Chapter 6

Biodiversity

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Executive summary

Biodiversity is in crisis. There is *well-established* evidence indicating an irrevocable and continuing decline of genetic and species diversity, and degradation of ecosystems at local and global scales. Scientists are increasingly concerned that, if anthropogenic pressures on Biodiversity continue unabated, we risk precipitating a sixth mass extinction event in Earth history, with profound impacts on human health and equity. {6.1}

Biodiversity provides many valuable goods and services – nature's contributions to people (*well established*). Biodiversity helps regulate climate through carbon storage and control of local rainfall, filters air and water, and mitigates the impact of natural disasters such as landslides and coastal storms. Direct benefits include timber from forests, fish from oceans and freshwater systems, crops and medicines from plants, cultural identity, and the health benefits gained from access to nature. {6.1}

Biodiversity loss has consequences for human health and equity (*well established*). Biodiversity contributes positively to human health and well-being. The livelihoods of more than 70 per cent of the world's population living in poverty depend on natural resources to some extent and over 80 per cent of global biodiversity is found in the traditional territories of indigenous peoples. Depleting this natural capital will therefore disproportionately affect the people least able to offset losses and reduce options for future generations. {6.1}

The loss of biodiversity reduces ecosystem resilience and increases vulnerability to threats including negative impacts of climate change (*well established*). At local scales, it is *likely* that ecosystems with greater biodiversity are more productive and more stable through time. {6.5.4, 6.5.6}

The critical pressures on Biodiversity are well recognized (*well established*). Biodiversity is being eroded by land-use change, direct exploitation, climate change, pollution and invasive alien species. While habitat loss and transformation is likely the most significant present pressure, climate change may be the most significant future pressure. {6.3.1, 6.3.2, 6.3.3, 6.3.4, 6.3.5}

Pressures often overlap and there are positive feedback loops between many of them (*well established*). Habitat changes may increase exposure to pollutants, pests, exotic pathogens and emerging infectious diseases harmful to humans, livestock and wildlife, and exacerbate human-wildlife conflicts. Forests are experiencing alteration due to multiple land-use changes such as logging, mining, road building and agricultural expansion; the resulting habitat fragmentation and loss of biodiversity can lower forest resilience to climate change impacts and the introduction of invasive species. {6.3.1}

Newly recognized and aggravating factors add to pressures on biodiversity (*well established*). Energy production, resource extraction, wildlife trade and poaching, chemical waste and plastics in the marine environment are exacerbating factors that contribute to biodiversity decline. {6.3.1, 6.3.3, 6.3.4}

Genetic diversity is the vital raw material allowing adaptation (*well established*). The decline in the population size of many species represents a loss in genetic diversity. Genetic diversity of crops, crop wild relatives and livestock provides resilience of agricultural systems to changing environments. The ongoing long-term loss of crop and livestock genetic diversity is a threat to food security. {6.4.1}

There is no slowing in the rate of species population decline globally (*well established*). The increase in species extinction risks through time is *well established*, and there is no slowing in the rate of population declines globally. Freshwater species have the highest rates of population declines, whereas amphibians, reef-forming corals and cycads are the taxa with the highest proportion of species currently considered at risk of extinction. There is less data on invertebrate groups, but recent evidence indicates large declines in local abundance. The loss of invertebrate pollinators has been highlighted as a growing problem, with major consequences for agricultural production, ecosystem functioning and human well-being. {6.4.2}

There is no global overview of ecosystem health (*well established*)., The status of many habitat types is very likely in decline. While global monitoring is challenging, across terrestrial habitats 10 out of 14 have seen a decrease in vegetation productivity, and just under half of all terrestrial ecoregions are classified as having an unfavourable status. Natural wetland areas and marine habitats, such as deep-sea ecosystems and coral reefs, are highlighted as of particular concern globally. {6.4.3}

Biodiversity loss is being experienced across all Earth's major biomes (*well established*). In the oceans, overexploitation of fish stocks is leading to fisheries collapse, warming is destroying coral reefs, and habitat destruction of coastal systems, such as mangrove forests, exposes communities to greater risks from erosion and extreme weather events. Marine plastic pollution is a major and growing threat to biodiversity. In freshwater systems, agricultural and chemical pollution, including increased nitrogen input, results in toxic algal blooms and a decline in drinking-water quality; invasive species are spreading through waterways; and freshwater species are declining at a faster rate than those in any other biome. In the terrestrial environment, rising temperatures are converting grasslands into deserts, and unsustainable irrigation has turned drylands into inhospitable, toxic landscapes unsuitable for wildlife or agriculture. Mountain ecosystems and polar regions are especially vulnerable to climate change, and extinctions may be likely for species at the upper limits of their thermal ranges and those dependent on sea ice. Tropical forests represent some of the most biodiverse terrestrial ecosystems, yet deforestation and forest degradation continue in many regions, often in response to demands for wood, fibre, food and fuel products such as palm oil, as well as external drivers. {6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.5.8}

A range of national and international instruments work to conserve biodiversity (*well established*). These include National Biodiversity Strategies and Actions Plans (NBSAPS)

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under the Convention on Biological Diversity (CBD), the Strategic Plan for Biodiversity 2011-2020 (encompassing the Aichi targets), the Cartagena Protocol on Biosafety, the Nagoya Protocol, and the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES). {6.6.1, 6.6.2}

Species and ecosystems are most effectively safeguarded through the conservation of natural habitats (*well established*). There has been significant progress in expanding the global network of protected areas, but the total area under protection remains insufficient, and habitats within protected areas are often degraded. {6.6.3}

Ex-situ conservation of biological material can contribute to conserving genetic diversity (*well established*). Seed banks and gene banks, aided by the use of these new genomic tools, have contributed to the conservation of the genetic diversity of crops and their wild relatives. Advances in technology allow cheaper and faster genome sequencing, however, genetic data for most wild species are still lacking. {6.4.1}

At a local scale indigenous people and local communities (IPLC) play a key role in protecting biodiversity (*well established*). IPLCs can offer bottom-up, self-driven, cost-effective and innovative solutions, and have potential to be scaled up and inform national and international practice. Such solutions provide a practical governance approach as an alternative to top-down policy-setting. This is essential to achieve many of the Sustainable Development Goals. {Box 6.6, 6.6.3}

Biodiversity policy responses are visible and operating at international, national and local levels, but they have been insufficient to slow or reverse the decline in global biodiversity (*well established*). There is an urgent need to bolster current policy responses. There are additional opportunities to maintain biodiversity and the contributions of nature through addressing distribution, access and governance, and by recognizing the role of IPLCs in biodiversity conservation. {6.6.3, 6.7}

The cost of inaction is large and escalating (*well established*)**.** The full cost of inaction is rarely quantified; however, failure to act now will impose much higher costs in the future as shown by many examples, such as the spread of invasive species, and extinctions have immeasurable costs for future generations. {6.3.2}

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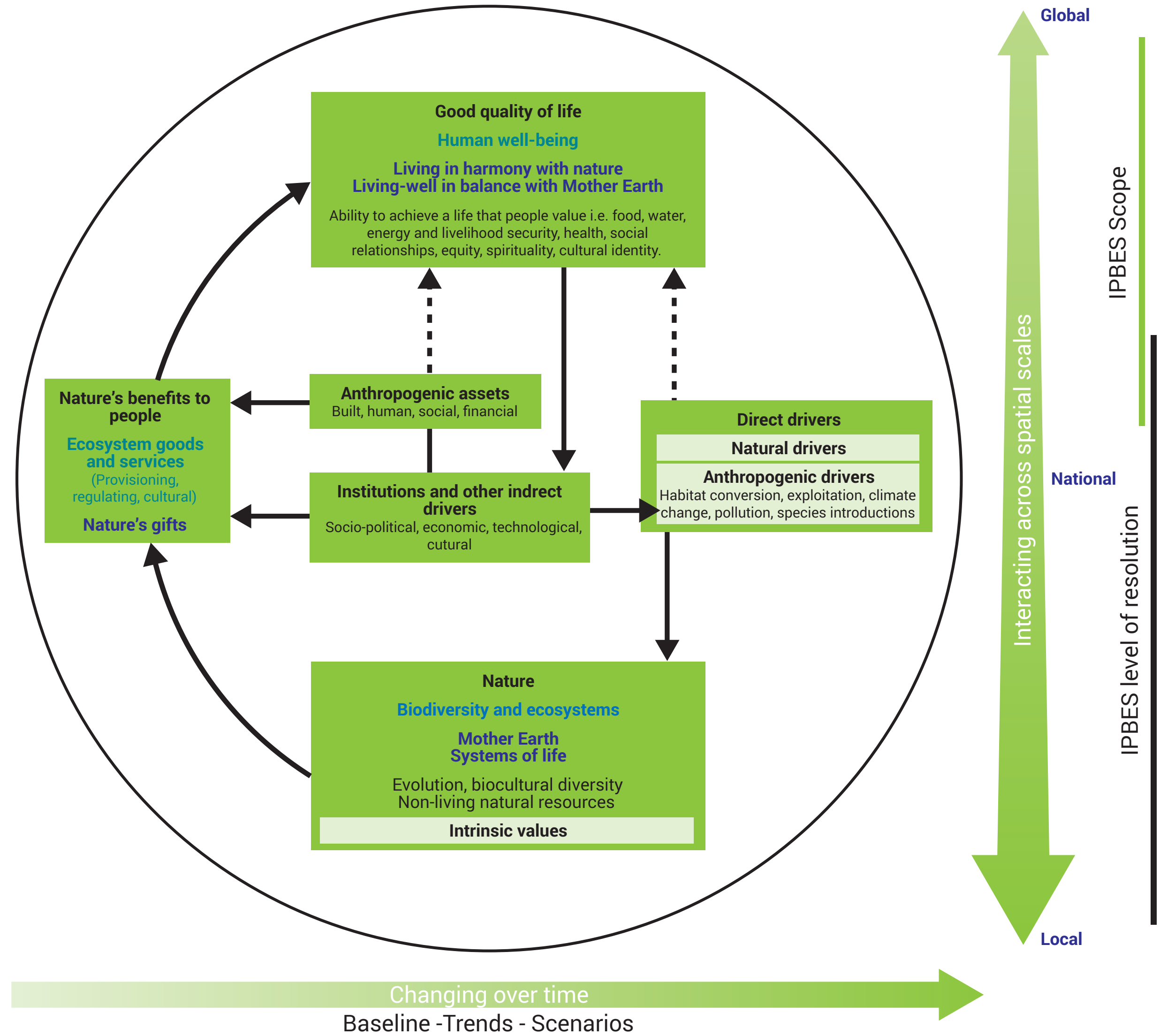
6.1 Introduction

Biodiversity – the "variability among living organisms from all sources including … diversity within species, between species and of ecosystems" (United Nations 1992, Article 2) – helps regulate climate through carbon sequestration and control of local rainfall, filters air and water, and mitigates the impact of natural disasters such as landslides and coastal storms. Direct benefits include food and fibres from natural vegetation, wood and non-wood products from forests, fish from oceans and freshwater systems, pollination of crops, medicines from plants, and psychological health (Clark *et al.* 2014; Harrison *et al*. 2014; World Health Organization [WHO] and Secretariat of the Convention on Biological Diversity [SCBD] 2015, p. 200; Pascual *et al*. 2017). Never before have we known so much about the biodiversity that enables ecosystems to function (Cardinale *et al*. 2012), yet biodiversity loss and habitat decline continues to accelerate, potentially beyond planetary boundaries (Tittensor *et al*. 2014; Steffen *et al*. 2015).

Current rates of species loss are estimated to be 1,000-fold greater than background rates (Pimm *et al.* 2014), sparking debate among scientists over whether we have already entered into a sixth mass extinction event (Barnosky *et al.* 2011; Ceballos, Ehrlich and Dirzo 2017). For many species, populations are in decline globally (Ceballos, Ehrlich and Dirzo 2017; McRae, Deinet and Freeman 2017), and genetic diversity – vital for future adaptation to global change – is eroding (Food and Agriculture Organization of the United Nations [FAO] 2015a). Natural communities of plants and animals are being reshaped through climate change and human-mediated movement of species (Pacifici *et al.* 2015); some displaced species are invasive, posing risks to human health, genetic diversity, and food and water security. These changes seem likely to reduce the efficiency by which ecosystems are able to capture essential resources, produce biomass, decompose and recycle nutrients (Cardinale *et al*. 2012), and decrease the resilience of ecosystems (MacDougall *et al*. 2013). The restoration and maintenance of biodiversity will enhance

Figure 6.1: Schematic from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services describing the main elements and relationships linking nature, biodiversity and ecosystem services, human well-being and sustainable development. (In this diagram, anthropogenic drivers equate to the pressures as described in Section 6.3)



Source: IPBES (2013, p. 2).

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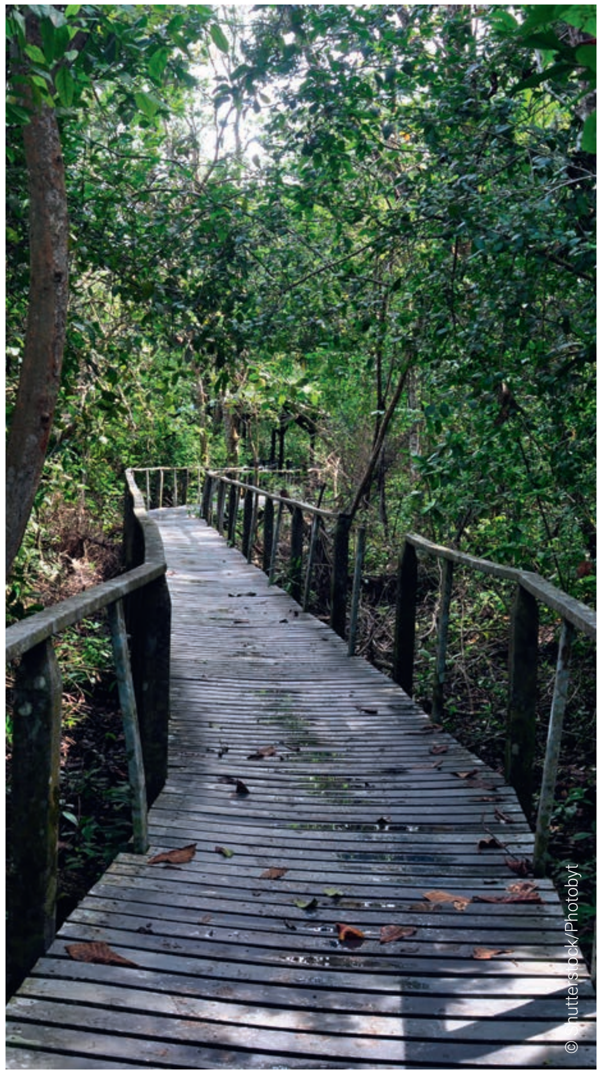
adaptive potential, and help sustain nature's contributions to people's livelihoods, health and well-being (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] 2016). These critical services are frequently neglected as they largely bypass the market and there are no clear price signals for them (e.g. Foale *et al*. 2013; Seddon *et al*. 2016; Costanza *et al.* 2017). The loss of biodiversity is also a significant equity issue: the livelihoods of 70 per cent of people living in poverty rely to some extent on natural resources (Green Economy Coalition 2012, p. 4); 80 per cent of global biodiversity is found in the traditional territories of indigenous peoples (Sobrevila 2008, p. xii); and future generations will experience relatively impoverished lives if losses continue (Naeem *et al.* 2016).

