

Biological Resources of South Adriatic Aquatorium and Coastal Zone of Montenegro: Human Impact and Possibilities for Sustainable Exploitation



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Abstract The availability of biological resources, their diversity and quantity, structure and geographical distribution, as well as related questions, were always of prime economic, social, and political importance to humans. Regions of high biodiversity with all their applicative potentials are analytically incorporated in relevant geostrategic and geopolitical studies and regional sustainable developmental plans.

It is pertinent to ask ourselves with which biological resources and how many of them do we possess, what is their current and potential values, how are they distributed, and what are their long-term perspectives of conservation, restoration, and sustainable exploitation?

According to the IUEP-WCMC (UN Environment Programme World Conservation Monitoring Centre) criteria, the territory of Montenegro, together with the territory of other Balkan Peninsula countries: Greece, Albania, Bosnia and Herzegovina, Serbia, and Bulgaria, represents one of the six European or one of the 153 world's centers of biological diversity. The territory of Montenegro is characterized by high genetic, species, and ecosystem diversity, which appeared as a response from living beings to the geological, geomorphological, climatic and hydrological diversity as well as complexity of historical changes that have occurred in this area during the past.

Both the territory and South Adriatic aquatorium of Mediterranean part of Montenegro have high potentials for exploitation of some components of biodiversity. However, it is necessary to emphasize that the majority of natural ecosystems have been exploited for centuries and that their recent state is different from climatogenic, since they represent progradation-degradational derivatives of climazonal ecosystems still under anthropogenic pressure and constant stress.

Concerning these facts, it is clear that in the present and future, exploitation of the components of biodiversity in the Mediterranean part of Montenegro has to be based on the principles of sustainability. Practically, this means that the components of biodiversity cannot be exploited without control, especially without a previous assessment of their quantity, model of use, conservation status, fragility, and renewable of resources.

In this paper the threat and degree of human impact, possibilities and regime of biodiversity exploitation were presented, for each natural ecosystem of the Adriatic part of Montenegro, in general.

For the purposes of preparing this paper, no special new field research was done, but a comparative analysis and synthesis are made by using existing scientific references, as well as actual relevant strategic documents of Montenegro.

Keywords Adriatic Sea, Biodiversity, Biological resources, Coastal zone of Montenegro, Sustainability

1 Introduction

1.1 Biodiversity

The term and concept of biodiversity today represent a commonly used expression in the biological sciences, and it has become a customary word. It was born as “BioDiversity,” at the session of the National Forum on BioDiversity held in Washington, D.C. in September 1986, under the auspices of the National Academy of Sciences and the Smithsonian Institution. At the Conference for Sustainable Development, held in Rio de Janeiro in 1992, the Convention on Biological Diversity (CBD) was created and adopted by governments when world leaders agreed on a comprehensive strategy for biodiversity conservation and sustainable development. The Rio Conference recognized the invaluable importance of biodiversity protection for the concept of sustainable development.

Convention on Biological Diversity defined this term as: *the variability among living organisms from all including inter alia, terrestrial, marine, and other aquatic ecosystems and ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*. Thus, the term can be considered a synonym for «life on Earth» [1].

The convention has three main goals: (1) conservation of biological diversity, (2) sustainable use of its components, and (3) fair and equitable sharing of benefits arising from genetic resources. In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development.

From the Rio Conference biodiversity has moved to the center stage as one of the focal issues, as well as one of the major scientific and political concerns worldwide. Ergo, what is it, and why its protection and conservation are so important? Biodiversity is the variety of all living things and their interactions. Scientists often speak of three levels of diversity: genetic, species, and ecosystem diversity. In effect, these levels cannot be separated. Each one is equally important, interacting with and influencing the others. A change at one level can cause changes at other levels.

Species and ecosystems they inhabit are permanently linked. The conversion or loss of ecosystems inevitably impairs the species that depend on them. Furthermore, changes in the life cycle of one species could have an impact on the life cycles of many other species (including human), alter ecosystems and their functions, and contribute to the local, regional, and ultimately global changes [2–5].

A total of 14 meetings, staged in the form of conferences between the signatory parties of the Convention on Biological Diversity, have been held since the Rio Conference. The Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 10, CBD) was held in Nagoya, Japan in October 2010. The importance of this conference is evidenced by the fact that a Strategic Plan for the 2011–2020 period was adopted at this conference, otherwise referred to as the Aichi Target and including 20 targets organized under five strategic goals. Member states were invited to create their own targets within a flexible framework, taking into consideration national needs and priorities and taking into account the attainment of global targets. The member states agreed, among other things, to halve, or where feasible reduced to close to zero, the rate of loss of natural habitats including forests, as well as to set a target of 17% of terrestrial and inland water areas and 10% of marine and coastal protected areas by 2020. At some conference, the EU member states as their Aichi Target until 2020 have recognized 20% of terrestrial and inland water areas and 20% of marine and coastal protected areas by 2020. Moreover, one of the targets is to prevent the extinction of known threatened species and improve their conservation status. On 22 December 2010, the UN declared the period from 2011 to 2020 as the UN Decade on Biodiversity.

As its Aichi Target until 2020 Montenegro has recognized an increase in the share of 10% of protected terrestrial and inland water areas and 10% of marine and coastal ecosystems, as well as an increase in the area under forests in 54% of the country's territory [6].

1.2 Benefits of Biodiversity

Biodiversity provides valuable ecosystem services free of charge, provides food, fuel, and fiber, provides shelter and building materials, purifies air and water, detoxifies and decomposes wastes, stabilizes and moderates Earth's climate, moderates floods, droughts, wind, and temperature extremes, pollinates plants, provides traditional medicines and high-tech pharmaceutical products for control pests and diseases, maintains genetic resources as key inputs to crop varieties, livestock breeds, and medicines, provides cultural and esthetic benefits, provides us the means to adopt to change. Life, as we know it, will not be the same if our rich heritage is dramatically altered [7, 8].

1.3 The Major Causes of Biodiversity Loss and Species Extinction

Scientists have coined an acronym **HIPPO** to denote the five primary causes of species decline and extinction: **H**abitat alteration, **I**nvasive species, **P**ollution, **P**opulation growth of human, **O**verexploitation (Overharvesting of species from the wild and **O**verconsumption of resources).

The rapid loss of biological diversity around the world should be setting off alarm bells. We are well on our way to the sixth global extinction of species in the history of the planet, and States are still failing to halt the main drivers of biodiversity loss, including habitat destruction, poaching and climate change. What is less well understood, is that the loss of biodiversity undermines the enjoyment of a wide range of human rights, including rights to life, health, food and water (John H. Knox, UN Special Rapporteur on human rights and the environment on World Wildlife Day Geneva, 1 March 2017).

1.4 Sustainable Development

The United Nation defines sustainable development as: *development that meets the needs of the present without compromising the ability of future generation to meet their own needs* [9]. Sustainability depends, in large part, on ability of the current human population to limit its environmental impact. For the successful future of both human civilization and nature, it is necessary that sustainability is maintained through the balanced contribution of their three integral elements (environment, society, and economy), achieved by adequate global policy. Environmental scientists recognize that human civilization depends on an intact and functional natural environment; in fact, civilization cannot exist without it. The human species depends on biological diversity for its own survival.

1.5 Biodiversity and Biological Resources as a Key Factor for Sustainable Development

Biological resources – genes, species and ecosystems that have actual or potential value to people are the physical manifestations of the global biological diversity. The availability of biological resources, their quantity and diversity, structure and geographical distribution, as well as other related questions, were always of prime economic and political importance for each country. Moreover, regions of high biodiversity with all their applied potentials, as well as their geographical position and human resources, are analytically incorporated both in the relevant geostrategic and geopolitical studies and regional developmental plans.

Biodiversity is a significant factor in the ability of natural systems to provide us with ecological goods and services. Human activities are themselves driven by economic, social, and environmental forces. Biodiversity therefore provides a large number of goods and services that sustain our lives. The serious and continuing loss of biodiversity is a reflection of the ongoing decline in the ability of ecosystems to sustain their natural production capacity and perform regulating functions. Concerning these facts, it is clear that in the present and future, exploitation of the components of biodiversity (biological resources) has to be based on the principles of sustainability. Practically, this means that the components of biodiversity cannot be exploited without control, especially without a previous assessment of their quantity, model of use, conservation status, resources fragility, and reproducibility of resources. The “ecosystem approach” espoused by the Biodiversity Convention acknowledges that our relations with the rest of the living world are truly interactive, and that what we do to nature will in turn reflect on nature’s ability to respond to our own needs. The convention foresaw a careful balance in the management of the Earth’s living wealth through conservation, sustainable use, and equitable sharing of cost and benefits [10].

1.6 Montenegro as Ecological State

On the session held on September 20, 1991 at Žabljak, the Parliament of Montenegro set out for the future its relationship with nature and adopted the Declaration of Montenegro as an Ecological State, which also states the following: *Bearing in mind our debt to nature, a source of health and our inspiration for freedom and culture, we are devoting ourselves to its protection for the sake of our survival and the future of our posterity.* . . . By adopting this Declaration, Montenegro defines its attitude toward nature as a state policy. International promotion of this Declaration was done in UN Conference on Environment and Development “Earth Summit” held in Rio de Janeiro in 1992. The Declaration was included in the documents of the Conference (A/Conf. 151/21).

Montenegro has developed a National Sustainable Development Strategy until 2030, which has given a vision of the future economic, social, economic, ethical, and cultural development of Montenegro, that is, long-term sustainable use and management of resources, bearing in mind the right of future generations to a quality life. This strategy until 2030 predicts a 20% reduction in the use of natural resources, [11, 12].

Finally, the State adopted the Spatial Plan of Montenegro until 2020. One of the clear goals defined in the Plan is *sustainable development of the coastal area, applying the principles of sustainable development and integrated coastal management instruments of public interest to Montenegro, including the priority of resolving the most significant, numerous problems and opposites, especially those related*

to spatial planning. Planning of marine waters and better use of resources and potentials of special value. Therefore, marine fisheries are of particular importance for the economic development of coastal countries such as Montenegro, which has valuable but underutilized resources in this sector [12–14].

In Montenegro, valuing the services provided by ecosystems and taking into account the real costs of using biodiversity in decision-making (in resource management, in development plans) is unfortunately still a rarity. The value of services provided by protected areas in Montenegro is estimated at around € 68 million in 2010 (2.2% of GDP or € 106 per capita), which is unfortunately not accompanied by an adequate allocation of funds for the management of these areas.

The basic value of selected parts of biodiversity and ecosystem services in the Montenegrin economy is estimated at € 982 million. Product provision services (wild edible species, livestock feed, wood biomass, and energy) contributed to the total value with about € 169 million or 17%, regulation and maintenance services, (fertility of cultivated land, pollination, protection of catchment areas and coastal areas, mooring carbon) with €276 million or 28%, while the category of cultural services (landscape and outdoor recreation services) contributed to the total value with €537 million or 55%. The total value of these ecosystem services exceeded the gross value of production realized in agriculture, forestry, and fishing (which in 2011 amounted to €425 million) by 2.3 times [15].

The coastal zone of the Montenegro, in addition to the high level of abiotic and biotic diversity, is also characterized by a high level of cultural features which in the best way confirm the possibilities of natural, cultural, and economic sustainability.

Ulcinj, Bar, Petrovac, Budva, Tivat, Kotor, and Herceg-Novi have remained typical coastal towns. Modern urbanization has not destroyed their Mediterranean soul, enriched by a singular mixture of religions and cultures. The old well-preserved town centers are precious monuments of bygone days, but they are as much a part of everyday life as are the modern-day buildings. The ancient palaces, ramparts, churches, cathedrals, towers, fortresses, defensive city walls, castles, monasteries, summer houses, and royal residencies are not just museums but places where people still live and work. Almost 70% of all historical and cultural monuments of the whole of Montenegro are situated on the territory of the Municipality of Kotor.

Due to all stated above, it is more than justified that the Boka Kotorska Bay (inner part from the Verige Strait – the Kotor-Risan Bay) was included in the UNESCO's list of cultural and natural heritage of the humankind, by the World Heritage Committee at the Conference held on 22–26 October 1979, in Cairo-Luxor (Egypt), for the purpose of preservation and valuation of authentic geological, geomorphological, biological, and cultural heritage [16, 17].

