Chapter 2

Europe's Nature and Conservation Needs

Graham Tucker

2.1 The Biophysical Geography and Natural History of Europe

Whilst it is only possible to provide a brief account of the natural history of Europe here, this section aims to provide some important context for the approaches that have been taken to nature conservation. It mainly summarises the biophysical influences on ecosystems, and the impacts of humans on them up to about 40 years ago, as more recent events are covered in the national chapters. This is primarily drawn from the following sources: Polunin and Walters (1985), Tucker and Evans (1997), Ellenberg (2009), Veen *et al.* (2009), Blondel *et al.* (2010) and BirdLife International (2017a).

2.1.1 Biogeographical Regions and Their Characteristics

Europe has a relatively diverse range of ecosystems and habitats, primarily as a result of its varied topography, geology and climate, as well as some historical impacts of human activities. An important influence on ecosystems in western Europe is the relatively warm oceanic waters that result from the north Atlantic current, which keep winter temperatures much higher than other areas of the world at a similar latitude. Thus the climate ranges from subtropical in parts of the Iberian Peninsula and around the Mediterranean to subpolar in the north-east of Norway and northern Russia. This underlying climatic pattern is then further modified by the continent's topography, especially its high mountain ranges but also its lowland plains. These climatic and other physical combinations give rise to 11 terrestrial biogeographical regions in Europe, as defined by the European Commission and the Council of Europe for nature conservation purposes (Roekaerts, 2002), with the 2016 version shown in Figure 2.1. It is noteworthy that the Alpine region represents areas with similar characteristics, rather than a geographical region centred on the Alps. It therefore also includes the Pyrenees, Apennines, Carpathians, Dinaric Alps, Balkans and Rhodopes, as well as the Urals and the Caucasus mountains on the border of Europe. The nine biogeographical regions that are relevant to this book are summarised in Table 2.1. A more detailed statistically derived stratification for Europe based on biogeophysical attributes has been produced by Metzger *et al.* (2012).

The marine waters covered in this book comprise the European parts of the Atlantic, Baltic Sea, Black Sea and Mediterranean Sea. In particular, they cover the marine regions and subregions as defined by the Marine Strategy Framework Directive (MSFD), as shown in Figure 2.2, with the exception of the Macaronesian subregion of the North-East Atlantic. MSFD region boundaries are, to the extent possible, harmonised with other EU legislation where maritime boundaries are of relevance, and specifically the biogeographical regions of the Nature Directives. This book mainly refers to the EU-28 waters that have been defined as the Atlantic (MATL), Baltic Sea (MBAL), Black Sea (MBLS) and Mediterranean Sea (MMED) marine regions, for the purposes of implementing the Nature Directives. In this respect, the Atlantic region comprises the following MSFD subregions: the Greater North Sea (including the Kattegat and English Channel), Celtic Seas, and the Bay of Biscay and Iberian Coast. Macaronesian waters are treated as a separate marine region under the Nature Directives.

As summarised in Table 2.2, these marine regions differ considerably in their biophysical properties such as their depth, tides, currents, exposure to ocean waves and wind, salinity and nutrient levels. These diverse properties in turn give rise to varying habitats and species communities. It should be noted that most HD Annex I marine habitats are only very broadly differentiated, and therefore most occur in all marine biogeographical regions. As listing them would be of little value, most are not referred to in Table 2.2. It is particularly noteworthy that the Mediterranean Sea is considered to be a biodiversity 'hotspot' as it has high species diversity for a temperate sea (Coll *et al.*, 2010).

2.1.2 The Legacy of the Last Ice Age

The flora and fauna of Europe have been profoundly affected by the glacial episodes that occurred over the Quaternary period, the most recent of which commenced about 110 000 years ago, with its maximum extension occurring about 20 000 years ago. The ice covered all of Scandinavia and the Baltic States and extended south to Poland and northern Germany, but no further south-west than western Denmark. In the Alps, ice extended down to the plains. The island of Ireland was mostly covered with ice, as were the northern three-quarters of Great Britain. As the sea-level was about 100 m lower than now, Great Britain and Ireland were connected by dry land to what is currently continental Europe. To the south, most of the rest of Europe was covered in steppe and tundra, with wooded tundra or forest steppe, mainly in Iberia and to the south and south-

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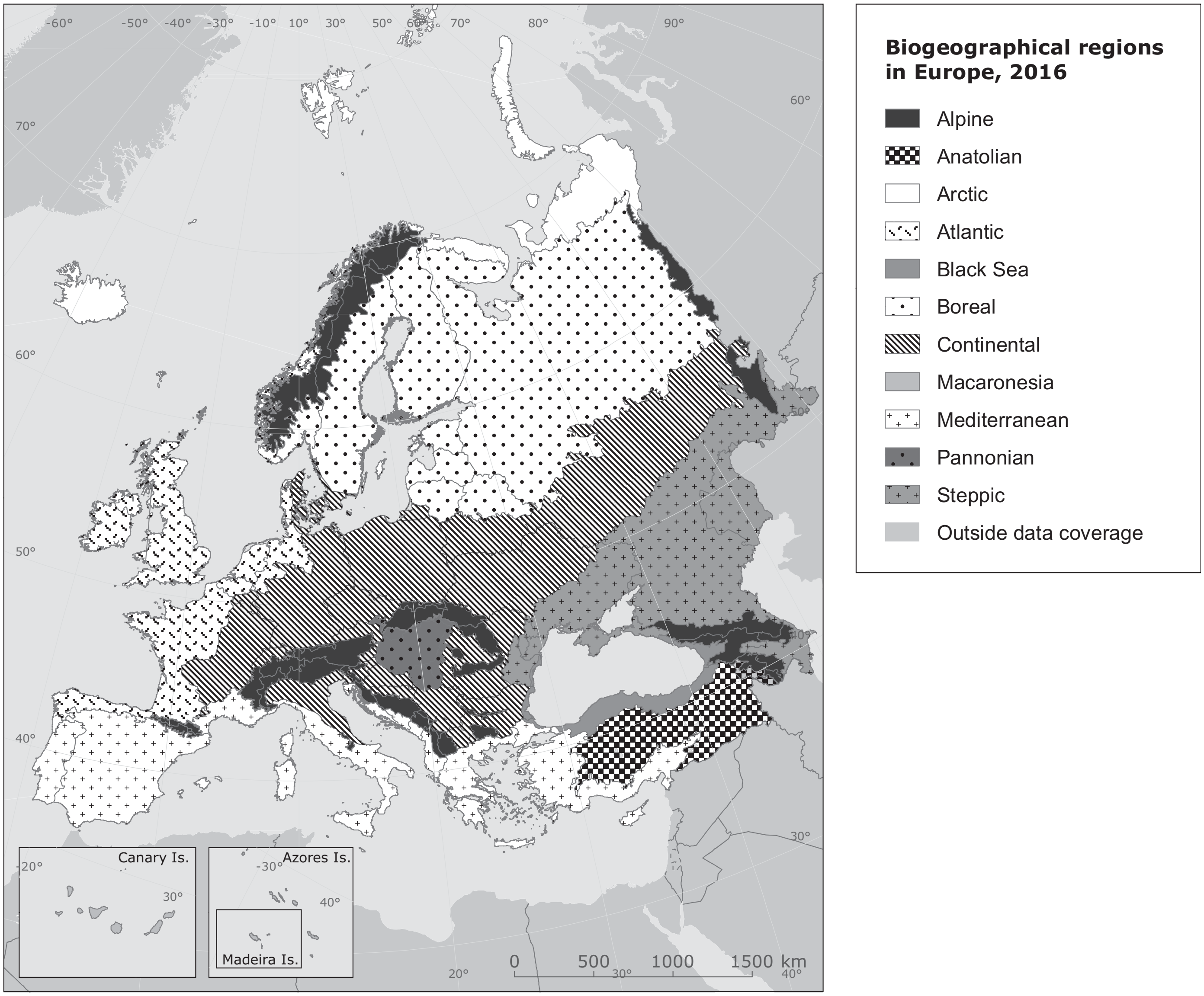

Figure 2.1 Terrestrial biogeographical regions in Europe.
Note. The Anatolian and Arctic biogeographical regions do not occur within the EU.
Source. Adapted from EEA (2017a).

east of the Alps. Mixed woodland was mainly confined to southern Italy, Greece and Mediterranean islands and the eastern Black Sea coast, but no woodland communities now present in central Europe were able to survive (Ellenberg, 2009).

With the warming of the climate and retreat of the ice about 10 000 years ago, surviving plants and animals moved north, recolonising some of their former areas. Following a succession of forest types, by 8 000–5 000 BP broad-leaved forests are thought to have become the climax vegetation across most of lowland temperate Europe. Traditionally it has been thought that this landscape was predominately closed-canopy forest, and that open habitats were limited to localised areas (e.g. too wet, dry, rocky or unstable). Open areas may also have been maintained by herbivores after fires or storms, but grazing animals did not create them by themselves.

More recently it has been suggested by Vera (2000) that in prehistoric times broad-leaved forests were more open than this, due to the activity of large herbivores, including deer, bison (*Bison* spp.), Beaver (*Castor fiber*), Wild Boar (*Sus scrofa*) and the now extinct Aurochs (*Bos primigenius*) and Tarpan/Eurasian Wild Horse (*Equus ferus ferus*). He has proposed that they created a half-open landscape with a cyclic shifting mosaic of scrub, closed-canopy stands (groves), degenerating groves and open ground with scattered trees and scrub. Some have suggested that these areas would have been similar to some pastoral woodlands in Europe today (e.g. the New Forest in the UK or *dehesa* in Spain).

Whilst the presence of half-open wood pasture is not supported by evidence (e.g. Svenning, 2002; Hodder *et al.*,

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Table 2.1 The key characteristics of the terrestrial biogeographical regions in Europe.

Region	Key abiotic characteristics	Characteristic ecosystems and HD habitat types
Arctic (not present in EU)	Maritime subarctic (−3 to 11 °C) – continental subarctic (−11 to 13 °C). Extreme annual variation in sunlight gives short intensive growing seasons.	Tundra in the north and coniferous forest in the south, with numerous mires, oligotrophic (i.e. nutrient poor) lakes and rivers. Largest area of true wilderness in Europe.
Alpine (ALP)	Maximum altitudes >4 000 m in the Alps, >3 000 m in the Pyrenees, and >2 000 m elsewhere in Europe. Extreme climates, with high winds and precipitation (as rain and snow) at altitude, high seasonal, altitudinal and aspect temperature variations (e.g. −21 to +35 °C in the Carpathians), long-lying snow, ice and glaciers (although retreating), steep terrain, and extensive areas of bare rock and soil. Large areas of unbroken pristine habitat, especially in the Scandes (i.e. Scandinavian mountains).	Forests and semi-natural grasslands on the lower slopes give way at the tree line (c. 2 000 m, 1 000 m Scandes), to alpine grasslands, fells and scrub heath with increasing altitude, and rock and snow habitats with just a few specialist species. Forests are predominantly coniferous, or beech/beech-fir (e.g. in Carpathians), or have a Mediterranean character with oak or pine on south facing slopes of the southern ranges. Scandes predominantly montane scrub and tundra. A wide range of natural and semi-natural (e.g. meadows) grasslands occur, with high plant diversity and levels of endemism. Numerous rivers, but many are human altered.
Boreal (BOR)	Cool and mainly continental climate, with 500–800 mm precipitation per year, and temperatures between −15 and 20 °C. Relatively flat (mostly below 500 m). Coastline with numerous shallow inlets and islands.	Mostly managed coniferous forest (western taïga) but 16 HD forests types occur, seven priority habitats, e.g. old growth western taïga (9010*)[1], Fennoscandian deciduous swamp woods (9080*) and natural forests undergoing primary succession on coasts (9030*). Also numerous rivers, oligotrophic lakes and mires (peatland >50% of land in northern areas), including extensive Boreal aapa mires (7310*). Some important grasslands include northern Boreal alluvial meadows (6450) and, in the south, Nordic alvar (6280*), Baltic coastal meadows (1630*) and rare Fennoscandian wooded pastures (9070). Four other types of Boreal Baltic coastal habitats.
Atlantic (ATL)	Oceanic climate with mild winters, cool summers, predominantly westerly winds and moderate rainfall throughout the year. E.g. rainfall is about 3 000 mm per year in the mountains of north-west Scotland, but can be as low as 700 mm, even 550 mm in small areas in the east. Mostly lowlands, but some hills and mountains (mostly <1 000 m). Sheltered and exposed coasts with a variety of young soft sedimentary and hard rocks. Most lowland terrestrial habitats are now highly fragmented.	Forest cover is low, and endemic yew woodlands (91J0*), old sessile oak woods (91A0), and Caledonian forest (91C0*), which are confined to the region, are scarce. Large expanses of mire, mainly blanket bog (7130* if active), acid grasslands and dwarf shrubland predominate in the uplands. Lowland heathlands are characteristic of the region but are much reduced, as are lowland floodplain, acid and calcareous grasslands. Diverse coastal habitats, from muddy estuaries, salt marsh, sandy beaches and dunes, to steep tall cliffs and fjords. Machair (21A0* in Ireland) is unique to the region.
Continental (CON)	Strong contrast between cold winters and hot summers especially in the east (e.g. −3 to 19 °C in Warsaw). Precipitation highest at 1 700 mm/year in the German Black Forest, but lower on the plains, e.g. 500 mm/year in Warsaw. Mostly flat lowlands, with hills in the south that grade into some mountain ranges. Mostly fertile soils. Major rivers flow through the region (e.g. Danube, Loire, Rhine and Po), which are heavily modified.	The climax vegetation is mainly deciduous forest, typically dominated by beech (e.g. *Luzulo-Fagetum* 9110) or sometimes oak and other species, such as *Galio-Carpinetum* oak-hornbeam forests (9170). Forests are now greatly reduced. Other habitats include riverine forests, fens, marshes, and grasslands (including subalpine grasslands), but all are much reduced, especially in the west. Some large marshlands remain in Poland and further east. More local habitats include karst landscapes with caves, and inland dunes. A range of coastal habitats remain, e.g. shingle, salt meadows, lagoons, dunes and dune heaths.