6.2 Further assessments since the fifth Global Environmental Outlook (GEO-5)

GEO-5 (United Nations Environment Programme [UNEP] 2012) concluded that pressure on biodiversity continues to increase through habitat loss, degradation from agriculture and infrastructure development, overexploitation, pollution, invasive alien species and climate disruption, as well as interactions between these pressures, and that the state of global biodiversity is continuing to decline with substantial ongoing losses of populations, species and habitats. Since GEO-5, a midterm assessment of progress towards the Aichi Biodiversity Targets concluded that while progress has been made, this was insufficient to achieve them by 2020 (SCBD 2014). A series of GEO regional assessments (UNEP 2016a; UNEP 2016b; UNEP 2016c; UNEP 2016d; UNEP 2016e; UNEP 2016f), State of Biodiversity reports looking at regional progress towards the Aichi Biodiversity Targets (United Nations Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] 2016a; UNEP-WCMC 2016b; UNEP-WCMC 2016c; UNEP-WCMC 2016d), and regional assessments on biodiversity and ecosystem services from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (https://www.ipbes.net/outcomes), have summarized evidence for declines in the state of biodiversity from different parts of the world while highlighting variation in responses to regional pressures. Among many other developments encouraged by these assessments, the gradual acceptance of the numerous benefits of biodiversity conservation for human health has been recognized (WHO and SCBD, 2015; see also **Box 6.1**).



Box 6.1: Biodiversity, disease and One Health

Several dimensions of global change, including shifts in urbanization, agricultural practices, land use and biodiversity, are altering ecological dynamics and in some cases facilitating human-animal contact that exacerbates the risk of zoonotic disease emergence and spread. Zoonotic diseases are transmissible from domestic or wild animals to humans through direct contact or through water, food and the environment (WHO and SCBD 2015; Centers for Disease Control and Prevention [CDC] 2017).

One Health is an approach that recognizes the opportunities and challenges related to these interconnections at the human-animal-ecosystem interface, and aims for optimal health outcomes for all; it is particularly relevant in the prevention and control of zoonoses, which account for more than 60 per cent of human infectious diseases (Karesh *et al*. 2012; WHO and SCBD 2015; CDC 2017).

The United States Agency for International Development (USAID) Emerging Pandemic Threats PREDICT project is expanding the detection and discovery of zoonotic viruses with pandemic potential through surveillance in 'hotspots' for emerging infectious diseases (EIDs), such as Ebola, to help track their circulation and understand factors driving their emergence (Kelly *et al*. 2017; Marlow 2017). Using the One Health approach, the project considers the behaviours, practices, and ecological and biological factors driving disease emergence, transmission and spread. Through enhanced understanding of EID risks, countries can be better equipped to prevent, prepare for and respond to the threat of an outbreak, ideally through taking preventive measures before major disease outbreaks. PREDICT partners include the University of California Davis One Health Institute, USAID, EcoHealth Alliance, Metabiota, Wildlife Conservation Society, and Smithsonian Institution.

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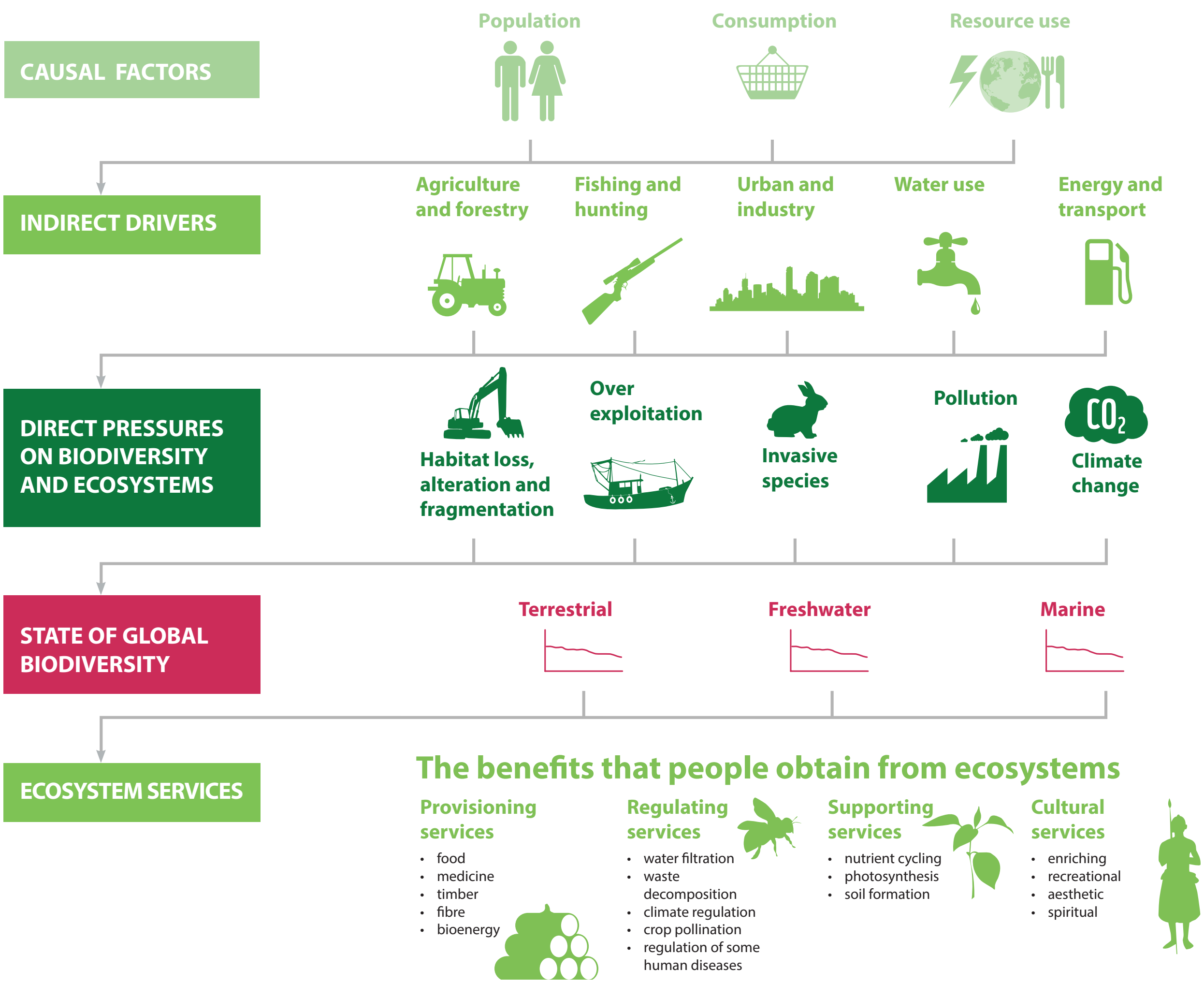
6.3 Drivers

Drivers of environmental change – population demography, urbanization, economic development, technology and innovation, and climate change (see Chapter 2) – impose multiple negative impacts on biodiversity, leading to loss of genetic diversity, population declines that have pushed some species towards a heightened risk of extinction, and the reshaping of natural communities, with ramifications for the stability and functioning of ecosystems **(Figure 6.2)**. While most drivers are projected to increase, climate change is likely to become the dominant driver of biodiversity change in the next few decades (Leadley *et al*. 2014; Newbold *et al*. 2015). Ultimately, reducing pressures on biodiversity will require addressing these drivers of change.

6.4 Pressures

The main direct pressures on global biodiversity are habitat stress and land-use change, invasive species, pollution, unsustainable use/overexploitation and climate change (mainly as a consequence of higher temperatures, changes in precipitation patterns and increasing frequency and severity of extreme weather events and wildfires) (UNEP 2012). The spatial distribution and combination of these pressures varies across the globe **(Figure 6.3)** and affects species groups in different ways **(Figure 6.4),** although detailed data for invertebrates, which comprise most of the diversity of life, are lacking (Collen *et al.* 2012).

Figure 6.2: Interconnections between people, biodiversity, ecosystem health and provision of ecosystem services showing drivers and pressures



Source: World Wide Fund for Nature (WWF) *et al.* (2012).

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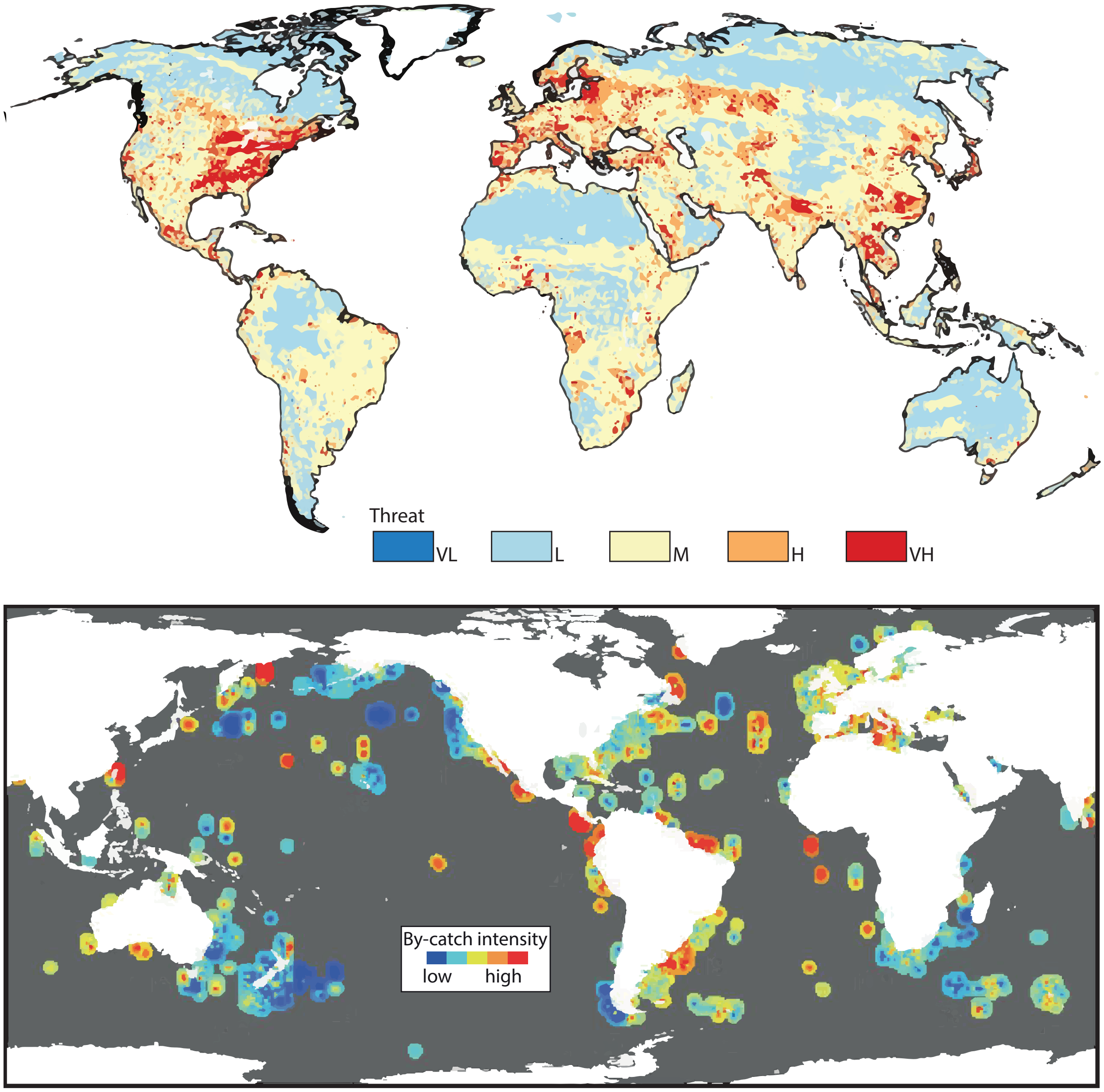
Figure 6.3: Examples of global distribution of pressures on (a) threat intensity (H: high; L: low; M: medium; VH: very high; VL: very low) from terrestrial invasive alien species and (b) cumulative fisheries by-catch intensity for seabirds, sea mammals and sea turtles, by all gear types (gillnet, longline and trawl)



Sources (a) Early *et al.* 2016 (b) Lewison *et al.* (2014).

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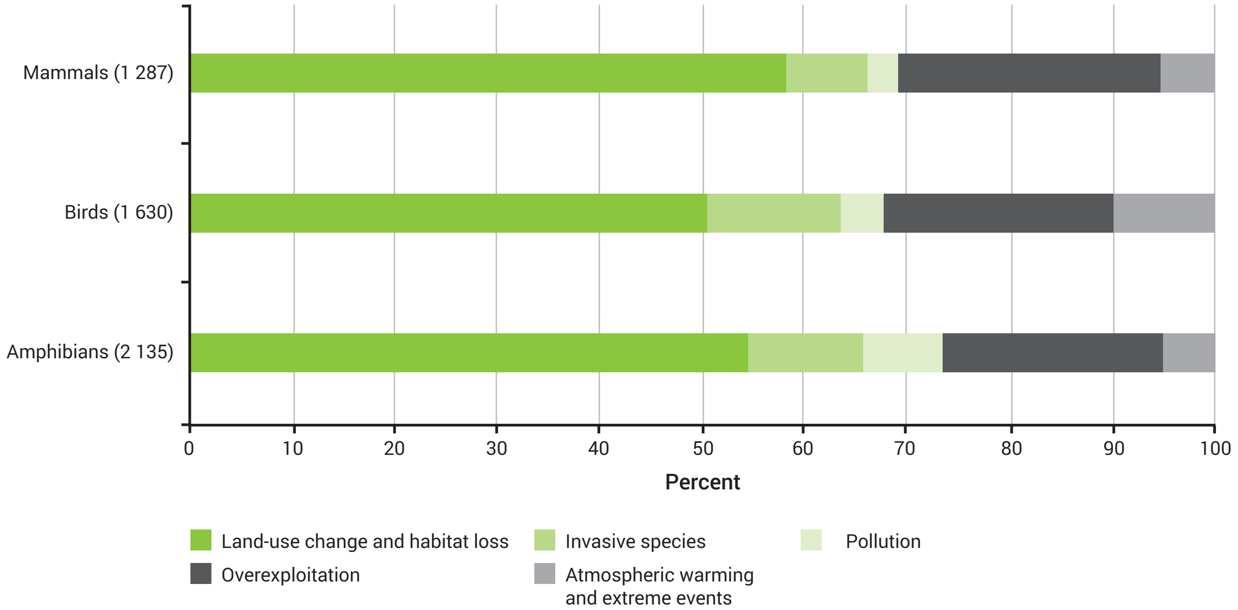
Figure 6.4: Percentage of threatened (critically endangered, endangered and vulnerable) and near threatened amphibian, bird and mammal species by major threat class



Number of threatened species in each taxonomic class in parentheses. Threat classes were aggregated as follows: 1 = Residential and commercial development, Agriculture and aquaculture, Energy production and mining, Transportation and service corridors, Human intrusions and disturbance, Natural system modifications; 2 = Invasive and other problematic species, genes and disease; 3 = Pollution; 4 = Biological resource use; 5 = Geological events, Climate change and severe weather.

