Chapter 22
Conservation of Cave Fauna, with an Emphasis on Europe and the Americas

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22.1 Introduction

There has been an increasing awareness and concern for subterranean biodiversity over the past two decades (Culver et al. 2000; Danielopol et al. 2000; Elliott 2000; Gibert and Deharveng 2002; Culver and Pipan 2009, 2014; Gibert and Culver 2009). Although the subterranean environment traditionally has been considered species poor, an exceptionally species-rich and phylogenetically diverse community of organisms exists in caves, groundwater, and other subterranean habitats of Europe, North America, Central America, and South America (Culver et al. 2000; Ferreira et al. 2007; Trajano and Bichuette 2009; Cordeiro et al. 2014; Gallão and Bichuette 2015). Subterranean biodiversity is particularly diverse in Europe where some 5000 troglobionts have been described (Gibert and Culver 2009; Deharveng et al. 2012). Most local hotspots of subterranean biodiversity globally, defined by Culver and Sket (2000) as caves or wells with 20 or more troglobionts, are known from southern Europe (Culver and Sket 2000; Culver and Pipan 2009). Five of the six caves with 40 or more species occur in Europe, including Postojna-Planina Cave System in Slovenia and Vjetrenica in Bosnia-Herzegovina, which are the two most biodiverse caves in the world with almost 100 species (Culver and Pipan 2009). The sixth cave

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is the Mammoth Cave System in Kentucky, USA. For South America, specifically Brazil, there are at least three cave systems with high diversity of troglobionts (Deharveng and Bedos 2012). More recently, four cave systems have been identified as areas of high diversity of troglobionts in Brazil: Areias Cave System (26+ troglobionts), Alambari Cave System (16 species), Parede Vermelha Cave (12+ species), and Olhos d'Água Cave (11+ species) (Trajano et al. 2016).

Several life history traits common to many troglobionts, and to some extent, cave-roosting bats, are associated with increased risk of extinction, including low reproductive rates and limited dispersal ability (Culver and Pipan 2009, 2014). Thus, population rescue is often much slower and risk of extinction much greater relative to populations of related surface species. Moreover, many troglobionts may be particularly sensitive to small fluctuations in abiotic variables such as temperature, humidity, dissolved oxygen, and concentrations of heavy metals, among others.

Obligate cave/subterranean fauna, as well as many facultative cave/subterranean species (such as bats), rely heavily on subterranean habitats and thus are highly vulnerable to threats that result in environmental change and habitat disturbance and degradation. These threats vary with respect to scope, source, severity, and timing among species, karst regions, and continents. Some threats, such as climate change and groundwater pollution, are global in scope (Culver and Pipan 2009). However, effects of climate change and sources of groundwater pollution vary at regional and local scales. Other threats affect cave/subterranean populations and species at a local or regional scale, such as mining and quarrying, impoundments, groundwater extraction, commercialization of caves, and amateur and scientific collection. Important threats to subterranean communities in caves, groundwater, and other subterranean habitats in Europe, North America, Central America, and South America have been reviewed and discussed in Juberthie (1995), Elliott (2000), Tercafs (2001), Culver and Pipan (2009, 2014), Reboleira et al. (2011), Trajano (2010), Simoes et al. (2014), and Gallão and Bichuette (2015, 2018), among others, and we direct those interested in specific threats to subterranean biodiversity in general to these publications (Fig. 22.1).

Box 22.1

Several biological factors common to many troglobionts are associated with increased vulnerability to threats and risk of extinction (reviewed in Culver and Pipan 2009, 2014). First, most subterranean species are geographically rare, often having small, highly restricted geographic ranges (Culver et al. 2006; Zagmajster et al. 2008; Deharveng et al. 2009; Gallão and Bichuette 2018). These animals often are endemic to a single or few cave systems (Christman et al. 2005; Deharveng et al. 2009; Niemiller and Zigler 2013). Many species also may be numerically rare. Several troglobionts are known from only one or a few specimens (e.g., Niemiller et al. 2017). However, it is often unclear whether such species are actually comprised of very small

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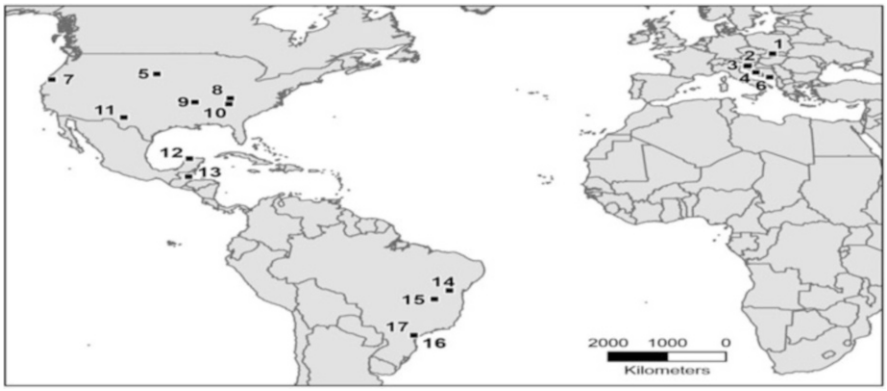

Fig. 22.1 Locations of caves, systems, features, and areas mentioned specifically in this chapter. *1* Caves of the Demänová valley; *2* Postojna-Planina Cave System; *3* Skocjanske Jame; *4* Dinaric Karst; *5* Wind Cave; *6* Vjetrenica; *7* Cave Creek; *8* Mammoth Cave; *9* Buffalo National River; *10* Hubbard's Cave; *11* Carlsbad Caverns; *12* Anillo de Cenotes; *13* Chiquibul Cave; *14* Parede Vermelha Cave; *15* Olhos d'Água Cave; *16* Alambari Cave System; *17* Areias Cave System

Box 22.1 (continued)
populations (i.e., observed rarity reflects actual rarity) or whether rarity reflects undersampling or sampling of suboptimal habitat. For example, some species may be common in epikarst but are very infrequently observed in caves.

Herein, we identify and review several important international and national legislation, policies, and conservation initiatives that have been implemented or proposed related to the protection and conservation of cave/subterranean biodiversity.

Box 22.2
Despite these biological factors and many documented and suspected threats, only a small fraction of subterranean biodiversity receives any direct protection under international, national, or regional legislation. Compared to vertebrates, subterranean invertebrates and other organisms have largely been neglected in conservation studies, assessments, and policy decisions, despite their significantly greater diversity, roles in groundwater and subterranean ecosystem services, sometimes high levels of endemicity, and benefits to mankind.

22.2 International Legislation

Four major international conventions that focus on biodiversity issues are relevant to the protection and conservation of subterranean biodiversity and ecosystems: Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention on Wetlands of International Importance, and World Heritage Convention (WHC). Each of these biodiversity-related conventions aims to implement conservation actions at the international, national, and regional levels. However, few subterranean species are currently protected under the auspices of these conventions.

The *Convention on Biological Diversity* (CBD) is an international treaty among 196 countries today that entered into force in 1993 to develop strategies for the conservation and sustainable use of biodiversity. All countries in Europe, North America, Central America, and South America are member parties, except for the United States. CBD has three main goals: conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits arising from genetic resources. These objectives are of particular importance for developing countries. The convention requires countries to prepare a national biodiversity strategy, called National Biodiversity Strategies and Action Plans (NBSAPs), and to ensure that NBSAPs are implemented into all relevant planning and activities that may have a positive or negative impact on biodiversity. Of the 196 member parties, 94% have developed NBSAPs. Cave and groundwater biodiversity and ecosystems are specifically addressed in several countries' NBSAPs. For example, the Slovenian NBSAPs has a specific objective on cave habitat types "to maintain subterranean habitat types in ecologically important areas, and the entire subterranean fauna, at favorable conservation status." However, the focus on subterranean fauna and ecosystems in NBSAPs appears to be highly variable among countries.