2 The Main Geographical Characteristic of Coastal Zone of Montenegro and South Adriatic Aquatorium

The Adriatic is one of the cleanest and most transparent warm sea, linked to the Central Mediterranean by the Strait of Otranto. It is widest between Montenegro and southern Italy (about 200 km). South Adriatic is differentiated from other parts of the Adriatic by the biggest water mass of 26,000 km³, compared to the total of 32,000 km³ of sea in the entire Adriatic, with the deepest part of the sea of 1,330 m (at a point 120 km southwest of Boka Kotorska Bay), the fastest sea currents (42–88 cm/s, which is up to 6 times the speed of the current in other parts of the Adriatic), more intensive direct water exchange with the Mediterranean as well as the greatest water transparency, reaching up to 60 m [18–23]. Water from the Ionian Sea got into the Adriatic Sea via the eastern part of the Strait of Otranto and generate the Eastern Adriatic Current which goes along the eastern coast of the sea from the south to the north, forming three gyres – South Adriatic Gyre, Middle Adriatic Gyre, and North Adriatic Gyre. Generally, currents flow contraclockwise from the Strait of Ontario, along the eastern coast and back to the Gulf along the Italian coast [24], (Fig. 1).

Interior waters of Montenegro cover about 360 km², territorial water (extending 12 nautical miles or 22,22 km from the coastline) are about 2,000 km², and the epicontinental zone is around 3,900 km². The total sea area of Montenegro comes to about 6,400 km² approximately one half of its land territory which is 13,912 km² (Fig. 2).

The Montenegro coast is very rugged. The coastline indentation ratio is about three: the full length of the coastline is 293.5 km, but only 90 km of aerial line. Montenegrin coast itself covers a narrow strip of land extending from Debeli Brijeg on the north-west to the Bojana River on the south-east of which about two-thirds (200 km) faces the open sea, and one-third 105.7 km belongs to the Boka Kotorska Bay. There are only a few small islands in Montenegrin water, with a total island coastal length of about 11.1 km [17].

The Montenegrin coast is divided into three parts from north to south – the Boka Kotorska Bay, the central part of the coast known as the Budva Riviera and the Bar-Ulcinj Region. There are numerous bays, inlets, flysch-like, and sandy parts of the coast (beaches) with limestone capes (cliffs), spurs, crests, famous for numerous rock shelters and caves. Throughout the length of the coast 52 km are sand beaches. The longest beach in the southernmost part on the Mediterranean coast is Velika Plaza in Ulcinj 13 km long and with an average width of 50 m, with finest sand imaginable. Many other, length from several hundred meters to kilometer are: Tršteno, Jaz, Mogren, Slovenska Plaža, Bečići, Kamenovo, Pržno, Miločer, Sveti Stefan, Petrovac, Lučice, Čanj, Sutomore, Topolica, Veliki Pjesak that in Bečići was declared Europe's most beautiful beach in 1936. Among many bays (Budva, Bar) and coves (Petrovac, Buljarica, Čanj, Ulcinj) the most beautiful of them being Boka Kotorska Bay [27]. Boka Kotorska Bay consisting of four smaller basins (Herceg-Novi, Tivat, Risan, and Kotor), crisscrossed by inlets and cutting deep into the

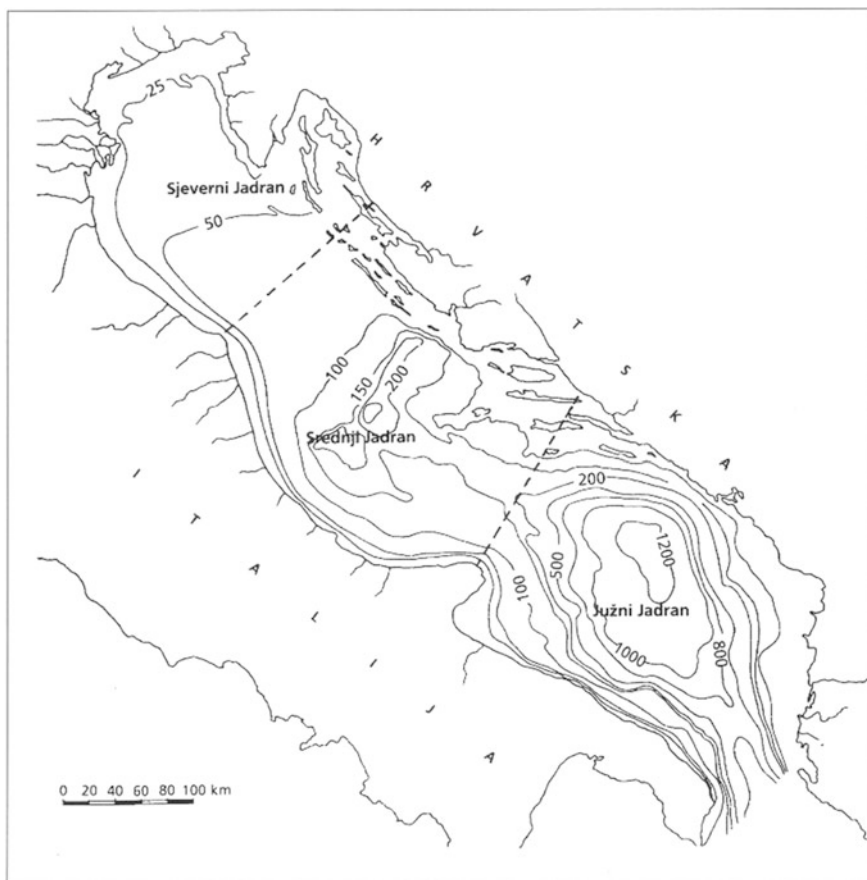


Fig. 1 Map of Adriatic Sea with isobaths and three sectors North (Sjevni), Middle (Srednji), and South (Južni) Adriatic (Jadran) ([19], according to [25])

mainland, is one of Europe's most beautiful bays and the world's southernmost fjord. From north-west to north-east, Montenegrin coast is surrounded by steep slopes of mountains Orjen (1895), Lovćen (1749), Sutorman (1180), and Rumija (1595) that divide it from the hinterland – the karst area and the Zetsko-Skadarska Depression (Fig. 3). The littoral is very narrow. It is widest in the region of Boka Kotorska Bay (about 10 km) and narrowest at Paštrovići (less than 2 km) [17, 28].

In terms of climatic characteristics, the coastal zone of Montenegro and the Southern Adriatic belong to the subtropical climate zone. The climate of this region is primarily determined by the cyclonic and anticyclonic activity over the middle and southern Europe. Cyclones usually travel from west to east over the Adriatic Sea. In summer the spur of Azores Anticyclone creates the steadily dry and warm summer with cloudless sky. In winter cyclonic activity determines the soft, humid, and cloudy winter with accidental sunny period [24]. The average annual precipitations

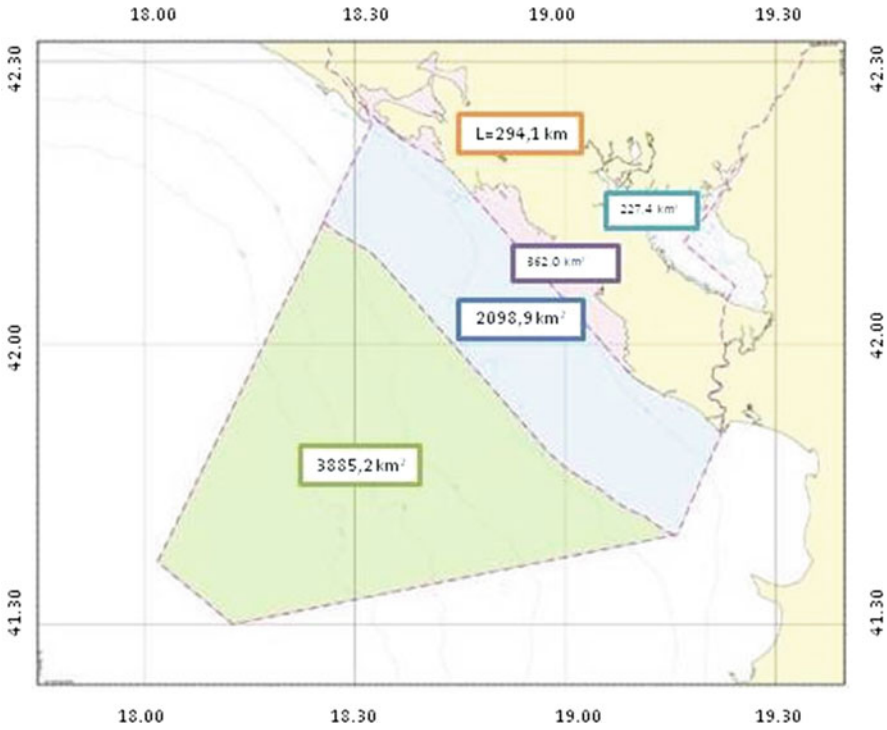


Fig. 2 The territorial waters and epicontinental shelf of Montenegro [12, 19, 26]

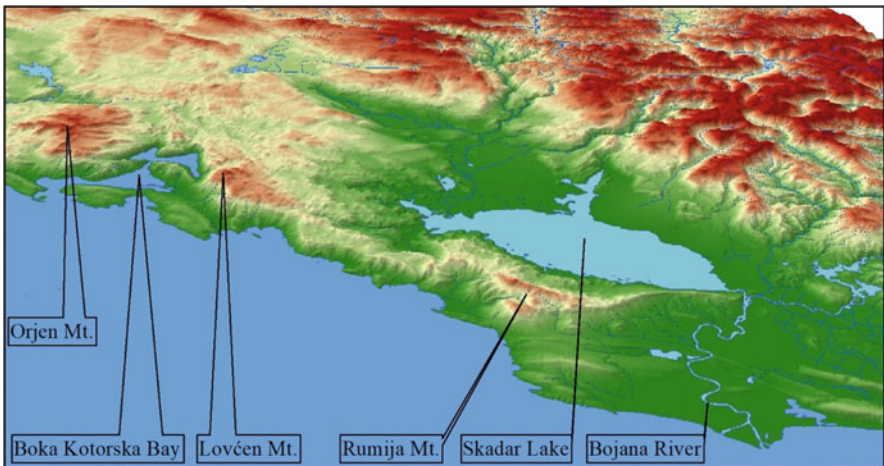


Fig. 3 3D Model of Montenegro coastal zone [28]

are around 1,700 mm, while the highest annual average precipitations in the area of the Orjen Mt. (Crkvice) ranging from 3,000 to 5,000 mm (maximum was recorded in 1938 year – 8,063 mm). The mean annual air temperatures of the entire Montenegrin Coast are high from 14.8°C Tivat, 15.4°C Bar, 15.5°C Budva, 15.9°C Ulcinj, and Herceg-Novi 15.9°C. The extreme maximum air temperature recorded in Herceg-Novi is 42°C [17] (Fig. 4).

Apart from precipitations and temperatures, it is the winds, their direction, frequency, and notably intensity, that form an important climatic element of the coastal zone of Montenegro. Winds characteristic for this region are *Bora*, *Sirocco*, *Mistral*, and *Tramontane* [17, 24]. *Bora* is typical for the whole eastern Adriatic coast. *Bora* blows from the north and north-east. It is mainly katabatic strong anticyclonic, rarely cyclonic wind, plummeting temperatures, reducing cloudiness and air humidity. In the area of the coastal zone of Montenegro, *Bora* “flows over” the mountain massifs of the Orjen Mt., Lovćen Mt., and Rumija Mt. bringing significant temperature drop. The *Bora* speed may reach 40 m/s and may cause extreme and dangerous situation in the coastal area including overturn cars and boats. *Bora* as a wind has a significant effect on the seawater quality in the Bay, since it creates short and strong waves, particularly in winter, which significantly contributes to seawater aeration, that is, increases dissolved oxygen levels. *Sirocco* is a warm wind from the southern quadrant, bringing clouds and heavy rainfall. Sometimes it blows for several days at the same speed, as a strong, but rarely stormy wind. When strong south flow of Africa, bringing volcano dust or volcano ash penetrates the warm cyclone sector from the Western Mediterranean, it can cause yellow or red rain in the Montenegrin coast. In winter it can reach, it can reach the hurricane magnitude with maximum wind force may reach 7 points. It may be also followed by a storm with waves 3–4 m high. Sometimes, *Bora* and *Sirocco* blow throughout the year, but they blow more frequently during the winter half of the year *Mistral* is southwest and west wind. It is an even, clear sky wind blowing from the sea toward the land, bringing pleasant refreshment in hot summer days. It is very good for sailing. *Tramontane* is summer daytime north-western wind which waves in South Adriatic may reach their maximum of 4 m height.