[1] Numbers in brackets are the HD Annex I habitat codes (see Appendix for full names). * Indicates a priority habitat.

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Table 2.1 *(cont.)*

Region	Key abiotic characteristics	Characteristic ecosystems and HD habitat types
Pannonian (PAN)	Dominated by the flat alluvial Great Hungarian Plain, which is almost completely enclosed by low-lying hills and mountains. The plain has mosaics of sand and loess and varying levels of water and salinity (due to high summer evaporation rates and shallow underground water sources). Average temperatures are −0.7 °C in January and 22 °C in July, and annual rainfall is moderate (700–800 mm), but the climate is complex and variable, as it is affected by neighbouring climate systems.	Forms a boundary between two vegetation belts: deciduous forests and forest-steppes, with a wide diversity of habitats and associated species (with high levels of endemism). The original, mostly oak, dominated forests now almost completely replaced by the extensive steppe landscape (the *Puszta*), with grasslands, including loess and sandy grasslands (e.g. 6250* and 6260*), but these are now scarce. Other localised characteristic habitats include Pannonic inland dunes (2340*), Pannonic salt steppes and salt marshes (1530*) and shallow alkaline lakes. In the hills, some woodlands occur (e.g. with *Quercus pubescens* 91H0*), as well as karst springs and calcareous grasslands.
Steppic (STE)	Mainly low-lying plains with some hills (e.g. 500 m in the Macin Mountains in Romania) and undulating high plateaus. Harsh continental climate with cold winters (−3 to −14 °C), hot summers (20–22 °C, but up to 30 °C), low precipitation (150–400 mm per year) and drying winds. The distinctive fertile black soils predominate.	Treeless steppic grasslands are the main natural vegetation type, i.e. dominated by grass species in the genera *Stipa*, accompanied by *Festuca, Agropyrum, Koeleria, Andropogon and Helictotrichon*, and other drought resistant plants. Due to the fertile soils, about 80% of the grassland has been converted to agricultural use. Woodlands occur in some damp valleys and hills.
Black Sea (BLS)	In Europe only occurs as a narrow coastal strip extending south from the Danube Delta in Romania, across low mountains in Bulgaria, to the Bosphorus outlet in Turkey. The continental climate is moderated by the sea, giving cool winters and warm summers (e.g. between −1 and 21 °C in Bulgaria). Annual rainfall is fairly low, e.g. 370 mm in Romania.	The Danube delta primarily consists of extensive reedbeds, lagoons, river channels, sandbanks and riverine woodland, but large areas have been drained and converted to agriculture. Other coastal habitats include brackish and saline lakes, and cliffs. Forests also occur outside the delta, especially on the low-lying hills in the south of Bulgaria and include a variety of rare HD habitats such as western Pontic beech forests (91S0*).
Mediterranean (MED)	The climate has a very strong influence, as it is particularly hot and dry in summer, often with long periods over 30 °C. Annual rainfall varies between 600 and 1 200 mm, but can be as low as 350 or even 100 mm. Winters are mild and humid (average 6 °C). Another characteristic is the considerable variability in weather conditions, including the influence of strong winds and rain storms. Fires are frequent, and have a strong influence on most habitats. Much of the region is hilly or mountainous, and altitude and aspect therefore have a high secondary influence on the climate. Soils lack organic matter and are prone to erosion. Most of the coastline is rocky or sandy.	A very wide range of natural and semi-natural habitats with high species diversity and exceptional levels of endemism. Sclerophyllous (evergreen hard-leaved) plants predominate, and forests are the main climax vegetation type. They normally have diverse tree species, but several HD types are dominated by evergreen oaks. Habitats with deciduous oaks and other trees and shrubs occur in less dry areas, and some distinctive conifer forests occur on mountains. Although not climax vegetation, sclerophyllous scrubland (*matorral*) is particularly characteristic and widespread. It includes tall dense shrubland (*maquis*) and vegetation with sparse dwarf shrubs (*garrigue* or *phrygana*). Semi-natural grasslands are also widespread, such as pseudo-steppe (6220*). Traditional grazing and cultivation of oak forests has created the highly distinctive *dehesa/montado* habitat (6310) of Spain and Portugal. Now much of the region is used for agricultural crops, including characteristic olive groves and vineyards. Wetlands, such as lagoons, are relatively localised.

Note. The Anatolian biogeographical region does not occur in Europe, and the Macaronesian region is not covered in this book.
Sources. Based on information in Polunin and Walters (1985), Sundseth (2009a–h), EEA (2008a) and Metzger *et al.* (2015).

Figure 2.2 Marine regions and subregions in the EU based on the Marine Strategy Framework Directive.
Note. The marine region boundaries are indicative only and do not imply any legal status. The Marine Atlantic region, as referred to in this book and used for HD Article 17 reporting, comprises three MSFD subregions: the Celtic Seas, Greater North Sea (including the Kattegat and the English Channel) and the Bay of Biscay and the Iberian Coast.
Source. EEA (2020a).

2005; Mitchell, 2005), it is now generally accepted that large herbivores probably affected forest structure more than previously thought, and that mixed landscapes occurred to some degree. However, this would have varied according to local conditions and the influence of other interacting disturbances, such as fire or floods. Vera’s ideas have also triggered debate on whether conservation objectives should be based on a different, prehistoric landscape model and more naturalistic grazing as, for example, pioneered at Oostvaardersplassen in the Netherlands (see Chapter 23).

The Ice Age has had lasting impacts on the distribution and diversity of natural vegetation and associated animal communities across most of Europe. Compared to similar areas in North America and eastern Asia, Europe has fewer plants, especially trees, due to their wide extermination and the presence of the Mediterranean Sea, which has acted as a barrier to recolonisation (Ellenberg, 2009). European mountain ranges that are predominantly aligned west–east (i.e. Pyrenees, Alps and Carpathians) also had a similar effect, creating barriers that hindered species’ southward retreat and then northward recolonisation. The diversity of native species in Great Britain and Ireland remains lower than on the continent, because some species were unable to return before the sea-level rose again and separated Ireland from Great Britain, and then Great Britain from the continent about 7 500 years ago. However, in some parts of Europe, plant and animal populations survived the last glacial periods in isolated refuges of suitable climate and habitat, and have evolved into new subspecies, thereby increasing biodiversity.

As the Mediterranean area escaped the worst impacts of the last Ice Age, much of its vegetation remained. Moreover, the

Table 2.2 Key characteristics of the Atlantic, Baltic Sea, Black Sea and Mediterranean Sea marine regions.

Region	Key abiotic characteristics	Characteristic ecosystems
Atlantic (i.e. Greater North Sea, Celtic Seas, Bay of Biscay and Iberian coast)	Includes deep water thousands of metres deep. Within the continental shelf depths are mostly <200 m, especially shallow in the North Sea. The north-west is influenced by the warm north Atlantic current, and so surface temperatures are typically 7–15 °C. Salinity is about 35 ‰ or above. Predominantly a high energy environment due to ocean waves and climate, high tidal ranges (up to 15 m) and strong currents. Mostly oligotrophic.	The varied abiotic conditions give rise to a wide range of habitats, including those that are characteristic of conditions of high exposure to waves and currents, as well as more sheltered bays, inlets and sea lochs. Whilst soft substrate habitats dominate most of the seabed away from the coast, there also physiographic features that form rocky reefs. The high productivity of the northern waters, especially the North Sea, supports high fish densities and large seabird populations.
Baltic Sea	Relatively shallow with almost no tide. Brackish with salinity of c. 6 ‰ in the main part but lower in the north and east. Intense seasonality in temperature (with northern areas ice covered in winter) and inflows. Stratification between low-salinity surface water and more saline water prevents the exchange of oxygen and nutrients, leading to naturally lifeless areas of seabed.	Mixed or soft substrate benthic habitats predominate, whilst rocky habitats occur closer to the coastline. Northern shores include numerous bays and inlets. Species diversity is low, but communities vary in response to the marked vertical and horizontal salinity gradients. Uniquely, there are areas where freshwater, brackish water and marine species are all present. Highest biodiversity in the south-west.
Black Sea	Tideless inland sea with only a narrow outlet to the Mediterranean. Highly stratified due to lower salinity surface layer (c. 18 ‰) overlying denser more saline water, which has created permanent anoxic conditions below 100–200 m. Surface water temperatures vary from 0 to 25 °C.	A highly specialised and sensitive marine ecosystem. The main habitats in shallow-water areas are more or less shelly, or sandy, with terrigenous muds. There are extensive biogenic reefs and Black Sea-specific 'fields' of the red alga *Phyllophora crispa*. Deep pelagic and benthic organisms are largely absent. The brackish nature of the water restricts the number of species that are present, most of which are also found in the Mediterranean Sea.
Mediterranean Sea	Average depth of 1 500 m, with 20% less than 200 m. Narrow continental shelf and littoral zone in the south, but wider in the north. Highly saline (average 38.5 ‰) and limited freshwater inflows. Mostly oligotrophic outside the coastal zone, especially in the east. Mean surface temperatures highly seasonal (16–26 °C) and no temperature boundaries at depth. Micro-tidal (mostly a few cm). Diverse environmental conditions.	Low primary production, combined with limited development of higher levels of the food chain, including low fish production, are characteristic. However, biodiversity is high (especially in the north-west) due to the variety of conditions and high endemism due to its partial isolation, estimated at 20%. Most biodiversity is concentrated in shallow coastal areas, including the characteristic seagrass beds, e.g. of *Posidonia oceanica* (1120*), and coralligenous reefs and maerl beds created by coralline red algae.

Sources. Based on information from EEA (2008b), Coll *et al.* (2010) and Gubbay *et al.* (2016).

region's natural vegetation is also highly diverse as a result of its geological history, diverse biophysical conditions and location at the intersection of three major landmasses. Approximately 25 000 species of flowering plants and ferns occur (including in non-European areas), compared with 6 000 species in non-Mediterranean Europe (Quézel, 1985). Furthermore, more than half of the plants of the Mediterranean basin are endemic, comprising 80% of the European total (Gomez-Campo, 1985). Consequently, in spite of profound human impacts (described later), the region is still considered to be a global biodiversity hotspot (Mittermeier *et al.*, 2004).

2.2 The Impacts of Human Activities on Biodiversity in Europe

2.2.1 Early Impacts and the Creation of Semi-natural Ecosystems and Cultural Landscapes

Since the arrival of humankind, European ecosystems and their species have been increasingly influenced by human activities, especially within the Mediterranean basin. This first became significant as the Neolithic agricultural transition spread from the south-east about 8 000 BP, arriving in the north-west around

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5 000 BP (Isern *et al.*, 2012). Settlements were established and agriculture developed with the domestication of crops and livestock and the creation of wood pastures. More widespread clearance of forest for the creation of pastures, meadows and cropland occurred from the Iron Age. In some parts of north-west Europe, the grazing and repeated burning of forest combined with turf cutting, and resultant leaching of exposed soils in heavy rainfall areas, created and maintained extensive heathlands. Forest clearance, and a change in climate to wetter and cooler conditions around 2 500 years ago, also led to an increase in mires.

Hunting also had indirect impacts on ecosystems, through its effects on the populations of large herbivores and the extinction of some, such as the Aurochs. Domestic livestock may have replaced the ecological functions of some natural herbivores, as woodland pasturing was widespread until about the nineteenth century, but there were some gaps in grazing niches. To protect livestock, large carnivores such as the Wolf (*Canis lupus*) and Brown Bear (*Ursus arctos*) were exterminated in many countries, with knock-on impacts on their prey species and ecosystems.

