Göbeklitepe, Urfa SE Turkey) following the lakes in Central Turkey (red-colored places are the early settlement areas in Anatolia). (Base map from: It.wikipedia.org)

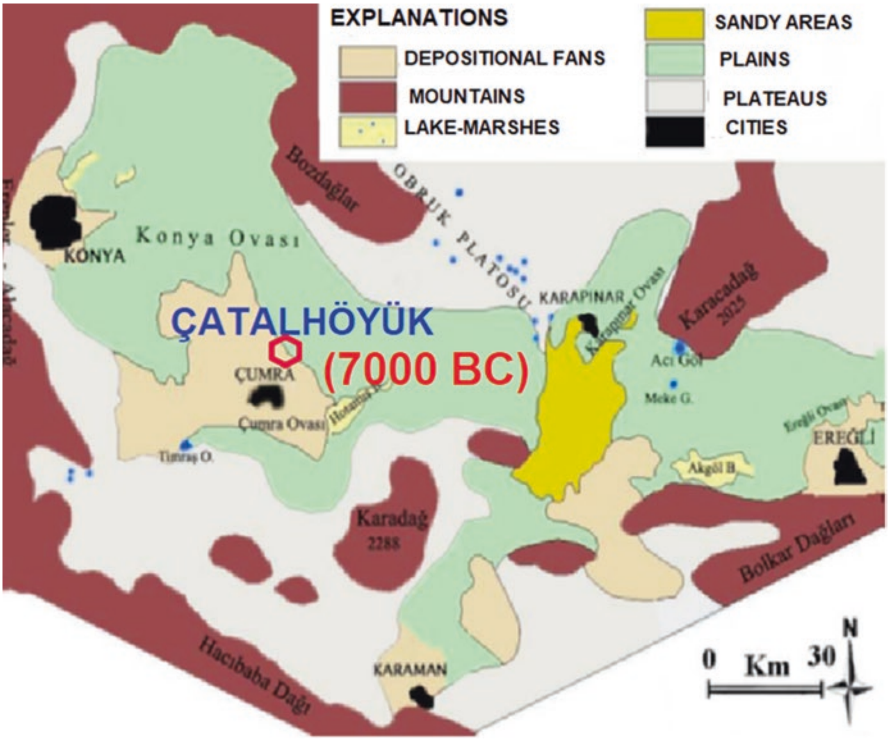


Fig. 23.21 Çatalhöyük archaeological site (Central Turkey). (Modified from Tapur 2009)

was the oldest Anatolian language. The name was given to them by Hittites for the people of Luwi (People of Light). Umar (1993) says that "These people never called themselves as Luwians"; they called themselves as "Mada" or "Amada." Mada or Amada means "People of Ma" in the Luwian language. The Luwian people had connections with the people of Harran and Harappa cultures. The Luwian language

Fig. 23.22 Luwian lands in Anatolia and distribution of the Luwian language (Zangger 2016)

is a Proto-Turkish language (Diker 2000). These people moved westward from the SE Turkey (Göbeklitepe) as the climate became warmer passing through the passages of the Taurus Mountains to the plains of Konya just after the Ice Age. They had given the place names in Anatolia. The rivers of Büyük Menderes, Küçük Menderes, Gediz, Bakırçay, and Karamenderes have very important delta plains, and they have significant effects on geomorphological changes during the geological period in western Aegean Shoreline. On these deltas, there were ancient towns such as, from south to north, Miletus, Ephesus, Smyrna, Pergamum, and Troia. With the end of the Ice Age, Anatolia had become habitable with the change of paleogeography. Anatolian people moved westward from the birth of civilization in SE Turkey (Harran Plain) after the cultivation of wheat—the starting date of agriculture (about 12 ka). Wheat cultivation reached Central Anatolia by 10 ka. In the meanwhile, Aegean deltas started to be formed at around 6 ka after the sea level reached the optimal status. All the towns of Miletus, Ephesus, Smyrna, Pergamum, and Troia developed on these deltas at around 5–6 ka.