3 The Main Characteristic of the Biodiversity of Montenegro

According to the IUCN-WCMC criteria, the territory of Montenegro, together with the territory of other Balkan Peninsula countries: Greece, Albania, Bosnia and Herzegovina, Serbia, and Bulgaria, represents one of the six European or one of the 153 world’s centers of biological diversity. Globally, Montenegro is one of the “hot spots” of biodiversity in the Mediterranean. The territory of Montenegro is located in two basic bio-geographical regions (Mediterranean and Alpine). In

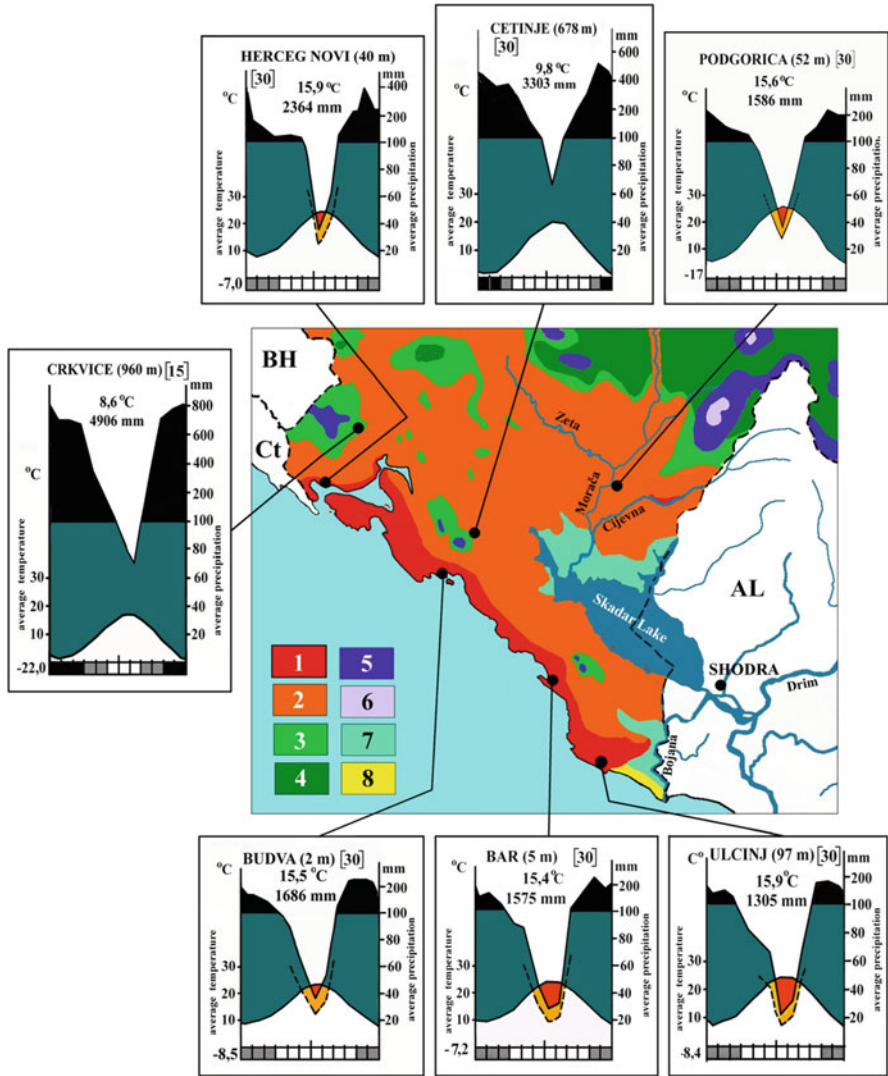


Fig. 4 Ombrothermic climatic diagrams [29] (after Walter and Lieth, 1960) of Mediterranean part of Montenegro with map of potential natural vegetation [30]. Legend: 1. Mediterranean evergreen forests, maquis, pseudomaquis, and garigue; 2. Various sub-Mediterranean thermophilous deciduous forests and scrubs; 3. Mediterranean mountain beech forests; 4. Montane beech forests incl. Fir-beech mountain belt; 5. Subalpine white-bark pine forests; 6. Alpine vegetation on limestone above upper timberline; 7. Hydrophilous forests and marsh vegetation; 8. Coastal sand dune vegetation [17, 31]

relation to the small area of 13,912 km², the Montenegrin territory covers a wide range of ecosystems and habitat types [27, 32, 33].

The main characteristic of the biodiversity of Montenegro is a high concentration of different species and ecosystems in limited area. On the territory of Montenegro from Adriatic Sea to Prokletije Mt., Durmitor Mt., and Bjelasica Mt. along the aerial distance not longer than 100 km, nearly all zonobiomes of Europe with more different ecosystems are present: marine ecosystem, freshwater ecosystems (eutrophic lakes, rivers), terrestrial ecosystems of coastal zone (sand and pebble coastlines, salt marshes, ecosystem of peat-bogs, eu-Mediterranean evergreen sclerophyllous, and sub-Mediterranean deciduous forest, scrub, and pasture), ecosystem of montane and subalpine beech and white-bark pine coniferous forests, ecosystem of scrub and grassland above timberline, and arctic and alpine tundra-like type vegetation.

High concentration of different species and ecosystems in a limited area, sometimes represented as “Europe in small,” indicates that most of the ecosystems distributed in limited areas are enclaves distant from the borders of main biomes in Europe. Besides, all basic types of ecosystems and landscapes in Montenegro have an adequate biome equivalent in Europe, but are specific in numerous endemics, particularly locally endemic species (the globally important component of biodiversity), special physiognomy and structure, thus emphasizing uniqueness and complexity of the biodiversity of Montenegro [27, 32, 33].

Extremely high diversity of Montenegrin habitats is presented in detail in the Catalog of Habitat Types in Montenegro, which was realized within the project Establishments of Natura 2000 network – Montenegro during 2017 and 2018 year. On the territory of Montenegro total 86 habitat types are recognized under eighth broad categories: Coastal and halophytic habitats (12), coastal and inland sand dunes (15), moderate peaks and shrubs (5), sclerophyll shrubs (6), natural and semi-natural grass formation (16), peats, swamps, and marshes (4), rocky habitats and caves (8), forests (20) [29].

Very high habitats diversity of Montenegro is also recognized in the framework of seamless vector database [18] which follows standard methodology of CLC 2000 (Corine Land Cover) as a part of European Commission program to CORINE – COoRdinate INformation of the Environment Habitats Codes by EEA (European Environmental Agency, 2006) aiming to provide information about land cover resources, environmental monitoring, and national/regional spatial planning strategies. Illustration of very high habitat diversity of Montenegro territory is the data that CLC in Montenegro is characterized by 32 out of 44 classes (total European) of the third level CORINE Land Cover Nomenclature. Only on the territory of the catchment area of Skadar Lake Region we can recognize 28 out of 44 classes of the third level CORINE Land Cover Nomenclature [30].

With some 3,600 plant species, the diversity of flora in Montenegro is among the largest in the region. The S/A ($S = \log$. Number of species; $A = \log$. Surface area of Montenegro) index for vascular plants in Montenegro is 0.858 – the highest recorded value in all European countries. A total of 223 endemic species and subspecies of plants were recorded. The density index of nesting birds in Montenegro is 0.557, which is significantly above the average in the Balkans of 0.435. Numerous areas of

international importance with rare, endemic, and endangered species have been identified in Montenegro: Areas of international importance for birds (Important Birds Areas) include 20 areas, four of which are located in the coastal zone of Montenegro: the Bojana River Delta, Skadar Lake, Rumija Mt., and Tivat Salts. Areas of importance for plants (IPA) includes a total of 22 localities, of which five belong to the coastal zone including Orjen Mt., Lovćen Mt., Rumija Mt., Skadar Lake, and Great beach in Ulcinj [27].

A review of available literature data can conclude that the Montenegrin coast is inhabited by 1,540 plant species, 113 lichens, 283 mosses, 232 fungi, 289 invertebrates (except insect species), 18 amphibians, 38 reptiles, 249 birds, and 69 mammals. Based on zoogeographical belonging the Montenegrin coast is distinguished by cosmopolitan species (widespread throughout the world); Holarctic species (inhabiting the northern hemisphere); palearctic species (inhabiting Europe, Asia, and North Africa); Mediterranean species (which may be considered Mediterranean endemics); and endemic species that inhabit a more or less limited area (eastern/western Mediterranean endemics, Adriatic, Balkan, Dinaric, Montenegrin, etc.) [21].

Areas protected under national legislation cover almost 125,000 ha or 9.05% of the total territory. There are five national parks (NP): Biogradska Gora, Durmitor, Prokletije, and two NP Lovćen Mt. and Skadar Lake which are located in the coastal zone. In addition, several sites are protected under international agreements. NP Durmitor has been on the UNESCO World Natural Heritage List since 1980 due to its exceptional universal values. Together with the canyon of the River Tara (the total area of the NP and the area of the canyon is close to 183,000 ha) it has been part of the UNESCO network Man and Biosphere Reserves (MAB) since 1977. Kotor-Risan Bay is also on the World Cultural and Natural Heritage List. Ramsar sites include Skadar Lake National Park (20,000 ha) and Tivat Saltworks (150 ha). A total of 307 plant species are protected by national legislation, including the Mediterranean tape weed *Posidonia oceanica*, 111 fungi, and 430 animal species (11 species of fish, 16 species of amphibians, 26 species of reptiles, 298 species of birds, 10 species of mammals + all species of bats) [15].

As a parties of the Berne Convention for the Protection of European Wildlife and Natural Habitats, Montenegro has developed (established) a list of 32 candidate areas for the Emerald Ecological Network of Areas (also defined as Areas of Special Interest for Conservation at European Level – ASCIs), covering a total of 234,399 ha, of which 12 are located in the coastal area or at sea: Skadar Lake, Great beach with Ulcinj Saltworks; Buljarica; Tivat salt; Šasko Lake; River Bojana, Knete, Ada Bojana; Kotor-Risan Bay; Orjen; Pecin beach, Spas hill in Budva; Katici, Donkova and Velja seka and Platamuni. Three areas have been identified for the proposal of marine protected areas: Platamuni, the Islands of Katica, and the Island of Stari Ulcinj [27]:

Marine species requiring special habitat protection measures (according to Resolution No. 6 of the Berne Convention) associated with the proposed Emerald sites are: dolphin (*Tursiops truncatus*), guinea pig (*Phocoena phocoena*), sea turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), sea lamprey (*Petromyzon marinus*), Adriatic sturgeon (*Acipenser naccarii*), Eleonora's falcon (*Falco eleonorae*),

seagull (*Laurus genei*), Mediterranean seagull (*Laurus melanocephalus*), Pygmy cormorant (*Phalacrocorax pygmaeus*), Arctic duck (*Gavia arctica*), Common duck (*Gavia immer*), red-throated duck (*Gavia stellata*) [27].

Through the Regional Center for Special Protected Areas (RAC/SPA), UNEP/MAP supported research on marine biodiversity (benthic and fish communities) in order to identify potential marine protected areas (MPA) in Montenegro [34]. Through projects, initiatives, and field research various techniques were applied for rapid key assessments habitats and biocenoses, qualitative and quantitative assessments benthic communities, for qualitative and quantitative assessments condition of *Posidonia oceanica* meadows (which are in several locations degraded and in regression, while the best preserved are still in front of Petrovac, Buljarica, and in the Bay of Trašte) as well as to assess damage from illegal and unsustainable fishing, collection practices, and other illegal activities along the coast. The research was completed in 2011 and covered more than 20 locations along the entire coast. Based on the detected habitats and benthic and fish communities that are important for protection, the following recommendations are given [34]:

- Protection from the aspect of fishing: Platamuni (from Cape Platamuni to Cape Žukovac) and Albanian Seka (in order to enable the regeneration of the fish stock, it is recommended to establish two or three no-take zones);
- Prevention of “harassment” caused by diving and tourism: in the area near Petrovac (Katič Island and Dubovica);
- Protection of coral reefs and sponge communities in the Bay of Kotor by establishing micro-reserves to protect communities from mechanical damage;
- Protection of the area from Cape Mendra (lighthouse) to Old Ulcinj by establishing a protected marine area;
- Additional research is needed for the Islands of Sveti Nikola and Mamula.

4 Review of the Basic Types of Ecosystems of the Mediterranean Part of Montenegro: Threat and Degree of Human Impact, Possibilities and Regime of Exploitation of Biological Resources

Based on the high-level diversity of the abiotic factors, it is more understandable why the waters of the Southern Adriatic and the coastal zone of Montenegro are characterized by high genetic, species, and diversity of ecosystems. The richness and diversity of the living world appeared as an evolutionary response from living beings to the geological, geomorphological, climatic, and hydrological diversity as well as the complexity of historical changes that have occurred in this area during the past.