Source: Maxwell *et al*. (2016) updated with International Union for Conservation of Nature [IUCN] (2018).

6.4.1 Land-use change and habitat loss

The global human footprint – infrastructure, land cover and human access into natural areas – is expanding **(Figure 6.5)** (Venter *et al.* 2016). Economic drivers and demographic pressures are the primary sources of accelerating land-use change. These drive agricultural expansion – the largest contributor to land-use change – for food, commodities, fodder and biofuels (Alexander *et al.* 2015), demand for extraction of mineral, metal and energy resources (Mudd and Jowitt 2017), urbanization, road building, land-take and deforestation, land degradation, desertification and habitat fragmentation.

Urban growth is a major driver of land-use change and habitat loss through deforestation. In developing countries, the establishment and expansion of urban areas (many of which lack adequate planning) and the growth of infrastructure can coincide with biodiversity hotspots (UNEP 2016d). Road construction facilitates the spread of invasive species, and allows for easier access into previously intact habitats, exposing them to threats from hunting and resource exploitation (Alamgir *et al.* 2017). Additional land-use practices, such as burning (or the suppression of natural fire) (Smith *et al.* 2016) and livestock grazing, impose further pressures on already degraded systems (Royal Botanic Gardens Kew2010). The marine environment is equally affected and heavily impacted by commercial fishing practices, such as bottom trawling, coastal development and dredging (Ocean Health Index 2017) (see Chapter 7). International trade can export threats to biodiversity, resulting from demand in developed countries, to developing countries (Lenzen *et al*. 2012). Many of the causes of habitat destruction also contribute to human population pressure and movement, which further compound threats to biodiversity (Black *et al*. 2011) (see Chapter 2).

Pressure from agricultural land use is widely expected to increase (Kehoe *et al.* 2017). Global food production is forecast to rise by between 60 and 100 per cent by 2050 as a result of population growth and economic development, with an accompanying minimum net increase in land under crop production of 70 million ha (Tilman *et al*. 2011; Alexandratos and Bruinsma 2012) (see Chapter 8). Large-scale industrial agriculture has many unfavourable environmental and social effects, such as land degradation, albedo changes, increase in methane emissions and loss of carbon sequestration capacities (Laurance, Sayer and Cassman2014; Dangal *et al.* 2017; Houspanossian *et al.* 2017). Agricultural intensification can reduce pressure on non-agricultural lands (Phalan *et al.* 2016), but may have detrimental impacts on wild plant and animal species that cohabit within diverse agroecosystems (Emmerson *et al.* 2016).

Rapid development-induced impacts result from the construction of dams, mines and other hard infrastructure developments, including those associated with energy production (Butt *et al*. 2013).

Climate warming and increasing frequency of extreme weather events contribute to habitat loss and degradation (see Chapter 2). Warming seas are reducing sea ice extent (critical hunting habitat for polar bears, seals and fishing birds) (Intergovernmental Panel on Climate Change [IPCC] 2014, p. 80) and, in conjunction with elevated atmospheric CO_2, acidifying ocean habitats (Hoegh-Guldberg *et al.* 2017). Extreme weather events, such as flooding, drought and fire, can accelerate the degradation of already vulnerable habitats (IPCC 2014, p. 294).

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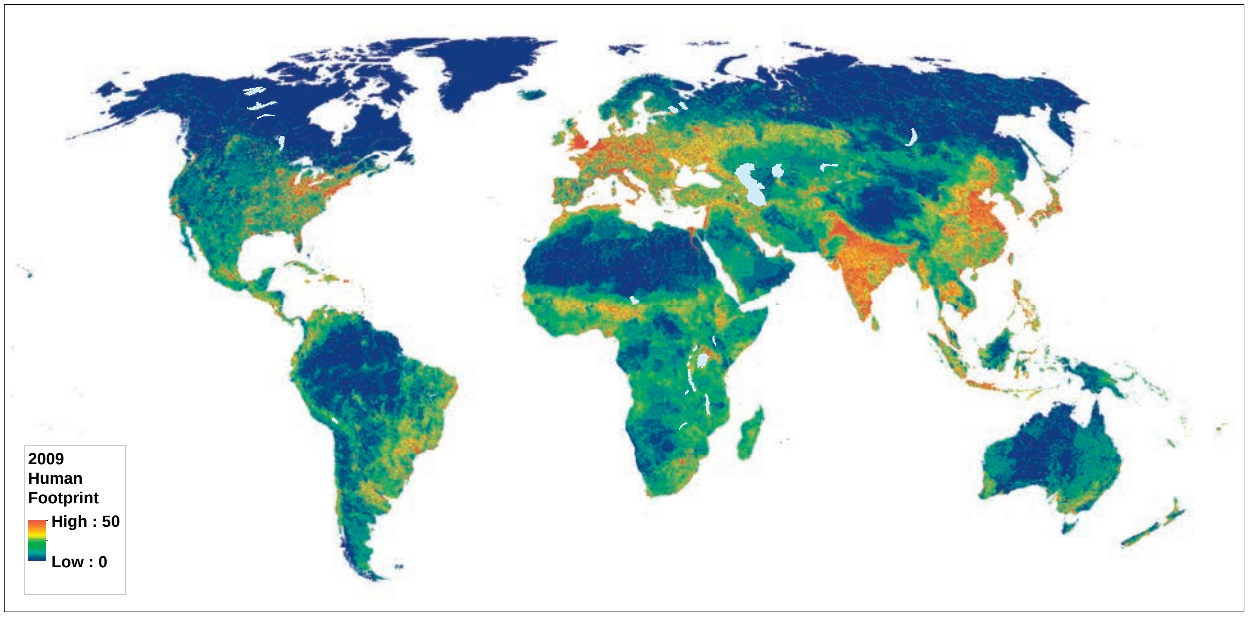
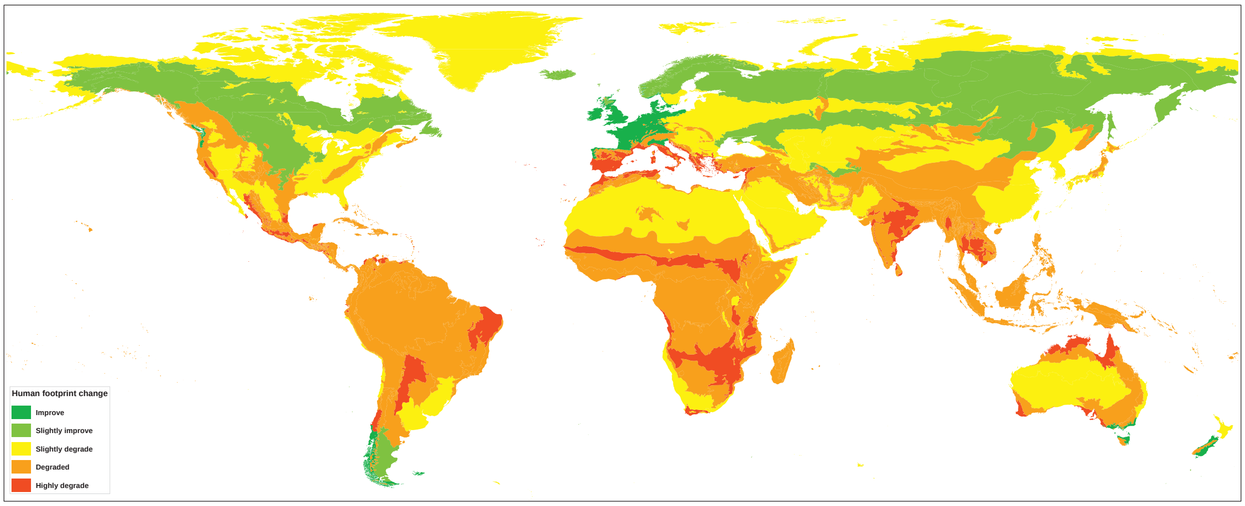
Land-use change, which may impact both aquatic and terrestrial environments, can result in:

- exposure to pollutants, exotic pathogens and emerging infectious diseases harmful to humans, livestock and wildlife (WHO and SCBD 2015, pp. 1-19);
- increased human conflict (Ghazi, Muniruzzaman and Singh 2016, p. ii);
- loss of habitat for wild species and the ecosystem services they provide, such as pollinators and predators of agricultural pests (Potts *et al*. 2016; Woodcock *et al*. 2016); and
- loss of human access to nature (see Chapter 8), with disproportionate impacts on vulnerable and indigenous communities (Haines-Young and Potschin 2010).

Figure 6.5: Map of the global human footprint for 2009 (combined pressures of infrastructure, land cover and human access into natural areas, using a 0-50 on a cool to hot colour scales) (a), and absolute change in average human footprint from 1993 to 2009 at the ecoregion scale (b)





Source: Venter *et al*. (2016).

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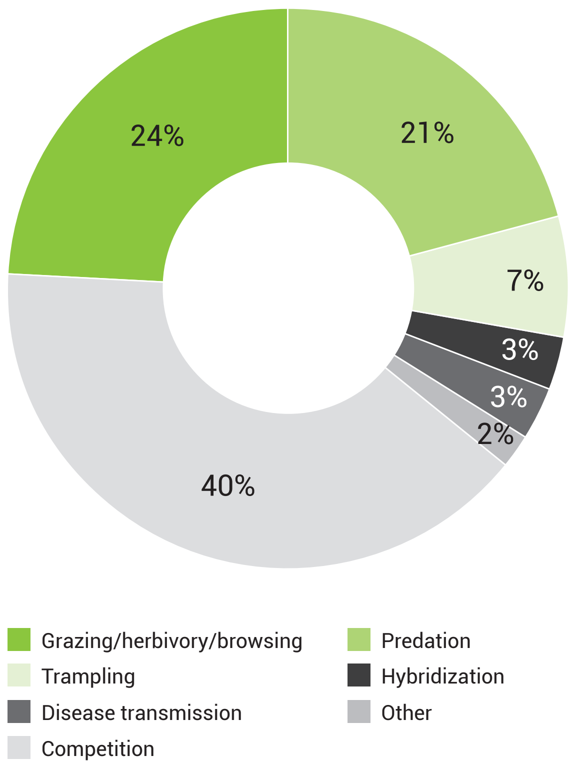
6.4.2 Invasive species

Invasive species threaten ecosystems, habitats and other species (Bellard, Cassey and Blackburn 2016). They are usually non-native (invasive alien species) but can also include expanding native populations (Nackley *et al.* 2017). The annual rate of first records of non-native species has increased during the last 200 years and the increase in numbers does not show any sign of saturation, meaning that efforts to mitigate invasions have not been effective (Seebens *et al.* 2017). The ecological impacts of invasive species are felt through direct and indirect competition, predation, habitat degradation, hybridization, and their role as disease agents and vectors – also a threat to human health and food security **(Figure 6.6)** (Strayer 2010; Paini *et al.* 2016).

Figure 6.6: Impact mechanism of invasive alien species on threatened species in Europe



Source: Genovesi, Carnevali and Scalera (2015).

Invasive plants can impact the provisioning of key ecosystem services, such as access to clean water, by the congestion and eutrophication of waterways, degradation of catchment areas, and viability of pasture and rangeland (Packer *et al.* 2017). Invertebrate species that have become invasive may pose an even greater risk. The population expansion of the invasive zebra mussel in the North American Great Lakes was so great that it impeded water flow of municipal water supplies and hydroelectric companies (Rapai 2016). Invasive pests, such as the gypsy moth, emerald ash borer and hemlock woolly adelgid in North America, have both large biodiversity and economic impacts (Aukema *et al.* 2011). Invasive insect vectors can also facilitate the spread of parasites and emerging infectious diseases (Rabitsch, Essl and Schindler 2017), including chikungunya, dengue and Zika, which are vectored by mosquitoes (Akiner *et al*. 2016). Invasive vertebrates present grave danger on islands (Spatz *et al*. 2017), where they may be the major driver of biodiversity loss (Leadley *et al.* 2014; Doherty *et al.* 2016).

The economic costs, both direct and indirect (e.g. costs of control efforts), amount to many billions of dollars annually (for regional estimates see Kettunen *et al.* 2008; Pejchar and Mooney 2009; van Wilgen *et al.* 2012). The cost of restoring lost ecosystem services following invasion of the Laurentian Great Lakes by the spiny water flea was estimated to be between US$86.5 million and US$163 million (Walsh, Carpenter and Vander Zanden 2016). These costs do not reflect the additional environmental and societal/cultural impacts of invasive species.

Major routes for species invasion include deliberate release, escape and accidental introductions via trade, tourism and ship ballast water (CBD 2014; Early *et al*. 2016). Good governance may decrease invasion risk from trade (Brenton-Rule, Barbieri and Lester 2016), whereas climate change may facilitate increased spread by opening up new niche space (Wolkovich *et al.* 2013) and lowering barriers to establishment, especially in more extreme environments (Duffy *et al.* 2017). Loss of native biodiversity is likely to enhance invasion risk, while rising temperatures in cold regions increase the likelihood of establishment (Molina-Montenegro *et al*. 2012; Cuba-Díaz *et al*. 2013; Chown *et al.* 2017). Future threats are posed by increased transport in the Arctic with the decrease in sea ice, commercial use of microbes in crop production, horizontal gene transfer from genetically modified organisms, and the emergence of invasive microbial pathogens (Ricciardi *et al*. 2017).

6.4.3 Pollution

Pollution can take many forms (e.g. waste and chemical products deliberately or accidentally released into the environment, but also light, noise, heat and microbes); major emitters include transport, industry, agriculture (Landrigan *et al.* 2017) and aquaculture (Klinger and Naylor 2012; Bouwman *et al.* 2013). Emerging pollutants include a wide range of synthetic chemicals, pesticides, cosmetics, personal and household care products, and pharmaceuticals (Gavrilescu *et al*. 2015; Landrigan *et al.* 2017).