Although forests and other natural habitats declined as early farming spread, the new and diverse semi-natural habitats, and their novel species communities, probably increased overall biodiversity (Pons and Quézel, 1985; Ellenberg, 2009). Diverse cultural landscapes were also created, as varied intertwined farming and cultural practices developed (Oppermann and Paracchini, 2012). As these diverse semi-natural agricultural systems evolved, so too did their vegetation and associated animal communities. New cropping systems and types of grasslands were formed, some in relatively modern times, such as litter meadows in the Alps in the nineteenth century (Poschlod *et al.*, 2009). Between the seventeenth and nineteenth centuries, major landscape changes widely occurred as a result of the enclosure of areas of common land. This gave rise to 'bocage' type landscapes with hedges and other field boundaries, as well as laws prohibiting forest grazing (Künster and Keenleyside, 2009).

2.2.2 The Industrial and Agricultural Revolutions – up to 1980

It is no exaggeration to say that the industrial revolution, which started in the late eighteenth century, and the later agricultural revolution have led to profound impacts on Europe's nature. The most significant and widespread have been changes in land use and management, particularly in agricultural systems. According to Jepsen *et al.* (2015), these were the result of three main drivers – technological, economic and institutional (e.g. land reforms) – and gave rise to similar stages of agricultural expansion, intensification and eventual industrialisation. However, the specific drivers and timing of these varied between countries, with initial intensification starting around 1850 in some (e.g. Belgium, West Germany and the Netherlands) as a result of the invention of the clay drain pipe, early machinery, the availability of some fertilisers, and railways increasing access to urban markets. By 1900, most of Europe was undergoing such initial intensification, the main exceptions being parts of Spain, Portugal and Italy.

Almost simultaneous major changes occurred across Europe from about 1945, as a result of World War II and the subsequent need to increase food production, which coincided with increased availability of mineral fertilisers, machinery and the use of irrigation. In most of Western Europe this resulted in further intensification, crop specialisation and large-scale farming (Potter, 1997), a period that is referred to as the industrialisation of farming by Jepsen *et al.* These developments were also supported by the establishment of the European Economic Community and its Common Agricultural Policy (CAP) in 1957. The CAP aimed to increase productivity, including by stabilising market prices and providing subsidies, which were initially linked to production, and grants to expand agricultural land and intensify management practices. Similar agricultural industrialisation occurred over much of the Eastern Bloc countries, driven by the political process of collectivisation (Jepsen *et al.*, 2015). However, as described in the country chapters, some mountain regions and other areas were less affected.

Much of the expansion of agriculture was at the expense of natural and semi-natural habitats (Baldock, 1990). For centuries, wetlands, especially peatlands, were targeted for drainage and conversion to agriculture, resulting in two-thirds being lost across Europe between 1900 and the mid-1980s (European Commission, 1995). Large areas of heathland and Mediterranean shrublands were converted to arable or permanent crops.

Agricultural intensification has followed similar pathways across Europe, especially in the west, but more slowly and less consistently in central and eastern Europe (e.g. Stoate *et al.*, 2001, 2009, Tryjanowski *et al.*, 2011; Kuemmerle *et al.*, 2016). Within grasslands, many of those that were wet were drained, and the use of nitrogenous fertilisers became common where it was possible to apply them using machinery, allowing increases in grazing intensity. To make best use of the fertiliser, grasslands have also been increasingly reseeded with high-yielding rye-grass cultivars (e.g. *Lolium perenne*), creating taller and denser species-poor swards. These reseeded grasslands are subject to higher grazing densities and/or conversion from hay fields to silage crops that are cut several times and earlier in the year than hay.

Industrial large-scale specialised crop production also resulted from increased usage of fertilisers, herbicides and other pesticides. This led to denser crops, reduced crop rotations, the near disappearance of fallow in the landscape and the removal of hedgerows and other field boundaries to create larger fields. Some pesticides had severe direct toxic effects on non-target species, in particular birds of prey, the most notorious being DDT[2] from the 1950s, until national bans

[2] The persistent organochlorine insecticide dichlorodiphenyltrichloroethane.

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started in the late 1970s. Since then, the main impacts of herbicides and pesticides have been their disruption of food webs, such as declines in broad-leaved weeds and invertebrates.

In contrast to the dominant trends of agricultural expansion and intensification, agriculture has been abandoned in some areas. This has mainly affected areas with poor and remote agricultural land, especially in the hills and mountains of southern and eastern Europe (Pointereau *et al.*, 2008; Keenleyside and Tucker, 2010). This has had varying, but probably mostly detrimental, impacts on biodiversity so far (as well as declines in cultural landscapes, rural traditions and communities). On the one hand, abandonment has reduced human disturbance and increased scrub and forest habitat area and connectivity, to the benefit of some species such as large carnivores. On the other hand, abandonment has led to substantial declines in biodiverse semi-natural grasslands, shrublands and other open habitats, and their associated threatened species. According to a global review of studies of agricultural abandonment, in Europe the impacts were reported as negative in 65% of studies, whilst they were considered to be positive in only 6% (Queiroz *et al.*, 2014). For example, in the Alps, whilst pastoral abandonment may increase bird diversity, this is to the benefit of common species whilst it is detrimental for the more specialist and threatened grassland specialists (Laiolo *et al.*, 2004). A broader study in Sweden of fungi, vascular plants and insects (Lepidoptera, Coleoptera and Hymenoptera) suggested that abandonment of traditional management in agricultural landscapes would lead to extinction rates two or three orders of magnitude higher than global background rates (Eriksson, 2021). A further problem is that, whilst the abandonment of some areas could be beneficial in the long term, producing high biodiversity habitats, abandoned areas have often been targeted for forest plantations (and bioenergy crops more recently).

The planting of forests for timber production began at the end of the nineteenth century and was widespread across Europe in the 50 years following World War II, increasing forest cover by 30% in western Europe, 20% in central and eastern Europe, and 10% in the south (Gold, 2003). This was often concentrated in the uplands or in other areas that were unfavourable for agriculture, such as on dunes, shrubland, heathland and drained peatland. Large areas of valuable natural and semi-natural habitat were lost in the process, often replaced with even-aged forest monocultures of low biodiversity value. Furthermore, in many cases plantations consist of non-native trees, most commonly conifers (especially species of *Pinus*, as well as *Pseudotsuga*, *Picea* and *Larix*), poplars (*Populus* hybrids) and Australian eucalyptus species. These trees typically support very few native species, and so result in a very simple and species-poor ecosystem.

Within ancient forests, traditional uses such as pasturage, pollarding, charcoal production and coppicing have been largely replaced by forest management for timber. This led to a change in woodland structure, with taller mature trees and a closed canopy. Since then there has been a trend towards increasingly intensive forest management over much of Europe. Thus, forests that are commercially managed have been drained, thinned, cleared of deadwood, clear-cut over large areas and replanted. This has resulted in biodiversity losses, as biodiversity declines considerably with increasing management intensity (Sing *et al.,* 2018).

Physical changes to other ecosystems have included the creation of reservoirs for water storage or hydropower, widespread canalisation of lowland rivers (for river transportation and flood protection), reduced water levels in wetlands due to abstraction (often for agriculture), and construction of coastal flood defences (with resulting losses of intertidal habitat).

Alien species have had important influences on terrestrial and marine species, communities and ecosystems since humans settled across Europe and started introducing new species, such as for food, materials or sport. This has accelerated since the beginning of the twentieth century, due to increasing intentional imports of plants and animals (such as for horticulture and the pet trade) and accidental introductions associated with increasing international travel and trade. Many alien species have not spread widely or had noticeable detrimental effects on native species, or other aspects of the environment. However, a substantial proportion have become invasive and had significant environmental impacts; these are hereafter referred to as invasive alien species (IAS).[3] Detrimental impacts have included competing with or consuming native species, spreading disease, causing genetic changes through interbreeding, and disrupting food webs and the physical environment (Scalera *et al.,* 2012).

Pollution has affected most ecosystems since the beginning of the industrial revolution, particularly in the most densely populated and industrialised areas of western and eastern Europe. The most severe and widespread biodiversity impacts have generally resulted from nutrient enrichment, that is, eutrophication (e.g. Galloway *et al.*, 2004; Fowler *et al.*, 2013), and ecosystem acidification (e.g. Schöpp *et al.*, 2003). Apart from in upland areas, a high proportion of rivers and lakes have been affected by eutrophication, primarily from increases in phosphorus, with the main sources being silty agricultural run-off, sewage and industrial effluent. Whilst eutrophication impacts are complex, low nutrient enrichment levels generally lead to increases in submerged plants, which increases the productivity of the ecosystem, benefiting some fish and birds. At higher levels, major changes in the ecosystem and its species result as algae tend to proliferate and submerged plants die out due to the reduced light levels. At very high levels, algal blooms can lead to oxygen depletion and the death of fish and other animals. Eutrophication impacts can be long-lasting and difficult to reverse where nutrient-rich sediments have built up.

Air pollution increased substantially due to the growth of industry and cities, and their use of coal, and later the invention of the internal combustion engine and the industrialisation of agriculture. This has led to major changes in the physiochemical conditions of sensitive terrestrial and aquatic ecosystems, and

[3] As in the Regulation (EU) 1143/2014 on invasive alien species.

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impacts on their species, across much of Europe (Stevens *et al.*, 2020). High concentrations of some pollutants in the air, such as sulphur dioxide, have caused the widespread destruction of lichen communities since the nineteenth century. Changes have also resulted from the deposition of air pollutants dissolved in rain or snow. This deposition, colloquially termed 'acid rain', acidifies the soil or water (if the dissolved pollutants are sulphur dioxide, nitrogen oxides or ammonia), as well as causing eutrophication through nitrogen enrichment (if the dissolved pollutants are nitrogen oxides or ammonia).

Sensitive ecosystems, such as rivers and lakes, have been significantly affected by acidification in many parts of Europe since the 1950s, especially in regions where the soils and rocks have a low buffering capacity, such as much of Fennoscandia. This resulted in wide-ranging impacts on the ecosystems and their species, including declines in species diversity and acid-sensitive groups (e.g. molluscs and amphipods) leading to massive declines in fish diversity and numbers (Muniz, 1990). Acid rain also led to the decline of coniferous forests in some mountain areas in central Europe, particularly in the Czech Republic, Germany, Poland and Slovakia (Stanners and Bourdeau, 1995). Eutrophication has mainly affected naturally low-nutrient ecosystems on acidic soils, such as mires, acid grasslands and heathlands, especially when close to areas with high livestock densities as they are a prime source of ammonia emissions (e.g. Bobbink *et al.,* 2010; Sutton *et al*., 2011). Typically, the biodiversity value of exposed vegetation declines as the characteristic specialist species tend to be sensitive to the pollutants and outcompeted by more competitive species, such as grasses. Consequently, eutrophication is one of the most widespread and significant threats to plant species richness in natural and semi-natural ecosystems (Stevens *et al.,* 2010).

Whilst not as obvious as on land, human actions have had major impacts on the structure, properties and species communities of marine ecosystems. Most have been profoundly affected by overfishing, which has occurred historically in all EU regional seas (Jackson *et al*., 2001). This has changed marine food webs, affecting species composition and abundance, and incidental catches of non-target species have increased the magnitude of such changes. For example, the depletion of lower trophic level species such as sand-eels, sardines and herring can result in declines in upper trophic level predators such as larger fishes, seabirds and marine mammals. Furthermore, intensive bottom-trawling and dredging for shellfish regularly disturbs large areas of seabed and damages sensitive habitats such as biogenic reefs, which can then take many years to recover, if at all (EEA, 2015). Some fish species, birds and cetaceans have also been affected by high levels of by-catch.

All seas have also been altered by pollution, especially the semi-enclosed Black and Baltic Seas, and parts of the North Sea, which have been heavily affected by eutrophication (e.g. increasing oxygen depletion, algal blooms and the death of fish and benthic fauna). In the marine environment, this mainly results from nitrogen enrichment (or phosphate in low-salinity waters), the main sources being sewage, agricultural run-off and atmospheric pollution. The other main pollutants have been synthetic organic compounds such as polychlorinated biphenyls (PCBs) (which have built up to levels that have harmed some species such as marine mammals and seabirds), oil, litter and, to a lesser extent, heavy metals (Stanners and Bourdeau, 1995).

2.2.3 The Situation since 1980

This book mainly focusses on nature conservation over the last 40 years, and the most recent decades in particular. Therefore, these periods are examined in more detail in the national chapters, and a brief overview is presented here to highlight the most widespread and severe pressures. Importantly, the main pressures on biodiversity have changed with time, and conservation strategies have therefore had to adjust accordingly. Much of the text in this section is based on the *2010 Biodiversity Baseline* (EEA, 2010) and six EEA *European Environment – State and Outlook* reports produced since 1995, especially the most recent (EEA, 2019) but also starting with the first, known as the *Dobříš Assessment of Europe's Environment* (Stanners and Bourdeau, 1995). In addition, the text draws from some chapters from the International Panel on Biodiversity and Ecosystem Services (IPBES) regional assessment report for Europe and Central Asia (Rounsevell *et al*., 2018; Visconti *et al*., 2018). Additional sources for marine pressures include EEA (2015), Gubbay *et al.* (2016) and Vaughan *et al.* (2019).