Both the territory and the aquatory of the Mediterranean part of Montenegro have high potentials for exploitation of some components of biodiversity. However, it is necessary to emphasize that the majority of natural ecosystems have been exploited for centuries and that their recent state is different from the climatogenic, since they

represent progradational-degradational derivatives of climazonal ecosystems still under anthropogenic pressure and constant stress. Concerning these facts, the exploitation of components of biological diversity of some ecosystems has to be harmonized with their state and sustainable capacities, where the establishing of critical points of sustainable capacities of each ecosystem is the prerequisite for rational and long-term exploitation of its biological components. The threat and degree of human impact (**TDHI**), possibilities of biodiversity exploitation (**PBE**), and regime of biodiversity exploitation (**RBE**) are presented for each natural ecosystem in general [31, 35–37].

1. **The threat and degree of human impact (TDHI)** on ecosystems could be recognized as: High (**H**), Moderate (**M**), Low (**L**), Insignificant (**I**);
2. **The possibilities of biodiversity exploitation (PBE)** as: High (**H**), Moderate (**M**), Low (**L**), Insignificant (**I**);
3. **The regime of biodiversity exploitation (RBE)** as: Liberal (**Li**), Restrictive (**R**), Highly Restrictive (**HR**); Exclusion of Using (**ExU**).

These qualifications are general and based on the recent state, historical dimension of anthropogenic impact, and distribution of some basic types of ecosystems in the Mediterranean part of Montenegro. In regard to their biological components, the possibilities and regimes of exploitation can be determined.

4.1 Biological Resources of Marine Ecosystems

The main characteristics of biodiversity of South Adriatic are that this region could be considered as the center of the Adriatic Sea biodiversity. About 456 fish species, from 581 in the Mediterranean Sea, have been observed in the Adriatic either permanently living or occasionally entering, 57 echinoderms species, i.e. 56,4% of Adriatic and 37% of current total number of Mediterranean echinoderms [38–42].

All existing data indicate that almost all plant and animal species found so far in the Adriatic live in its southern part as well. Even more so, many of the species, especially those belonging to the fauna of the profound are solely to be found in the South Adriatic. High-level diversity of the abiotic factors provides conditions for diversity in flora and fauna of the South Adriatic, which is incomparably higher than the biological diversity in the northern part. The total biodiversity index decreases if going from the South to North Adriatic. In some time, the organic productivity and with it biomass and number of specimens are growing from South to North Adriatic [12, 26].

Fish species and other biological resources of the South Adriatic represent the population of edible organisms or populations of organisms used for some other industrial purpose (obtaining raw material for chemical and pharmaceutical industry, for use in some other industries, jewelry production, etc). Fish species and other biological resources in world's fishing industry are constituted by the population of various species of fish, mollusks, and crustaceans caught with different fishing gear

and different types of fishing. The resources of the marine fishery provide a sufficient amount of healthy food from the sea. Among animal food resources on annual production at the world level fish is on the first place with 70 millions of metric tons, relatively to pork 42, beef 41 and poultry with about 20 millions of metric tons [43].

The share of the fisheries sector in Montenegro GDP is only 0.5% and 3.1% of the total gross product of the agricultural sector. Marine fisheries sector in Montenegro represents 0.3% of the total fisheries sector of the European Union Mediterranean state (561,288 t/year). Fish consumption in Montenegro is among the lowest in Europe (about 4.5 kg per capita per year). On the other side the fish prices in Montenegro are much higher than in European Union Mediterranean state [12].

Methods of commercial fishing and mariculture, which are used in the fishing areas of Montenegro coast are:

- Fishing of pelagic fish (small and large bluefish) by purse seine nets, seines (drift net), and static nets;
- Fishing for demersal (bottom) fish species, crustaceans, and cephalopods by near-bottom fishing nets – trawls.
- Small-scale fathering (a vessel of up to 12 m length overall) of coastal, pelagic, semi-pelagic, and demersal species of fish, crustaceans and cephalopods by various types of gear: gillnets and trammel nets, fish pots and traps, harpoons, longlines, hook and beach seines.
- Marine aquaculture – artificial breeding (farming) of marine organisms.

In order to speak about the use of marine biological resources, we should define the fishing waters of Montenegro. Approximately 6,000 km² of the sea belongs to Montenegro and that makes almost 50% of the land territory. Under applicable low legislatives [44–48] the fishing waters of Montenegro cover the part of coastal sea and epicontinental shelf located within the state borders of Montenegro. The border of the fishing sea in the rivers, which flow into the sea, is considered to the line where the water ceases to be constantly salty. For fishing and collecting the benthic and semi-pelagic species the most important is the coastal area of the inland sea and the shelf area (depth up to 200 m), which is very narrow, as it is on the territory of the entire southern Adriatic Sea. On the level on the entrance to the Boka Kotorska Bay, the shelf boundary is the distance of about 9.5 n.m., wears at the mouth of the Bojana River is about 34 n.m. from the coast. In addition to the shelf, fishing of benthic species (in accordance with the Italian data) is profitable on the continental slope to a depth of 500–600 m, because that is where the shrimp crabs community is. Unlike the hunting of benthic species, the fishing area of pelagic species is extremely profitable from the economic point of view to the border of Italian territorial waters [49, 50].

In Montenegro three ports are important for fishing: Herceg-Novi, Budva, and Bar. They are not fishing ports in the true sense of the world, as there are no organized landing sites or fishing auction markets. In all three ports bottom trawlers, small purse seiners, trammel netters, and long-liners are present.

4.1.1 Biological Resources of Pelagic Species

Pelagic fish populations that permanently or periodically inhabit the open waters of southern Adriatic, such as sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), mackerel (*Scomber scombrus*), Spanish mackerel (*Scomber japonicus*), and Atlantic bluefin tuna (*Thunnus thynnus*) are of a great economic significance for the development of the sea fishery in Montenegro. This component of fish resources is far from being completely utilized in regard to its potential. Montenegrin industrial fishing of sardine and anchovy is still undeveloped. Two existing purse seiners (pelagic trawlers) are not active due to a problem with unorganized fish markets and lack of trained crew. These two species are mainly caught through small-scale fishery, mostly using beach seines or small mesh size (5–6 mm) in the Boka Kotorska Bay, and targeting small, juvenile individuals in small amounts in coastal areas, using small purse seiners. Since there were no organized catch and landing data, it was impossible to estimate biomass and maximum biological permitted level of the exploitation of this resource per year MSY (maximum sustainable yield).

For that reason, in 2002 Institute for Marine Biology, Kotor, in cooperation with the ISMAR CNR Institute from Ancona, Italy, under the auspice of Ministry of Agriculture and Rural Development of Montenegro and FAO AdriaMed Project introduced direct methods for biomass estimation of anchovy, sardine, and other pelagic species (OPS) based on echo-survey, and since 2005 DEPM (daily egg production method) has also been used for anchovy biomass estimation. Estimates of biomass of pelagic species in this area were performed according to acoustic data collected by echo-survey, as well as the biological data on average length and per cent in weight of all species caught in experimental pelagic trawls. Based on research performed, during 2002, 2004, and 2005 the estimated biomass of the small pelagic fish in Montenegro waters averages between 30,000 and 100,000 tons [12, 19]. The results of AdriaMed surveys in Montenegrin waters (2002, 2004, and 2005) as well as surveys in Montenegrin and Albanian territorial and adjacent international waters (2008, 2010) are presented in Table 1.

The biomass of pelagic species estimated with both methods, calculated growth and mortality parameters, MSY was estimated on 30,910 tons of anchovy and 9,721 tons of sardine, i.e. relations of biomass between these two species are anchovy/

Table 1 Estimated biomass of anchovy, sardine, and OPS (tons) in Montenegrin Waters (2002, 2004, 2005) and in Montenegrin and Albanian territorial and adjacent international waters (2008, 2010) during AdriaMed surveys [49]

Year	Method	Anchovy	Sardine	OPS
2002	Echo-survey	90,383	30,763	14,907
2004	Echo-survey	3,454	31,638	4,163
2005	Echo-survey	23,220	7,479	18,185
2005	DEPM	3,842		
2008	Echo-survey	22,835	96,301	4,964
2008	DEPM	21,014		
2010	Echo-survey	8,875	14,693	3,244
2010	DEPM	10,691		



Fig. 5 Catching sardines and anchovies with a pelagic trawlers [19] (Photo by: M. Mandić)

sardine = 3/1 and found that optimal fishing effort would be achieved with 33 purse seiners vessels [49, 50]. Having in mind, that there are currently only two vessels exploiting these resources in Montenegro, and their catches are very poor due to a problem with untrained crew and technical problem. Even when catches are good, there is a problem with an unorganized fish market in Montenegro (Figs. 5 and 6) [26, 49].

Although tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*) and other large pelagic species pass along the Montenegrin coast on their migratory routes so far, these resources have not been sufficiently used. This type of fishery still doesn't exist in Montenegro and recommendations are to form a fleet and exploit those fish resources. In the coming period, on the open sea more intensive commercial fishing of sardine, anchovy and tuna with swimmer nets of and floating trawl nets, as well as fishing for tuna and swordfish with floating long-lines, should be initiated. In the function of the capability of the commercial catch of blue fish and its placement to customers, it would be necessary organized landing sites or auction markets fish, as well as, to modernize and intensify the processing of fish in the factory Ribarstvo in Rijeka Crnojevića [12].

Negative human impacts: Pollution, exploitation of oil, changes in nutrient regime, changes of current pattern and temperature of seawater correlated with global climate changes, invasive-introduced species.

TDHI: M (Moderate) – L (Low); **PBE:** H (High) – M (Moderate); **RBE:** Li (Liberal) – R (Restrictive).

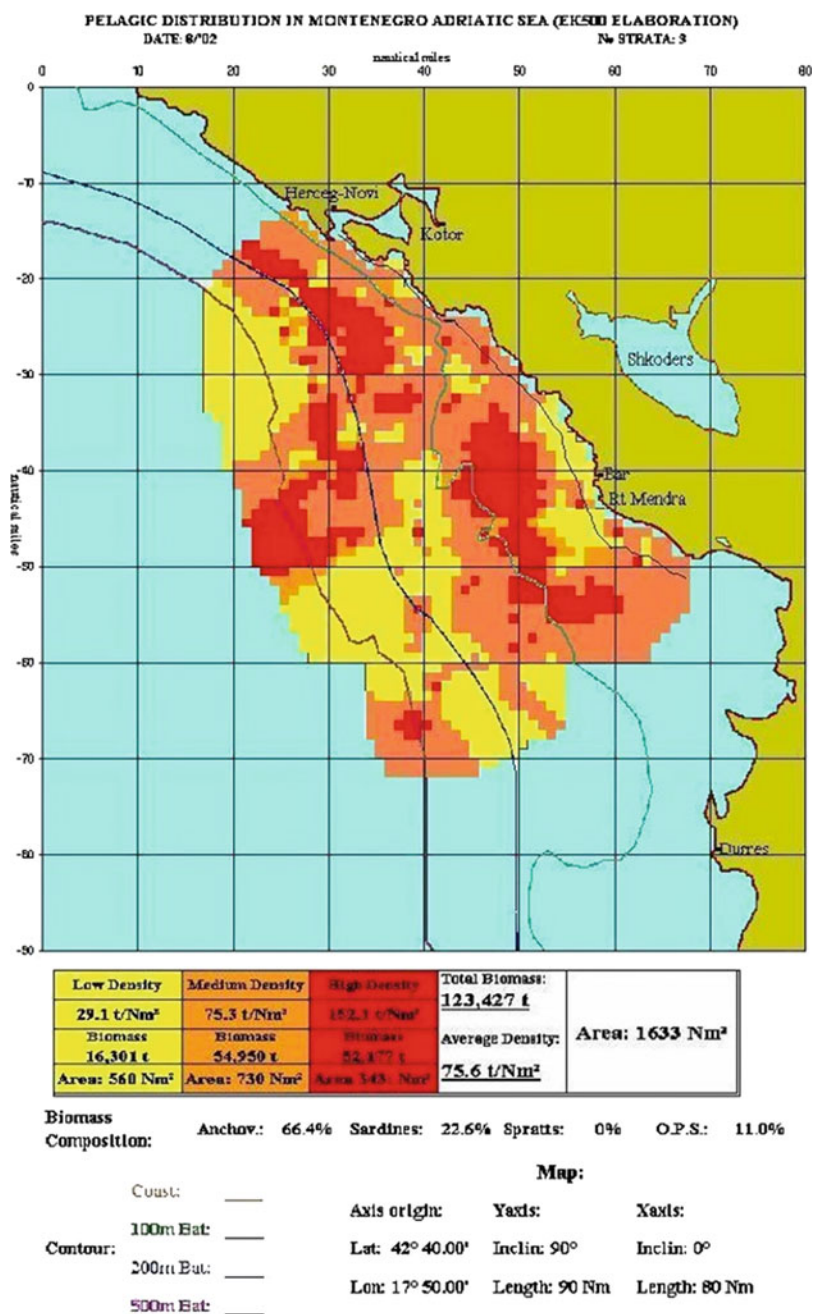


Fig. 6 The map of distribution of pelagic resources: sardine and anchovies [41]

4.1.2 Biological Resources of Benthic (Demersal) Species

In the period 1970s and 1980s only one Montenegrin trawler fished on populations of benthic (demersal) organisms (fishes, crustaceans, and mollusks) inhabiting lower parts of littoral and sublittoral zones in this area, while Italian vessels fished outside the territorial waters, beyond 12 n.m. Owing to this situation, the state of demersal fish stocks was good, and catch per unit effort was very high, about 60 kg/h. Around 1992 year the number of vessels started to increase rapidly, and in 1997/1998 there were 196 licensed vessels for professional and supplemental fishery; 31 of these were vessels for demersal fishery. After 2000 the number of vessels decreased and since then 17 trawlers are active [19, 49].