The *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) is an international agreement signed in 1973 and entered into force in 1975 between governments to ensure that international trade of wild animals and plants of conservation concern does not further threaten their continued survival. Today, 181 countries, including most countries in Europe, North America, Central America, and South America (Table 22.1), are member parties. Some 5600 species of animals are protected by CITES. However, only about 40% of the species listed are invertebrates. These species are listed in one of the three CITES Appendices according to how threatened they are by international trade. No troglobionts from Europe, North America, Central America, or South America are listed; however, some non-troglobiotic taxa that rely on caves are included (e.g., cave-roosting birds, *Steatornis caripensis*).

The *Convention on Wetlands of International Importance (Ramsar Convention)* is the oldest global international environmental agreement adopted in 1971 and entered into force in 1975. Its mission is the conservation and wise use of all wetlands through local and national actions and international cooperation. Some 169 countries are contracting parties to the convention, including most countries in

Table 22.1 Important international and national legislation relevant to the conservation and protection of subterranean biodiversity and ecosystems in countries of Europe, North America, Central America, and South America

Country	Bern	Bonn	CBD	CITES	RC	WHC	Legislation
Europe							
Albania	1999	2001*	1994	2003	1996	1989	Law on Biodiversity Protection (2006) Law on Protected Areas (2002, 2008) Law on Wild Fauna Protection (2008)
Andorra	2001		2015		2012	1997	Law of Protected Species (2001)
Austria	1983	2005	1994	1982	1983	1992	Flurverfassungsgrundsatzgesetz (1951)
Belarus		2003	1993	1995	1991	1988	Law on Protection of the Environment (2002) Law on the Animal World (2007)
Belgium	1990	2003*	1997	1983	1986	1996	Regional policy
Bosnia and Herzegovina	2009		2002	2009	1992	1993	Law on Environmental Protection (2013)
Bulgaria	1991	1999*	1996	1991	1976	1974	Nature Protection Act (1967, 1991) Biological Diversity Act (2002, 2011)
Croatia	2000	2000*	1997	2000	1991	1992	Cave Protection Act (1900) Nature Protection Act (2005) Regulation on Protection of Wild Species (2006)
Cyprus	1988	2001*	1996	1974	2001	1975	Law on the Protection and Management of Nature and Wildlife (2003)
Czech Republic	1998	1994*	1994	1993	1993	1993	Act on the Protection of Nature and Landscape (1992, 2004)
Denmark	1983	1983*	1994	1977	1978	1979	Nature Conservation Act (2009, 2013)
Estonia	1992	2008*	1994	1992	1994	1995	Animal Protection Act (2000) Nature Conservation Act (2004)
European Union	1982	1983	1994	2015			
Finland	1986	1989*	1994	1976	1975	1987	Nature Conservation Act (1923, 1996) Nature Conservation (Amendment) Act (1991)
France	1990	1990*	1994	1978	1986	1975	Environment Code (2010)
Germany	1985	1984*	1994	1976	1976	1976	Federal Nature Conservation Act (2010)
Greece	1983	1999	1994	1992	1975	1981	Biodiversity Law (2011)

(continued)

Table 22.1 (continued)

Country	Bern	Bonn	CBD	CITES	RC	WHC	Legislation
Hungary	1990	1983*	1994	1985	1979	1985	Act on Nature Conservation (1996)
Iceland	1993		1994	2000	1978	1995	Nature Conservation Act (1999)
Ireland	1982	1983*	1996	2002	1985	1991	Wildlife Act (1976) Wildlife (Amendment) Act (2000)
Italy	1982	1983*	1994	1979	1977	1978	Law on Protected Areas (1991)
Latvia	1997	1999*	1996	1997	1995	1995	Law on the Conservation of Species and Biotypes (2000, 2005) Law on Specially Protected Nature Territories (1993, 2007) Law on Subterranean Depths (1996)
Liechtenstein	1982	1997	1998	1979	1991		Law on the Protection of Nature and Landscape (2004)
Lithuania	1997	2002*	1996	2001	1993	1992	Law on the Protected Fauna, Flora and Fungi Species and Communities (1997) Law on Protected Areas (2001) Underground Law (1995)
Luxembourg	1982	1983*	1994	1983	1998	1983	Law on Nature Protection and Natural Resources (2004)
Malta	1994	2001*	2001	1989	1989	1978	Flora, Fauna, and Natural Habitats Protection Regulations (2006, [amended] 2013)
Moldova	1994	2001*	1996	2001	2000	2002	Law on the Animal Kingdom (1995)
Montenegro	2010	2009*	2006	2007	2006	2006	Law on Nature Protection (1977, 1989)
Netherlands	1982	1983*	1994	1984	1980	1992	Nature Conservation Act (1998) Flora and Fauna Act (2002)
Norway	1986	1985	1993	1976	1975	1977	Nature Diversity Act (2009)
Poland	1996	1996*	1996	1989	1978	1976	Nature Conservation Act (2004)
Portugal	1982	1983*	1994	1980	1981	1980	Nature Conservation Act (2008)
Romania	1993	1998*	1994	1994	1991	1990	Law no. 49 (2011) for the approval of Government Emergency Ordinance no. 57 on the regime of natural protected areas, conservation of natural habitats, wild flora and fauna (2007)
Serbia	2008	2008	2002	2006	1992	2001	Law on Nature Conservation (2010)

Slovakia	1997	1995*	1994	1993	1993	1993	Act on Nature and Landscape Protection (2002)
Slovenia	2000	1999*	1996	2000	1991	1992	Nature Conservation Act (1999) Cave Protection Act (2004)
Spain	1986	1985	1994	1986	1982	1982	Law on Natural Heritage and Biodiversity (2007)
Sweden	1983	1983	1994	1974	1975	1985	Environmental Code (1998)
Switzerland	1982	1995*	1995	1974	1976	1975	Federal Act on the Protection of Nature and Cultural Heritage (1966)
The Former Yugoslav Republic of Macedonia	1999	1999*	1998	2000	1991	1997	Law on Nature Protection (2004)
Ukraine	1999	1999*	1995	1999	1991	1988	Law on Animals (2001)
United Kingdom	1982	1985*	1994	1976	1976	1984	Wildlife and Countryside Act (1981) Countryside Rights of Access Act (2000) Nature Conservation (Scotland) Act (2004) Protected Species Act (2003)—Bermuda
North and Central America							
Antigua and Barbuda		2007	1993	1997	2005	1983	Environmental Protection and Management Act (2014)
Bahamas			1993	1979	1997	2014	Forestry Act (2010)
Barbados			1994	1992	2006	2002	
Belize			1994	1986	1998	1990	Wildlife Protection Act (1981)
Canada			1993	1975	1981	1976	Species at Risk Act (2002)
Costa Rica		2007	1994	1975	1992	1977	Biodiversity Law (1997) Law on Wildlife Conservation (2012)
Cuba		2008	1994	1990	2001	1981	Wild Animals Protection Act (1968)
Dominica			1994	1995		1995	Forestry and Wildlife Act (1976)
Dominican Republic			1997	1986	2002	1985	General Law on Environmental and Natural Resources (2000)
El Salvador			1994	1987	1999	1991	Wildlife Conservation Law (1994)
Grenada			1994	1999	2012	1998	Birds and Other Wildlife Protection Act (1957)
Guatemala			1995	1979	1990	1979	Forestry Law (1996)
Haiti			1996			1980	