A particularly important change is that the overall expansion of agricultural area has largely stopped, as a result of the productivity increases resulting from intensification, socio-economic changes and increasing imports of some foods and other commodities. CORINE land cover (CLC) data indicate that net changes in land cover have been mostly very small. In 27 European countries (and Turkey), between 1990 and 2000, there were annual declines of 0.04% for both cropland and pastures, 0.05% for semi-natural vegetation and 0.07% for wetlands (EEA, 2017b). The rate of forest expansion also slowed, resulting in a net annual increase of just 0.02%, in part as a result of agricultural abandonment and natural regeneration. The main changes in land cover resulted from the expansion of housing, industry and infrastructure (i.e. artificial areas), which increased by 0.5% per year.

More complete European CLC data are available for 2000 to 2018, and these are summarised in Table 2.3 (excluding Turkey in this case). For a more detailed analysis by the EEA, see Petersen *et al.* (2021). Some CLC trends were similar to the 1990–2000 period, including the relatively small net declines in agricultural land (although less so on cropland outside the EU). The rate of wetland loss declined further, to be probably stable. According to the CLC data in Table 2.3, there was a small decline in forest area. However, EEA analysis suggests it has been stable (Petersen *et al*., 2021), and a Forest Europe (2020) analysis has indicated an ongoing small increase in the area of forest and other wooded land of 0.3% per year for Europe over 1990–2020. These discrepancies may be due to differences in the way in which forest, transitional woodland and scrubland are categorised.

Table 2.3 CORINE land cover areas (km^2) and changes in Europe between 2000 and 2018.

	EU-28 (European territories*)					Other EEA-39 countries				
	2000	2018	% in 2018	Annual change	Annual % change	2000	2018	% in 2018	Annual change	Annual % change
Forest	1 403 487	1 374 813	31.4	−1 593	−0.114%	194 903	190 315	28.2	−255	−0.131%
Crops	1 223 088	1 216 224	27.8	−381	−0.031%	43 308	43 243	6.4	−4	Stable?
Grass and mixed	777 275	771 824	17.6	−303	−0.039%	71 687	71 169	10.5	−29	−0.040%
Other nat/semi	545 036	572 466	13.1	1 524	0.280%	305 046	309 221	45.7	232	0.076%
Wetland	113 915	113 521	2.6	−22	−0.019%	30 163	30 108	4.5	−3	Stable?
Inland water	107 978	109 291	2.5	73	Stable?	19 751	19 780	2.9	2	Stable?
Artificial	208 884	221 612	5.1	707	0.349%	11 121	12 155	1.8	57	0.517%
Total area	4 379 662	4 379 752				675 979	675 991			

Note. * EU European territories exclude those in the Macaronesian biogeographical region. The other EEA countries covered are: Albania, Bosnia and Herzegovina, Iceland, Kosovo, Liechtenstein, Montenegro, North Macedonia, Norway, Serbia and Switzerland. 'Grass and mixed' comprises pastures and heterogeneous agricultural areas. 'Other nat/semi' are other natural and semi-natural habitats, and mostly comprise scrub and shrubland, but also sparsely vegetated areas, moorland and heathland, and natural grasslands. 'Wetland' includes inland and coastal. 'Stable?' indicates that the scale of change is insufficient to be certain of trends according to the thresholds used by Petersen *et al.* (2021).
Source. Based on EEA CORINE land cover and change statistics 2000–2018[4] (downloaded 31 December 2020).

The area of combined CLC categories for 'other natural and seminatural' increased slightly, mainly in the EU. More detailed analysis of CLC data shows that this was probably partly due to further agricultural abandonment, as there was an increase in transitional woodland-shrubland of nearly 11% over the same period in the EEA-39 (Petersen *et al.*, 2021). The same study shows that, over the same time, there were small declines in sclerophyllous vegetation (−2%), natural/semi-natural grassland (−0.7%) and moors and heathland (−0.4%). However, it is important to note that these statistics do not capture all losses of semi-natural habitats, as many will be too subtle and/or small-scale to be detected using CORINE remote sensing methods and classes.

The growth of urban areas, infrastructure and other artificial areas continued at a similar rate to the 1990–2000 period. Although the area converted is relatively small, the losses can be considered permanent and often targeted areas of low agricultural value. Thus, impacts have tended to be disproportionately high on semi-natural habitats and species. Urban sprawl and the spread of roads and other infrastructure in the countryside have also contributed to further habitat fragmentation and increased human disturbance of wildlife.

Although farmland use has not expanded in most parts of Europe, widespread major impacts have continued from previous and further **agricultural improvements and intensification**, especially in western Europe. Most semi-natural grasslands have been lost through fertilisation and other agricultural improvements, and now a high proportion of lowland grasslands are temporary sown-grass monocultures. This has led to the almost complete loss of lowland hay fields, and declines in pastures, as livestock are now often kept in stockyards for most, or even all, of the year. The total area of grasslands has also decreased as they have been converted to crops for human food, livestock feed (e.g. maize) or, in recent decades, bioenergy. Low-intensity arable crops, which had relatively high levels of biodiversity, have also almost completely disappeared, apart from in parts of Iberia and eastern Europe (Hoffmann, 2012). Within intensive cropland the rate of intensification may have declined, but new biodiversity impacts have arisen. Most notably, neonicotinoid insecticides have been found to have widespread chronic impacts upon invertebrates, especially bees and other pollinators, and aquatic insects, which appear to be especially susceptible (Hladik *et al.*, 2018). Farming has also become more specialised, such that mixed farming is much less common. Over much of lowland Europe, these changes in farming have resulted in a strong decline in landscape diversity, with scarce and fragmented patches of remaining semi-natural vegetation (Jongman, 2002).

The lasting compounded impact of all these agricultural improvements has been the widespread impoverishment of wildlife in European agricultural landscapes, especially in the West, as the biodiversity value of habitats decreases in proportion to its degree of modification. The decline in semi-natural components in the landscape has been particularly detrimental, as they contribute most to overall species richness (Hoffmann *et al.*, 2000, cited in Billeter *et al.*, 2008; Oppermann and Hoffmann, 2012).

Evidence of the biodiversity impacts of this progressive intensification of agriculture comes from long-term monitoring of birds that has revealed substantial declines in farmland bird

[4] www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

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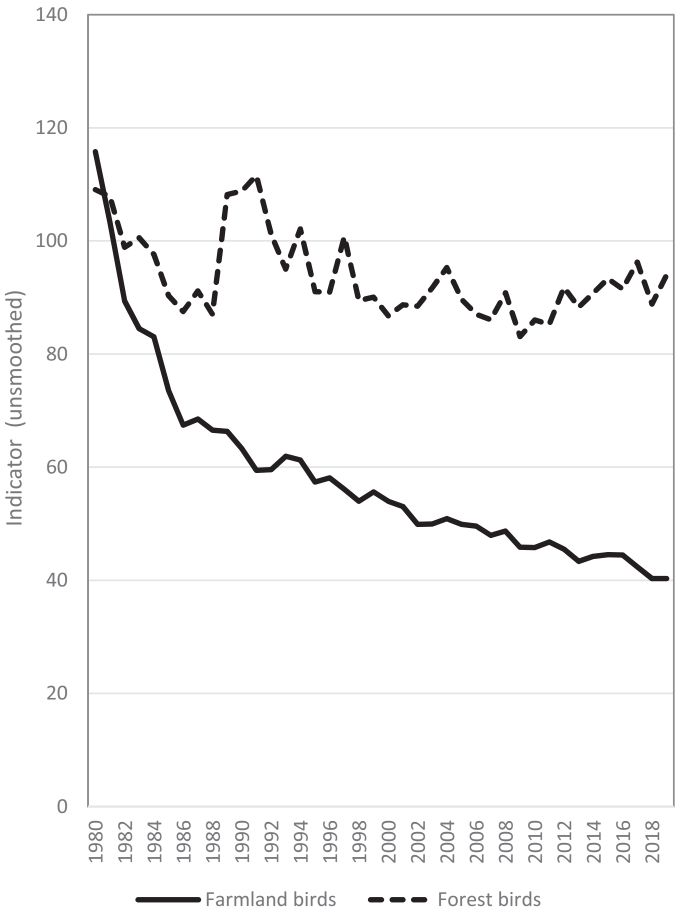

Figure 2.3 Common bird indicator values for farmland and forest species in Europe.
Notes. 1980 base year. Based on 28 countries' data. See the PanEuropean Common Bird Monitoring Scheme for methods, and included countries and indicator species (https://pecbms.info/trends-and-indicators/).
Source. EBCC/BirdLife/RSPB/CSO (2022).

populations (Figure 2.3). Between 1980 and 2000 the European farmland bird index fell by 53%. Whilst the rate of decline has since slowed, the index decreased by another 11% by 2019. Analysis of the bird trend data by Donald *et al*. (2001, 2006) revealed that the declines were closely associated with indicators of agricultural intensification. The authors also noted in 2001 that declines and intensification had been highest in the EU at the time, and therefore predicted similar agricultural trends and resulting bird declines in countries joining the EU.

For some time, there have been growing concerns in the EU over the environmental impacts of agriculture and the need to address overproduction; in the 1990s this unease stimulated a process of gradual changes towards a more sustainable CAP (Robson, 1997; Jepsen *et al*., 2015). These changes included the replacement of most production-based subsidies with area-based subsidies, and the introduction of environmental support measures, as described further in Section 4.3 and online Annex 3.[5]

In the former Eastern Bloc, around 1990, more sudden and very different changes occurred in agriculture. These were a result of the collapse of communism, and led to state farms and collectives being dissolved, with the land distributed to private owners. This initially resulted in two diverging effects on land use. Much of the land was subject to commercialisation and agricultural intensification, especially where bought up by large agri-companies. In contrast, elsewhere de-intensification occurred, or even abandonment where the new owners were absent or uninterested in farming. For a while a large proportion of former farmland remained unused for agriculture, estimated to be 15–20% of cropland in Slovakia, Poland and Ukraine (Keenleyside and Tucker, 2010).

In more recent decades, the region has been characterised by rapid economic and social development and urbanisation, especially in countries that have joined the EU, such that they increasingly resemble those in Western Europe (Rounsevell *et al*., 2018). Whilst semi-natural habitats and biodiversity levels had been much higher in Eastern Europe, especially in agricultural areas that had escaped collectivisation (Tryjanowski *et al*., 2011), this difference has been gradually reduced. Despite the CAP's environmental reforms, agricultural intensification and industrialisation, with associated biodiversity declines, have continued over the EU, and especially in new Member States, as the CAP and other EU support measures have helped them 'catch up'. Evidence of this comes from bird monitoring in the Czech Republic, where EU accession was followed by increases in agricultural intensification that correlated with steep declines in bird populations (Reif and Vermouzek, 2019), as predicted by Donald *et al*. (2001).

Economic growth in the former Eastern Bloc has also led to the loss of some remaining wetlands and other semi-natural habitats, particularly along the coasts as these have been the focus of many tourist developments. This has long been the case in much of western and southern Europe, where recreational pressures have damaged coastal habitats and resulted in declines in sensitive species such as beach-nesting birds and turtles.

Within **forests** the main biodiversity impacts over the last 40 years have resulted from forestry management, as about 80% of forest area is available for wood supply. This supply has been primarily used for timber and pulp, but increasingly for fuelwood, which in 2018 accounted for 22% of roundwood use (EEA, 2019). At its most intensive, forest management has included the conversion of semi-natural forest to even-aged plantations, with profound ecosystem changes and biodiversity losses. Calculation of the proportion of European forests that is intensively managed plantations (including from afforestation) is difficult as it depends on the interpretation of definitions. The EEA (2016) estimated that plantations constitute 9% of forest area in the EEA-39 countries (based on FAO 2015 data), whilst a much lower estimate of 3.8% is given for the larger area assessed by Forest Europe (2020).[6] It should be

[5] All annexes are free to access online at CUP: www.cambridge.org/natureconservation

[6] Forest Europe data cover all of Europe, except for the Russian part, and include Georgia and Turkey.

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noted that these estimates exclude planted forests that have not been subject to forestry operations for a long time. It is arguable whether this is justified, as such forests are still likely to be dense monocultures with a highly artificial even-aged structure.

About half of plantations are dominated by introduced species (as described earlier). However, the overall proportion of forest dominated by introduced tree species is much larger: estimated to be 31% according to Forest Europe (2020) for 31 European countries, and as much as 48% for the EU-28 and 41% for the EEA-39.

Most of Europe's forest is now considered to be semi-natural[7]: estimated to be 87% by the EEA (2016) and as much as 94% by Forest Europe (2020). However, these figures seem to be overestimates given the proportion of forest that is dominated by non-native species. Furthermore, 60% of forests in Europe are even-aged, and the proportion of old forests (>100 years) has decreased substantially in some northern and western EEA countries (EEA, 2016). These are all signs that the majority of so-called semi-natural forests have in fact been relatively intensively managed, with the resulting biodiversity impacts discussed earlier (Sing *et al.*, 2018). In recent years more sustainable forest management practices have been widely adopted, and there are some indications of slight improvements in the ecological condition of forests, such as small increases in deadwood, which is of particular importance for biodiversity (EEA, 2016; Forest Europe, 2020). The common forest bird indicator has also increased slightly since 2009 (see Figure 2.3). Nevertheless, most 'semi-natural' forest ecosystems are far below their potential biodiversity value, and thus need more ambitious environmentally sensitive forestry practices to increase their naturalness and undisturbed areas.