In the decade from 1990 to 2000, there as a period of intensive fishing of quality white fish demersal resources without control and inspection, during which time forbidden nets and explosive devices were used. All of those activities led to a reduction of demersal stocks, catch per hour decreased to 20 kg/h [51].

For these reasons, during the period 1997–2004 the intensive research of the demersal fish resources was realized by the Institute for Marine Biology Kotor within the project of monitoring and evaluation of demersal biomass resources on the shelf of the Montenegrin coast by the method of surface sample test using commercial trawlers and maximum biological permitted level of the exploitation of this resource per year MSY is 600 tons. Structure of weight of the trawl catch according to species of organisms in the period 1998–2000 is: bony fish (66%), cartilaginous fish (20%), Cephalopoda (10%), and Crustacea (3%) (Table 2).

In 2004, in context of the AdriaMed Project, Montenegro joined the MEDITS (MEDIterranean Trawl Survey) group and started monitoring demersal communities on 10 station, based on MEDITS protocol (annually, during the spring–summer period). The estimated biomass of benthic species (fishing by trawler) was 1,700 tons, half of the 3,400 tons estimated in 1973 [49, 52]. Decrease in catch per unit effort from 60 kg to 20 kg also indicates a significant decrease in commercially important fish population densities in the sea. Based on the biomass of demersal resources the MSY was estimated at 602 tons per year, and optimal fishing effort was placed at 190 days per year [49, 51].

The analysis of the spatial distribution of benthic resources made by Kriging method has indicated that there are two areas in which it is greater than in other areas [51]. Those areas are between Budva and Petrovac to the isobath of 100 m and in front of the entrance to the Boka Kotorska Bay to the isobath of 150 m. Those higher biomass values are probably consequence of the specific hydrographic conditions in the area, mostly likely of the existence of permanent front zone in the first area and the flow of the water from the Boka Kotorska Bay, which is richer in nutrients than the open sea [26].

Conversely, in the area in front of the Bojana River estuary, the biomass of benthic species is small, while the number of juvenile samples in the catch is far higher than in other parts of the shelf. This area is probably nursery and feeding

Table 2 Mean structure of weight trawl catch according to species in the period 1998–2000 according to data from [51]

Species	Common name	%
<i>Merluccius merluccius</i>	Hake	24.66
<i>Scylliorhinus canicula</i>	Lesser spotted dogfish	11.20
<i>Trachurus mediterraneus</i>	Horse-mackerel	10.46
<i>Mullus barbatus</i>	Red mullet	6.17
<i>Lophius piscatorius</i>	Common angler	5.58
<i>Eledone moschata</i>	Lesser octopus	4.18
<i>Loligo vulgaris</i>	Common squid	2.85
<i>Trigla lyra</i>	Piper	2.60
<i>Squalus acanthias</i>	Spur dog	2.48
<i>Raja (Raja) miraletus</i>	Brown ray	2.38
<i>Parapenaeus longirostris</i>	Shrimp	2.14
<i>Pagellus erythrinus</i>	Pandora	1.94
<i>Conger conger</i>	Conger	1.61
<i>Aspitrigla cuculus</i>	Red gurnard	1.45
<i>Sepia officinalis</i>	Common cuttlefish	1.29
<i>Citharus linguatula</i>	Spotted flounder	1.26
<i>Zeus faber</i>	John Derry	1.25
<i>Trachurus trachurus</i>	Horse-mackerel	1.17
<i>Trisopterus minutus capelanus</i>	Poor cod	1.16
<i>Squalus blainvillei</i>	Blainville i's spur dog	1.06
<i>Raja (Dipturus) oxyrhynchus</i>	Longnose skate	1.06

ground for juveniles and in the future special attention should be paid with specific management regime [49, 53] (Fig. 7).

A total of 160 demersal species were caught and examined during the 8 MEDITS surveys [54]. The most abundant species in biomass (kg/km^2) are represented in Table 3.

Comparing results from the MEDITS survey with those from the HVAR expedition (1948/1949), a sharp decline of the cartilaginous fish (Elasmobranchii) was found. Sharks and rays, which accounted for 36–42% of the total fish catch in the early 1970s declined to 17–30% in 2000s. With the exception of *Scylliorhinus canicula* and *Squalus blainvillei*, a decrease or disappearance occurred for all the most common selachians species. The decrease of these fish greater than 10% is regarded as a first sign of overfishing [49, 55].

Teleostean fish (Teleostei) did not show a clean pattern, in particularly hake and red mullet. Anglerfish (*Lophius budegassa*) and horse-mackerel (*Trachurus trachurus*) seem to be more abundant in recent surveys than in old expeditions. The opposite was observed for John Dory (*Zeus faber*) [49].

However, it is important to remark that Montenegrin waters are still characterized by occurrence of quite a high proportion of demersal sharks, such as *Squalus* spp., and different species of rays, which have been dramatically reduced to near-

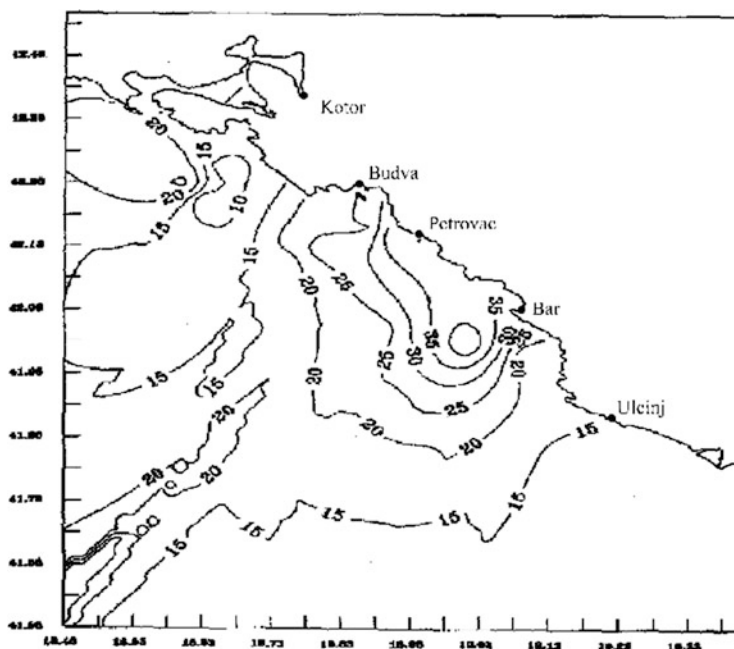


Fig. 7 Biomass spatial distribution of demersal resources for the period 1999–2012 in the Montenegrin waters, according to data from [26, 49]

Table 3 Species with the highest biomass index kg/km^2 according to data from (MEDITS) [49, 54]

Species	Common name	kg/km^2
<i>Merluccius merluccius</i>	Hake	65.4
<i>Scyliorhinus canicula</i>	Lesser spotted dogfish	37.1
<i>Mullus barbatus</i>	Red mullet	30.3
<i>Parapenaeus longirostris</i>	Shrimp	25.7
<i>Lophius budegassa</i>	Anglerfish	23.2
<i>Illex coindetii</i>	Southern shortfin squid	20.7
<i>Trachurus trachurus</i>	Horse-mackerel	18.4
<i>Aspitrigla cuculus</i>	Red gurnard	14.5

extinction in many others areas of Mediterranean Sea. This indicates better conditions for the Montenegrin demersal fish community and a high level of biodiversity [49].

The results of the MEDITS 2013 show a decrease in total biomass compared to the results of 2012. In 2013, the biomass index of all demersal resources along the Montenegrin coast was estimated at $623.82 \text{ kg}/\text{km}^2$. As the total study area was

about 5,000 km², the total biomass thus can be estimated at 3119.12 tons. In 2012, the biomass index was 847.79 kg/km², and total estimated biomass at 4238.93 tons on the same 5,000 km² study area. The noticeable reduction in trawl resources biomass in 2013 can likely be considered as a result of natural fluctuations in biomass caused by available food resources in the sea, temperature fluctuations, and other hydrographic factors. The fact that the contribution of Montenegrin fleet in total catch of demersal resources was 1% implies that the biomass reduction is not connected to the fishing effort intensity, which in Montenegro has remained fairly constant for a long time (Table 4) [53]. Regardless, it is necessary to reverse the ongoing negative pattern and preserve the current richness of Montenegrin seawaters, with special attention to reduce the long-term input of waste to the sea [56].

Negative human impact: Overfishing and overharvesting of benthic communities by trawl catch, particularly between 50 and 100 m depth; pollution by urban and industrial waste waters, marine litter, invasive-introduced species.

Table 4 Species with the highest biomass index kg/km² (MEDITS, 2013) according to data from [53]

Species	MEDITS acronym	kg/km ²	Faunistic category
<i>Illex coindetii</i>	ILLE COI	80.96	C (cephalopods)
<i>Mullus barbatus</i>	MULL BAR	71.08	A (fish)
<i>Spicara flexuosa</i>	SPIC FLE	52.41	A
<i>Merluccius merluccius</i>	MERL MER	47.07	A
<i>Trachurus trachurus</i>	TRAC TRA	38.86	A
<i>Pagellus erythrinus</i>	PAGE ERY	25.63	A
<i>Raja clavata</i>	RAJA CLA	23.54	A
<i>Scyliorhinus canicula</i>	SCYO CAN	20.44	A
<i>Zeus faber</i>	ZEUS FAB	19.63	A
<i>Stichopus regalis</i>	STIC REG	17.17	E (noncommercial species – Edible)
<i>Boops boops</i>	BOOP BOO	16.03	A
<i>Lophius budegassa</i>	LOPH BUD	15.23	A
<i>Todaropsis eblanae</i>	TODA EBL	12.04	C
<i>Galeus melastomus</i>	GALE MEL	9.98	A
<i>Engraulis encrasicolus</i>	ENGR ENC	9.89	A
<i>Trachyrhynchus trachyrhynchus</i>	TRAC TRA	9.86	A
<i>Trachinus radiatus</i>	TRAC RAD	8.34	A
<i>Trachurus picturatus</i>	TRAC PIC	8.33	A
<i>Pagellus bogaraveo</i>	PAGE BOG	8.31	A
<i>Raja miraletus</i>	RAJA MIR	8.11	A
<i>Sardina pilchardus</i>	SARD PIL	6.77	A
<i>Phycis blennoides</i>	PHYC BLE	6.44	A
<i>Spicara smaris</i>	SPI SMA	6.15	A
<i>Micromesistius poutassou</i>	MICR POU	5.88	A
<i>Squalus blainvillei</i>	SQUA BLA	4.94	A

Benthos of littoral zone:

TDHI: **H** (High) – **M** (Moderate); **PBE:** **M** (Moderate) – **L** (Low); **RBE:** **R** (Restrictive) – **HR** (Highly Restrictive).

Benthos of sublittoral zone:

TDHI: **H** (High) – **M** (Moderate); **PBE:** **M** (Moderate) – **L** (Low); **RBE:** **Li** (Lyberal) – **R** (Restrictive).

4.1.3 Biological Resources of Small-Scale Fisheries

The importance of small-scale fisheries on population of coastal, pelagic, semi-pelagic, and demersal species of fish, crustaceans, and cephalopods in the coastal Mediterranean is highlighted in the last few years. Legal framework in Montenegro recognized small-scale fisheries, which differ from large-scale fisheries in vessel size, type and number of fishing gears. Small-scale fishing recognized a vessel of up to 12 m length overall with various types of gear: gillnets and trammel nets, beach seines, pots and traps for fish and lobster, harpoons, longlines, and hook, which targets high quality fish, cephalopods, and crustacean species. During the first half of 2016 in Montenegro, there was a total of 140 licensed fishing vessels for commercial fisheries [57]. In total 63% vessels in the fleet could be considered as multipurpose (polyvalent) vessel. Gillnets are the most common type of fishing gear, followed closely by trammel nets and beach seines targeting sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). In Montenegro most of the SSF catches were landed by beach seines (52%), gillnets and trammel nets (27%), and set longlines (21%). The most dominant species in the SSF catch are *S. pilchardus* and *E. encrasicolus* (33%, Atlantic bonito *Sarda sarda*, European conger *Conger conger*, red porgy *Pagrus pagrus*, bullet tuna *Auxis rochei*, and round sardinella *Sardinella aurita* make together 29%). All other fish species (20) correspond to 38% of the SSF catch [58].