(continued)

Table 22.1 (continued)

Country	Bern	Bonn	CBD	CITES	RC	WHC	Legislation
Honduras		2007	1995	1985	1993	1979	Forest, Protected Areas, and Wildlife Law (2007)
Jamaica			1995	1997	1998	1983	Endangered Species Act (2000) Wildlife Protection Act (1945)
Mexico			1993	1991	1986	1984	General Wildlife Act (2000)
Nicaragua			1996	1977	1997	1979	Law on Use and Conservation of Biodiversity (2012)
Panama		1989	1995	1978	1990	1978	General Environmental Law (1998) Wildlife Law (1995)
Saint Kitts and Nevis			1993	1994		1986	National Conservation and Environment Protection Act (1987)
Saint Lucia			1993	1982	2002	1991	Wildlife Protection Act (1980)
Saint Vincent and the Grenadines			1996	1988		2003	Wildlife Protection Act (1987)
United States				1974	1986	1973	Endangered Species Act (1973)
South America							
Argentina		1992	1995	1981	1992	1978	Law on Wildlife Conservation (1997)
Bolivia		2003	1995	1979	1990	1976	Law on the Rights of Mother Earth (2010) Supreme Decree 22641 (1990)
Brazil		2015	1994	1975	1993	1977	Environmental Crimes Law (1999)
Chile		1983	1994	1975	1981	1980	Environmental Law (1994) Hunting Law (1996)
Columbia			1995	1981	1998	1983	General Environmental Law (1993)
Ecuador		2004	1993	1975	1991	1975	Forestry and Conservation of Natural Areas and Wildlife Law (1981) Biodiversity Law (2004)
Guyana			1994	1977		1977	Environmental Protection Act (1996)
Paraguay		1999	1994	1976	1995	1988	Law of Wild Life (1992)
Peru		1997	1993	1975	1992	1982	Forest and Wildlife Act (1975) Biological Diversity Conservation and Sustainable Use Act (1997)
Suriname			1996	1980	1985	1997	Nature Conservation Law (1954)

Trinidad and Tobago			1996	1984	1993	2005	Conservation of Wildlife Act (1958, 1980)
Uruguay		1990	1994	1975	1984	1989	
Venezuela			1994	1977	1988	1990	Protection of Wildlife Act (1970) Biological Diversity Act (2000)

International legislation includes several important conventions: the Bern Convention (Bern), Bonn Convention (Bonn), Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention (RC), and World Heritage Convention (WHC). EUROBATS member parties are denoted by an asterisk (*) under the Bonn Convention column. Entry dates for each country are presented

Europe, North America, Central America, and South America. At the time of joining the convention, each contracting party must designate at least one wetland site for inclusion in the List of Wetlands of International Importance. Ramsar Sites are designated based on nine criteria, eight of which are related to biodiversity. When a wetland is officially included in the list, it is recognized as being of significant value for humanity as a whole. Each contracting party must take the necessary actions to ensure that the ecological character of the Ramsar Site is preserved. Many Ramsar Sites are also protected under other international and national protection conventions and schemes, such as the World Heritage List under the UNESCO World Heritage Convention. Karst and other subterranean hydrological systems are broadly defined as wetlands, including marine, inland freshwater, and man-made types. Thirty-seven Ramsar Sites are inland karst wetlands that cover over 850,000 ha and occur in Europe, including notable cave systems such as Skocjanske Jame in Slovenia and Caves of the Demänová valley in Slovakia. In North and Central America, 44 karst and subterranean wetland Ramsar Sites occur that cover over 3.4 million ha, predominantly in Mexico, including the Anillo de Cenotes in the Yucatan. Only two Ramsar Sites in Chile are karst or subterranean wetlands in South America.

The *Convention Concerning the Protection of the World Cultural and Natural Heritage or the World Heritage Convention* (WHC) was adopted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) General Conference in 1972 and came into force in 1975. WHC aims to promote cooperation among nations to protect cultural and natural heritage globally that is of outstanding universal value to humanity. Today, 191 parties have agreed to identify, protect, and conserve World Heritage Sites. A site has outstanding universal value, as defined by the Operational Guidelines for the Implementation of the World Heritage Convention if it has cultural and/or natural significance that is so exceptional that it transcends national boundaries and is of importance to current and future generations of all humanity. Nomination and inclusion in the World Heritage List represents a formal pledge by the host country to take steps necessary to protect a site, which includes the appropriate legal, scientific, administrative, and financial measures for the identification, protection, conservation, preservation, and rehabilitation of sites with outstanding universal value. Listing as a World Heritage Site is often accompanied by increased tourism at some sites and prioritization for funding and technical assistance, but also controversial debates regarding how to protect some threatened sites.

Several sites included in the UNESCO World Heritage List contain significant cave and karst systems (Table 22.2). Of these sites, seven are specifically recognized for their outstanding biodiversity value under the biodiversity criteria (ix) and/or (x): criterion (ix) “to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal, and marine ecosystems and communities of plants and animals”, and criterion (x) “to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science and

Table 22.2 List of UNESCO World Heritage Sites and Tentative List Sites (T) within cave and karst terrains in Europe, North America, Central America, and South America

Continent	Country	World heritage site	Year inscribed	Natural criteria
Europe	Bulgaria	Pirin National Park	1983	vii, viii
	Bulgaria	Vratsa Karst Nature Reserve	T	vii, viii, ix, x
	Croatia	Kornati National Park and Telascica Nature Park	T	vii, viii, x
	Croatia	Plitvice Lakes National Park*	1979, 2000	vii, viii, ix
	Croatia	Velebit Mountain	T	vii, viii, ix, x
	France	Ensemble de grottes à concretions du Sud de la France	T	vii, viii, ix
	France/ Spain	Pyrenees-Mont Perdu*	1997, 1999	vii, viii
	Greece	Meteora	1988	vii
	Hungary	Hydrothermal Caves and Thermal Karst Systems of the Rozsadomb Area	T	viii
	Hungary/ Slovakia	Caves of Aggtelek and Slovak Karst*	1995, 2000	viii
	Italy	The Murge of Altamura	T	vii, viii
	Montenegro	Durmitor National Park	1980, 2005	vii, viii, x
	Norway	Svalbard Archipelago	T	vii, viii, ix, x
	Serbia	The Tara National Park with the Drina River Canyon	T	x
	Slovenia	Skocjan Caves*	1986	vii, viii
North America	Canada	Canadian Rocky Mountain Parks*	1984	vii, viii
	Canada	Nahanni National Park*	1978	vii, viii
	Cuba	Alejandro de Humboldt National Park	2001	ix, x
	Cuba	Desembarco del Granma National Park*	1999	vii, viii
	Mexico	Reserve de la Biosphere Selva El Ocote	T	n
	Mexico	Sian Ka'an	1987	vii, x
	United States	Carlsbad Caverns National Park*	1995	vii, viii
	United States	Grand Canyon National Park	1979	vii, viii, ix, x
	United States	Mammoth Cave National Park*	1981	vii, viii, x
South America	Brazil	Canyon du Rio Peruaçu, Minas Gerais	T	vii, viii, ix, x
	Venezuela	Canaima National Park*	1994	vii, viii, ix, x

Natural criteria for each site are listed and sites with outstanding universal value are denoted with an asterisk (*)

conservation." There are several additional areas not listed in Table 22.2 that have cave and karst of national rather international significance or have cultural rather than natural value (Williams 2008). Although caves and karst are well represented in World Heritage sites in humid tropical and temperate regions, particularly in the Northern Hemisphere, representation of caves and karst in World Heritage sites is deficient in several regions (Williams 2008), particularly the arid to semiarid zone of the tropics to subtropics, the periglacial zone, and in the Southern Hemisphere, including South America.