On land, open waste dumps have local impacts on plants and animals (see Chapter 8), and soil pollution can affect the microbial population and reduce important ecosystem functioning (Wall, Nielson and Six 2015). Pesticides, fertilizers and other chemicals used in agricultural processes can harm pollinators and natural predators of pests (Woodcock *et al.* 2016), with surface run-off also impacting freshwater and coastal biodiversity (see Chapters 7 and 9). Bioaccumulation of toxins, including heavy metals (Araújo and Cedeño-Macias 2016), may have cascading impacts across the entire food chain, including humans. In marine and freshwater environments, the accumulation of microplastic and nanoplastic pollution (see Chapter 7 and **Box 6.2**) has been identified as an emerging issue (SCBD 2016).

The accumulation of endocrine-disrupting chemicals (EDCs) and persistent organic pollutants (POPs) in natural ecosystems pose additional threats to wildlife (Bergman *et al.* eds. 2013), particularly in aquatic systems (Wang and Zhou 2013) (see Chapter 9).

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Box 6.2: The threats to biodiversity from marine litter and microplastics

Marine litter, including marine plastic litter and microplastics, is considered a major threat to biodiversity, with serious impacts reported over the last four decades (SCBD 2012). Recent research shows that more than 800 marine and coastal species are now affected through ingestion, entanglement, ghost fishing or dispersal by rafting (SCBD 2016). Between 2012 and 2016, aquatic mammal and seabird species known to be affected by marine litter ingestion increased from 26 per cent and 38 per cent to 40 per cent and 44 per cent, respectively (SCBD 2016). Plastics, which constitute 75 per cent of marine litter, have been shown to act as carriers for persistent bioaccumulative and toxic substances (PBTs); provide habitats for unique microbial communities; act as a potential vector for disease; and provide a means to transport invasive alien species across oceans and lakes (Rochman *et al.* 2013; SCBD 2016). Research on the physical and toxicological effects of microplastic provides evidence of trophic transfer in planktonic food chains as well as the direct uptake of microplastics by marine invertebrates (Wright, Thompson and Galloway 2013; SCBD 2016). Ingestion of microplastic by fish has been shown to cause physiological stress, liver cancer and endocrine dysfunction, affecting female fertility and the growth of reproductive tissue in male fish (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection [GESAMP] 2015). According to the United Nations, 51 trillion microplastic particles, 500 times more than stars in our galaxy, litter our seas, seriously threatening marine wildlife (van Sebille *et al.* 2015).

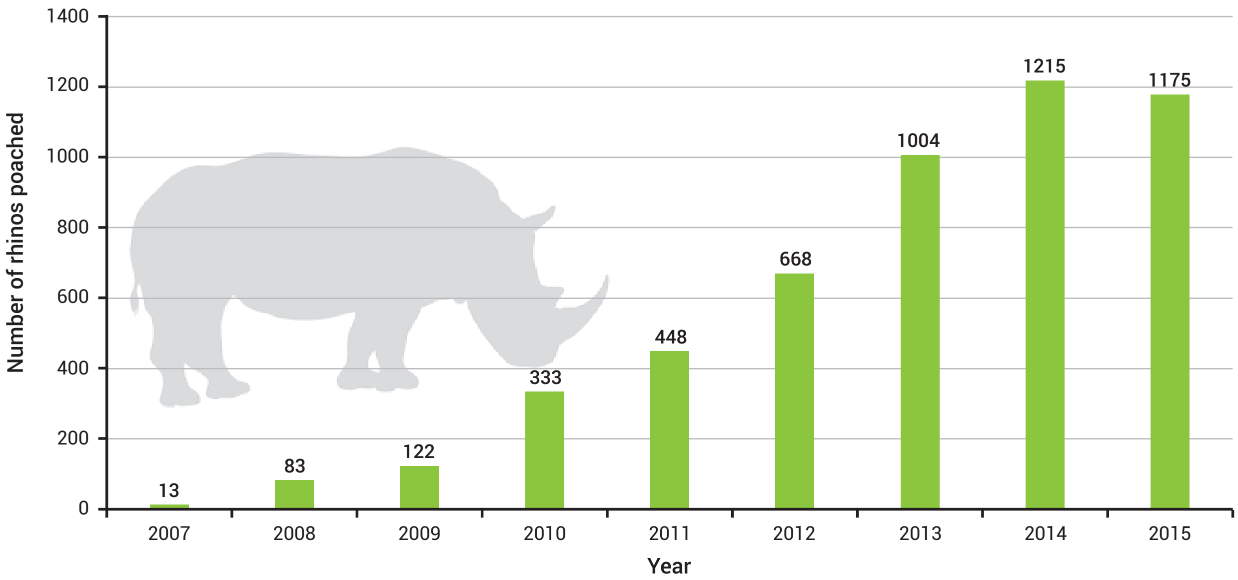
Air pollution contributes to the acidification and eutrophication of terrestrial ecosystems, lakes, estuaries and coastal waters (O'Dea *et al.* 2017; Payne *et al.* 2017), and to mercury bioaccumulation in aquatic food webs (Lavoie *et al.* 2013) (see Chapter 5).

6.4.4 Overexploitation

Overexploitation includes illegal, unreported and unregulated fishing, illegal and unsustainable logging, overgrazing, unregulated bushmeat consumption, wildlife poaching and illegal killing (often for foreign markets). It also includes legal but ecologically unsustainable harvesting as a consequence of poorly designed quotas, lack of knowledge of the resource base or new advances in technology that allow more efficient resource exploitation. Direct exploitation has resulted in threats to iconic land and marine species alike, such as the beluga sturgeon prized for caviar (He *et al.* 2017), sharks harvested for their fins (Worm *et al.* 2013), rhinoceros species targeted by poachers for their horns **(Figure 6.7)**, African elephants hunted for their ivory (Maxwell *et al.* 2016), the Andean condor of South America hunted for feathers and bones (Williams *et al.* 2011), and agarwood (*Thymelaeaceae*) harvested for perfume and incense (United Nations Office on Drugs and Crime [UNODC] 2016, p. 59).

Illegal trade in wildlife, fisheries and forest products is extensive, with estimates of their combined value between US$90- 270 billion per year, and links to transnational organized crime (UNEP 2014; Stimson Center 2016; Stoett 2018; see also 'Project Predator' case study in Section 13.3.2). Poverty provides a strong incentive for poaching, while economic development can improve infrastructure that facilitates access to wildlife-rich areas and fuels demand for wildlife products (UNODC 2016, p. 19). However, legal but unsustainable exploitation of wildlife is likely an even greater threat to biodiversity than currently illegal practices (FAO 2018a). The impact of mismanaged harvesting is perhaps most clearly evident in marine fisheries (see Section 6.6.1, and Chapter 7), although future projections are less certain (Costello *et al.* 2016).

Figure 6.7: Recorded number of rhinoceros poached in South Africa, 2007-2015. In 2011, the rhino population in South Africa numbered just over 20,000



Source: South Africa Department of Environmental Affairs (2016).

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The overexploitation of wildlife has implications for equity as it deprives poor and vulnerable local communities and indigenous peoples of sustenance, traditional medicines, tourist income and other ecosystem benefits (Haines-Young and Potschin 2010; O'Neill *et al.* 2017). Conversely, increased regulation of wildlife harvesting can have positive societal consequences, such as strengthening women's leadership roles, which may feed back into biodiversity conservation policy designs (FAO 2016).

6.4.5 Climatic warming and extreme events

The impacts of anthropogenic climate change on biodiversity are most evident in natural systems (IPCC 2014, p. 40), and manifest as changes in both average climate and frequency of extreme weather events **(see Box 6.3)**. One estimate suggests that up to one in six species could be threatened with extinction by 2050 if current warming trends continue (Urban 2015). However, known impacts are not distributed evenly and our knowledge of impacts remains incomplete **(Figure 6.8)**.

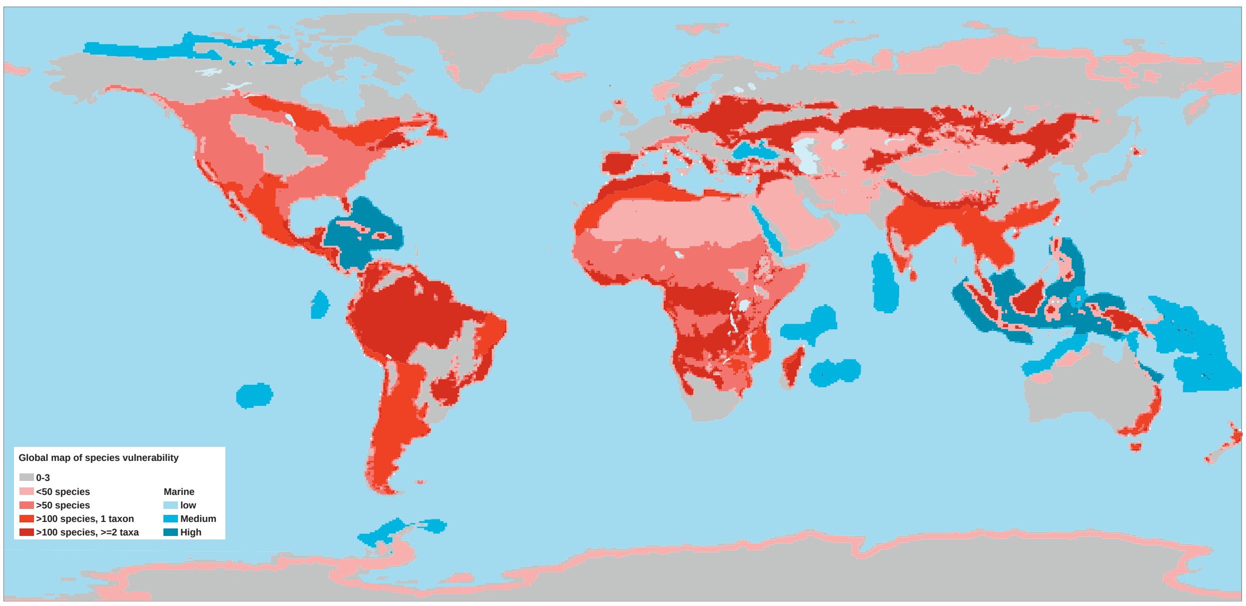
In response to rising temperatures, species may move to cooler locations or alter their phenology to flower, breed or migrate sooner (Parmesan 2006; Scheffers *et al.* 2016). Evidence suggests they are doing both: species are moving, on average, 16.9 km per decade to higher latitudes or 11 m per decade upward in elevation (Chen *et al.* 2011), and advances in flowering phenology are suggested to be between 2.3 and 5.1 days per decade (Wolkovich *et al.* 2012; IPCC 2014). There is increasing speculation that such climate-induced shifts in distributions and phenologies might cascade through trophic interactions, resulting in species asynchronies, such as between flowers and their pollinators. An analysis of over 10,000 time series suggests climate sensitivity (i.e. phenological shift in response to climate change) differs among trophic groups (Thackeray *et al.* 2016), but data on interacting species remains sparse (Kharouba *et al.* 2018).

Box 6.3: Extreme events – further pressures on biodiversity

Natural disasters, such as earthquakes and tsunamis, or floods, landslides, wildfires and droughts following extreme weather events kill and injure hundreds of thousands of people a year, cause widespread destruction to ecological habitats, and threaten wildlife populations with local extinction. Following the 2011 Great East Japan earthquake and tsunami, there was an overall decline in local species diversity, and coastal forests and other vegetation on sandy beaches and low-lying coastal areas were severely damaged (Miura, Sasaki and Chiba 2012; Hara *et al.* 2016). The loss of natural coastal habitat, such as mangrove forest and coral reefs, through pollution, habitat transformation and increased sea surface temperatures, can further undermine protection of coastlines from waves, storm surges and coastal erosion. When communities are rapidly rebuilt post-disaster, building material is often gathered unsustainably, posing an additional threat to local habitats, and communities can be relocated to environmentally sensitive areas.

In the marine environment, warming and acidifying oceans are associated with coral bleaching events, with unprecedented pan-tropical bleaching recorded during 2015-2016 (Hughes *et al.* 2017) (see Section 7.3.1). Ocean acidification may also have negative impacts on other marine systems, including mussel beds and some macroalgal habitats (Sunday *et al.* 2017). Warmer waters additionally impose direct metabolic costs on reef fish, reducing swimming capacity and increasing mortality rates (Johansen and Jones 2011). In polar regions, decrease in sea ice and greater surface run-off may increase primary and secondary productivity, altering food-web dynamics (Post *et al.* 2013), and increase the probability of the establishment of invasive species (Duffy *et al*. 2017) (see Section 4.4.2).

Figure 6.8: Global map showing species vulnerable to climate change



Terrestrial areas with high numbers of vulnerable species were identified on the basis of the number of species assessed and the taxonomic ranks higher than species considered.

Source: Pacifici *et al.* (2015).

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6.5 Global state and trends of biodiversity

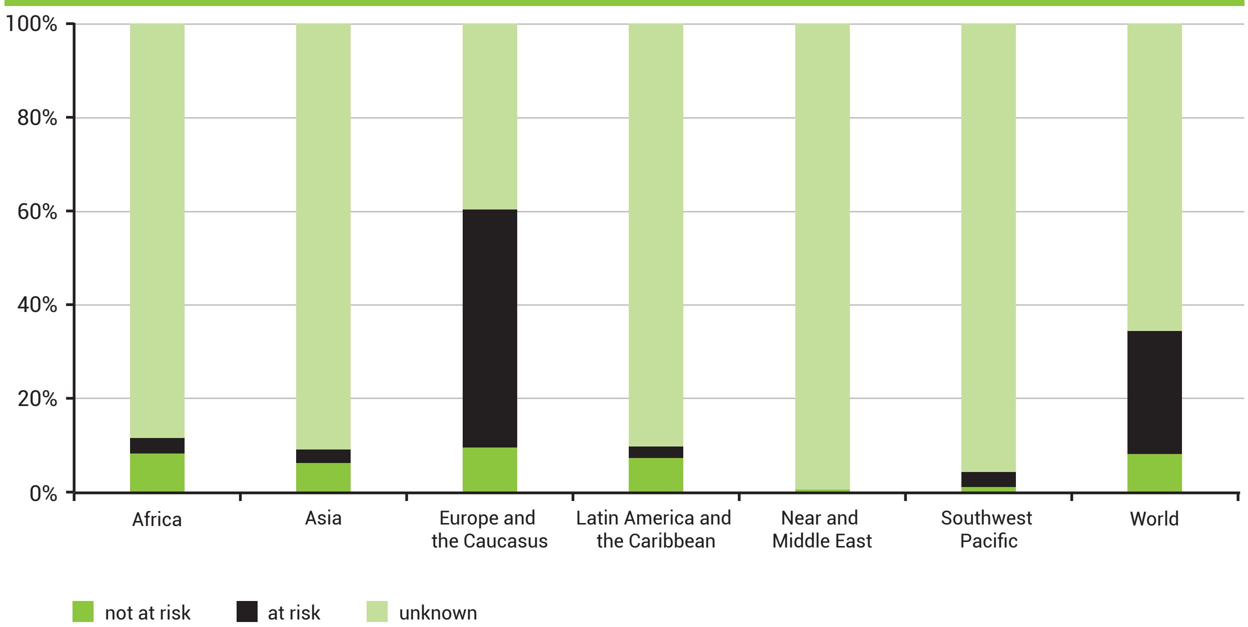
Global change is having negative impacts across all dimensions of biodiversity, from genes to ecosystems. However, the genetic diversity of most natural populations remains unmeasured, population baseline data is often lacking, and the status of ecosystems is under evaluated. More data and science-based targets for evaluation are needed urgently.