The total catch of Montenegro amounted to 534,7 tons annually. Most of the catch came from bottom trawls landings (35%), purse seines catches comprised of around 25%, beach seines (20%), gillnets and trammel nets (10%), and longlines (8%). Therefore, the estimated landings per SSF are around 203 tons annually [58].

These data indicate a significantly lower amount of estimated catch compared to previous estimates. Namely, these data indicate a significantly lower amount of catch compared to previous estimates. Namely, earlier research based on interviews of fishermen, a rough estimation is that the catch of small-scale fisheries is approximately 1.200 tons annually [59] (Fig. 8).

With a view to protecting the fish stocks and biocoenoses in Boka Kotorska Bay, the Low on Marine Fisheries and Mariculture prohibits certain types of fishing gears within the Bay, thereby the way to a certain extent proclaimed a fishery restricted area. Fishing with the bottom trawls, pelagic trawls, and encircling purse seine nets of large-scale fishery is prohibited. In this way, only the small commercial fishing gear may be used within the Bay, such as set nets, seine nets, longlines, traps, spears, and harpoons. The Low lays down also the period in which their use is allowed or



Fig. 8 Small-scale fisheries (fish, crustaceans, mollusks, sponges) (Photo by: A. Joksimović)

prohibited in order to protect the species in spawning period. Apart from its economic significance, the fishing with traditional gear in the Boka Kotorska Bay also has a strong culturological and sociological importance for a local population and represent tourist attraction [60].

The shellfish fishing in Montenegro is regulated by the Law on Marine Fisheries and Mariculture by which is allowed to collect edible shellfish tool manually, without the use of dredges. Each year, there is possibility for issuing a total of 5 licenses for manually collecting shellfish and allowed quantity of harvest is 1 tone per license. The licenses do not define the shellfish species that can be harvested.

Negative human impact: Overfishing and overharvesting, use explosives, use prohibited fishing tools especially diving bottle and fishing rifle, fishing at times when it is not allowed, pollution by urban and industrial waste waters, marine litter, collecting shellfish especially Date shell (*Lithophaga lithophaga*) and destruction of coastal rock and littoral tidal zone community, invasive-introduced species.

TDHI: H (High) – M (Moderate); **PBE:** M (Moderate) – L (Low); **RBE:** R (Restrictive) – ExU (Exclusion of Using).

4.1.4 Biological Resources of Marine Aquaculture

By FAO definition (1990) aquaculture includes all activities related to artificial breeding, the farming of aquatic organisms (fish, mollusks, crustaceans, and algae), while the term “mariculture” describes aquaculture in marine or brackish water in coastal areas and in the open sea.

Research on the possibility of developing mariculture on the Montenegrin coast began in the 1970s at the Institute of Marine Biology, Kotor, related to the possibility of growing shellfish oyster *Ostrea edulis* and mussel *Mytilus galloprovincialis* in the Bay of Kotor Bay [61]. During the period 1990–2000 years, Institute for Marine Biology together with the Norwegian Institute for Aquaculture “Aquaforsk” is actively engaged in the programs of estimation and establishing of mariculture in Montenegro. Bearing in mind the specific physical characteristics of seawater in the Boka Kotorska Bay, especially according to temperature and salinity, sea farming of rainbow trout (*Onchorinchus mykiss*) and Atlantic salmon (*Salmo salar*) in floating cages is applicable. Research has shown that farming brown trout (*Salmo trutta*) is also possible in the Montenegrin zone of the Adriatic Sea [62]. From this period a joint project with the Institute of Marine Biology in Trieste on breeding of the Mediterranean mussel (*Mytilus galloprovincialis*) and oyster (*Ostrea edulis*) was realized, as well as the joint program with the Chinese Academy of Science on possibilities of the lagoon breeding of the prawn (*Penaeus vanamei*). A significant attention is also paid to the condition of the fish stock in the region of Ulcinj and the river mouth of the Bojana River, particularly of the eel (*Anguilla anguilla*), bass (*Dicentrarchus labrax*), and Gray mullet *Mugil cephalus*, as well as to the determination of the condition of populations of the brine shrimp *Artemia salina* in Boka Kotorska Bay [63, 64].

Marine fish farming, with the commercial capacity, in Montenegro began to develop in 1988, when started to work with the company “MegaFish” from Kotor. Today in Montenegro there are two farming company, both located in the area of Boka Kotorska Bay (Orahovac and Stoliv). Although farming of white fish in Montenegro shows a slight increase over the last few years, it is still very low, especially when compared with some Mediterranean country that belong to the country with low production (Croatia, Albania, Morocco, Tunisia). This company uses floating cages with sea bass (*Sparus aurata*) and sea bream (*Dicentrarchus labrax*). Existing farms are located in a protected area of the Bay, and the maximum sustainable amount of farmed fish should not exceed 100 tons per farm, which would ensure the protection of environmental quality, given that this type of farming is intensive. The limitation of biomass per cage under conditions of Boka Kotorska Bay would prevent an increase in the level of eutrophication and harmful impact on sediment, benthic fauna, water quality, sanitary, level of biotoxin and of the trophic status of the sea ecosystem [65, 66].

Although marine aquaculture sector has been stagnant for a long time, there have been significant improvements over the past two years. First of all, new, potentially suitable locations for aquaculture development at open part of Montenegrin coast have been defined. All locations are now part of the spatial plan of the coastal zone management, as a prerequisite for aquaculture development. In parallel with the inclusion of sites in the spatial plan, detailed scientific investigation of each zone has been initiated in accordance with GFCM FAO AZA principles (AZA – allocated zones for aquaculture). In recent years there is a growing interest for growing not only sea bass and sea bream, but also tuna (*Thunus thynnus*) [67].

In comparison with semi-enclosed and sheltered area of Boka Kotorska Bay, multiple open-sea sites are available for intensive offshore aquaculture, but they involve engineering and biological aspects that have to be considered as risk factors. Submersible cages could be a solution to prevent a risk of undesired situation (for example, a storm) [67].

It should be noted that shellfish farming as well as fish farming on the Montenegrin coast is concentrated only in the Boka Kotorska Bay. The first shellfish farms in Boka Kotorska Bay were stationary parks, which in the 1980s were replaced by floating parks that are still used in breeding today. Mussel farming is now taking place on over 20 farms located in the Kotor Bay, Risan Bay, and Tivat Bay. Commercial oyster farming started only in 2009, while mussel farming has been taking place for the last 30 years. The survey made by Institute of Marine Biology, Kotor, shows that Boka Kotorska Bay represents an ideal habitat for mussel farming with estimated annual production of high quality shellfish of about 600 tons [49]. According to Monstat data, mussel production in 2014 was 178 tons, 2016 was 179 tons and 2018 was 228 tons. In 2018 production of oyster was 17 tons [68]. In terms of the impact on the quality of the environment, shellfish farming (mussels and oysters) is “extensive” in intensity, because it does not imply additional supplementation, except for food that shellfish take from the sea. This type of farming does not cause any pollution. One of this type of fish farm is located in Boka Kotorska Bay and have significant production. In particular case, besides sea bream and sea bass farming, mussels are farmed, as well. This is an example of good practice that should be continued and which we suggest to all fish farms. Studies have shown that the condition index of mussels which is farmed in some location with sea bream and sea bass is slightly higher throughout the year than in the condition index of mussels that are farmed in monoculture [65, 66, 69, 70]. Namely, bivalves are characterized by a filtration type of diet recycled allochthonous organic matter product by fish and contribute to the reduction of environment pollution, increasing the profitability of farming [65, 70] (Fig. 9).

Negative human impact: Pollution by urban and industrial waste waters, marine litter.

TDHI: H (High) – **M** (Moderate); **PBE: M** (Moderate); **RBE: Li** (Liberal) – with applying the principle of integrated multitrophic aquaculture.

4.2 *Biological Resources of Freshwater Ecosystems*

4.2.1 **Biological Resources of Eutrophic Lakes – Skadar Lake**

Skadar Lake is the largest lake in the Balkans and is located on the border of Montenegro and Albania. Its total area is between 354 km² (minimum) and 530 km² (maximum) from which 2/3 belong to Montenegro and 1/3 to Albania. Average deep is 6.64 m. The lake is a crypto depression because some parts of its bottom are below sea level. Lake is separated from the Adriatic Sea by the Mountain



Fig. 9 Farming mussels with sea bream and sea bass in Boka Kotorska Bay [28] (Photo by A. Joksimović)



Fig. 10 Skadar Lake: view from above Virpazar toward islet Vranjina and mouth of the River Morača (Photo by V. Stevanović)

Rumija (10–12 km as the crow flies), and the River Bojana connects it with Adriatic Sea (Fig. 10). In the total balance of water inflow into Skadar Lake, the Morača River is the most important tributary with catchment area of about 3,200 km² which makes

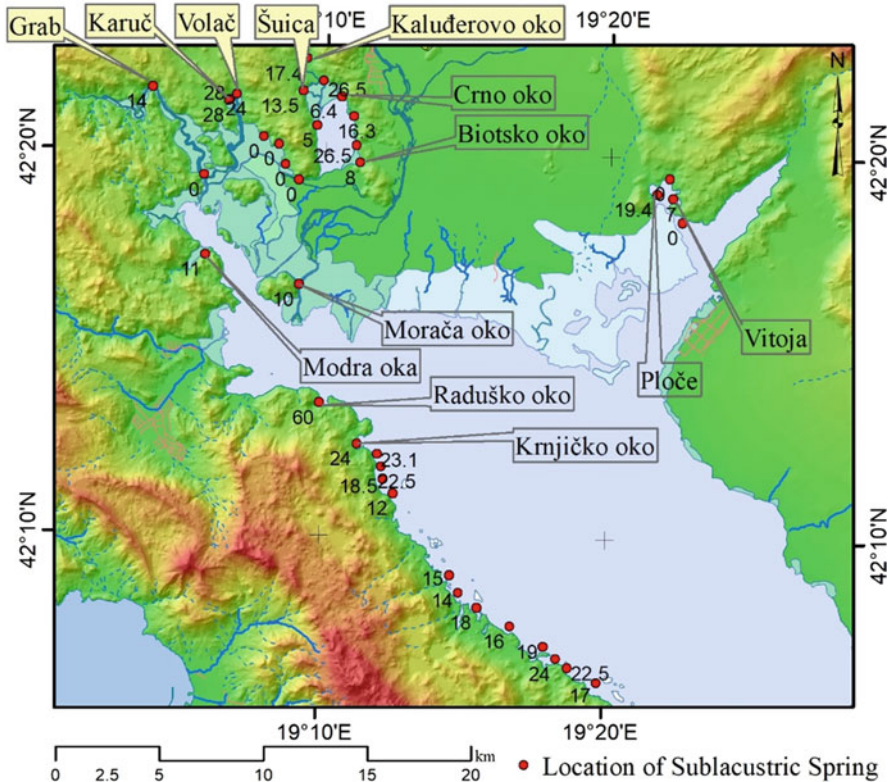


Fig. 11 Location and depth of sub-lacustric springs “oka” (eyes) in the Skadar Lake, according to data presented in [28]

up 60% of the catchment area. The Skadar Lake also received significant amount of underground water, from numerous sub-lacustric springs the “eyes” whose depth is between 15–30 m, with the depth of the Raduško Eye as much as 60 m (Figs. 11 and 12) [28].