In contrast to most forests, some semi-natural forest areas have suffered from neglect following the abandonment of some traditional forms of forestry (e.g. coppicing), leading to forests with low structural diversity. High population densities of deer in some countries have resulted in little tree regeneration. Forests are also increasingly being affected by climate change, including increased temperatures, droughts, fires and extreme weather events. These effects are reducing forest ecosystem condition and resilience to pests, diseases and IAS.

Some reductions in **air pollution** have occurred across much of Europe, most notably sulphur with rapid substantial declines in deposition since the 1970s (Fowler *et al.*, 2007). Nevertheless, the deposition of airborne nitrogen across Europe as a whole only declined slightly between 1980 and 2003 (Fagerli and Aas, 2008). As a result, in 2005, 67% of European ecosystems and 78% of Natura 2000 sites were exposed to nitrogen deposition exceeding their critical loads[8] (EEA, 2019). More recent data indicate that ammonia emissions from agriculture only slightly decreased between 2000 and 2013, and then increased by about 3% by 2017 (EEA, 2019). However, ammonia emission levels vary greatly between countries, being highest in those with high-density intensive livestock production (e.g. see the Netherlands, Chapter 23).

Some progress has been made in tackling **water pollution** and other pressures on **rivers, lakes and other wetlands**, in part driven by better technology but also EU policies and legislation (described in Section 4.3). The main improvements have been in relation to point sources of pollution (e.g. sewage and industrial discharges) and nitrogen surpluses from agriculture. Despite these improvements, by 2018 only 40% of Europe's surface water bodies had achieved a good ecological status and wetlands remained widely degraded (EEA, 2018, 2019). The main pressures constraining further improvements are diffuse pollution, water abstraction (although it has declined) and hydromorphological changes, such as dams or river channel re-engineering. Over recent decades, an increasing pressure on rivers has been the growth in hydropower, and especially the cumulative effects of micro-hydro schemes on river hydrology and migratory fish (European Commission, 2018a).

Another biodiversity pressure that has particularly affected wetland species has been the poisoning of birds, and sometimes other animals, from the use of lead ammunition for hunting (Watson *et al.*, 2009). This primarily affects waterbirds that ingest some of the large amounts of lead shot that are now in the environment as a result of the use of shotguns. As a result of this it has been estimated that approximately one million wildfowl (representing 17 different species) or 8.7% of the total population may die every winter from lead poisoning caused by ingestion of lead gunshot in Europe (Mateo, 2009). Predators and scavengers, such as eagles and vultures, may also suffer secondary poisoning if they consume the flesh of animals that have been killed or wounded with lead shot or bullets.

In the **marine environment**, the main human impacts on ecosystems since 1980 have continued to be from fisheries and pollution, although the pressures have declined in some areas. Decreased fishing pressure in the north-east Atlantic Ocean and the Baltic Sea in recent years has led to signs of recovery of many stocks, but overfishing has continued in the Mediterranean and Black Seas (EEA, 2019). Furthermore, by-catch of non-target fish, seabirds and marine mammals remains of concern, and intensive fishing activities frequently continue to affect benthic habitats in many areas. This has been revealed by a spatial analysis of fishing activities, which found that, in six[9] out of nine studied areas in Europe, more than 25% of the seabed was trawled each year (Amoroso *et al.*, 2018).

[7] That is, they are influenced by forest operations but retain the characteristics of natural forest ecosystems with regard to their structures and functions.

[8] That is, a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.

[9] The Adriatic, west of Iberia, Skagerrak and Kattegat, Tyrrhenian Sea, North Sea and western Baltic.

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Some marine pollutants have declined locally, particularly from point sources but less so from diffuse sources, which primarily come from agriculture. Despite the reductions in nitrogen and phosphate pollution, the Black Sea and Baltic Sea remain eutrophic. Some toxic contaminants have remained at high levels, such as certain heavy metals and PCBs (despite being banned decades ago), and marine litter levels have increased. The PCB levels are of particular concern, as they accumulate in high-level predators, and there is evidence that they are threatening the survival of the Killer Whale (*Orcinus orca*) in parts of the region (Desforges *et al*., 2018).

Marine ecosystems have been historically affected by IAS, many of which arrived attached to ships or in their ballast water, whilst some were deliberately introduced, such as the Pacific Oyster (*Magallana gigas*). In recent decades there has been a noticeable acceleration in the occurrence of IAS in European seas (EEA, 2015), and these are increasingly affecting marine ecosystems, especially in the Black Sea and the Mediterranean Sea. Whilst the impacts of many IAS are uncertain, some have led to obvious ecosystem changes. Perhaps the most serious change arose from the predatory comb jelly *Mnemiopsis leidyi*, which became super-abundant in the Black Sea in the 1980s. In combination with over-fishing pressures, this disrupted the food web sufficiently to trigger a regime change in the ecosystem,[10] with a collapse in fish stocks (Möllmann and Diekmann, 2012). Since then, its population has declined and predation by another alien comb jelly species, *Beroe ovata*, which arrived in 1999, has meant that the Black Sea ecosystem shows signs of recovery (Vaughan *et al*., 2019). The number and impacts of IAS are still increasing on land, as well as in the sea, despite increased legal and social responses in recent years (Rabitsch *et al*., 2016).

The direct effects of **climate change** (e.g. increases in temperatures, changes in precipitation, and increases in extreme weather events) and indirect effects of human responses (e.g. renewable energy and infrastructure to mitigate impacts such as flood defences) have become much more significant over recent decades. The sea has also become more acidic as a result of increasing carbon dioxide concentrations in the atmosphere. In European seas, observed ecosystem impacts have included changes in species distributions and the timing of biological events. Such changes have added to the other existing pressures, including over-fishing and eutrophication, and led to regime shifts in the Baltic, Mediterranean and north-east Atlantic Seas at the end of the 1980s/early 1990s (Möllmann and Diekmann, 2012; EEA, 2015).

Terrestrial impacts of climate change have mostly not been so severe, but there is evidence of growing disruption of ecosystems in Europe by increasing temperatures, changing rainfall patterns, droughts, fires, flooding, other extreme weather events and sea-level rise (EEA, 2017c; IPCC, 2021). In freshwater lakes and streams, higher water temperatures and darkening of water colour or 'browning' by elevated concentrations of dissolved organic carbon may lead to serious ecosystem impacts (e.g. Weyhenmeyer *et al.,* 2016). These climate effects, and the knock-on complex impacts on species interactions, are already leading to changes in species distribution and declines in some vulnerable species (Hickling *et al*., 2006; Ockendon *et al*., 2014; Martay *et al*., 2017). Such impacts can be confidently expected to increase due to the further climate changes that are already inevitable from greenhouse gas emissions so far. In fact, Europe is expected to be especially affected as temperatures in Europe are predicted to continue increasing faster than the global average all through the twenty-first century under all scenarios (IPCC, 2021). However, the severity and nature of the impacts will vary regionally, with the highest temperature increases in north-eastern Europe and Scandinavia during winter, and in southern Europe in summer (Jacob *et al*., 2014).

2.3 Europe's Remaining Biodiversity and Its Priority Conservation Needs

2.3.1 What Is Left and Where Is It?

To place the following section and country chapters in context, Figure 2.4 indicates the proportion of each EEA-39 country that comprises forests, wetlands, other semi-natural habitats (e.g. natural grasslands, heathlands, shrublands and rocky habitats), agricultural land and artificial areas, based on CLC data. This has been ordered in relation to the proportion of 'other semi-natural habitats', as these are of particular importance for biodiversity in most countries. As further discussed below, a high proportion of forest habitat is also considered to be semi-natural, as are some areas of agricultural land, but it is not possible to separate them out using CLC data.

No ecosystem in Europe is pristine; all are affected by the legacy of past human actions (e.g. extinction of key species, drainage and eutrophication) and ongoing modern day pollution (nutrients, toxins and plastic, etc.). Nevertheless, despite the profound changes to ecosystems and landscapes, described in Section 2.2, Europe retains a relatively high diversity of habitats and associated species (especially in the Mediterranean region). Extensive areas of some near-natural ecosystems[11] remain, such as some rivers, lakes, tundra, mires, grasslands, karst features and caves, cliffs, screes, dunes, salt

[10] That is, a sudden, persistent reorganisation of the structure and function of the ecosystem.

[11] That is, those that would exist in the absence of human actions and show low levels of human impacts.

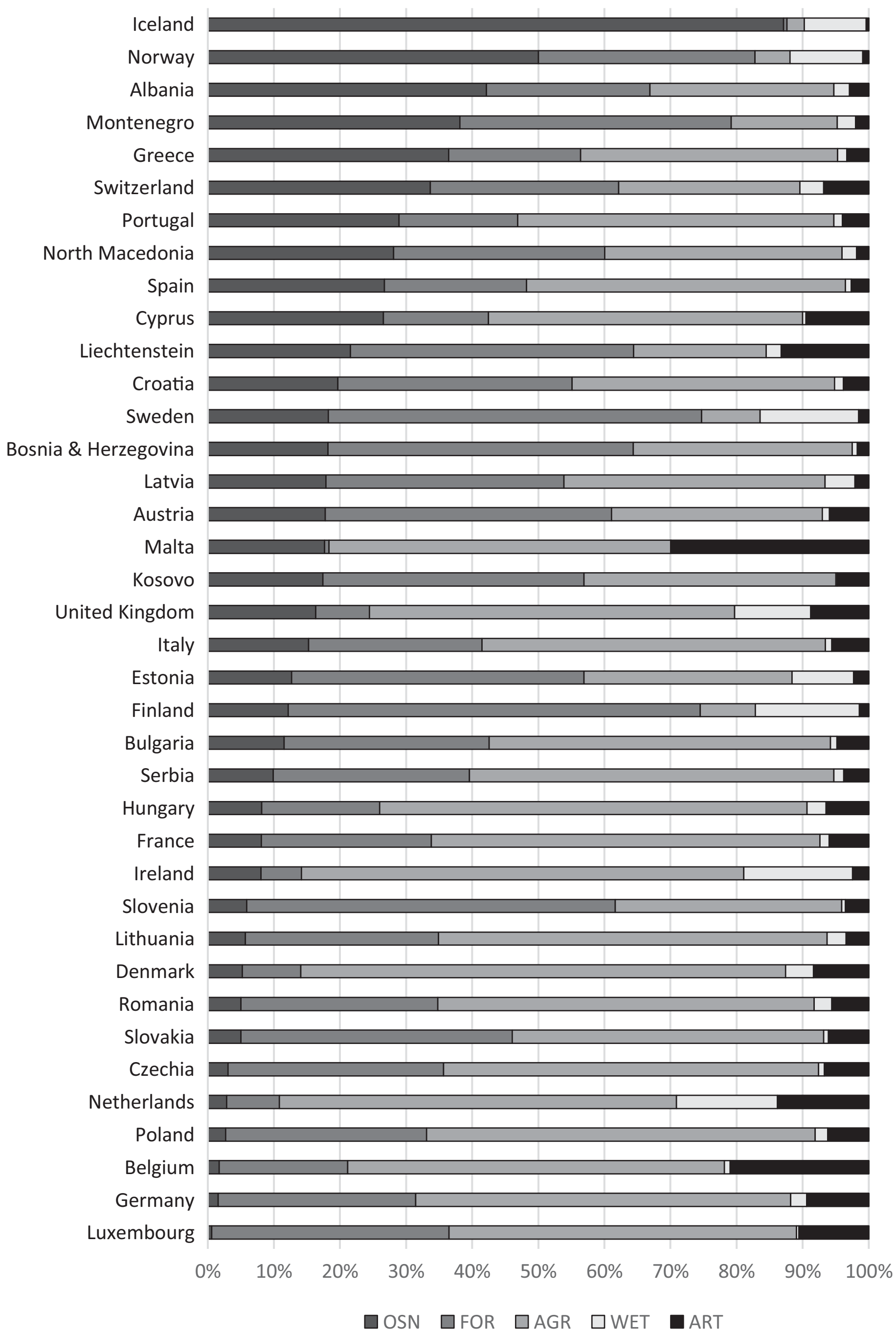

Figure 2.4 Proportional land cover in European countries in 2018 according to CORINE land cover classes.
Key. OSN = other seminatural (e.g. shrublands, rocky habitats); FOR = forests; AGR = agricultural habitats; WET = inland and coastal wetlands and inland water bodies; ART = artificial areas (see Table 1.1 for details). Covers EEA-39 countries other than Turkey, and excludes areas within the Macaronesian biogeographical region.
Source. Based on CORINE Land Cover Level 2 data for 2018, downloaded from the EEA www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics (31 December 2021).

marshes, mudflats, beaches and diverse benthic habitats – although many of these are remnants that are mostly confined to remote northern latitudes, high mountains and offshore marine areas. Some near-natural forests also occur, but they form a tiny proportion of Europe's forest area and are mainly confined to the Boreal region, as well as mountains in central and eastern Europe. According to the EEA (2016) and Forest Europe (2020), such undisturbed forests[12] have been estimated to comprise just 2% of European forests. Sabatini *et al.* (2018)

[12] That is, naturally regenerated stands of native species, with natural dynamics (which requires sufficient area and natural structures). They are always of high nature conservation value. No clearly visible indications of human activities are acceptable.