22.3 Conservation Organizations

Several organizations are important partners and leaders for conservation worldwide, working to protect and conserve biodiversity, including subterranean fauna. These organizations, highlighted by the International Union for the Conservation of Nature and Natural Resources and NatureServe, work at global, national, and regional scales to assist government agencies and other conservation organizations on many biodiversity conservation issues, setting priorities for funding, research, and conservation efforts and developing sound conservation policies, legislation, and practices.

The *International Union for the Conservation of Nature and Natural Resources* (IUCN) was founded in 1948 and is the world's oldest international environmental and conservation organization, which today includes 200+ government and 900+ nongovernment organizations as members. IUCN assists governments and other conservation organizations with national and international biodiversity policies and initiatives. The IUCN Global Species Programme, in conjunction with the IUCN Species Survival Commission (SSC), produces, maintains, and manages the IUCN Red List of Threatened Species. The IUCN SSC is a group of more than 10,000 volunteer experts that provide valuable information and advice on biodiversity to IUCN. Most experts belong to the more than 140 Specialist Groups, Red List Authorities, Task Forces, and Subcommittees. Although most Specialist Groups focus on particular taxa, some groups are more ecosystem focused, including the Cave Invertebrate Specialist Group. Information on the life history, ecology, status, trends, and threats of species provided by these experts is used in the IUCN Red List, which is a list that highlights species that are at greatest risk of extinction and greatest need of conservation. The IUCN Red List is widely recognized as the most comprehensive, objective global approach for evaluating the conservation status of flora and fauna (Lamoreaux et al. 2003). The IUCN Red List is used to help raise awareness about threatened species, set priorities for and guide conservation efforts and funding, and influence environmental policies and legislation (Rodrigues et al. 2006; Baillie et al. 2008; Cardoso et al. 2011a, b). A species may be classified on the IUCN Red List as critically endangered (CR), endangered (EN), or vulnerable (VU) on a global scale if it meets specific conditions under any one of these five criteria (IUCN 2001): (A) past, present, or projected reduction in population size

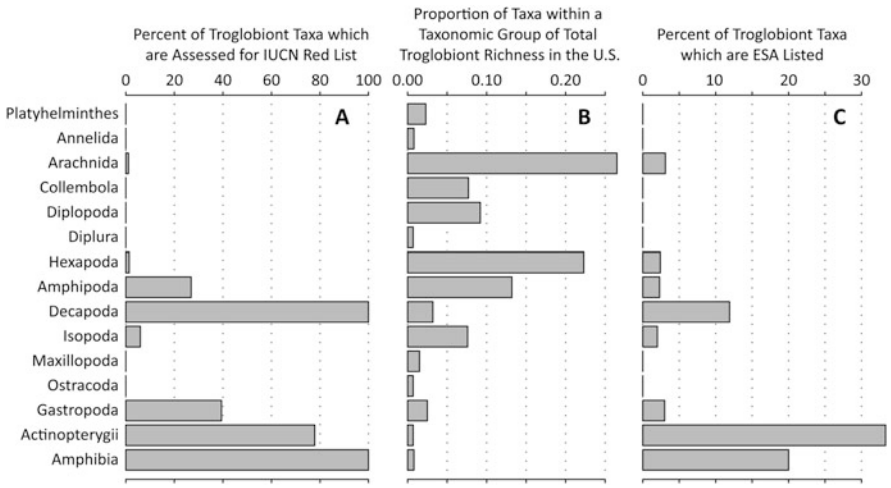

Fig. 22.2 Percentage of species assessed under IUCN Red List criteria (**a**), troglobiont diversity for various groups of invertebrate taxa (**b**), and percentages of troglobionts listed under the United States Endangered Species Act as endangered or threatened (**c**)

over three generations; (B) small geographic range in combination with fragmentation, population decline, or fluctuations; (C) small population size in combination with decline or fluctuations; (D) very small population or very restricted distribution; and (E) a quantitative analysis of extinction risk. Species should be assessed against all criteria, when possible, to confirm that the most accurate threat classification is obtained (IUCN 2001).

Although the IUCN Red List has been widely accepted and has many strengths (Rodrigues et al. 2006), several biases and limitations have been noted (Cardoso et al. 2011a). Taxa that have been evaluated are biased toward those occurring in terrestrial ecosystems and those which are vertebrates (IUCN 2010). Most mammals, birds, and amphibians have been evaluated, yet only 0.5% of described arthropods have been assessed (Cardoso et al. 2011a, b). Subterranean fauna of Europe (outside of Croatia and Slovenia), North America, Central America, and South America are poorly represented in the IUCN Red List, with only 10% of subterranean species having been evaluated. Of the subterranean species evaluated, taxonomic composition is biased toward fishes, salamanders, and decapods, where >75% of taxa within these groups have been evaluated (Fig. 22.2a). In contrast, just 14% of arachnids and hexapods, which collectively account for 48% of subterranean biodiversity overall in the United States, have been evaluated.

Cardoso et al. (2011a) cited two primary reasons for the taxonomic bias against invertebrates on the IUCN Red List. First, even if most necessary biological data could be gathered for Red List criteria, thresholds suggest that they were defined based on the requirements of large vertebrate species and, thus, may not be appropriate for most invertebrates, Second, current Red List criteria are difficult to apply to invertebrates because of four main shortfalls (Cardoso et al. 2011b): (1) most species

are undescribed (the Linnean shortfall); (2) the full distributions of most species are unknown (the Wallacean shortfall); (3) the abundances of most species and how they change spatially and temporally are unknown (the Prestonian shortfall); and (4) the ecology of species and sensitivity to habitat changes are largely unknown (the Hutchinsonian shortfall). These shortfalls are the consequence of limited research on—and funding for—invertebrates, especially related to taxonomy and life history (Cardoso et al. 2011b). Consequently, it is difficult to gather the necessary information to classify most subterranean invertebrate species under the IUCN Red List criteria. These same shortfalls apply not only globally, but also to most subterranean species in most karst regions of Europe, North America, Central America, and South America. To address these issues, recommendations have been suggested to modify current IUCN Red List criteria to increase the feasibility and adequacy of the assessment process, in hopes of achieving greater representation of invertebrates on priority species lists (Martin et al. 2010; Cardoso et al. 2011a).

IUCN Red List Categories and Criteria also are applied at smaller spatial scales—including regions and countries—which are more practical for management and conservation planning. To date, Regional and National Red Lists have been developed in 26 regions, 113 countries, and 45 subnational entities. A database of these Regional and National Red Lists is maintained by the IUCN National Red List project (http://www.nationalredlist.org). As is the case for the global IUCN Red List, few subterranean species are included in Regional and National Red Lists. An exception is the subterranean fauna of Croatia, which includes over 450 cave obligate species from caves in the richest cave biodiversity region in the world, the Dinaric Karst (Culver and Sket 2000; Gottstein-Matocec 2002; Ozimec 2011). The Croatian Red Book of Cave Fauna is the first Red List assessment of troglobionts and stygobionts of its kind in the world, covering 186 taxa spanning 16 classes, 29 orders, and 54 families. Thirty-five percent (60 taxa) of the taxa included were assessed as Critically Endangered. Several specific threats to Croatian cave fauna have been identified, such as threats associated with urbanization and heavy tourism, groundwater pollution and exploitation, and illegal collection (Ozimec 2011).