Skadar Lake Region represents one of the most important centers of geodiversity and biodiversity for Western Balkan and SE Europe. Skadar Lake Region is a unique example of well-preserved freshwater ecosystems with specific geomorphologic, hydrological, geological, soil, and climatic features. It is also characterized by high biodiversity including numerous endemic and relict species of flora and fauna including many species of European conservation concern [71]. The part of Skadar Lake Region has the status of the National Park since 1983. International recognition of the importance of Skadar Lake ecosystems came in 1995, when the Region was designated as Ramsar site. This region is also on the list of Important Bird Areas of Europe (IBA, 1989) with 281 species [72]. The Union of European herpetologists (SHE, 1995) has included this area as the *Adriatic triangle* to be one of the research priorities for further investigation [73]. During Joint International Workshop on

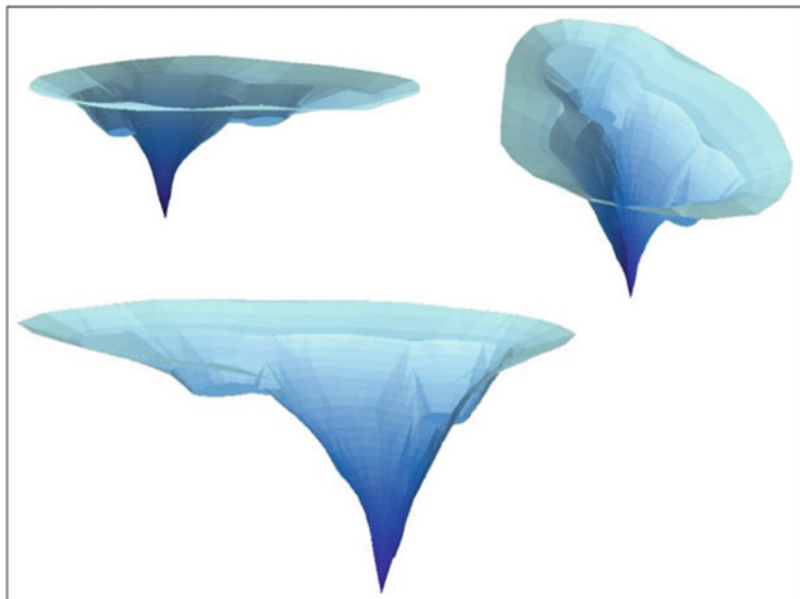


Fig. 12 3D model of Raduško "oko" (eye) according to data presented in [28]

«MAB Biosphere Reserves and Transboundary Cooperation in SEE Region» (held in Podgorica and Skadar in October, 2005, under the auspices of the UNESCO/ROSTE – IUCN) Skadar Lake NP was nominated for the MAB Reserve and transboundary Park between Montenegro and Albania. From November 2005 Albania also has pronounced its part of the Lake for a National Park [28].

From the aspect of the use of biological resources, its ichthyofauna and ornithofauna are especially important. Skadar Lake is known for a large number of fish species. For the total number of species in the Skadar Lake basin Filipović and Ziu list 56 species [72, 74], Dhora and Sokoli 61 species [28, 75].

The lake is dominated by cyprinid (carp) species (26). The second largest family is salmonids (trout) and out of 7 species registered in the basin, 4 were recorded in the lake itself. A significant feature of the ichthyofauna of the Skadar Lake basin is the high presence of 15 endemic species (at the level of the northern Mediterranean basin), which represents about 25% of the total number of fish species in the lake basin. The entire freshwater ichthyofauna of Montenegro is characterized by the presence of 24 species of this level of endemism [28, 76]. It should be noted, however, that 14 non-native (introduced) species live in Skadar Lake today, which also makes a high percentage of about 25% of the ichthyofauna of the lake.

With the exploitation of biological resources the Skadar Lake Basin is the most diverse and significant freshwater fishing facility in Montenegro. Skadar Lake participates in the total annual catch of Montenegrin fish with over 95% of the catch of all open waters. Namely, out of the total number of species, about ten are commercially viable, and among them the most important fishing species, which are

Table 5 Average annual catch of fish in multiannual periods (in tons) according to [77]

The most important fishing species	1947–1956	1957–1966	1967–1976	1977–1985
1. Bleak	502	537	470	203
2. Scadar crap	186	197	123	118
3. Eel	15	13	10	20
4. Trout	3	3	1	1
5. Twaite shad	26	36	3	9
6. Thinlip mullet	4	4	1	11
7. Other fish	195	255	431	401
Total	931	1,045	1,039	763

a kind of symbol of Skadar Lake are: Skadar carp – *Cyprinus carpio*, Bleak (*Alburnus alburnus alborella*), Thinlip mullet (*Lisa ramada*), sea bass (*Dicentrachus labrax*), Eel (*Anguilla anguilla*). It is estimated that 50–100 kg fish/ha are present, which still makes it the richest natural fishing area in Montenegro. According to statistical data, the annual catch in previous periods was about 1,000 tons per year (Table 5) [28, 77, 78].

In addition to the number of fish species, Skadar Lake is also characterized by an extremely high number of waterfowl populations, especially during the winter period (International Waterfowls Census, IWC).

Available data show that in mid-January, an average of 210,000 waterfowl spend the winter on Skadar Lake. Taking into account the regular fluctuations and movements of birds during autumn and winter, it is estimated that over one million birds pass through Skadar Lake during autumn migration and wintering. Comparing this with the known abundance in the most important wintering grounds of Europe and the Mediterranean, Skadar Lake erupts at the very top of important bird wintering grounds in that area. Ornithological research indicates that the survival of about 10% of the total Eastern and Central European waterfowl population is directly dependent on Skadar Lake.

The results of this census show that in just one year, more than 150,000 individuals of *Fulica atra* (coot), 15,000 *Anas platyrhynchos* (wild duck, woodpecker), 40,000 *Aythya ferina* (gray float), etc. were counted on Skadar Lake. 1999 census recorded the maximum number of wintering birds, at around 250,000. Among the nesting birds, there are species that have been suppressed in Europe from almost all former nesting sites and are not sparse or endangered on the lake itself. One such example is the pygmy cormorant (*Phalacrocorax pygmeus*), which occurs in masse on the Lake. The total number of this species in the Mediterranean and the Black Sea is estimated at 25,000 individuals. In the winter period, about 5,000 individuals (20%) live on Skadar Lake, and in some years as many as 11,000 individuals were recorded, i.e. 44% of the total number of this species in the Mediterranean and the Black Sea. The pygmy cormorant colony, which averages about 2,200 pairs, is the largest colony of this bird in the world [79]. The Albanian part of Lake is also known for its high number of birds.

At some time, waterfowl is favored for hunting, which represent a significant part of Montenegrin tourism, and one of the many cases where hunting and conservation are opposed and incompatible. However, waterfowl hunting can be approved when organized and controlled, especially of those species with numerous populations and not affecting their age structure and abundance. Waterfowl represent an exceptionally important element of the biodiversity of wetland areas of Montenegro, as well as stability of wetland and water ecosystems.

Among the birds of Skadar Lake, the rare Dalmatian pelican (*Pelicanus crispus*) stands out for its importance, which can be described as a bird that symbolizes this region, i.e. the cult bird of Skadar Lake. The colony of the curly pelican on Skadar Lake is its westernmost nesting ground. The Dalmatian pelican is the largest species of waterfowl, with wingspan reaches a range of 2.5 m. and they are outstanding pilots.

Negative human impacts: Overfishing during whole season; overhunting of waterfowl, particularly during winter season; trade of rare birds; pollution by urban and industrial waste waters, rapid eutrophication.

Populations of freshwater fishes in the lakes:

TDHI: H (High); **PBE:** H (High) – M (Moderate); **RBE:** L (Liberal) – R (Restrictive).

Birds of eutrophic lakes and salt marshes:

TDHI: H (High); **PBE:** M (Moderate); **RBE:** R (Restrictive) – HR (High Restrictive): Depending on the game bird species and hunting closed seasons. The majority of waterfowl is permanently protected by law. Similar exploitation policy can be applied on some sibling species of frogs, among which some are endemic.

4.2.2 Biological Resources of Rivers

The Bojana River is only 41 km long. It flows out of Skadar Lake and flows into the Adriatic Sea, representing at the same time the border between Montenegro and Albania. It is characterized by a small drop of 0.6% due to which a large part of its flow mixes fresh and salt water, thus making a very complex ecosystem with subtropical and Mediterranean species. It is characterized by an extremely high diversity of 143 species of fish and about 280 species of birds. The average flow of Bojana River at the exit from Skadar Lake is 310 m³/s, and at the place Reč after receiving the inflow water 640 m³/s [80].

From the aspect of biological resources, the catch of fish, Gray mullet *Mugil cephalus*, is especially important. Its typical habitats are estuaries and lakes that have a connection with the sea. Its settlements on the entire Adriatic Sea are the richest right at the mouth of the Bojana. Every spring hundreds of tons of Gray mullet started from the direction of Skadar Lake to Adriatic Sea for spawning. Unfortunately, local fishermen use metal nets, baskets, and constructions, intertwined with ordinary fishing nets, and set across the width of the entire Bojana riverbed dramatically prevent the migration of fish in both directions. Ultimately, this kind of fishery can lead to an ecological catastrophe and the extinction not only Gray mullet but also



Fig. 13 Bojana River and “Kalimero” trap (Photo by M. Mandić)

the other anadromous and catadromous species. The nets are formed in the shape of the Latin letter “V,” which limits the direction of movement of shoals of fish, forcing them straight into the trap, from where catch them with improvised “kalimero.” Due to these obstacles, very small amounts reach the Adriatic Sea (Fig. 13).

In addition to Gray mullet, sea bass (*Dicentrarchus labrax*), seabream (*Trachinotus ovatus*), and Eel (*Anguilla anguilla*) are of special importance as fishing resources. In regard to the amount of the fish caught and the type of fishing, the Bojana River, as a migration route (the Adriatic Sea – Lake Skadar – inland rivers of the Adriatic Sea basin and vice versa) for a large number of anadromous and catadromous commercially important fish species, has to be more strictly controlled [19].

Negative human impact: Overfishing without control during whole season, fishing with prohibited gears, disturbance of benthic and littoral habitats by pebble exploitation; pollution by urban and industrial waste waters. Habitat disturbance by intensive tourism.

Fish populations of oligotrophic rivers:

TDHI: H (High); **PBE:** M (Moderate); **RBE:** R (Restrictive) – **HR** (High Restrictive).

Populations of anadromous and catadromous fishes:

TDHI: H (High); **PBE:** M (Moderate); **RBE:** R (Restrictive) – **HR** (High Restrictive).

4.3 Biological Resources of Terrestrial Ecosystems

4.3.1 Biological Resources of Coastal Zone (Sand and/or Pebble Coastlines)

As we mentioned early the full length of the Montenegrin coastline is 293.5 km Throughout the length of the coast 52 km are sand and pebble beaches. The longest beach in the southernmost part on the Mediterranean coast is Great beach in Ulcinj



Fig. 14 Great sand beach of Ulcinj with characteristic clumps of marram grass (*Ammophila arenaria*) (Photo by V. Stevanović)

13 km long and with an average width of 50 m, with finest sand imaginable. Except on Great beach of Ulcinj natural vegetation from class Ammophiletalia at few small beaches is completely destroyed. Several characteristic species of Mediterranean coastal sand dune such as *Pancratium maritimum*, *Euphorbia paralias*, *Convolvulus soldanella*, *Ammophila arenaria*, *Cyperus rotundus*, *Echinophora spinosa*, *Eryngium maritimum*, etc. occur only on Great beach of Ulcinj (Fig. 14) [31, 35, 36].

Negative human impact: Tourism including various ways of habitat disturbance and removal and destruction of natural vegetation.

TDHI: H (High); **PBE: L** (Low) – **I** (Insignificant); **RBE: R** (Restrictive) – **HR** (High Restrictive).

4.3.2 Biological Resources of Salt Marshes, Swards, and Mud Flats of Coastal Zones

The high tide river mouths, low muddy highly saline coasts influenced by high tides and overgrown by communities of *Thero-Salicornion* and *Arthrocnemion fruticosi*, as well as coastal salty meadows, salty pseudo steppes, and pastures of *Limonion dalmaticum* (river mouth of the Bojana, bay Solila (Tivat) in Grbaljsko polje (Fig. 15), salt basins in Ulcinj, Igalo), are mainly used as salt pans, active (Ulcinj), or abandoned (salt pans of Tivat). Ulcinj salt pans represent an internationally important bird area (IBA YU 045), which consists of circa 1,350 ha of salt basins, mud flats, reedbeds, pools, canals, mud banks, freshwater and brackish pools and lakes (former Zagajsko Blato). Being the last nesting places of the shelduck (*Tadorna tadorna*) and one of the last habitats of oystercatcher (*Haematopus ostralegus*), they are of special importance for the biodiversity of Montenegro, but also internationally important as nesting places for several species of birds



Fig. 15 Solila-former saltern in vicinity of Tivat (Boka Kotorska Bay) is currently transformed into salt marsh ornithological reserve (Photo by V. Stevanović)

(*Himantopus himantopus*, *Glareola pratincola*, *Charadrius alexandrinus*, and *Sterna albifrons*) as well as an internationally important concentration site for a great number of water birds during migration (especially *Platalea leucorodia* and *Egretta alba*). In the same time, the salt pans are the only habitats in Montenegro for some species such as the brine shrimp (*Artemia salina*), which is very important for aquaculture [31, 35, 63].

Negative human impacts: Bird hunting, trade of rare species.