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attempted to map equivalent areas of primary forest[13] across Europe (excluding Russia), but the mapped areas amounted to only 0.7% of forest area due to knowledge gaps.

Over most of Europe, terrestrial biodiversity-rich areas are now mainly associated with semi-natural habitats, the most extensive of which are forests. As discussed earlier, the EEA and Forest Europe consider that the majority of forest in Europe is 'semi-natural', although this is based on a very broad interpretation of the term. Whilst forest is the climax vegetation that would occur in most lowland areas, few such semi-natural forests closely resemble their equivalent natural communities in species composition and structure, because most are managed for forestry. Nevertheless, forest habitat types of high intrinsic nature importance remain, including 81 habitat types listed in HD Annex I (i.e. 35%). These cover 491 900 km^2, which is about 27% of the EU forest area (EEA, 2020b).[14]

HD forests support a high diversity of species, a large proportion of which are of high conservation importance, as many are habitat specialists, endemic, rare or otherwise threatened. HD Annex II species that are dependent on forest habitats include the iconic Brown Bear, Wolf, Eurasian Lynx (*Lynx lynx*) and Wolverine (*Gulo gulo*), which have recovered much of their range in recent decades (for reasons described in several chapters). Europe is alone in the world in having increasing populations of large carnivores that are not confined to protected areas, and are sharing the same land as people (Chapron *et al*., 2014).

Most of the other remaining biodiverse semi-natural habitats are the grasslands, heathlands, Mediterranean shrublands and pastoral woodlands that are the result of traditional low-intensity farming. These are often complex labour-intensive farming systems using livestock breeds, crop types and husbandry practices that are highly adapted to local soils, vegetation and climate. Among extensive pastoral systems of high conservation, some are of particular scientific interest because to some extent they mimic natural grassland ecosystems that were formerly present and maintained by wild native herbivores. It has been suggested that species in these landscapes reflect a species pool from Pleistocene herbivore-structured environments, which, after the extinction of the Pleistocene mega-fauna, was rescued by the introduction of pre-historic agriculture (Eriksson, 2021).

Semi-natural grasslands and some other habitats also often have very high levels of small-scale species diversity. In fact, according to Wilson *et al.* (2012), pastoral woodlands in Estonia and some semi-natural grasslands in eastern central Europe have amongst the highest levels of small-scale species richness in the world (e.g. shoots of 43 species over 0.1 m^2 in an area of semi-dry basiphilous grassland in Romania). Of Europe's endemic vascular plants, 18% are bound to grassland habitats, which is nearly twice as many as in forests, despite the latter covering a much greater area (Hobohm and Bruchmann, 2009, cited in Habel *et al*., 2013). Semi-natural grasslands are also very important for a wide range of associated animal species, for example hosting 88% of European butterflies, although the proportion of endemics is low (Wallis DeVries and van Swaay, 2009).

As a result of their high biodiversity value, and because many are now scarce and/or declining, most semi-natural agricultural habitats in the EU are listed in HD Annex I, and many associated species are listed in HD Annex II or BD Annex I. In fact 58 HD Annex I habitats (about 30%) are considered to be key farmland habitats because they are dependent on, or associated with, extensive agricultural practices (European Commission, 2018b). HD Annex II includes 197 species or subspecies that are associated with agro-ecosystems or grassland ecosystems, and 62 BD Annex I birds are considered to be key farmland species.

The nature conservation and cultural importance of the farming systems that maintain semi-natural habitats and their associated 'cultural landscapes' is now generally recognised. To highlight their biodiversity importance, the term High Nature Value (HNV) farming was coined by Baldock *et al.* (1993). This concept has been widely adopted, incorporated into EU policy and further developed, including for forests (e.g. IEEP, 2007). Three types of HNV farmland are now recognised (Paracchini *et al*., 2008):

- Type 1: Farmland with a high proportion of semi-natural vegetation.
- Type 2: Farmland with a mosaic of low-intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers, etc.
- Type 3: Farmland supporting rare species or a high proportion of European or world populations.

Type 1 HNV farmland comprises a wide range of habitats (many of which are HD Annex I habitats), including coastal, floodplain, steppic and alpine meadows and pastures, heathlands, sclerophyllous scrub (matorral) and wood pastures. As well as including mixed low-intensity farmland with hedges and woods, etc., Type 2 also includes extensive open dry croplands with traditional rotations and grazed stubbles, which are now scarce. Such habitats have diverse plant and invertebrate communities, and are especially important for steppe birds, such as the globally Vulnerable Great Bustard (*Otis tarda*) (Bota *et al*., 2005). Type 2 HNV may also include traditional

[13] In accordance with the FAO and Buchwald (2005), these are 'Relatively intact forest areas that have always or at least for the past sixty to eighty years been essentially unmodified by human activity. Human impacts in such forest areas have normally been limited to low levels of hunting, fishing and harvesting of forest products, and, in some cases, to historical or pre-historical low intensity agriculture.' They include primeval, virgin, near-virgin, old-growth and long-untouched forests.

[14] This appears to be based on the EEA 2016 forest estimate which uses the FAO definition of forests. It would be 36% of EU forest cover based on the CLC 2018 data in Table 2.3.

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orchards, vineyards and olive groves, when they retain large old trees and a semi-natural understory that is extensively grazed by livestock. More detailed descriptions and examples are provided in Oppermann *et al.* (2012). In reality, the HNV types are not mutually exclusive. It should also be noted that Type 3 HNV farmland often includes more intensive farmland. For example, conventionally farmed cropland on the Black Sea coast is an important feeding ground for wintering Red-Breasted Geese (*Branta ruficollis*), another globally vulnerable species.

Mapping and quantifying HNV farmland is difficult in practice, as the different types are rather subjectively and loosely defined (especially Type 2) and the necessary datasets are currently lacking. Nevertheless, mapping has been carried out biannually in Germany since 2009 in sample areas, to monitor HNV extent (Benzler *et al.*, 2015). Predictive maps of the likelihood of HNV farmland across Europe have been produced by the EEA using CLC, farming and biodiversity data (Paracchini *et al.*, 2008), the latest update being produced using CLC 2006 data (Schwaiger *et al.*, 2012). According to its estimates for each country, over the EU-28 excluding Greece (due to data gaps), the HNV area was estimated to be 787 517 km^2, which is about 34% of the agricultural area. HNV farmland in the other EEA-39 amounted to 124 925 km^2, which is about 66% of the agricultural area based on CLC data and the HNV map. This high proportion is mainly due to the predicted large HNV areas in Iceland and Norway. As the study notes, care should be taken in interpreting the estimates due to data gaps and limitations. It should also be borne in mind that the methods and data are best able to predict Type 1 HNV, and Type 3 only for some species groups. Type 2 HNV is only indirectly predicted and is possibly underestimated.

A more recent study by Keenleyside *et al.* (2014) compiled the best available national estimates, both minimum and maximum, of HNV farmland extent in each of the EU-28 Member States. The authors did not provide overall totals for the EU, as they felt the estimates were too variable and uncertain. This seems overly cautious as the national estimates are probably at least as reliable as the predictions by the EEA for most countries, and where this is not the case then the EEA data are used. Adding the EU-28 estimates (which omit Malta) gives minimum and maximum total HNV areas of 579 047 km^2 and 827 790 km^2, which equate to 25% and 36% of the agricultural area estimated by the EEA. Thus, both sets of estimates are reasonably close, which gives some reassurance that they provide useful indications of HNV area, although both have similar limitations especially regarding Type 2 HNV farming.

Building on initial concepts by IEEP (2007), the EEA (2014) has defined HNV forest as 'an area covered by forests or other wooded lands having a current ecosystem state similar to its natural state.' The EEA has also carried out exploratory studies to identify and map HNV forest and develop a related European-level forest naturalness indicator. However, HNV forest areas have yet to be mapped or quantified at an EU or wider scale.

Rivers, lakes, lagoons, mudflats, salt marshes, mires, fens and other wetlands remain relatively common and extensive over much of Europe, especially in the north and west. They make up about 5% of the EU's area and 7% of other countries in the EEA-39 (Table 2.3). Whilst most have been modified by humans and remain polluted (especially nutrient enrichment), they still provide essential habitat for a wide range of species, some of which are rare, and/or endemic to isolated water bodies. Wetlands are also very productive habitats and therefore often support huge numbers of particular species of invertebrates, fish and waterbirds. Furthermore, most of the larger sites, such as the Volga Delta, Danube Delta and Waddenzee, are also of crucial importance as migratory staging posts and wintering areas for birds (Heath and Evans, 2000).

As described earlier, most of Europe's seas show severe impacts from the effects of fishing, pollution and other pressures. Despite this, due to their variety of biophysical conditions, they still retain a wide range of marine habitats (although they are only broadly categorised in the Habitats Directive) such as rocky shores, shallow seagrass and kelp beds, dynamic sandbanks and biogenic reefs. These in turn support a high diversity of species, especially in the Mediterranean, where there is also a high proportion of endemics, and a number of rare species including turtles and the endangered Mediterranean Monk Seal (*Monachus monachus*). Part of the north-east Atlantic is also characterised by its very high productivity, which in turn supports large numbers of seabirds and sea mammals, including high proportions of the global population of certain species, such as the Manx Shearwater (*Puffinus puffinus*) and Grey Seal (*Halichoerus grypus*). Cetacean numbers remain depleted from past hunting, but they are increasing and a diverse range of species occur, including the largest animal on the planet – the globally Endangered Blue Whale (*Balaenoptera musculus*).

2.3.2 Species' Distribution Patterns and Concentrations of Species of High Conservation Concern

To provide contextual information for the later chapters, it is useful to know the relative importance of each country with respect to its species richness, especially in relation to those of high conservation concern at a European level. Ideally this should draw on comprehensive lists using consistent criteria that cover all (or at least most) species groups, and each European country. Unfortunately, such compiled information is not available for most species groups across all European countries, but it is possible to get an indication of the importance of each country with respect to bird species richness and Species of European Conservation Concern (SPEC) that have been identified by BirdLife International, most recently in 2015. SPECs include species that, according to IUCN Red List criteria, are threatened (i.e. Critically Endangered, Endangered or Vulnerable) or Near Threatened globally and/

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or in Europe (BirdLife International, 2015). They also include species that are moderately declining or depleted. Table 2.4 indicates the number of species and SPECs that occur in each country. It should be noted that the list of globally threatened species has since been updated, a new Red List has been published (BirdLife International, 2021) and SPECs are to be revised. However, these updates are not likely to alter substantially the broad pattern of bird species conservation importance across Europe.

There is an obvious tendency for large countries, most notably the Ukraine, France and Spain, to have the most species and SPECs. This is not surprising as it reflects the general species richness area relationship that has been widely observed in nature (e.g. Rosenzweig, 1995). One reason for this relationship is the tendency for large areas to have greater variation in their abiotic conditions and habitats. To explore this further, and to show which countries have disproportionately high species richness, Figure 2.5 plots the number of species in relation to the terrestrial area of the country. Each country's marine area has not been included as a very small proportion of bird species spend all their time at sea other than at their nest site.

The graph confirms that there is a clear relationship between species richness and the area of the country, which is best described by the logarithmic curve. Thus, countries that are above the curve can be said to be particularly species rich, for example, as a result of their particularly high geological, topographical or climatic diversity and relatively low levels of human impact. This indicates that Ukraine, and especially France and Spain, are not just species rich because of their size. Other countries that are particularly rich in birds for their size include Bulgaria, Greece, Serbia and Romania. In contrast, the UK, Ireland and Iceland are notably species poor for their size. For the UK, and especially Ireland, this is partly due to their isolation since the Ice Age, as discussed earlier. For instance, Ireland lacks some birds with short dispersal distances, including the Tawny Owl (*Strix aluco*) and three out of four woodpeckers that occur in Great Britain. As well as being absent from Ireland, some other woodpeckers that occur close by on the continent are lacking in Great Britain, such as Black Woodpecker (*Dryocopus martius*). Similar results to those shown in Figure 2.5 are obtained if the numbers of SPECs are plotted against the area of the country.

More detailed information on species richness and the distribution of SPECs is available from the maps in the second *European Breeding Bird Atlas* (Keller *et al*., 2020). There is clearly a high level of coincidence between areas with high overall species richness and the number of SPECs, with concentrations of both in southern Sweden, southern Finland, the Baltic States, Belarus, Poland, Bulgaria, south-east Romania and parts of Spain.