The Greeks started to settle in Anatolia after occupying Troia around 1,200 BC. Therefore, the earlier Harran and Mesopotamia cultures were naturally transferred to the west through the Anatolian peninsula, through the Konya region in central Turkey, as stated by Zangger (2016).

23.12 Sumerian Culture

The territory is called Mesopotamia, “country between two rivers,” *where the* rivers of Tigris and Euphrates follow a tortuous course from the northwest to the southwest, traversing modern Iraq on their way to the Persian Gulf. This delta was formed around 5–6,000 ka during the very hot climate of the world where the sea levels almost reached optimum levels. Temperatures were higher during 3–4,000 BC, and ices were melted away very much during this period from the mountains of Eastern Anatolia. Euphrates and Tigris rivers and their branches flooded down and brought immense amount of sediments down to Mesopotamia. This was a worldwide phenomenon wherein the world’s ocean sea levels reached optimum level with the formation of deltas. This explains why the civilization moved from north to south (i.e., “proto-Euphrates” or “Ubaidians”). Therefore, the findings about Göbekli Tepe are going to change our ideas and views fundamentally (Fig. 23.23). Sumerians called themselves as karabashly people. “Kara” is noble in old Turkish, and “bash” is head, embodying the concept of civilized noble people. Sumers were such people that their language was the first language of the world.

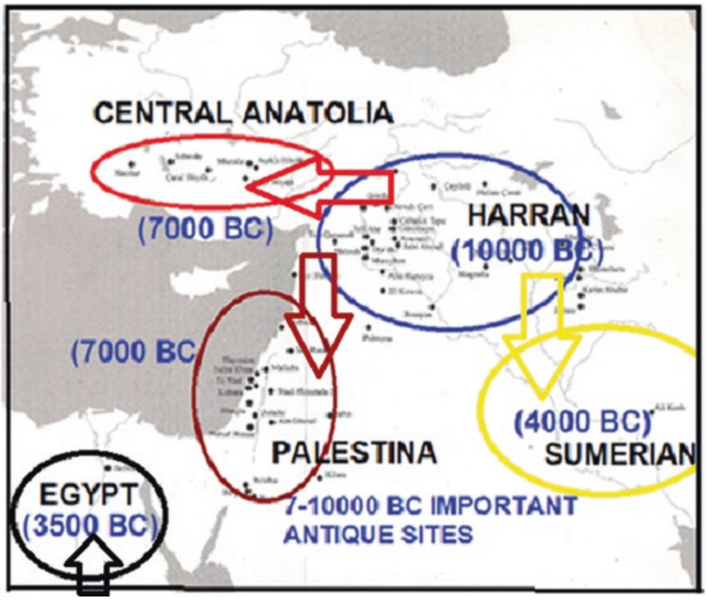


Fig. 23.23 Progression of the civilization to Central Anatolia (7,000 BC), Palestine (7,000 BC). Sumerian civilization (4,000 BC) and Egyptian (3,500 BC) civilizations were after the delta formations. (Compiled from Schmidt 2012)

23.13 Concluding Remarks

The *Caspian Sea* is the largest enclosed inland body of water on earth. It is surrounded by the Alborz Mountains in northern Iran and the Caucasus Mountains in the west. The east of the Caspian Sea is made up of the Karakum Desert of Turkmenistan. The north is made up of the steppes of Russia and Kazakhstan. We must understand the paleogeography quite well in accordance with climatic and environmental circumstances. During the Ice Age period (120 to 12 ka), all waters were kept in the polar regions up to 40–45° latitudes. From here down to the equator, all the earth's surface was covered with desert because of very little rain. Living things could only survive at the narrow band of the equatorial region and suitable places at the boundaries of 35–40° latitudes. The Southern Caspian Sea area had been the best place during the ice age (the Caspian Sea water level was probably -150/200 m then) for living. Noah Flood most probably occurred there with lash of water pouring down from the Aral Sea and Uzboy Strait at around 15 ka due to breakage of ice dam in the western Siberia. The words of "Hazar" and "Sefer" mean "Settled" and "On move" respectively in the Turkish tradition. Turkish people called the Caspian Sea as "Hazar" with a deep meaning in the Turkish history. I think it is time to give this sea its original name, "Hazar."