Brazil has 158 described troglobionts distributed in 13 states, with the greatest diversity in Bahia (Serra do Ramalho karst area and São Desidério region—part of Bambuí group, Una-Irecê and Rio Pardo groups, Canudos supergroup, and sandstone Chapada Diamantina) and São Paulo (part of Açungui group) (Gallão and Bichuette 2018). Only 33 troglobionts were included in the Brazilian Red List of 2004 and another 30 species known as of 2003 were not evaluated. From 2004 to 2014, the number of troglobionts included in the Brazilian Red List increased to 83 species. Many of these species are listed as Endangered or Critically Endangered. Mining and hydroelectric projects are the main threats to subterranean biodiversity in Brazil, but other impacts, such as pollution of aquifers by pesticides and deforestation for agriculture and pastureland, also represent significant threats (Gallão and Bichuette 2018).

There is a pressing need to address higher levels of biodiversity, such as habitats, communities, and ecosystems (Nicholson et al. 2009; Rodriguez et al. 2011, 2012;

Keith et al. 2015). IUCN is currently developing categories and criteria for a Red List of Ecosystems (RLE) as a global standard for ecosystem risk assessment at multiple scales (Rodriguez et al. 2011, 2012; Keith et al. 2015). Much like the IUCN Red List of Threatened Species, RLE has eight categories of risk for each ecosystem based on five quantitative criteria designed to evaluate symptoms of risk in terrestrial, subterranean, freshwater, and marine ecosystems (Keith et al. 2013). The RLE will establish an objective, robust, and repeatable international standard for ecosystem risk assessment and losses of ecosystem functions and services that will allow for comparisons among regions and time periods. Subterranean ecosystems are being considered in the development of RLE criteria, which has a target date of 2025 to achieve global coverage of ecosystems.

NatureServe is a nonprofit organization that provides scientific expertise, resources, and data for conservation action. The NatureServe Network includes over 80 Natural Heritage programs and conservation data centers throughout the Western Hemisphere, including the United States, Canada, Mexico, Brazil, and several other countries and territories in the Caribbean, Central America, and South America. NatureServe offers several tools and services for conservation science and biodiversity assessment, which includes standards and methods for collecting, managing, mapping, and sharing biodiversity data and conducting assessments of species conservation status, ecosystem ecological integrity, and climate change vulnerability, among others. NatureServe maintains biodiversity data for over 77,000 species and 870 ecosystems in the United States and Canada, which can be accessed through a web-based product, NatureServe Explorer (http://explorer.natureserve.org). A similar product, NatureServe Infonatura (http://infonatura.natureserve.org), provides information for some 8700 species of birds, mammals, and amphibians in the Caribbean, Central America, and South America. NatureServe also partners with IUCN by providing data and coordination of their own assessments to IUCN Red List assessments, as well as working together on conservation assessments.

Of particular usefulness are standards and methods for conservation status rank assessment to determine relative extinction risk of a species or ecosystem (Faber-Langendoen et al. 2009; Master et al. 2009). NatureServe conservation status ranks are based on a one to five scale, from most to least at risk of extinction: G1 (Critically Imperiled), G2 (Imperiled), G3 (Vulnerable), G4 (Apparently Secure), and G5 (Secure). Two additional ranks associated with extinction exist: GH (Possibly Extinct) and GX (Presumed Extinct). Status ranks can be assessed at three geographic scales: global (G), national (N), and state (S). Conservation ranks are based on ten primary factors grouped into three main categories: rarity, trends, and threats (Master et al. 2009). Rarity factors include range extent of occurrence (EOO), area of occupancy (AOO), number of occurrences, number of occurrences with good viability or ecological integrity, population size, and environmental specificity. Trend factors include both short-term and long-term trends in population size, EOO, AOO, number of occurrences, and viability or ecological integrity of occurrences. Threat factors include threat impact and intrinsic vulnerability to threats.

The comprehensive and rigorous biodiversity information data maintained and the tools and services developed by NatureServe have made NatureServe Conservation Status Assessment, like the IUCN Red List, a key tool in conservation from regional to global scales in the Western Hemisphere. Approximately 12% of troglobiotic taxa in the United States and Canada remain to be evaluated, which is a large improvement over taxa that remain to be evaluated under IUCN Red List criteria. Seventy-four percent of taxa have been assessed at an elevated risk of extinction (G1 to G3). Two species, *Bactrurus cellulanus* and *Pseudanophthalmus krekeleri*, may have already been lost and are presumed extinct (GX) (Elliott 2000; Taylor and Niemiller 2016), while ten additional species may possibly be extinct (GH). This conservation tool, however, is also not without its shortcomings with respect to subterranean biodiversity. The conservation status of most subterranean fauna has not been reviewed in 10+ years, and much subterranean biodiversity remains to be assessed in many regions, including Mexico, the Caribbean, Central America, and South America. Only mammals, birds, and amphibians have been assessed to date in these regions. Moreover, biological surveys are likely needed for many taxa assessed as possibly (GH) or presumed extinct (GX) in the wild, as there is hope that some of these taxa have been lost already. For example, a recent study by Niemiller et al. (2017) rediscovered two species of cave carabid beetles, *Pseudanophthalmus insularis* and *P. paulus*, which were classified as Possibly Extinct (GH), as they had not been observed in 60 and 50 years, respectively.

22.4 National Legislation

Most countries in Europe, North America, Central America, and South America are member parties to the conventions mentioned at Sect. 22.2, although there are notable exceptions (Table 22.1). Relatively few countries have enacted national endangered species legislation, despite worldwide threats and decline in biodiversity. Even when enacted, few subterranean taxa are directly protected under endangered species legislation. Important legislation related to the conservation and protection of subterranean biodiversity and ecosystems in Europe, North America, Central America, and South America are listed in Table 22.1. Several of these new pieces of national legislation are related to specific provisions of international conventions listed above. Unfortunately, there is considerable variation among countries in the level of protection enacted for subterranean biodiversity and ecosystems. Numerous local and regional ordinances and regulations exist in several countries in Europe, North America, Central America, and South America that may also protect cave systems and cave and groundwater fauna (Juberthie 1995; Lamoreaux et al. 1997; Tercafs 2001; Huppert 2006). This includes the establishment of city parks or ordinances to protect groundwater from karst groundwater pollution.

22.4.1 European Legislation

European bats were protected under the Bonn Convention by the Agreement on the Conservation of Populations of European Bats (EUROBATS). However, with notable exceptions, troglobiotic invertebrates receive limited if any specific protection in most European countries. For example, no subterranean invertebrates are specifically protected under the Biodiversity Diversity Act in Bulgaria, while in Slovenia, which possesses one of the most diversity subterranean faunas in the world (Culver and Sket 2000; Sket and Zagmajster 2004), the subterranean environment in total, including biodiversity, is protected by the national Cave Protection Act and other legislation. Many stygobionts and troglobionts are also strictly protected under the Regulation on Protection of Wild Species in Croatia.

Although some cave systems and associated fauna are locally protected in their respective countries, in general no national conservation programs directed specifically for subterranean habitats and diversity have been established in most European countries. In contrast, subterranean waters—and by proxy their biodiversity—are universally protected, mainly for reasons associated with public health (e.g., Belgium). Many European cave systems are directly protected by national legislation and the establishment of protected areas such as national parks, nature reserves, and Natura 2000 sites (reviewed in Juberthie 1995). In Belgium, several nature reserves have been established by the Royal Commission of Monuments and Sites to protect karst environments, including caves, and in Greece, caves are considered natural and cultural heritage monuments and therefore protected. Similar cave protection legislation exists in other European countries such as Hungary and Italy.