TDHI: M (Moderate); **PBE:** M (Moderate) – L (Low); **RBE:** R (Restrictive) – HR (High Restrictive).

4.3.3 Biological Resources of Forest and Scrub Ecosystems

Biological Resources of Sclerophylls' Evergreen Mediterranean Forests and Scrubs

Well-preserved forest ecosystems of evergreen Mediterranean holm oak (*Quercus ilex*) are almost completely absent from the Montenegro coast due to long-term cutting. However, holm oak occurs as a shrub or small tree everywhere along Montenegrin coast in the maquis. Today only single trees or small groups of this species can be found in Luštica, surrounding of Budva, Čanj, Bar, Kruti, and Ulcinj as remnants of former wide distributed forest ecosystem, while interesting stands occur deeper in mainland (Cijevna canyon and ravines of northern side of



Fig. 16 Steep slopes of coast are covered with maquis and small group of holm oak (signed by circle) (left); fertile branch of holm oak with acorns (right) (Photo by V. Stevanović)

Mt. Rumija above Skadar Lake). The wood of holm oak is hard and durable. For that reason, it has been used in the Mediterranean for centuries in construction, for making ships, for carpentry, making tools, and for fuel. Today, due to a drastic reduction Holm oak represents European forest genetic resources (Fig. 16) [31, 35, 36]. Kermes oak (*Q. coccifera*) is distributed in the Montenegro only between Bar and Ulcinj in the form of shrub as a member of maquis vegetation.

Negative human impact: Selective cutting of holm oak (*Quercus ilex*) for fuel, fire, and building of tourist settlements.

TDHI: H (High); **PBE: L** (Low) – **I** (Insignificant); **RBE:** No protected. Must be **HR** (High Restrictive).

One of the cultivated plant species on the Montenegrin coast, whose range actually defines the borders of the Mediterranean, is certainly the olive tree (*Oliva europea*). Olive is one of the oldest agricultural crops and is grown at the foothill of the mountain massifs of Orjen Mt., Lovćen Mt., and Rumija Mt. at altitudes up to 500 m, more than 2000 years. The oldest olive tree in the vicinity of Bar (Stara Maslina) is 2,240 years old, and the age of the tree in Ivanovići near Budva is estimated at 2,000 years. Namely, favorable ecological conditions have enabled the olive to become the leading fruit species on the Montenegrin coast. It is an impressive fact that there are over 100,000 olive trees in the area of Bar, most of which are over between 500 and 1,000 years old (Fig. 17) [81].

The importance of olives for the life of the local population is perhaps best illustrated by the story related to the toponymy of the small coastal town Stoliv in the Boka Kotorska Bay. This story about the emergence of the name Stoliv says that every boy wanting to marry had to plant a hundred (sto) olive trees and ones who did not possess any land had to clear some for themselves.

During the last period, significant changes in Montenegrin olive growing have been made in terms of modernization of this industry, primarily in the field of agricultural techniques and technology of olive oil processing. This created the



Fig. 17 Old olive grow above Valandos Bay between Kruče and Ulcinj (Photo by V. Stevanović)

conditions for the production of extra quality olive oil. Further measures for the increasing of using this resource must be taken in terms of marketing because the consumption of olive oil per capita in Montenegro is now very low – about 0.5 l per year [82].

Negative human impacts: Fire, clear cutting, goat browsing, building of human settlements, tourism with their infrastructure.

TDHI: M (Moderate); **PBE: M** (Moderate, as genetic resource); **RBE: R** (Restrictive).

Biological Resources of Mediterranean Forests of Aleppo Pine and Stone Pine

Autochthonous forests of Aleppo pine (*Pinus halepensis*) have restricted distribution in the Mediterranean part of the Montenegro coast, mainly in the southern part. However this species is commonly planted whether in groups, as a part of coastal landscapes, or as single old specimens in urban areas. The Aleppo Pine grows in full sun and is very heat and drought tolerant. It also is highly tolerant of wind exposure, salt spray, as well as soil salinity and alkalinity. It can survive in any type of soil, including rocky and extremely poor soils, but prefers well-drained soils. The Aleppo Pine often is planted to help achieve soil stabilization. It is used in leather tanning, production of dye, and resin extraction. It also has various uses in traditional medicine [31, 35, 36]. Natural forest of Stone pine (*Pinus pinea*) occurs only in Luštica peninsula, while it is frequently planted in the urban area (Fig. 18). Edible seeds are used in the diet.



Fig. 18 Old forest of stone pine (*Pinus pinea*) near Village Mrkovi, Luštica Peninsula (Photo by V. Stevanović)

Negative human impact: fire, building of human settlements, tourism with their infrastructure.

TDHI: M (Moderate); **PBE:** L (Low) – I (Insignificant); **RBE:** HR (High Restrictive).

Biological Resources of Mediterranean Evergreen Scrub Vegetation

The most common type of evergreen Mediterranean vegetation in Montenegro is maquis, pseudomaquis, and garigue, in their well-developed stage and stable coenotic structure composed of usual evergreen Mediterranean shrubs such are *Arbutus unedo*, *Pistacia lentiscus*, *Myrtus communis*, *Viburnum tinus*, *Phyllirea latifolia*, *Erica arborea*, *Rhamnus alaternus*, *Juniperus macrocarpa*, *Spartium junceum*, *Laurus nobilis*; *Smilax aspera*, *Cistus incanus*, *Cistus salviaefolius*, *Erica, manipuliflora*, etc. Evergreen Mediterranean shrub vegetation is restricted to more or less narrow belt along Adriatic coast of Montenegro. Transitional zone toward sub-Mediterranean deciduous scrub and forests is represented by pseudomaquis. Particularly interesting are evergreen laurel forest and scrubs in various coenotic combinations from pure stands to mixed with chestnut or frequent element of maquis. Laurel (*Laurus nobilis*) is common in Boka Kotorska bay but it is distributed along the coastline, although they can be found in pure stands on islets of Lake Skadar as well. The tradition of collecting laurel leaves is long and is still



Fig. 19 Well-preserved maquis at Luštica Peninsula (Photo by V. Stevanović)

maintained today, since the laurel represents a valuable spice in food industry, and its oils are used in pharmaceutical and cosmetics industry (Fig. 19) [31, 35, 36].

Biological Resources of Sub-Mediterranean Deciduous Forest and Scrub Ecosystems

This type of ecosystem covered vast areas of eroded karst terrains in the hinterland of Adriatic coast of Montenegro. These ecosystems are in different phases of succession to forests or vice versa degradation to rocks. Their economic value is small with lower economic value, but with indispensable anti-erosion protective function. Primarily, these ecosystems are used by local residents concentrated in karst depressions of the mainland as fuel wood. This type of ecosystem on the limestone karst includes the sub-Mediterranean thermophilous, rather scrubs than forests of the Macedonian oak (*Quercus trojana*), *Quercus pubescens*, *Ostrya carpinifolia*, *Carpinus orientalis*, *Acer monspessulanum*, *Punica granatum*, *Paliurus spina-christi*, *Pistacia terebinthus*, *Fraxinus ornus*, etc. Chestnut (*Castanea sativa*) forests grow in acid soils and flysch bedrock belongs to sub-Mediterranean vegetation formation. Particularly interesting are mixed chestnut-laurel forest in Boka Kotorska bay (Kostajnica, Morinj) and pure old chestnut stands in northern slopes of Mt. Rumija above Skadar Lake between Livari and Ostroz (Fig. 20) [31, 35, 36].

Negative human impacts: Three cutting for fuel; fire, goat browsing, overgrazing.



Fig. 20 Sub-Mediterranean low forests and scrubs of Oriental hornbeam, Macedonian oak, Hop hornbeam, downy oak, etc. mixed with chestnut stands at northern slopes of Mt. Rumija above Skadar Lake (Photo by V. Stevanović)

TDHI: H (High); PBE: L (Low) – I (Insignificant); RBE: R (Restrictive) – HR (High Restrictive) due to its most important role against water erosion.

Biological Resources of Secondary Ecosystems of Sub-Mediterranean Scrubs and Limestone Grounds

These ecosystems originate during the degradation of Eu-Mediterranean and sub-Mediterranean types of forest vegetation. With protective anti-erosive function, they represent a successive phase of progradation toward spontaneous renewal of the forest vegetation. Unfortunately, a large amount of precipitation slows down the regeneration of shrubby and forest vegetation, so these ecosystems are maintained for a long time. Many aromatic plants are used in folk medicine and as a very good bee forage. The most important plant species in limestone rocky grounds is *Salvia officinalis* (Fig. 21) [31, 35, 36].

Negative human impacts: Three cutting for fuel, fire, goat browsing, overgrazing.

TDHI: H (High) – M (Moderate); PBE: M (Moderate) – L (Low); RBE: Li (Liberal) – R (Restrictive).



Fig. 21 Limestone rocky slopes of Mt. Lovćen above village Mirac (left); Inflorescence of Sage (*Salvia officinalis*) (Photo by V. Stevanović)

Biological Resources of Upper Timber Line of Outer (Maritime) Chain of Dinaric Alps – Oro-Mediterranean Mountains

The subalpine belt and upper timberline on the limestone coastal mountains Mt. Orjen, Mt. Lovćen and Mt. Rumija as well as mountains of hinterlands under influence of Mediterranean climate (Prokletije, Žijovo, Kapa Moračka) in Montenegro is constituted of Bosnian or White-bark pine “munika” (*Pinus heldreichii*). It is naturally distributed in Calabria and mountains of Balkans (Bosnia and Herzegovina, Montenegro, Albania, Serbia, Macedonia, Greece, and Bulgaria). Most preserved forests occur in Mt. Orjen where some specimens or group of trees are more than 1,000 years old. The forests of *Pinus heldreichii* at the Mt. Lovćen and Mt. Rumija are very restricted on small plots at deep limestone slopes. Coniferous ecosystems of these species represent one of the most important vegetation belts of the Dinaric mountain chain above the Adriatic coast of Montenegro (Fig. 22) [31, 35, 36].

Negative human impacts: Forest cutting of old stands and fire.

TDHI: M (Moderate); **PBE:** L (Low, only as genetic resource); **RBE:** ExU (Exclusion of Using).

4.4 Genetic Resources of Wild Flora and Fauna

The component of genetic level of biodiversity of the Mediterranean part of Montenegro and South Adriatic has not drawn too much attention recently, but concerning the fact that genetic resources represent the focus of interests of scientists worldwide, it is very likely that this interest will increase in the future as a result of



Fig. 22 Subalpine forests of *Pinus heldreichii* in Mt. Orjen; more than a thousand years old “munika” tree on Mt. Orjen (Photo by V. Stevanović)

the constant demand for new biotechnologies [83]. High genetic potentials of wild flora and fauna of Montenegro coast can be summarized as follows:

Marine species of Pisces, Mollusca, Spongia for pharmaceutical industry (existing excellent results in medical treatment of psoriasis, the latest research even indicates the possibility of using substances extracted from sponges *Aplisina aerophoba* as potential components for COVID-19 control)

- Endemic and relic flora and fauna, especially of international (global) significance,
- Relic or ancestral populations of widely distributed species of trees in Mediterranean and sub-Mediterranean canyons and gorges,
- Wild relatives or ancient hybrids of cultivated plants and domesticated animals,
- Well-preserved populations with stable age structure of widely used wild plants and animals.

Possibilities for the exploitation of this level of biodiversity components may be recognized as high to moderate and the regime of exploitation as restrictive.

5 Conclusions

Scientific arguments confirm the statement that both the territory and the aquatory of Montenegro have a high species, ecosystem, and landscape diversity. The biodiversity of Montenegro and its Mediterranean part is unique and of global significance, especially concerning the internationally important species with majority of Montenegrin endemics.

Both the South Adriatic aquatory and coastal zone of Montenegro have high potentials for exploitation of some components of biodiversity. Nevertheless, it is

necessary to emphasize that nearly all-natural ecosystems in Mediterranean part of Montenegro are more or less sensitive (fragile), depending on their size, duration, and kind of anthropogenic influence. Ecosystems with high species diversity, as major ecosystems in Montenegro, are more fragile in comparison with those that have lower species diversity and simpler structure.

The majority of natural ecosystems Montenegrin coastal zone have been exploited for centuries and that their recent state is different from climatogenic, since they represent progradation-degradational derivatives of climazonal ecosystems still under anthropogenic pressure and constant stress.

Today, it is clear that the exploitation of biological resources of the Mediterranean part of Montenegro has to be based on the principles of sustainability. As basic criteria of conservation and exploitation of these biological resources, including relict, endemic-relict, and endemic species, we recognize the following categories: quantity of resource, modes of use, period of use, conservation status, resource fragility, and resource reproducibility.

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