Although such detailed Europe-wide distribution information is not available for many other taxa than birds, areas of high conservation importance with respect to species richness, European endemics and threatened species have been mapped for a number of species groups as part of the preparation of European Red Lists. Summaries of such information are therefore presented in Table 2.5, primarily to highlight the varying conservation importance of the groups and the areas of particular importance for them. Whilst some Red Lists are now rather old, and some have been partly revised (Table 2, Neubert *et al*., 2019), the distribution patterns of interest here are unlikely to have changed since they were produced. Some higher plant Red List results are not included in the table as they focussed on selected groups that would not provide a broadly representative picture as required here. Besides, plant diversity in Europe has been more broadly studied, and 24 centres of diversity identified, of which nine occur within the Iberian Peninsula and 14 are mountain ranges (e.g. the Alps, Pyrenees, Troodos Mountains and Carpathians) (WWF and IUCN 1994, cited in Bilz *et al*., 2011).

For many species groups there is an obvious geographical gradient, with species richness increasing from north to south, such that Iberia, the Mediterranean region and the Balkans are particularly species rich (e.g. for trees, grasshoppers, etc., bees and reptiles). However, for some others, mid latitudes in central and eastern Europe tend to have the highest species richness (e.g. dragonflies, freshwater fish and amphibians). Mountains also have a marked influence on these patterns, being, for example, particularly rich in species of ferns, butterflies and mammals. Marine fish and mammals contrast in their species richness patterns: the Mediterranean is particularly rich in fish, whilst most European marine mammals are found along the continental shelf of the north-east Atlantic.

Endemics often show similar patterns to overall species richness, but tend to be more concentrated in the glacial refugia of the Mediterranean, as well as mountains and islands, where their isolation has led to speciation. Whilst it is not always apparent from the Red List maps of concentrations of endemics, many islands have their own endemic forms of some more widely distributed species. Although not covered in this book and Table 2.5, the Macaronesian islands and seas are particularly important for endemic species. Threatened species tend to have more concentrated distributions, typically where high species richness and endemism coincide with intense land use change and other human developments over recent decades (e.g. in Iberia, the Mediterranean and Black Sea coasts and the Alps).

This brief analysis reveals that, although there are obvious patterns in spatial biodiversity importance, and similarities amongst some species groups, there are also significant complex variations. Hence, it is necessary for conservation strategies and targeting to understand and take these variations into account, and not be focussed on a few selected and well-studied species groups.

For the EU-28 countries, it is possible to assess their importance more formally with respect to the species identified in the Nature Directives as requiring conservation measures, as listed in BD Annex I and HD Annexes II and/or IV or V. The proportions of the species in BD Annex I, and the combined

Table 2.4 The proportion of European* bird species and Species of European Conservation Concern (SPEC) that occur in each country.

Country	Code	All species		SPEC	
		Number	%	Number	% of SPEC
Europe*		541		218	
Albania	AL	224	41	78	36
Andorra	AD	111	21	35	16
Austria	AT	215	40	72	33
Belarus	BY	224	41	83	38
Belgium	BE	184	34	62	28
Bosnia & Herzegovina	BA	223	41	71	33
Bulgaria	BG	256	47	87	40
Croatia	HR	228	42	72	33
Cyprus	CY	95	18	39	18
Czech Republic	CZ	218	40	76	35
Denmark	DK	191	35	69	32
Estonia	EE	219	40	76	35
Finland	FI	247	46	88	40
France	FR	281	52	103	47
Germany	DE	246	45	85	39
Greece	GR	251	46	86	39
Hungary	HU	217	40	75	34
Iceland	IS	75	14	35	16
Ireland	IE	134	25	50	23
Italy	IT	250	46	85	39
Kosovo	XK	180	33	58	27
Latvia	LV	218	40	75	34
Liechtenstein	LI	134	25	36	17
Lithuania	LT	214	40	76	35
Luxembourg	LU	129	24	43	20
Malta	MT	24	4	8	4
Moldova	MD	177	33	67	31
Montenegro	ME	210	39	68	31
Netherlands	NL	186	34	67	31
North Macedonia	MK	228	42	74	34
Norway	NO	250	46	89	41
Poland	PL	234	43	82	38
Portugal (inc. Azores, etc.)	PT	213	39	90	41
Romania	RO	254	47	88	40
Serbia	RS	238	44	78	36
Slovakia	SK	221	41	75	34
Slovenia	SI	209	39	65	30

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Table 2.4 *(cont.)*

Country	Code	All species		SPEC	
		Number	%	Number	% of SPEC
Spain (inc Canaries etc.)	ES	281	52	117	54
Sweden	SE	256	47	91	42
Switzerland	CH	189	35	61	28
Ukraine	UA	272	50	104	48
United Kingdom	UK	211	39	77	35

Note. * Europe here includes European Russia, all of Turkey, and the Caucasus.
Source. Based on data provided by A. Staneva, BirdLife International, from BirdLife International (2017b).

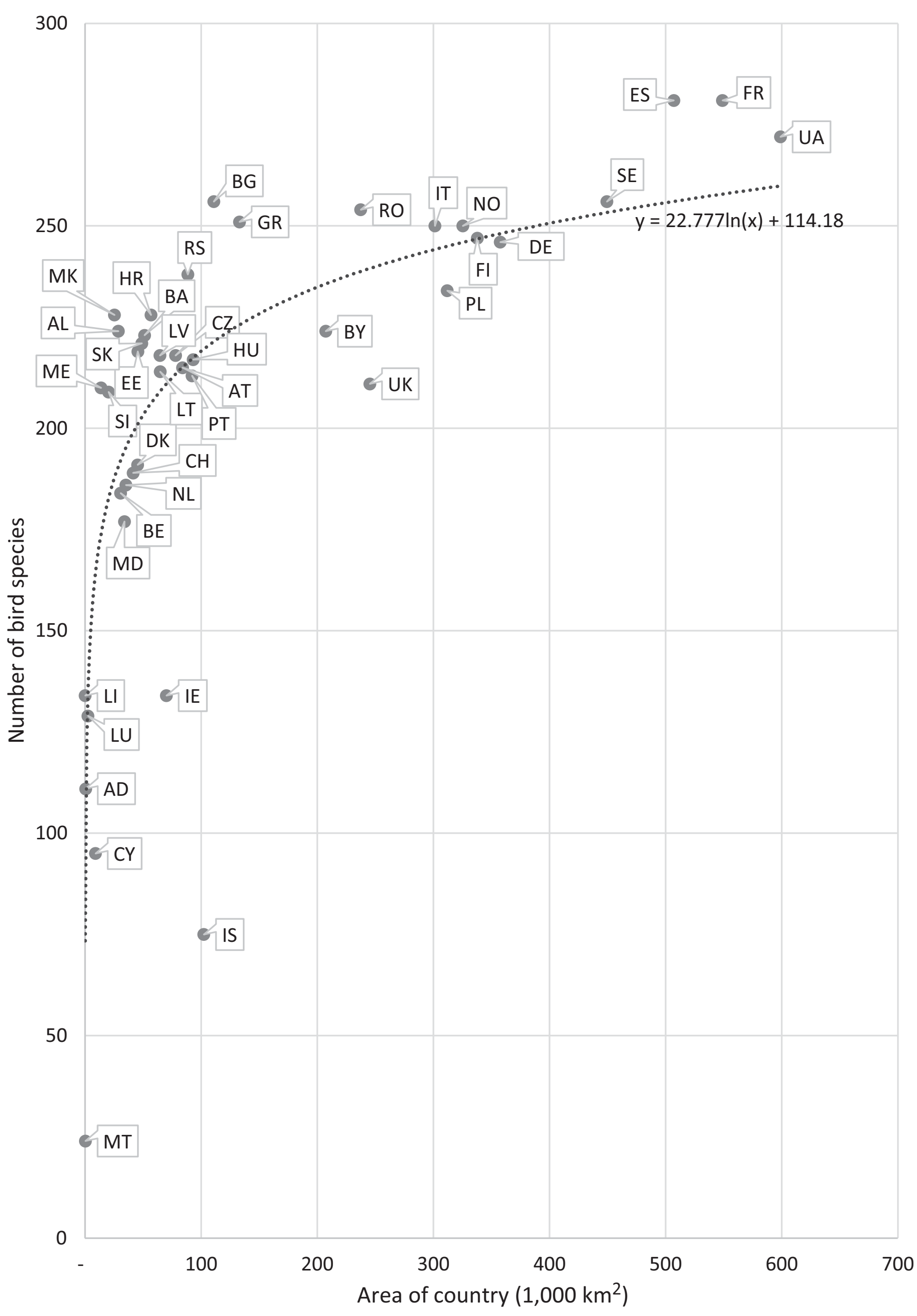

Figure 2.5 The number of bird species that occur in each European country in relation to the country's terrestrial area.
Notes. See Table 2.4 for country codes. R^2 for the logarithmic curve = 0.593.
Source. Based on data provided by A. Staneva, BirdLife International, from BirdLife International (2017b).

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Table 2.5 The numbers and distribution of European species, endemics and threatened species.

Species group and source	Total species, % endemic, % threatened in Europe*	Areas with high species richness relating to		
		All species	Endemic and near endemic species	Threatened species
Mosses, liverworts and hornworts (Hodgetts *et al.*, 2019)	1 817 species, 10% endemic, 22% threatened	Central Europe, esp. Alps, also Pyrenees, Carpathians, Scandinavia and UK	Few endemics, evenly distributed with some high numbers in the Alps, UK and Ireland	Alps (esp. E), followed by the Carpathians, E Pyrenees and some Scandinavian mountains
Lycopods and ferns (García Criado *et al.*, 2017)	194 species, 27% endemic, 20% threatened	Mountainous areas, inc. Alps, Pyrenees, Massif Central and Carpathians	Alps, locally N Sardinia, mainland Italy and S Spain	Alps, esp. in Switzerland
Trees (Rivers *et al.*, 2019)	454 species, 58% endemic, 42% threatened	Mediterranean region and Balkan Peninsula	S and central Europe, inc. Alps, Pyrenees, Carpathians, Apennines and the Balkan Peninsula	Widespread, some concentrations of *Sorbus* spp., e.g. in UK, Carpathians and Hungary
Freshwater molluscs (Cuttelod *et al.*, 2011)	856 species, 87% endemic and 44% threatened	Iberia, Mediterranean, Alps, Carpathians and Balkans	As all species, esp. ancient lakes in Balkans and Mediterranean islands for narrow range species	Similar to endemics, e.g. Iberia, S France, Germany, Austria and Greece
Terrestrial molluscs (Neubert *et al.*, 2019)	2 480 species, 92% endemic and 22% threatened	Mid latitudes of central Europe, esp. Pyrenees, Alps, Carpathians and Balkans	As for all species	Greece notable hotspot
Dragonflies (Kalkman *et al.*, 2010, 2018)	138 species, 13% endemic and 15% threatened	France, central Europe, Poland, Belarus, Slovenia and parts of the Balkans	Most in S France and Iberia, some in Balkan Peninsula and islands	Iberian Peninsula, S France, Balkan Peninsula and Crete
Grasshoppers, crickets and bush-crickets (Hochkirch *et al.*, 2016)	1 082 species, 68% endemic, 26% threatened	S Europe, esp. Spain, S France, and the Balkans	As for all species, but also Italy, Alps and Carpathians	S Spain, S France, Italy and Greece
Saproxylic (deadwood) beetles (Cálix *et al.*, 2018)	c. 4 000 species and endemics unknown. Of 688 assessed, 18% threatened, but 24% data deficient	Mid latitudes, esp. mountain forests of the Pyrenees, Alps and Carpathians	Similar to all species	Central and E Europe, esp. Hungary and surrounding countries
Butterflies (van Swaay *et al.*, 2010)	482 species, 13% endemic, 8% threatened	Mountains in S Europe, esp. Pyrenees, Alps and Balkans	Esp. Alps & Pyrenees, and other mountains of Spain, Italy and the Balkans	Central and E Europe
Bees (Nieto *et al.*, 2014)	1 965 species, 20% endemic, 9% threatened	Increases towards the S, esp. the Mediterranean climatic region	High proportions in S Europe	South-central Europe, and probably more widely in the S
Freshwater fish (Freyhof and Brooks, 2011)	531 species, 80% endemic, 37% threatened	E and central Europe, Balkan Peninsula, catchments of the Elbe and S Baltic Sea basin	Central Europe (e.g. subalpine lakes in Austria, Germany, Switzerland and France), Balkan Peninsula and parts of N Europe	S central Europe, N Mediterranean coast, Balkan Peninsula and Bulgarian coastal streams