The *Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats* of 1979, also known as the Bern Convention, was the first international treaty to protect species and habitats in Europe. To date, 50 European countries, as well as some African countries, and the European Union have acceded to the convention, which came into force in 1982. The Convention aims to ensure conservation and protection of species and habitats by imposing restrictions on the take and trade of protected flora and fauna and constitutes a commitment to protect habitats of imperiled species. The Convention imposes legal obligations of contracting parties for the protection of over 500 plants and over 1000 animal species and their habitats, listed in Appendices I, II, and III. The only troglobiont listed on the Bern Convention is *Proteus anguinus* (Appendix II); however, some non-troglobiotic vertebrates that rely on caves are listed, such as *Atylodes genei*, *Speleomantes* spp., and most species of European cave-dwelling bats.

The Convention on the Conservation of Migratory Species of Wild Animals, also called the Bonn Convention or CMS, aims to conserve species that regularly move across national borders. The Bonn Convention was adopted in 1972 and came into force in 1985. Some 122 parties, including the European Union, work cooperatively to conserve endangered migratory species and their habitats. The Agreement on the Conservation of Populations of European Bats (EUROBATS) under the Bonn Convention came into force in 1994. This agreement aims to conserve all 53 European

bat species through legislation, education, and other conservation actions with international cooperation of the 36 parties of EUROBATS.

The *European Union Habitats Directive* (EUHD) is a primary piece of legislation adopted in 1992 to protect habitats and species in freshwater, terrestrial, and marine habitats in Europe as a European Union response to the Bern Convention. Many provisions of the Ramsar Convention and Bonn Convention also have been incorporated in the EUHD. The EUHD contains a series of annexes that identify species and habitats of conservation concern in the 27 Member States of the European Union. In addition, the EUHD provides for the creation of a network of Special Areas of Conservation (SACs), called the Natura 2000 Network. The Natura 2000 Network also includes Species Protected Areas designated under the Birds Directive. Over 26,000 Natura 2000 sites have been designated across Europe to date, including SACs designated for subterranean biodiversity. For example, 55 localities for the olm (*Proteus anguinus*) have been protected within 26 SACs in the Slovenian Natura 2000 Network (Hudoklin 2011).

The EUHD aims to protect some 230 habitats and over 1000 species listed in the Directive's five annexes. Annex I contains a list of priority habitat types. In relation to subterranean biodiversity and ecosystems, the following habitat types are listed: caves not open to the public (Natura 2000 code 8310), fields of lava and natural excavations (Natura 2000 code 8320), and submerged or partially submerged sea caves (Natura 2000 code 8330). Annex II is a list of species whose core areas of habitats are designated as Sites of Community Importance (SCIs) that ultimately must be protected under the Natura 2000 Network as SACs. A strict protection protocol must be implemented for species listed in Annex IV across their entire distribution both within and outside of Natura 2000 sites. Annex V includes a list of species whose exploitation and taking in the wild may be subject to management actions. Some species appear on multiple annex lists.

Very few troglobionts and stygobionts are included in Annexes II, IV, or V but include the salamander *Proteus anguinus* (II and IV), the beetle *Leptodirus hochenwartii* (II and IV), and the bivalve *Congeria kusceri* (II and IV). All European bats species as well as six species of the salamander genus *Speleomantes* are listed on Annex II and/or IV. Several biases and criticisms have been noted in the list of species protected under the EUHD (Cardoso 2012). As in many aspects of conservation (Clark and May 2002), vertebrates dominate over invertebrate taxa on the list. Even among the list of arthropod taxa that are included in Annexes II, IV, and V, 94% of taxa belong to the more "charismatic" insect orders Lepidoptera, Coleoptera, Odonata, and Orthoptera (Cardoso 2012). Cardoso (2012) also noted other bias in the listing of arthropod species related to taxonomy, geography, range size, body size, and aesthetic value. These biases in the species lists have significant legal and financial implications. Species that are not listed in the Annexes cannot be used as justification for support for LIFE Nature sub-program conservation projects (Cardoso 2012). Consequently, non-listed species are neglected in conservation policy and funding.

The *EU Groundwater Directive* of 2006 (GWD) establishes a regime that sets groundwater quality standards and introduces measures to prevent or limit inputs of

pollutants into groundwater, which complement the EU Water Framework Directive. The GWD emphasizes the importance of protective measures for groundwater ecosystems by proposing increased monitoring and research to provide better standards for groundwater quality (Griebler et al. 2010; Stein et al. 2012). This directive has led to new research on ascertaining and evaluating biological criteria as indicators for groundwater quality assessment (Griebler et al. 2010; Korbel and Hose 2011; Stein et al. 2010, 2012).

22.4.2 North, Central, and South American Legislation

In North and Central America, the primary legislation for species protection is the Endangered Species Act of 1973 (ESA) in the United States and similar legislation, the Species at Risk Act of 2002 (SARA), in Canada. In contrast to the European Union Habitats Directive (see above), which focuses more on habitats, species are the primary focus of the ESA and SARA. Similar endangered species legislation has been passed in Mexico (General Wildlife Act of 2000), Costa Rica (Biodiversity Law of 1998), and other countries (Table 22.1). In Bermuda, 24 species of cave invertebrates are protected under the Protected Species Act (2003). As in Europe, several additional pieces of legislation afford at least indirect protection of cave and karst landscapes and, in turn, subterranean biodiversity in North America, the Caribbean, and Central America (reviewed in Kueny and Day 2002). However, little legislation directly targets the conservation and protection of caves. In Central America, 18% of karst is afforded some protection, with the highest level of karst protection in Belize (Kueny and Day 2002).

Brazil is the only country with a government agency devoted specifically to the study, protection, and management of caves, the National Cave Research and Conservation Center (CECAV), created in 1997. However, no current legislation specifically protects caves and karst areas in Brazil. In 1996, a Decree (99556) was published that effectively offered some protection to Brazilian caves by stating that the "the use of caves is restricted to speleological activities, tourism, education, scientific, and preserving its physical integrity." In the past decade, however, changes to existing laws, due to pressure from the mineral and other sectors, have significantly weakened protections. Decree 99556 was replaced by Decree 6640 in 2008, which requires that caves be classified according to criteria proposed in the Instruction Normative no. 2 of 2009, and in its revised form of 2017, as low, medium, high, and maximum relevance. Caves of maximum relevance are completely protected, but caves of lesser relevance are subject to lesser protection and can possibly be destroyed. However, other existing legislation can sometimes be applied to protect caves and cave biodiversity, such as laws related to groundwater aquifer and fauna protection.