6.5.1 State and trends in genetic diversity

Genetic diversity is of fundamental importance not only as the raw material for continued adaptation of wild species by natural selection, but also in maintaining and enhancing the diversity of cultivated plants and breeds of livestock underpinning the resilience of agricultural systems and food security (Khoury *et al.* 2014; FAO 2015a; Bruford *et al.* 2017). Conservation of genetic diversity can be implemented *in situ* in the wild or crop fields, or increasingly *ex situ* in gene banks and seed collections maintained at local and national levels (see Section 13.2.4).

Long-term declines in the number of varieties of crops and breeds of livestock continue, and much of this diversity, alongside that of wild relatives and lesser used species, still lacks sufficient protection (FAO 2015a). More than 35 species of birds and mammals have been domesticated for use in agriculture and food production, and there are about 8,800 recognized breeds (FAO 2018a). An assessment of extinction risk for existing local animal breeds found 65 per cent are classified as 'status unknown' because of missing population data or lack of recent updates, 20 per cent as 'at risk' and only 16 per cent as 'not at risk' (FAO 2018a). These proportions vary regionally, particularly with respect to the availability of data **(Figure 6.9).**

Figure 6.9: Proportions of local animal breeds, classified as being at risk, not at risk or unknown level of risk of extinction



Source: FAO (2018a).

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New genomic tools that allow rapid and increasingly low-cost DNA sequencing have become an integral part of conserving genetic diversity *ex situ*, helping us to understand the genetic potential of crop wild relatives for enhancing productivity, nutritional content and resilience to environmental change (Royal Botanic Gardens Kew 2016). As of 2017, some 225 species of plants, mostly crops, had complete genome sequences (Royal Botanic Gardens Kew 2017; see **Figure 6.10**). However, this remains an expensive enterprise and there is an ongoing need to share related information with those whose livelihoods are dependent on biodiversity but lack the resources to access such data.

Traditional approaches to breeding-enhanced varieties of plants and breeds of livestock still predominate; however, genetically modified (GM) organisms continue to draw attention and new advances, such as the CRISPR/Cas genome editing techniques, are advancing synthetic biology (SCBD 2015; CBD 2016). There is evidence of the positive contribution of genome-editing techniques through the control of invasive species (Webber, Raghu and Edwards 2015) due to the lessened need for insecticides that are harmful to non-target organisms (e.g. Li *et al.* 2015). However, the propagation of genome-edited crops may also contribute to negative biodiversity and environmental outcomes, such as facilitating the spread of herbicide-resistant weeds (Rótolo *et al*. 2015) and reduced insect diversity (Schütte *et al*. 2017; Tsatsakis *et al.* 2017), and the natural adaptation of ecosystems to GM traits may ultimately require further technological innovation and increased use of herbicides and insecticides (Rótolo *et al.* 2015).

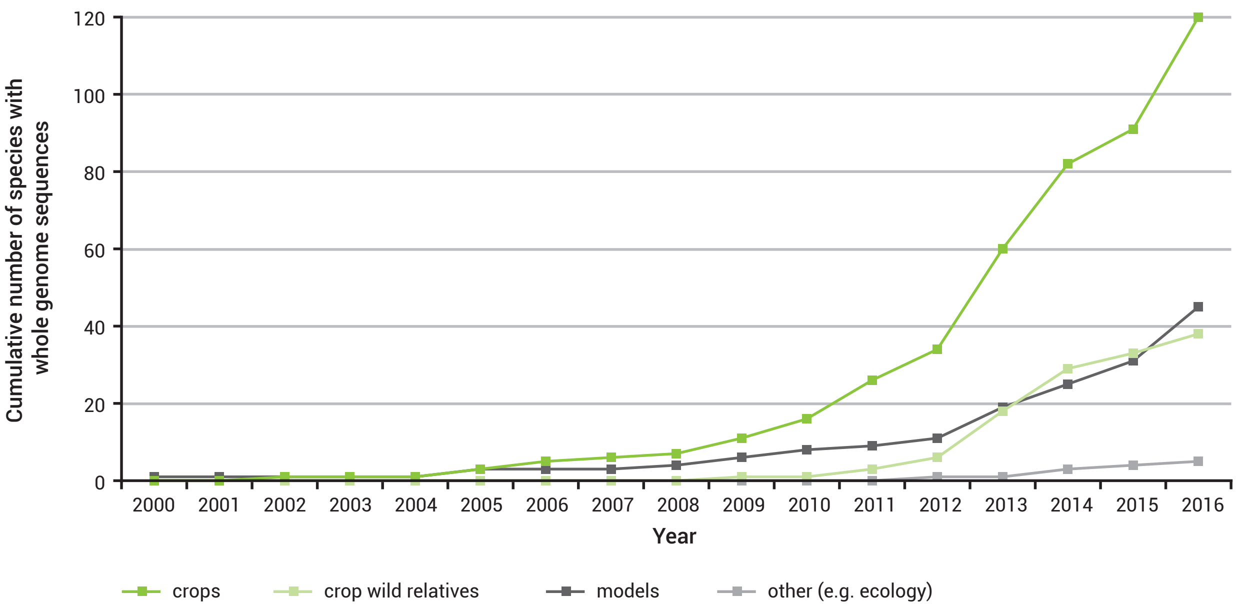
The conservation status of genetic diversity for most wild species unrelated to agricultural crops and livestock remains poorly documented (although there are concerted efforts to close this gap, see http://www.genomicobservatories.org/). Yet population declines are increasingly commonplace (Ceballos, Ehrlich and Dirzo 2017; McRae, Deinet and Freeman 2017). A loss in population size, particularly when persisting over several generations, frequently translates into a loss in genetic diversity. Thus, the drivers that threaten species and populations also likely erode the genetic diversity within them.

6.5.2 Global state and trends in species

The global decline in biodiversity as illustrated by trends in species remains striking (Dirzo *et al.* 2014). Many observers have suggested that we are witnessing a new mass extinction event (Ceballos *et al.* 2015), although there is as yet no scientific consensus. The International Union for the Conservation of Nature's (IUCN) **(Box 6.4)** Red List of Threatened Species (http://www.iucnredlist.org/) provides the most comprehensive inventory of the global conservation status of plant, animal and fungi species. The status of vertebrates has been relatively well studied (Rodrigues *et al.* 2014), but fewer than 1 per cent of described invertebrates (Collen *et al.* 2012) and only about 5 per cent of vascular plants (Royal Botanical Gardens Kew 2016) have been assessed for extinction risk.

According to IUCN's latest estimates, cycad species face the greatest risk of extinction with 63 per cent of species in this plant group considered threatened **(Figure 6.11)**. The most threatened group of vertebrates are amphibians (41 per cent). Of the few invertebrate species assessments completed, 42 per cent of terrestrial, 34 per cent of freshwater and 25 per cent of marine species are considered at risk of extinction (Collen *et al.* 2012). Among well sampled invertebrate groups, reef-forming corals have the highest proportion (33 per cent) of species under threat.

Figure 6.10: Cumulative number of species with whole genome sequences (2000-2016)



Colours denote the type of species: crops, usually for food; crop wild relatives; model species to help understand plant ecology or evolution; other species, e.g. dominant species in an ecosystem.

Source: Royal Botanic Gardens Kew (2017).

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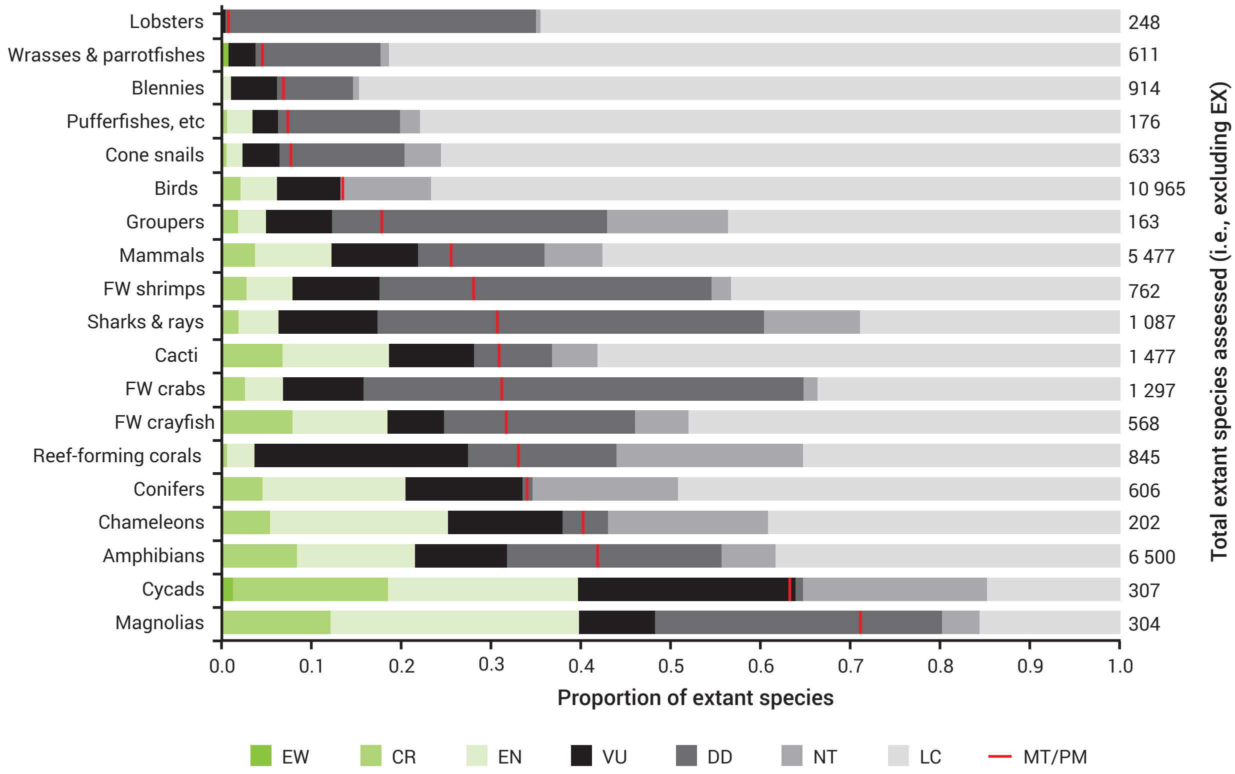
Figure 6.11: The proportion of species in each extinction risk category of the IUCN Red List of Threatened Species



The numbers to the right of each bar represent the total number of existing species assessed for each group. EW: Extinct in the wild; CR: Critically endangered; EN: Endangered; VU: Vulnerable; NT: Near threatened; DD: Data deficient; LC: Least concern.

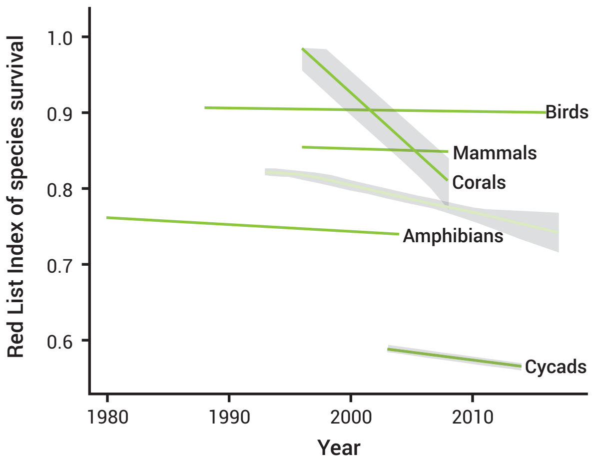
Source: IUCN 2018 (Red List Version 2018-1).

Box 6.4: International Union for the Conservation of Nature (IUCN)

The International Union for Conservation of Nature (IUCN) has, since 1948, served as a science-policy interface for biodiversity and ecosystem services. IUCN has a membership of which the governance weight is exactly 50 per cent intergovernmental (with over 200 state and government agency members) and exactly 50 per cent civil society and indigenous peoples' organizations (over 1,000 civil society members). The Union mobilizes independent commissions to provide expert input into pressing challenges of nature conservation; there are currently six commissions (Ecosystem Management, Education and Communication, Environmental Economic and Social Policy, Species Survival Commission, World Commission on Environmental Law, and World Commission on Protected Areas), comprising over 10,000 specialists in total. The IUCN Red List of Threatened Species, initiated in 1964, remains the most authoritative global inventory of endangered species today **(Figure 6.11)**.

For those groups that have been comprehensively assessed more than once, changes in extinction risk through time have been examined using the IUCN Red List Index. The evidence suggests an increase in risk of extinction for all groups individually and as an aggregate from 1993 to 2017 **(Figure 6.12)**.

Figure 6.12: Red List Index of species survival for birds, mammals, amphibians, corals and cycads, and an aggregate (in light green) for all species



A decline in the trend line indicates either more species have become at risk of extinction over time or there has been an increase in the level of extinction risk over time for some species. The shading denotes 95 per cent confidence intervals.

Sources: IUCN (2017a), Hoffman *et al.* (2018).