References

Berberian M (1983) The southern Caspian – a compressional depression floored by a trapped, modified oceanic crust. Can J Earth Sci 20:163–168

Chepalyga AL (2002) Morskie basseiny (Marine basins). In: Velichko AA (ed) Dynamics of terrestrial landscape components and inner marine basins of Northern Eurasia during the last 130,000 years. GEOS, Moscow, pp 165–213

Chepalyga AL (2007a) Noah's flood in Ponto-Caspian region: theory, influence on the Black Sea-Mediterranean Corridor, Noah's voyage reconstruction. In: Black Sea e Mediterranean Corridor during the last 30 ka: sea level change and human adaptation. Rosselkhozakademiya, Moscow, pp 35–37

Chepalyga AL (2007b) The late glacial flood in the Ponto-Caspian basin. In: Yanko-Hombach V, Gilbert AS, Panin N, Dolukhanov PM (eds) The Black Sea flood question: changess in coastline, climate and human settlements. Springer, Dordrecht, pp 119–148

Childe VG (1969) New light on the most ancient East. Norton & Company, London

Churchward J (1935) The children of Mu. BE. Books/Brotherhood of Life, Inc, New Mexico

Cıg MI (2008) Floods in Sumerians and Turks during floods. Kaynak Yayinlari, Istanbul, p 168

Diker S (2000) Anadolu'da On Bin Yıl; Türk Dili'nin Beş Bin Yılı. Oral Matbası, İzmir, 538 p

Dolukhanov PV, Chepalyga AL, Lavretova NV (2000) The Khvalynian transgression and the Caspianbasin. Quat Int 225:152–159

Ergün M (2016) General tectonic/geologic framework of the Caspian Sea and its water connection with the Black Sea and Mediterranean. In: Proceedings of CCCS-2016, Tehran-Iran

Gerey B (2003) 5000 years of Sumer-Turkmen connections, Berlin

Grosswald MG (1980) Late Weichselian ice sheets of Northern Eurasia. Quat Res 13:1–32

Luckwert WL (2015) Göbekli Tepe. Alfa Printing, Istanbul, 420 p

Mangerud J, Jakobsson M, Alexanderson H et al (2004) Ice-dammed lakes and rerouting of the drainage of northern Eurasia during the Last Glaciation. Quat Sci Rev 23:1313–1332
Ozturk M, Gul A (eds) (2020) Climate change and food security with emphasis on wheat. Academic, 384 p
Renfrew C (2008) Prehistory: the making of the human mind. Weidenfield & Nicolson, London
Schmidt K (2012) Göbekli Tepe. A stone age sanctuary in South-Eastern Anatolia. Exoriente, Berlin, p 286
Tapur T (2009) Eski Konya Gölü'nün ilk yerleşmelere etkileri. Karadeniz Araştırmaları 6(23):99–115
Umar B (1993) Türkiye'NİN Eski Yer Adları. İnkilap Kitabevi, Ankara, 565 p
www.innerx.net/personal/tsmith/iceciv.html. Accessed Jan 2020
www.It.wikipedia.org. Accessed 25 Jan 2020
Yanina TA (2014) The Ponto-Caspian region: environmental consequences of climatechange during the Late Pleistocene. Quat Int 345:88–99
Zangger E (2016) The Luwian civilization: the missing link in the Aegean Bronze Age. Ege Yayınları, İzmir, p 292
Zonenshain LP, Le Pichon X (1986) Deep basins of the Black Sea and Caspian Sea as remnants of Mesozoic back arc basins. Tectonophysics 123:181–211

Index

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-59928-7

H

Q

R