The *Endangered Species Act* (ESA) of 1973 is the foremost tool for the protection of biodiversity in the United States. The primary purpose of the ESA is to protect and recover imperiled species and their associated habitats and ecosystems. Under the ESA, species may be listed as either endangered or threatened. "Endangered" status

is warranted when a species is at high risk of extinction throughout all or a significant portion of its range, whereas "Threatened" status is warranted when a species is likely to become endangered within the foreseeable future. The U.S. Fish and Wildlife Service (USFWS) oversees the listing and protection of all terrestrial animals and plants and freshwater animals, while the National Marine Fisheries Service oversees marine animals. The ESA prohibits "take" of listed species as well as interstate and international trade. Take includes such actions as harassing, harming, hunting, trapping, capturing, trapping, killing, or collecting. Protections also include prohibition of acts that result in significant habitat modification or degradation that may result in the death or injury of wildlife. The ESA also requires federal agencies to use their legal authorities to conserve listed species and consult with USFWS to ensure that any actions authorized, funded, or implemented by a federal agency do not jeopardize the continued existence of a listed species. USFWS is required to develop recovery plans for each listed species unless it is determined that such a plan will not promote the conservation of a species. Recovery plans serve as essential guides in the management and recovery of listed species. The ESA also requires the designation of critical habitat of some listed species. Critical habitat is defined as specific geographic areas that contain features critical to the conservation of a listed species that may require special management and protection. The designation of critical habitat provides protections of listed species by prohibiting federal agencies (but not private landowners) from activities that adversely modify designated areas.

Of the 1200+ troglobionts in the United States, only 35 species are listed as federally endangered or threatened under the ESA, including seven species of beetles, seven spiders, three harvestmen, one pseudoscorpion, two crayfish, three shrimps, four amphipods, two isopods, one snail, three fish, and two salamanders. Six additional taxa are Candidate species, which are taxa under consideration for listing under the ESA. Candidate species are not afforded protection under the ESA. Seven bats that regularly use caves, either as summer roosts or winter hibernacula, are listed under the ESA. In addition to species native to the United States, the ESA offers protections for foreign species, which includes bans on the importation and sale in the United States of foreign species listed. The only foreign troglobiont listed on the U.S. ESA is the Mexican Blindcat (*Prietella phreatophila*), a catfish from Mexico.

The small percentage of troglobionts listed or considered for listing under the ESA is somewhat surprising, given that most troglobionts have restricted distributions or are known from just a few occurrence records (Culver et al. 2000; Elliott 2007; Niemiller and Zigler 2013). Rarity, as well as presumed low reproductive rates, poor dispersal ability, and susceptibility to environmental change, renders these species extremely vulnerable to anthropogenic threats (Culver and Pipan 2009). There are marked biases in diversity and geography of listed species (Fig. 22.2). Five of the 19 vertebrate troglobionts (26.3%) are listed, despite comprising just 1.4% of all troglobionts in the United States. In contrast, just 2.2% of invertebrate troglobionts, which comprise 98.6% of troglobionts in the United States, are listed. In fact, the only invertebrate group with >5% of species listed

are decapods (crayfish and shrimp) at 11.6% (Fig. 22.2b). Some critics have argued that the ESA and USFWS are biased against insects and other invertebrates in the listing of species (Greenwald et al. 2005) and in the amount of money spent on conservation when compared to listings and expenditures for vertebrate species (Bossart and Carlton 2002; Male and Bean 2005). It has also been suggested that the paucity of invertebrates listed under the ESA may be attributed more to a lack of scientific data and lack of qualified biologists to file and review listing petitions (Lugo 2007). This may also hold true for some groups of invertebrate troglobionts for which few experts exist.

Geographically, 57% (20 of the 35) of the troglobionts listed under the ESA occur in central Texas karst, including the Edwards Aquifer. The high number of listed species from this karst region does not reflect greater diversity and endemism relative to other karst regions in the United States. Rather, it reflects greater vulnerability and risk of extinction from higher levels of development and demands for groundwater associated with continued growth of the cities of San Antonio, Austin, and areas in between relative to other karst regions (Culver and Pipan 2009).

Other U.S. federal laws have been passed that provide varying degrees of protection to caves and karst on federal and private lands, and—directly or indirectly—subterranean biodiversity. This legislation has been reviewed in depth by Huppert (1995, 2006), Lera (2002), Seiser (2013), and others. Caves designated as "significant caves" that occur on federally owned lands in the United States are protected by the Federal Cave Resources Protection Act of 1988. This act requires federal land managers to account for all cave resources under their jurisdiction (Huppert 2006). However, only significant caves under the Department of Agriculture and Department of the Interior are covered by the act. Federal lands under the jurisdiction of the Department of Defense and other extensive tracts of land are not included under provisions of this act (Huppert 1995, 2006). In addition, there is considerable debate regarding the definition of a "significant cave" and levels of protection for caves not deemed significant. The U.S. National Park Service Act of 1916 protects caves that occur on National Park Service lands, including prominent national parks where the protection of specific caves is the primary focus, such as Mammoth Cave National Park in Kentucky, Carlsbad Caverns National Park in New Mexico, and Wind Cave National Park in South Dakota. This act also protects caves that occur in national parks and other lands managed by the U.S. National Park Service (national monuments, national scenic rivers, etc.).

The Wilderness Act of 1964 established a means to designate wilderness areas where activities such as logging, mining, and even road development are prohibited and created the National Wilderness Preservation System. This system now protects some 110 million acres of wilderness areas in the United States. Caves within the boundaries of these designated wilderness areas are protected. However, this legislation has largely focused on the surface environment and does not specifically define which ecosystems are and are not to be considered (Seiser 2013). Consequently, there have been efforts to designate select cave systems as Cave Wilderness. Unfortunately, despite four attempts since 1967 to create a Cave Wilderness designation, including two by the Cave Research Foundation, one by the National

Speleological Society, and by a unit within the National Park Service, no Wilderness designation has been made to date to protect and preserve a specific cave or area within a karst region in the United States (Seiser 2013).

Some caves that occur along rivers designated as Scenic Rivers are protected by the Wild and Scenic Rivers Act of 1968. Notable Scenic Rivers important for cave conservation include the Buffalo National River in Arkansas and the Ozarks National Science River in Missouri (Huppert 2006). A bill, the Oregon Caves Revitalization Act, was introduced in the United States Senate in 2013, which included a Scenic River designation for the subterranean section of Cave Creek, also known as River Styx. Unfortunately, this bill passed the Senate but was never passed by the House of Representatives. If passed, this legislation would have represented the first time that the Wild and Scenic Rivers Act was specifically applied to a subterranean stream or river (Seiser 2013).

Several other federal acts exist that may have a bearing on the protection of cave resources in the United States, including biodiversity (reviewed in Huppert 2006). These include the Archaeological Resources Protection Act of 1979, Antiquities Act of 1906, Eastern Wilderness Act of 1975, Endangered American Wilderness Act of 1978, Historical Sites Act of 1935, National Environmental Policy Act of 1969, National Forest Management Act of 1976, National Historic Preservation Acts of 1966 and 1976, National Parks and Recreation Act of 1978, National Wildlife Refuge System Administration Act of 1966, and several others. Moreover, several "clean water acts" may be used to help protect karst aquifers, and, in turn, groundwater fauna (Jones et al. 2003), such as the Resource Conservation Recovery Act, the Comprehensive Environmental Resource Compensation Liability Act, and the Safe Drinking Water Act.

In the United States, cave-dwelling species may be afforded protection under state endangered species acts. For example, some species are protected under the Virginia Endangered Species Act of 1972 and the Virginia Endangered Plant and Insect Species Act of 1979. Species that are listed under the federal U.S. Endangered Species Act of 1973 are automatically listed under state law in Virginia. Both state and federal agencies have regulatory authority, while the Virginia Natural Heritage Program in the Virginia Department of Conservation and Recreation provides technical expertise to aid in the recovery and long-term protection of a species culminating in its removal from the list of protected species (Orndorff 2005). Although scope, details, enforcement, and punishments vary by state, in general it is unlawful to kill, harm, collect, possess, or traffic imperiled species listed as protected in their respective states. Most of the existing state endangered acts simply provide a measure for listing and prohibition of taking and trafficking of listed species, but lack mechanisms for the recovery, consultation, or critical habitat designation (George and Snape 2010). Just six US states have a provision requiring critical habitat designation, and only five states require recovery plans for listed species. Penalties for violation of state endangered species acts range from a misdemeanor with fines up to $1000 and/or 90 days imprisonment to up to $10,000, 180 days imprisonment, and possible seizure and forfeiture of property in some states.