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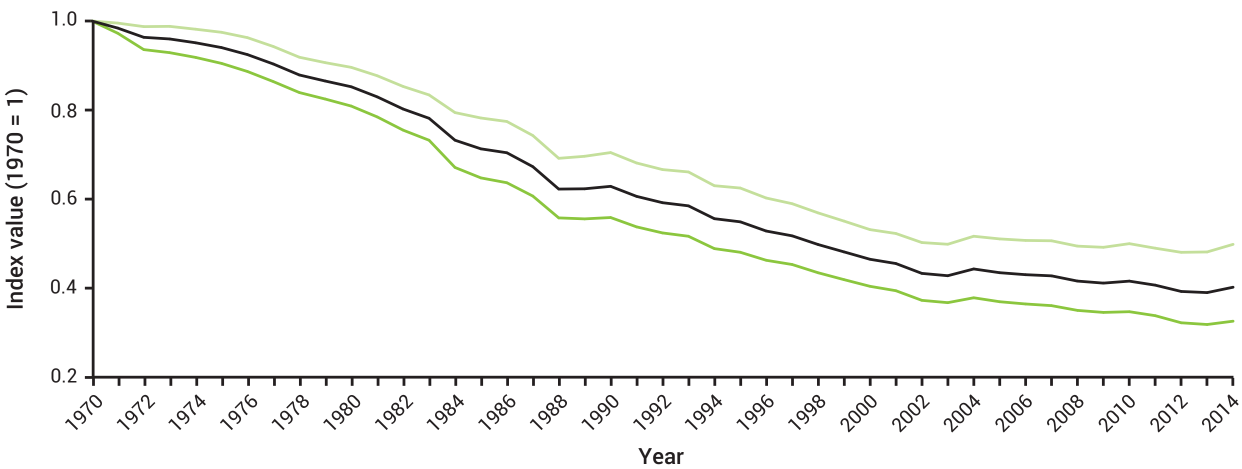
Figure 6.13: Global Living Planet Index



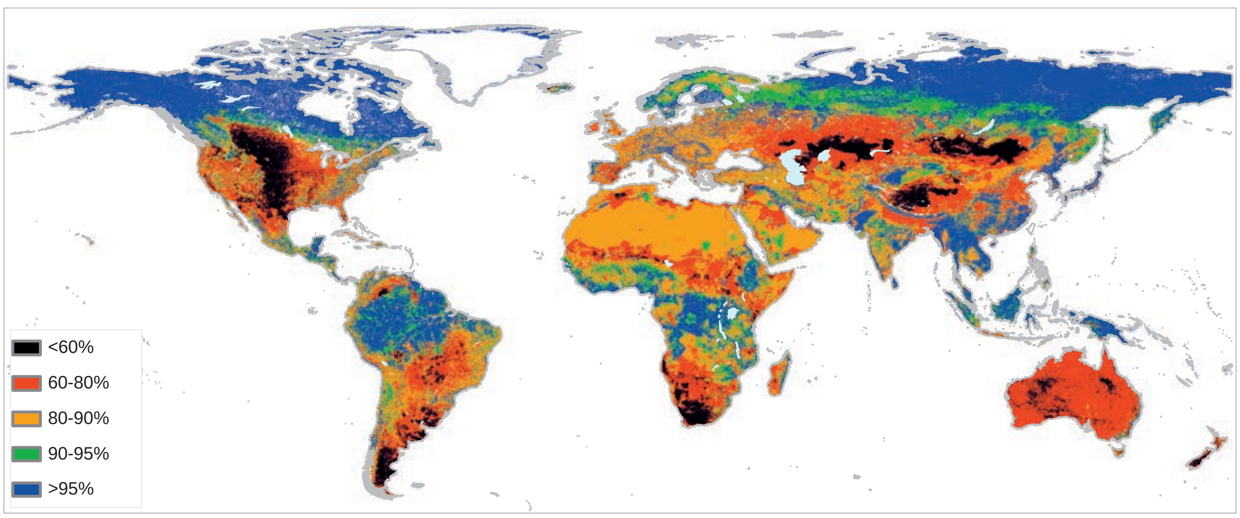
The centre line shows the index values indicating a 60 per cent decline between 1970 and 2014 and the upper and lower lines represent the 95 per cent confidence limits surrounding the trend. This is the average change in population size of 4,005 vertebrate species, based on data from 16,704 time series from terrestrial, freshwater and marine habitats.

Source: WWF (2018).

Monitoring the abundance of species provides a complementary indicator of status and trends. Although lacking the comprehensive coverage of many taxonomic groups found in the IUCN Red List Index, these indicators provide finer spatial and temporal resolution. Trends in global vertebrate species population abundances as measured by the Living Planet Index **(Figure 6.13)** show an average decline of 60 per cent between 1970 and 2014 (McRae, Deinet and Freeman 2017; WWF 2018). Freshwater species have higher rates of population declines than either terrestrial or marine species (McRae, Deinet and Freeman 2017). Globally, average local abundance of terrestrial species is estimated to have fallen to 85 per cent of modelled abundances in the absence of anthropogenic land-use change (Newbold *et al.* 2016), although the intactness of biodiversity varies spatially (Newbold *et al*. 2015; Newbold *et al.* 2016; **Figure 6.14**), and data on species population trends of both flora and fauna are sparse.

Trends in invertebrates may well echo those observed in vertebrates. A global index sampling populations of 452 invertebrate species revealed an average 45 per cent decline in abundance over 40 years (Dirzo *et al*. 2014) and recent reports of declines greater than 75 per cent in biomass of flying insects has been found in protected areas in Germany (Hallmann *et al*. 2017), with similar findings emerging elsewhere in Western Europe (Vogel 2017) and central Europe (Hussain *et al*. 2017;

Figure 6.14: Terrestrial Biodiversity Intactness Index



Intactness value is the average abundance of species as a percentage of the modelled abundance in an undisturbed habitat.

Source: Newbold *et al.* (2016).

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Hussain *et al.* 2018). Particularly steep declines were observed in hoverflies, which are important pollinators (Vogel 2017). Declines in pollinator abundance have also been documented elsewhere, for example, bumble bee species in North America (Bartomeus *et al.* 2013).

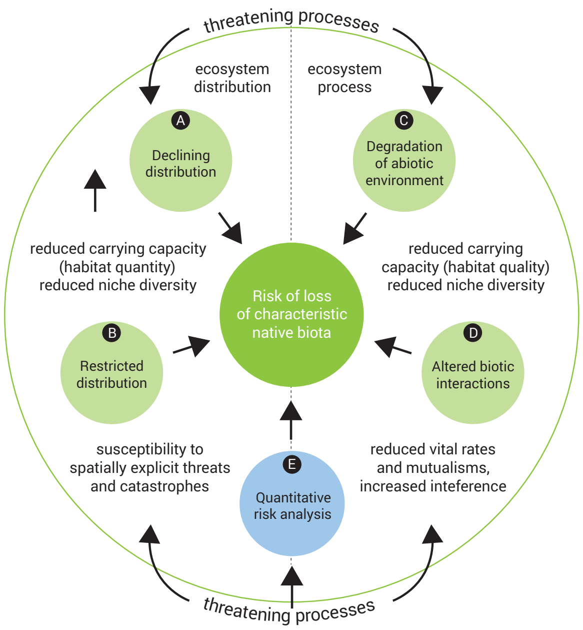
The Living Planet Index **(Figure 6.13)** and the Biodiversity Intactness Index **(Figure 6.14)** both indicate that terrestrial species abundance has declined as a result of anthropogenic land-use change, and that the trend of population decline in the last 44 years has shown no sign of slowing (McRae, Deinet and Freeman 2017; WWF 2018). It has been suggested from the Biodiversity Intactness Index that a terrestrial planetary boundary has been crossed (based on a reduction of 10 per cent in Biodiversity Intactness); from this, it is inferred that ecosystem function may be impaired (Newbold *et al.* 2016).

6.5.3 Global state and trends in ecosystems

There is a pressing need to expand ecosystem assessments. The IUCN has begun to issue a Red List for Ecosystems to complement its global species-based assessment (Keith *et al.* 2015), and a few ecosystems have been assessed by global and regional criteria. One ecosystem, the Aral Sea, has been assessed as 'collapsed' **(Figure 6.15)** (Sehring and Diebold 2012; Keith *et al.* 2013), and several others, such as the gnarled mossy cloud forest on Lord Howe Island of Australia, and the Gonakier forests of the Senegal river floodplain shared by Senegal and Mauritania, have been listed as 'critically endangered' (see Red List of Ecosystems; IUCN 2017b).

Collapse may be reversible if all the component parts of the collapsed ecosystem still exist in other ecosystems (Rodríguez *et al.* 2015). However, shifts to alternative stable states, such as that documented in coral reef systems, from coral dominated to algal dominated, with human-induced eutrophication, cannot be simply reversed (Hughes *et al.* 2017).

Figure 6.15: Mechanisms of ecosystem collapse, and symptoms of the risk of collapse



Source: Keith *et al.* (2013).

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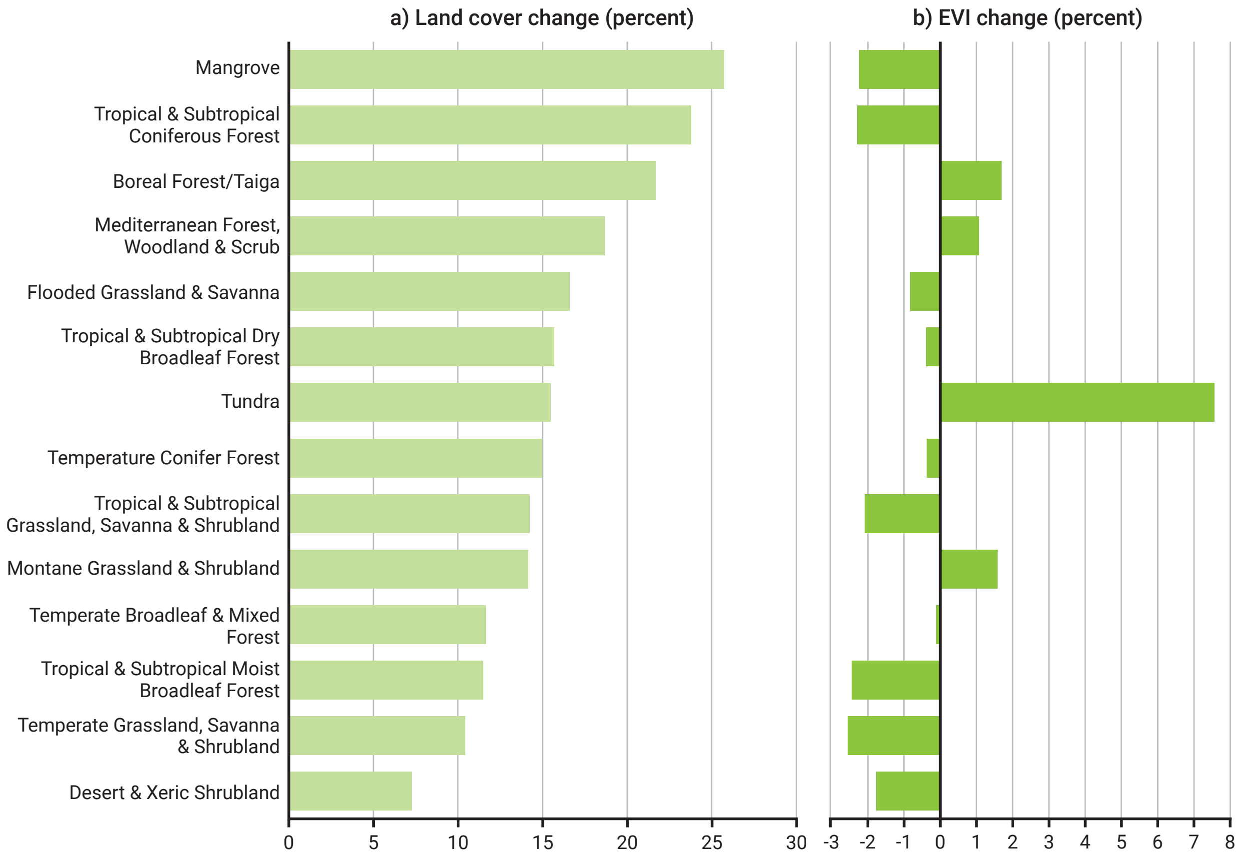
Figure 6.16: Mean percentage change in each broad habitat type based on satellite imagery: (a) change from original land-cover type between 2001 and 2012; (b) vegetation productivity as measured using the Enhanced Vegetation Index between the years 2000-2004 and 2009-2013



Source: Royal Botanical Gardens Kew (2016).

Some information is available at a large scale for broad terrestrial habitat types, and it is estimated that 10 out of 14 experienced a decrease in vegetation productivity between 2000 and 2013, while 4 increased in productivity **(Figure 6.16)**, with anthropogenic factors thought to be driving these trends (Royal Botanical Gardens Kew 2016). At a finer scale, 24 per cent of terrestrial ecoregions have been classified as 'Nature imperilled' (Dinerstein *et al*. 2017).

More is known about the status of terrestrial species and ecosystems than their aquatic counterparts. However, an average decline in natural wetland area of about 30 per cent between 1970 and 2008 was observed globally (Dixon *et al.* 2016), varying from a 50 per cent decline in Europe to 17 per cent in Oceania. While the spatial extent of anthropogenic impacts on marine ecosystems has been estimated (Jones *et al.* 2018), relatively little is known about their current status. Nonetheless, the impact of pressures on the marine environment is thought to be increasing, as evidenced by marine wildlife loss (McCauley *et al*. 2015) and the current critical status of coral reefs (Hughes *et al.* 2017). The deep-sea ecosystem is probably one of the least well studied and is expected to be particularly vulnerable to habitat loss and climate change (Barbier *et al.* 2014).

The status of biodiversity that explicitly underpins nature's contribution to people has not yet been comprehensively assessed, although a global assessment of biodiversity and ecosystem services will be published by IPBES in 2019. However, many of these ecosystem processes are thought to be under threat as a consequence of observed wildlife declines and ongoing threats to biodiversity (Cardinale *et al*. 2012; Mace, Norris and Fitter 2012). Mammal and bird species that are used for food and/or medicine are at greater risk of extinction than those not used; the opposite was found for the same assessment of amphibian species (Almond *et al.* 2013). The perceived value of a species may impose an additional pressure on biodiversity conservation: of the 28,187 plant species that are recorded as being of medicinal use, there are controls on international trade for 1,280 to reduce threats from overexploitation (Royal Botanical Gardens Kew 2017).

6.6 Impacts on the world's biomes

A biome is defined as a major ecological community of organisms adapted to a particular climatic or environmental condition across a large geographic area. Within biomes, several ecosystems may coexist. This section examines eight broadly defined biomes that encompass most of Earth's biodiversity.

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6.6.1 Oceans and coasts

The primary pressures on open ocean biodiversity are overexploitation, pollution from land-based activities and climate change; coastal ecosystems have additional pressures associated with habitat destruction, aquaculture and invasive species (see Section 7.2). Although data are limited, these pressures affect the state of marine biodiversity from populations to ecosystems.

Coastal systems are particularly vulnerable; for example, between 20 and 35 per cent of mangrove area has been lost since 1980 (Innis and Simcock eds. 2016) and the current annual rate of seagrass habitat destruction is about 8 per cent (Innis and Simcock eds. 2016). Coral reefs are among the most biodiverse marine ecosystems, yet they are also among the most fragile (see Section 7.3.1).