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Table 2.5 *(cont.)*

Species group and source	Total species, % endemic, % threatened in Europe*	Areas with high species richness relating to		
		All species	Endemic and near endemic species	Threatened species
Amphibians (Temple and Cox, 2009)	85 species, 75% endemic, 23% threatened	Mid latitudes, inc. NW Iberia, France, Germany, Czech Republic, N Italy and Slovenia	Iberia, France and Italy	NW and SE Iberia, Italy, Slovenia and Balkan coast
Reptiles (Cox and Temple, 2009)	151 species, 48% endemic, 19% threatened	Strong increase from N to S, high in Iberia, Italy, Cyprus and esp. the Balkan Peninsula	Concentrated in Iberia, also some in S France, Balkans and Mediterranean islands	Concentrated in the Iberian Peninsula, some also in the Balkans and Cyprus
Birds (BirdLife International, 2015, 2021)	540 species, 19% endemic or near endemic and 13% threatened	Spain, S Balkans, N and W Ukraine, Belarus, Baltic States, E Poland	Spain, France, E Germany, Czech Republic, Slovakia, Poland, Lithuania, W Belarus and W Ukraine	Spain, Ukraine, Belarus and Estonia
Mammals – terrestrial (Temple and Terry, 2007)	219 species, 27% endemic, 14% threatened	Central European and Mediterranean mountains and Balkan Peninsula	Iberia, the Alps and Italy	Iberia, Italy and the Balkan Peninsula, esp. Bulgaria
Mammals – marine (Temple and Terry, 2007)	41 species, none endemic, 22% threatened	NE Atlantic, inc. to W of Ireland, Britain, France and Iberia	No European endemics occur	As all species, and some in E Mediterranean
Marine fish (Nieto *et al.*, 2015)	1 220 species, 15% endemic, 7% threatened	Mediterranean coastal waters, W coast of Portugal, shelf edge of W France and UK, S Iceland	Similar to all species, esp. high along European coast of Mediterranean, e.g. the Balearic, Ligurian, Tyrrhenian, Adriatic and Aegean Seas	Similar to all species, with highest concentration around Iberia and in the Mediterranean Sea

Notes. * Europe here includes the Canaries, Azores and Madeira, European Russia, Armenia, Azerbaijan, Georgia and all of Turkey. Distribution information on areas outside the scope of this book in Russia, Turkey and the Caucasus is not included in the table. Species totals generally refer to native or naturalised species in Europe before 1500 CE. Threat assessments exclude 'Not Applicable' species (e.g. non-native), which are normally a small proportion unless indicated. % threatened assumes that the same proportion of Data Deficient species are threatened.

HD Annexes, that occur in each EU-28 Member State are indicated in Figure 2.6. Both sets of Annex listed species show a rather similar pattern to the bird SPECs (Table 2.4), including a clear species–area relationship. A relatively large proportion also occur in areas with generally high levels of species richness and endemism: thus particularly around the Mediterranean and elsewhere in south-east Europe. For instance, it is noticeable that Greece and Italy have the highest number of Annex listed species, despite not being the largest EU countries. These results are similar to those found in a Red List assessment of plants protected by the Habitats Directive, Bern Convention and CITES, which revealed concentrations of the species within Iberia, France and the Balkan Peninsula (Bilz *et al.*, 2011).

It should be borne in mind that levels of conservation importance may vary considerably within countries. This is apparent from inspection of the smaller-scale bird atlas data, which reveals, for example, that large areas of Italy and Greece have relatively low numbers of Annex I birds (Keller *et al.*, 2020).

As EU conservation priorities for species are closely linked to the Annexes, it should be borne in mind that they are neither comprehensive nor based on clear consistent scientific criteria. As a result, they are uneven in their taxonomic and geographical representation. HD Annex II is notable for being dominated by higher plants and including very few invertebrates. Furthermore, the selection of birds for inclusion in Annex I was politically influenced, and the list is now very old. Although the species Annexes were expanded as Member States joined the EU, they have not been adjusted in response to changes in the status of species over the years.

In response to these problems, some scientists have suggested that the Annexes should be updated (e.g. Hochkirch *et al.*, 2013). This is a complex and controversial issue and cannot be adequately discussed here, but it was concluded during the Fitness Check of the Nature Directives that updating them now would be counter-productive (European Commission, 2016). This is because updating the Annexes would be a distraction when the priority is to protect and

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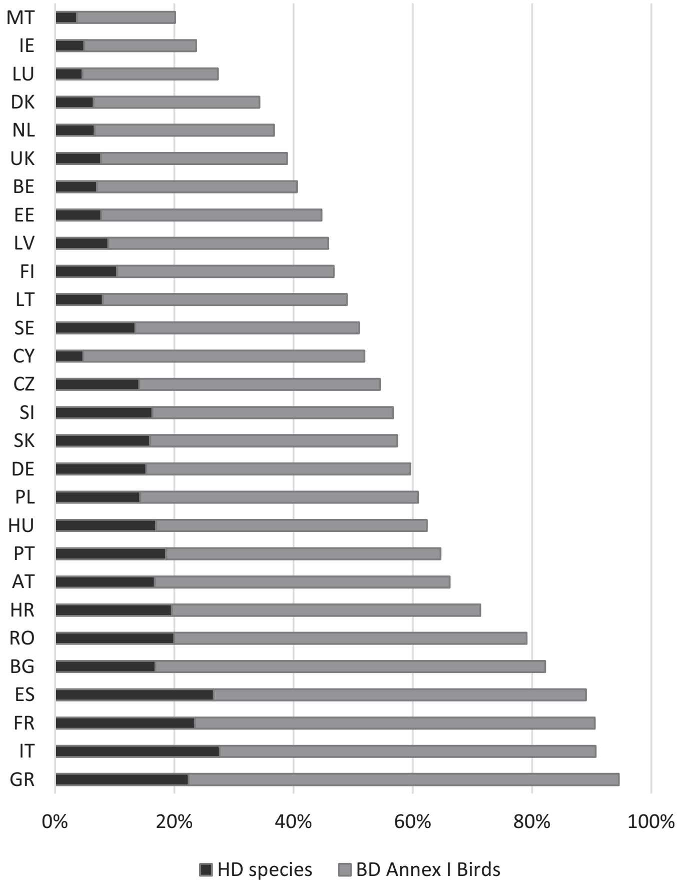

Figure 2.6 The percentages of HD species and BD Annex I species that are native and occur regularly in the European part of each EU Member State.
Notes. HD species are 'species of Community interest' listed in HD Annexes II and/or IV or V. HD species occurring in the Macaronesian terrestrial and marine regions are excluded. UK data exclude species only occurring in Gibraltar.
Source. BD Article 12 reporting checklist (https://cdr.eionet.europa.eu/help/birds_art12) and HD Article 17 reporting checklist (https://cdr.eionet.europa.eu/help/habitats_art17) (both June 2020 versions).

manage better the protected areas that have been designated. Furthermore, Natura 2000 sites have been found to protect a high proportion of other species besides those listed in the Annexes for which the sites were designated (Milieu *et al.*, 2016), particularly in the case of butterflies, plants and birds (van der Sluis *et al.*, 2016).

2.3.3 The Implications for Nature Conservation Approaches and Priorities

The fact that much of Europe's remaining terrestrial biodiversity is associated with semi-natural habitats that have been created and maintained by human activities has fundamental implications for the way nature conservation is carried out. In particular, it means that the conservation of many important threatened habitats usually depends on continuing the key human activities that created them. Many species are also reliant on habitat manipulation (Luoto *et al.*, 2003), including for many threatened species, a high proportion of which are dependent on open habitats and mosaics. Thus a considerable amount of effort in Europe goes into maintaining HNV farming systems for biodiversity. This contrasts with many other parts of the world where the main nature conservation aim is to minimise human influences and allow nature to look after itself. The latter is more applicable to the marine environment in Europe, where the principal priorities are to reduce pollution, the various impacts of fishing and IAS.

In recent years there have been calls from some conservationists for fewer interventions within terrestrial ecosystems, allowing instead natural processes to become predominant in greater areas, through rewilding.[15] This is often with the associated aims of re-establishing native keystone species, such as Beavers and large herbivores and carnivores. In practice, rewilding, as well as 'traditional' nature conservation, normally requires interventions to maintain biodiversity, which is highly dependent on habitat mosaics of various scales created by succession and disturbance processes. Hence, intervention and rewilding are actually complementary nature conservation approaches (Van Meerbeek *et al.*, 2019; Fuller and Gilroy, 2021). Most obviously and frequently, rewilding requires some grazing and browsing of the vegetation. Therefore, low-intensity livestock farming takes place, using appropriate ancient hardy breeds, as the former wild herbivores are normally absent. Interventions are also sometimes needed to address the legacy of past detrimental impacts, before natural processes can be allowed to become predominant. Forests represent a widespread example, as many managed forests have low structural and species diversity. Therefore, some felling and selective planting is needed to improve their naturalness and biodiversity, at least in the short term. Many highly eutrophicated wetlands require removal of the accumulated nutrients before they can return to their previous natural regime. Over the longer term, conservation interventions are usually required to address ongoing pressures, such as those from further nutrient pollution and colonisation of IAS.

Over recent decades, there has been little need to proactively promote rewilding over much of Europe as it has been occurring incidentally as a result of agricultural abandonment, especially in mountainous areas and other remote regions. This has had some conservation benefits, including contributing to the recovery of populations of large carnivores, but has probably been mostly detrimental for HD habitats and associated specialist threatened species. Whilst more rewilding of agricultural land could be beneficial if judiciously targeted, the higher priority has been to avoid large-scale agricultural abandonment of HNV farmland as it would lead to substantial losses of biodiversity as well as unique cultural landscapes. Given ongoing rural socio-economic trends, priorities in most of Europe continue to be conserve semi-natural habitats and the HNV systems that maintain them – protecting them from

15 'Letting nature take care of itself, enabling natural processes to shape land and sea, repair damaged ecosystems and restore degraded landscapes. . .' https://rewildingeurope.com/what-is-rewilding/

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abandonment or conversion to more intensive farming systems, forest plantations, bioenergy crops, solar parks or other uses.

Another important consideration is the fact that remaining natural and semi-natural habitats, outside high mountains and remote northern areas, are highly fragmented in most parts of Europe, especially in densely populated western and central areas (EEA-FOEN, 2011). This fragmentation is partly a result of habitat change, as natural and semi-natural habitat patches have become surrounded by inhospitable areas in the landscape. Fragmentation also results from artificial barriers to movement, such as transport infrastructure or dams on rivers. Fragmentation impacts depend on their context and the habitats and species in question; some fragmentation can be beneficial (Fahrig, 2017; Fahrig *et al*., 2019). More frequently, fragmentation is considered to be detrimental, as it disrupts ecosystem processes, reduces habitat quality, increases disturbance levels and external pressures, constrains species movements across the landscape and increases the risk of local extinctions of small populations of species (EEA-FOEN, 2011; Haddad *et al*., 2015; Fletcher *et al*., 2018). As a result, it also exacerbates the impacts of other pressures and constrains the ability of species to adapt to climate change (Opdam and Wascher, 2004)

To tackle losses and fragmentation of habitats, the first priority has been to conserve what is left, especially of the most depleted natural and semi-natural habitats, through effective protection and management. Relatively small patches of poor habitat also need to be maintained where they have important landscape-scale connectivity functions. Secondly, ecosystem/habitat restoration has been increasingly necessary over recent decades, to maintain ecological processes and the viability of small and isolated species populations. At the same time, restoration can increase connectivity, also helping to maintain the viability of meta-populations (Hanski, 1999) as well as species movements where necessary, between important patches of habitat within a wider network (Crick *et al*., 2020).

In addition to ecosystem/habitat measures, specific additional actions are also sometimes required to conserve threatened species. In this respect, it is necessary to bear in mind that there are indications of a substantial extinction debt among European species of various taxonomic groups. As found by Dullinger *et al*. (2013), the national Red Lists for 22 countries reflected past pressures from the early and mid, rather than the late twentieth century. Thus, lags in impacts on threatened species need to be taken into account when establishing species conservation strategies and priorities. Whilst such threatened species persist, previous pressures and declines that would otherwise lead to extinction can be reversed if relevant measures are taken rather than just maintaining the status quo (Kuussaari *et al*., 2009; Krauss *et al*., 2010).

At present, most of Europe is dominated by highly modified or completely artificial habitats, including intensively managed forests and farmland, and cities and other human created habitats. Whilst these have a greatly impoverished biodiversity, dominated by common and generalist species, they still merit conservation and enhancement where this is possible. Indeed, their species are the most often encountered and enjoyed by people and are therefore particularly valued for aesthetic, educational, recreational and other cultural reasons. More fundamentally, it is now widely recognised that biodiversity both underpins and forms ecosystem services that provide a wide range of essential social, health and economic benefits for humankind (MEA, 2005; TEEB, 2012; IPBES, 2019; Dasgupta, 2021). Thus, to use the current terminology, all ecosystems, habitats and species are key components of natural capital that need to be valued and maintained (Barbier, 2011; Helm, 2015).

From the preceding analysis it is clear that nature conservation in Europe has had broad and evolving objectives and multiple challenges. It has been necessary to give precedence to the many species and unique habitats that are threatened, giving priority according to scale (i.e. preventing global extinctions first) and the biogeographical importance of the population/area concerned. However, nature conservation has increasingly also needed to encompass all ecosystems and native species, conserving and restoring biodiversity in the wider countryside and urban areas. Tackling these differing objectives has required a variety of approaches and interacting measures, which are described in the next two chapters.

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