Twenty-eight US states have laws aimed at the protection of caves and their resources, with most passed since 1976 (Huppert 1995, 2006; LaMoreaux et al. 1997; Lera 2002). Puerto Rico and the Cherokee Nation also have similar legislation. Other US states, in addition to the 28 states that have cave protection legislation, have passed resource protection legislation that mentions cave resources. These laws vary in their definition of a cave, application, and effectiveness in cave protection. Many state cave protection laws only apply to caves on state lands, while those that also cover caves occurring on private lands usually require landowner consent to seek prosecution (Huppert 1995, 2006). Caves fall under the definition of wilderness in some states and may be afforded varying levels of protection under state wilderness acts. Caves may be protected in some states if they occur on specific state-owned or managed lands, such as state parks, wildlife management, or natural areas. In addition, several states have passed legislation prohibiting the contamination and pollution of surface waters and groundwater. Similar legislation has been passed in some Canadian provinces to protect caves and cave resources, such as the Cave Protection Act in British Columbia.

The Nature Conservancy (TNC) is a US-based nonprofit organization dedicated to the conservation of lands and waters of ecological importance. TNC is the largest environmental nonprofit organization in terms of assets and revenue in the Western Hemisphere. TNC has helped protect almost 48 ha of land and 8000 km of rivers in all 50 US states and more than 35 countries worldwide. TNC owns or manages several properties with significant cave and karst resources, including some where the primary features are cave resources. An example is Hubbard's Cave in Tennessee, which contains one of the largest hibernacula of the federally endangered Gray Bat (*Myotis grisescens*). TNC also works with state, federal, and other organizations and researchers to monitor bat populations, to document subterranean biodiversity, and to develop strategies to protect endangered species and subterranean ecosystems. For example, TNC staff and Chiquibul National Park officials in Belize developed a 5-year management plan for the Chiquibul Cave system, the largest cave in Belize and longest in all of Central America. TNC in Tennessee constructed an artificial cave to assist in bat and White-Nose Syndrome research.

22.4.3 Regional and Local Conservation Organizations

There are organizations that work at national and regional scales to assist government agencies and other conservation organizations on many biodiversity conservation issues, setting priorities for funding, research, and conservation efforts and developing sound conservation policies, legislation, and practices. The *National Speleological Society* (NSS) is the world's largest organization dedicated to the exploration, study, and conservation of caves and their environments, with over 10,000 members and 250 grottos. NSS and affiliated cave conservancies own or manage over 100 caves in the United States, which includes several biologically significant caves. NSS has also been actively involved in response to White-Nose

Syndrome since its discovery in New York in 2007, including raising grant money to support WNS research (e.g., NSS White-Nose Syndrome Rapid Response Fund), participating and organizing WNS conferences and symposia, and participating and planning in WNS-related research and state and federal planning. The *Brazilian Speleological Society* (SBE—http://www.cavernas.org.br), founded in 1969, has ca. 1800 members, including speleological organizations. SBE and other independent speleological organizations in Brazil (e.g., Grupo Bambuí de Pesquisas Espeleológicas/GBPE and Grupo Pierre Martin de Pesquisas Espeleológicas/GPME) conduct projects related to cave discovery and documentation, as well as cave conservation. SBE maintains a catalog of more than 10,000 caves in Brazil. Recent conservation-based projects involving SBE include the creation of Conservation Units, such as Natural Heritages and Parks to protect caves and cave fauna, such as the karst of Mambaí, central Brazil). Another Brazilian organization is the *Boticario Foundation of Nature Protection* (FBPN), which provides grants for conservation projects to project many environments and biodiversity, including projects related to caves and karst.

22.5 Conclusions

A variety of legislation has been proposed and enacted worldwide that may directly (e.g., endangered species acts) or indirectly (e.g., water quality legislation) provide some protection for subterranean fauna. Conservation efforts have largely focused on protecting sites of exceptional species richness or phylogenetically unique biodiversity (Culver and Sket 2000; Danielopol et al. 2009; Gibert et al. 2009). Levels of protection for subterranean life offered by international and national and regional legislation vary greatly throughout Europe and the Americas. At the international level, subterranean fauna appearing on lists and in appendices as protected species, including CITES, IUCN Red List, Bern Convention, and EU Habitats Directive, are largely biases toward vertebrates, particularly bats. This is despite the fact that the overwhelming biodiversity of subterranean ecosystems comprises invertebrates. The importance of and threats to subterranean invertebrate fauna in Europe have been known for some time (Juberthie 1995), specifically recognized in Recommendation no. 36 of the Bern Convention (1992) in which it is recommended that national inventories of subterranean invertebrates and subterranean habitats to protect be compiled and that species of conservation concern be identified. Unfortunately, this recommendation remains to be completed (Haslett 2007). This marked taxonomic bias is also observed in national and regional legislation, such as the list of species protected under the United States Endangered Species Act. The taxonomic biases favoring conservation and protection of vertebrates over invertebrates are not limited just to subterranean ecosystems (Cardoso et al. 2011a, b). The four main shortfalls in invertebrate conservation identified by Cardoso et al. (2011b), as well as other impediments, apply to the conservation of subterranean biodiversity and ecosystems. In particular, the Linnean shortfall (i.e., much subterranean biodiversity remains to

be described) is the primary driver behind the other three shortfalls: the Wallacean, Prestonian, and Hutchinsonian shortfalls in the conservation of subterranean invertebrate faunas. In some regions, these shortfalls also apply to vertebrate subterranean biodiversity. Gallão and Bichuette (2012) emphasized the importance of the IUCN Red List for protection of cavefishes in Brazil and highlighted limitations of some criteria in the inclusion of taxa on the IUCN Red List. These shortfalls also can have significant political implications, as the presence of IUCN Red Listed species is one of the most important tools to prioritize caves based on biological criteria for protection in Brazil, for example.

A major factor behind taxonomic bias in subterranean biodiversity conservation is the lack of biologists qualified to study subterranean taxa and ecosystems. This is particularly evident in the continuing decrease in taxonomic experts that can describe and properly identify often difficult groups, such as springtails, flatworms, and annelids. Correct species identification, generally requiring a high degree of familiarity with taxon-specific morphological characters, is paramount to addressing the other major shortfalls in subterranean biodiversity conservation, including elucidating accurate species distributions and habitats, determining abundance and population size, and predicting species responses to habitat change. Some progress has been made in recent years to address the Wallacean shortfall in subterranean conservation of Europe and the Americas, highlighted by the PASCALIS project (Gibert 2005). The PASCALIS (Protocols for the Assessment and Conservation of Aquatic Life in the Subsurface) project was a 3-year (2002–2004) large-scale groundwater bioinventory initiative that developed standard sampling protocols for comparing stygobiont biodiversity in six European regions in five countries: Belgium, France, Italy, Slovenia, and Spain. Unfortunately, limited prospects for securing employment for newly trained taxonomic experts, reflecting a lack of value society places on invertebrate taxonomy, continues to discourage young scientists from placing emphasis on taxonomy during their graduate training, especially in the United States.

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