The decline in the health of marine ecosystems and biodiversity is increasingly affecting people (WWF 2015). Marine capture fisheries provide healthy food and support livelihoods (see Section 7.3.2). However, overexploitation is leading to population declines in marine fisheries with the percentage of global stocks fished at biologically unsustainable levels increasing from 10 per cent in 1975 to 33 per cent in 2015, with the largest increases in the late 1970s and 1980s (FAO 2018b; **Figure 6.17**). In 2015, over 50 per cent of the stocks in the Mediterranean, Black Sea, the Pacific Southwest and the Atlantic Southwest were fished at biologically unsustainable levels (FAO 2018b).

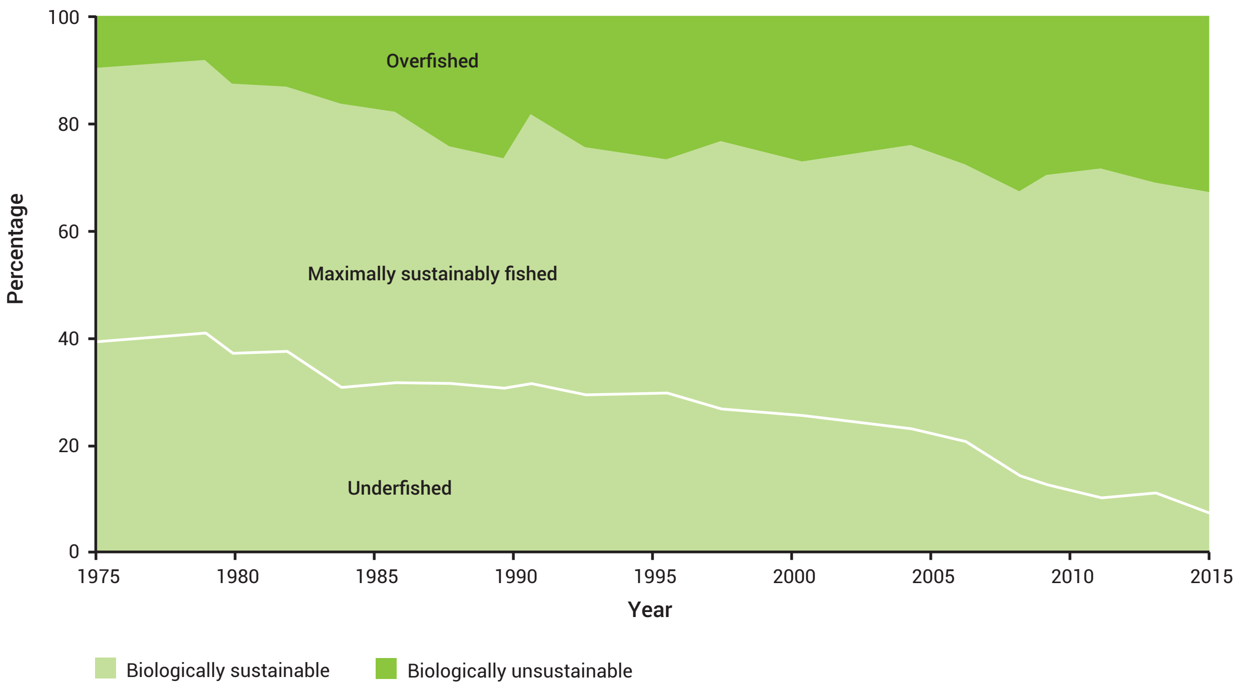
Exploitation of target species is coupled with additional negative biodiversity impacts from by-catch and damage to benthic environments from trawling, although some seabird populations have increased through feeding on discards (Foster, Swann and Furness 2017). The rise of aquaculture can reduce pressures of exploitation for some wild species, but can also lead to invasive species, inter-species breeding, eutrophication and disease spread (Ottinger, Clauss and Kuenzer 2016) (see Section 7.4.3).

Pollution, including marine plastic litter and microplastics **(see Box 6.2)**, and loss and degradation of habitat leads to further reduced contributions from natural systems, such as declining fish nursery grounds or mangrove wood supply (Nordlund *et al.* 2016; Quinn *et al.* 2017), as well as increases in vulnerability to extreme events **(see Box 6.3)** through reduced coastal protection.

6.6.2 Freshwater

Freshwater systems are exposed to the full gamut of multiple pressures with changes in land use, habitat loss, invasive species, use of watercourses for development of hydroelectric power, and pollution creating widespread and significant impacts (see Section 9.2). Wetland loss has been long term and extensive, and freshwater species, especially in tropical ecosystems, have declined at a faster rate than those in any other biome (see Section 6.4.1).

Figure 6.17: Global trends in the state of the world's marine stocks 1975-2015



Source: FAO (2018b).

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The abundance of monitored populations of freshwater vertebrate species declined an average of 81 per cent over the past 42 years (WWF 2016). A summary of extinction risk of global freshwater fauna indicates that reptiles have the highest estimated risk among the six groups assessed **(Figure 6.18)**. About a third of the more than 7,000 freshwater invertebrate species on the IUCN Red List are considered threatened, with gastropods being the most threatened group (Collen *et al.* 2012). These species combine to provide a wide range of critical services for humans, such as flood protection, food, water filtration and carbon sequestration (Collen *et al*. 2014).

Industrial-era agriculture results in nitrogen- and phosphorous-driven eutrophication of terrestrial, freshwater and nearshore marine ecosystems, and pesticide use can further degrade freshwater ecosystems (Malaj *et al*. 2014; Mekonnen and Hoekstra 2015). Globally, it is estimated that the number of lakes with harmful algal blooms will increase at least 20 per cent by 2050 (United Nations Educational, Scientific and Cultural Organization [UNESCO] 2014). Cyanobacterial algal blooms can result in lowered value for recreational uses, reduced aesthetics, lower dissolved oxygen concentrations, decline in drinking water quality and the production of toxins, which can impact both wildlife and human health (Brooks *et al*. 2016).

6.6.3 Grasslands

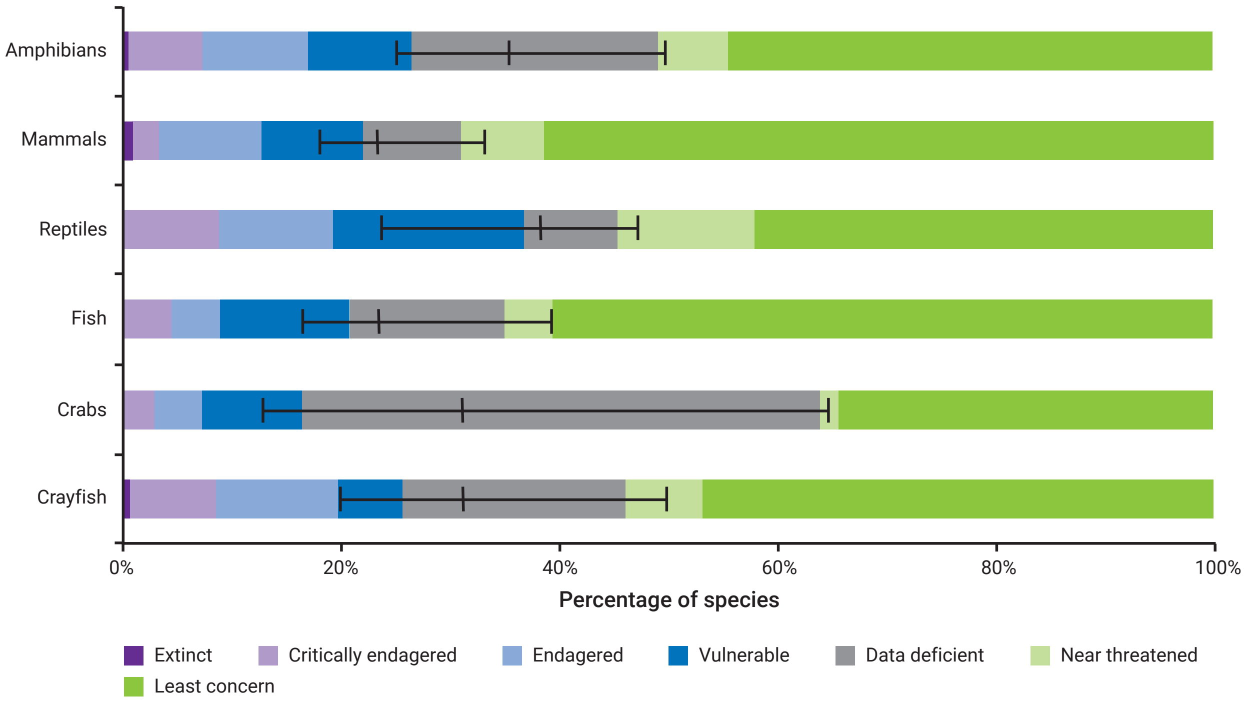
Grasslands cover about 8 per cent of total land area and were once home to some of the largest wildlife assemblages on Earth (IUCN 2017c). They are now considered the most altered terrestrial ecosystem worldwide and the most endangered ecosystem on most continents, facing multiple pressures including land-use change, overgrazing, fragmentation, invasive species, suppression of natural fire, climate change and afforestation (IUCN 2017c).

Though grasslands contain high plant diversity, agricultural expansion is causing habitat destruction and fragmentation; for example, soybean production has replaced traditional livestock subsistence on natural pastures in much of the cerrado, a woodland savanna ecosystem, of South America (Aide *et al*. 2013). The Brazilian Cerrado holds roughly five per cent of global biodiversity and has lost close to 50 per cent of its original range (Brazil, Ministério de Meio Ambiente 2015). Rising temperatures are associated with woody encroachment and desertification across Africa (Midgley and Bond 2015; Engelbrecht and Engelbrecht 2016), South America and, to a lesser extent, Australia (Stevens *et al.* 2017).

It is estimated that 49 per cent of grassland ecosystems experienced degradation over a ten-year period (2000-2010), with nearly 5 per cent experiencing strong to extreme degradation (Gang *et al*. 2014), greatly decreasing the ability of these ecosystems to support biodiversity. Currently, 4.5 per cent of global grasslands have protected status (IUCN 2017c).

The strong relationship between grassland biodiversity and biomass (Cardinale *et al.* 2012), which is often used for animal fodder, agricultural products and raw textile materials for local populations, suggests that reductions in biodiversity will have negative implications for small-scale economic productivity and livelihoods.

Figure 6.18: Extinction risk of global freshwater fauna by taxonomic group



Note: Central vertical lines represent the best estimate of the proportion of species threatened with extinction, with whiskers showing confidence limits. Data for fish and reptiles are samples from the respective group; all other data are comprehensive assessments of all species (n = 568 crayfish, 1191 crabs, 630 fish, 57 reptiles, 490 mammals and 4147 amphibians).

Source: Collen et al. (2014).

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Box 6.5: Agrobiodiversity and gender

In many societies, women have traditionally been the keepers of deep knowledge of the plants, animals and ecological processes around them. The use of hybrid seed varieties (to which there has been a widespread shift in recent decades) can prevent women collecting seeds, undermining their status as seed collectors, as well as food security, especially in developing countries (Bhutani 2013). The erosion of biodiversity driven by industrial agriculture has therefore had specific impacts for women, including a loss of knowledge related to seeds, food processing and cooking (International Panel of Experts on Sustainable Food Systems 2016). In recent years, community seed banks that preserve local seeds have been re-established in some areas and are frequently managed by women, including through local seed exchanges. Participatory plant-breeding schemes to improve seeds further enhance women's status in farming (Galiè *et al*. 2017).

6.6.4 Agricultural landscapes

Beginning about 8,000 years ago, agricultural expansion and intensification has led to biodiversity loss in many biomes (United Nations Convention to Combat Desertification [UNCCD] 2017). Global demand and supply chains concentrate production in 'breadbasket' regions (Khoury *et al.* 2014), where landscape transformation reduces and fragments natural habitat, and yield-enhancing inputs (fertilizers and pest control) can impact non-cropped areas, watercourses and air quality. Recent decades are notable for marked land-use change in tropical regions associated with increasing oilseed production, in particular for soya and oil palm, much of which has come at the expense of highly biodiverse biomes (Foley *et al*. 2011). A dramatic decline in animal populations both inside and outside protected areas (Keesing and Young 2014) is associated with increased risk of predators attacking livestock (Zheng and Cao 2015; Malhi *et al.* 2016), negatively impacting agricultural livelihoods. Agricultural practices, such as tillage, crop combinations, and application of fertilizers and pesticides, also have impacts on below-ground biodiversity. (FAO and the Platform for AgroBiodiversity Research 2011, p. ix). Importantly, agricultural landscapes can sometimes maintain rare species in semi-natural habitats, while abandonment of agricultural practices may even lead to biodiversity decline (Plieninger *et al.* 2014).

Loss of diversity in agroecosystems increases their vulnerability and thus reduces the sustainability of many production systems. Reduction in the provisioning of regulating and support services can drive additional chemical use and may create harmful feedback loops (WHO and SCBD 2015, p. 5). There is some evidence that farmers in homogeneous landscapes have higher incomes than farmers in heterogeneous landscapes (Watts and Williamson 2015), but their resilience to pressures such as climate change is often lower and income variability is greater (Abson, Fraser and Benton 2013). In addition, the homogenization of crop production has health impacts, contributing to the homogenization of diets and increasing consumption of processed foods associated with obesity and diet-related non-communicable diseases (Khoury *et al*. 2014). In contrast, production diversity is strongly associated with dietary and nutrition diversity among smallholder farmers whose market participation is limited (Sibhatu, Krishna and Qaim 2015) and local knowledge about seed varieties is often held by women farmers **(see Box 6.5)**.

In some cases, intensive agriculture might also increase the prevalence of infectious diseases (Cable *et al.* 2017). For example, oil palm plantations in South America appear to increase the risk of Chagas disease (Rendón *et al*. 2015), and in Kalimantan, Indonesia, the burning of forests to plant oil palm may have contributed to the migration of bats, known to carry Nipah virus (Pulliam *et al.* 2011).

Biodiversity in agricultural landscapes is key to food and nutrition security **(see Box 6.6)**. Pollination by about 100,000 species of insects, birds and mammals accounts for 35 per cent of global crop production (SCBD 2013; IPBES 2016), and up to 15 per cent of the value of economies based on cash crops (IPBES 2016, p. 209). Production is declining at local scales in places where the diversity of pollinators has been declining (IPBES 2016, pp. 154,185-186). Maintaining remnant patches within a few hundred metres of farms can help support pollinator populations and increase crop yield (Pywell *et al.* 2015; IPBES 2016, p. 394).

Box 6.6: Importance of traditional practices and knowledge in pollinator conservation

Indigenous and local knowledge has been recognized as an important source of expertise in finding solutions to declines in animal pollinators – wild species such as birds, bats, bumblebees and hoverflies, and managed species such as honeybees (Lyver *et al*. 2015; IPBES 2016, p. xxii). In 2013, the Indigenous Pollinators Network was established with a view to combining traditional knowledge of indigenous peoples with modern science for the benefit of conserving pollinators and their vital services (Platform for AgroBiodiversity Research 2013). As well as conserving pollinators, traditional practices of beekeeping may have wider benefits for biodiversity, for example strengthening watershed conservation in the face of climate change (Kumsa and Gorfu 2014) and in forest conservation (Wiersum, Humphries and van Bommel 2013).

Ethiopia is the largest producer of honey and beeswax in Africa (Begna 2015). These products are used for making candles and Tej or honey wine (an important drink in cultural life), and white honey from the Bale mountain region is used medicinally (IPBES 2016, pp. 312-314). Women contribute to this value chain, usually by manufacturing honey products rather than beekeeping itself. However, there is potential for beekeeping to provide income generation and empowerment for women in rural areas of Ethiopia (Ejigu, Adgaba and Bekele 2008; Serda *et al*. 2015).

6.6.5 Drylands

Though drylands are less diverse than other ecosystems, they contain thousands of species that are highly adapted to the dryland environment yet often neglected in conservation efforts. Arid and semi-arid rangeland ecosystems have seasonal climatic extremes and unpredictable rainfall patterns, but dryland species have evolved to be highly resilient by recovering quickly from drought, fire and herbivore pressure. Desertification (also known as land degradation in drylands) is a worldwide phenomenon (see Section 8.4.2).

Dryland degradation has many causes, including human conflicts. Large amounts of waste, garbage and toxic material were dumped and burned in desert ecosystems due to the Islamic Republic of Iran-Iraq war (UNEP 2016f). Drought, overgrazing, overuse of groundwater and unsustainable agricultural practices impose additional pressures (O'Connor and Ford 2014; Southern Africa Development Community 2014), though the extent of human versus natural causes are often difficult to disentangle.

The degradation of semi-arid and arid landscapes reduces capacity in terms of freshwater supply and food production, decreases wild food availability, and presents a threat to emblematic species and genetic resources (Low ed. 2013). Desertification has a damaging effect on soil health and vegetation, leading to adverse impacts that cascade through the food chain (Assan, Caminade and Obeng 2009). Salinization, mostly due to unsustainable irrigation systems, irrigated areas with poor drainage and poor quality of irrigation water, is a major problem in arid and semi-arid regions (see Section 9.5.6). The almost complete desiccation of the Aral Sea has led to the creation of the Aral Kum desert, which has caused degradation of riparian forests, pastures and other vegetation cover (Kulmatov 2008).

6.6.6 Forests

Forests provide habitat for large numbers of animal and plant species, and deforestation is one of the top threats to species diversity (FAO 2015b; Alroy 2017). Deforestation and forest degradation continue in many regions, often in response to demands for biomass as well as drivers outside the forest sector, such as urban expansion and agriculture, energy, mining and transportation development (see Section 8.4.2). Recent estimates show that tree cover loss is high across all forest types but differs across regions (Leadley *et al.* 2014). Tree cover density is associated with both losses and gains, but losses are especially high in the tropics and boreal forests; tropical rainforest accounted for 32 per cent of global tree cover loss over the period 2000-2012, with half of this loss occurring in South America (Hansen *et al*. 2013). Rates of forest gains approach or exceed rates of tree cover loss in some areas, particularly in temperate regions, reflecting forestry-dominated land management.

Recent work suggests that more biodiverse forests contribute a greater range of ecosystem services (Gamfeldt *et al*. 2013). Forests supply essential regulating services, including carbon sequestration, important for the regulation of climate, and protection of soil and water (Foley *et al.* 2007; Brockerhoff *et al.* 2017). With increasing deforestation and forest degradation, however, forest ecosystems can transform from net carbon sinks to carbon sources (Baccini *et al*. 2017).

The total number of people deriving benefits from forests — in the form of food, forest products, employment, and direct or indirect contributions to livelihoods and incomes — is estimated to be between 1 billion and 1.5 billion (Agrawal *et al*. 2013). In Africa, approximately 80 per cent of people are dependent on fuelwood (including charcoal) as their sole source of energy (UNEP 2016a, p. 76). Global exports of forest products were worth US$226 billion in 2015, with wood fuel comprising 9 million m^3 and industrial roundwood 122 million m^3 (FAO 2015b). Non-wood forest products, including wild plant resources, typically contribute less to local economies, but can have high global market value. Contributions of forests to economies of the developing world are estimated at over US$250 billion (Agrawal *et al*. 2013). These economic benefits can only be maintained if forests are managed sustainably (FAO 2015a).

Though there are short-term employment gains from deforestation, the loss of forests translates into a loss of livelihoods: over 13 million people are employed in the formal forest sector, and another 40-60 million people may be employed in informal small and medium-sized forest operations (Agrawal *et al*. 2013; FAO 2018c). A well-documented gender gap in access to forest resources suggests that poor management or loss of forest ecosystems may have different impacts on women and men (WWF 2013; Djoudi *et al*. 2015).

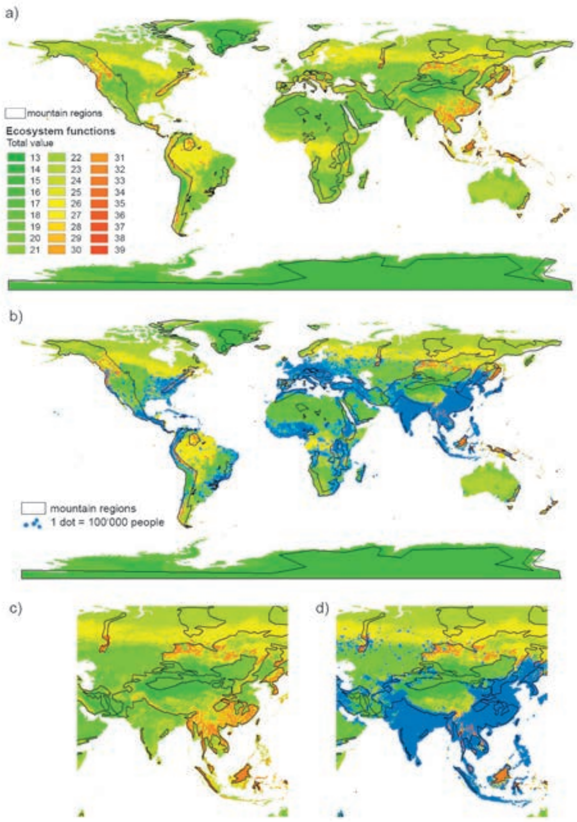
The direct health consequences of deforestation are complex: there is some evidence that forests can promote physical and mental well-being (Oh *et al.* 2017), while forest loss may increase exposure to infectious diseases, including malaria (Guerra, Snow and Hay 2006; Fornace *et al*. 2016) and other vector-borne parasites (Plowright *et al.* 2015; Hunt *et al.* 2017; Olivero *et al.* 2017).

6.6.7 Mountains

Mountain ranges cover around 22 per cent of the terrestrial space of the planet and provide multiple ecosystem services. At lower elevations, mountain habitats, especially those in tropical regions, are often more biodiverse and have higher levels of endemism than adjacent lowlands. However, habitat degradation and fragmentation has impacted many mountain ecosystems (Shrestha, Gautam and Bawa 2012; Chettri 2015; Venter *et al*. 2016) (see Section 4.3.2).

Mountain ecosystems are especially vulnerable to climate change: effects include shifts in species ranges and composition, with notable impacts on those organisms whose dispersal might be limited, or which are restricted to high altitudes, and local extinctions can occur for species in the upper margins of elevation gradients (Pauli *et al*. 2012; Khan *et al.* 2013; Grytnes *et al.* 2014; Knapp *et al*. 2017). Climate-induced warming can change ecosystem functioning, advance spring phrenology, and increase productivity and carbon uptake (Piao *et al.* 2012; Shen *et al.* 2016). Localised pressures include road construction, deforestation, mining, tourism, grazing of domestic livestock, burning and armed conflict (see Epple and Dunning 2014; Young 2014).

Figure 6.19: Capacity of mountains to provide ecosystem services



The maps display the proxy capacity of land to provide ecosystem services, measuring to what degree 15 selected ecosystem services are supported by the underlying land characteristics: (a) global analysis; (b) population density data highlighting regions of high demand for ecosystem services; (c) and (d) high supply of and high demand for ecosystem services in the Himalayas.

Source: Grêt-Regamey, Brunner and Kienast (2012).

Most mountain areas today are under high human pressure, including the Tropical Andes and Central Asian Mountain biodiversity hotspots. The Himalayas, with approximately 19,000 species (Khan *et al*. 2013), have been documented as highly vulnerable to climate change (Shrestha, Gautam and Bawa 2012). In Europe, warming has driven many species upward, resulting in local increases of boreal and temperate mountaintop diversity; but the opposite effect has been noted for Mediterranean mountains, which have lost some species (Pauli *et al*. 2012). In some areas, the abandonment of agricultural land in mountain ranges has also led to decreases in biodiversity, especially among bird populations (Hussain *et al.* 2018).

Loss of biodiversity reduces nature's contributions to people in both mountains and lowlands **(Figure 6.19)** (Grêt-Regamey, Brunner and Kienast 2012). Degradation in mountain ecosystems will result in changes in air quality and climate regulation, such as the reduction of greenhouse gas sequestration (Ward *et al.* 2014). Threats to local communities include loss of food security, medicinal plants, and water quality and provision, and increased exposure to risks associated with landslides, sedimentation of rivers and flooding modifying their livelihoods and land cover (Eriksson *et al.* 2009; Khan *et al*. 2013; Young 2014). A few mountain areas still maintain the traditional use of species (e.g. Andes, Himalayas), while ethnobotanical knowledge in the Alps has been lost due to changes in land-use patterns (Khan *et al.* 2013). Glacier loss impacts water security, with some populations in South Asian countries dependent upon the flow of rivers from the western but also central and eastern Himalayas (Khan *et al*. 2013; see **Box 6.7**). Economic costs of land-use change may also be high; for example, a 75 per cent reduction in economic benefits from nature-based recreation has been reported following replacement of mountain forest with crops in Nepal (Thapa *et al*. 2016).

6.6.8 Polar regions

Biodiversity in the Arctic and Antarctic regions is under particular stress (Bennett *et al.* 2015) (see Section 4.3.2). Many native species are in decline; rising temperatures and invasive species, especially in the sub-Antarctic and Antarctic Peninsula, are major pressures (Hughes, Cowan and Wilmotte 2015; Amesbury *et al.* 2017). Industrial development, pollution and local disturbances present additional pressures (Conservation of Arctic Flora and Fauna [CAFF] 2013), with polar regions acting as a sink for many anthropogenic pollutants such as persistent organic pollutants (POPs) and other synthetic organic chemicals (Alava *et al.* 2017).

Box 6.7: Climate change and the need for ecosystem-based adaptation: the Hindu Kush Himalayas

While climate change may bring some benefits to mountain regions (e.g. longer growing seasons), the preponderance of impact is negative. Increased variability in precipitation patterns (including variability in monsoon and more frequent extreme rainfall) coupled with glacial ice melt, is predicted to increase risks of floods (carrying rock, sediments and debris), landslides, fire, soil erosion and spread of water-related and vector-borne diseases (Ebi *et al*. 2007; Armstrong 2010; Ahmed and Suphachalasai 2014). Of particular concern are the potentially devastating impacts from glacial lake outburst floods which have become more frequent since the middle of the 20th century (Armstrong 2010; International Centre for Integrated Mountain Development 2011).

The Hindu Kush Himalayas, the greater Himalayan region extending from eastern Nepal and Bhutan to northern Afghanistan, are among the most extensive areas covered by glaciers and permafrost on the planet. They contain water resources that drain through ten of the largest rivers in Asia, from which over 1.3 billion people derive their livelihoods and upon which many more depend for water and other resources (Eriksson *et al*. 2009). The region has been recognized as a unique biodiversity-rich area with equally unique topographic characteristics and socioeconomic and environmental challenges. The accelerated rate of warming, glacier ice melt and related implications on the hydrological systems are among the most pressing challenges to this unique mountain ecosystem (Gerlitz *et al*. 2017). It is essential that these macro-climatic effects are integrated into plans to conserve the fragile biodiversity of the region.

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Substantial changes expected to Antarctic ice sheets before the turn of the century may have considerable global consequences (Chown *et al.* 2017) (see Section 4.3.2). Under most climate scenarios, the Arctic is projected to be ice-free in summer by 2050 (IPCC 2013, p. 1090), although remnants of multi-year ice will remain off the coasts of Canada and Alaska. The retreat of sea ice is likely to result in major ecological shifts linked to:

a) an increase in primary productivity as a result of more open water and greater freshwater flow carrying nutrients;
b) a comparable shift in the source and quality of food for species at higher trophic levels such as krill, fish and marine mammals (Frey *et al.* 2016; Alsos *et al*. 2016); and
c) an influx of new species into the polar regions with productivity and food web relationships changing as coastal and sea ice systems of polar regions experience earlier spring bloom and longer growing periods for microalgae (Potts *et al.* 2016).

Average abundance of Arctic vertebrates increased from 1970 until 1990 and then remained fairly stable through to 2007, as measured by the Arctic Species Trend Index (McRae *et al*. 2012; CAFF 2013). However, some food resources are being lost in areas of diminishing sea ice, posing health risks to species such as the walrus, ivory gull, polar bear and Barents Sea harp seal (CAFF 2017). Penguins are one of the more regularly monitored species groups in Antarctica, and populations have been changing over the last century with recorded declines in some colonies of macaroni, Adélie and chinstrap penguins (Trathan, Lynch and Fraser 2016).

It is likely that, due to higher productivity, the availability of some natural resources will increase for circumpolar peoples and communities (Arrigo 2014), but changes in hunting conditions will have a detrimental impact on the Inuit and other groups that have relied on seal hunting and other traditional food sources for which sea ice provides access. Some negative impacts are already being felt; for example, a significant die-off of seals and walruses in the Pacific Arctic in 2011 affected food sources for indigenous communities in the United States of America, Canada and Russian Federation (CAFF 2017). Breaks in the dormancy of pathogenic bacteria and viruses in thawing permafrost are a direct threat to human health (Sutherland *et al.* 2018).

The opening of potential new fishing zones, oil and gas development and shipping may result in future conflicts, especially with regard to economic use, governance, cultural interests and marine protected areas. As the Antarctic has no indigenous people or local communities and is outside the range of the Convention on Biological Diversity's Nagoya Protocol, the equitable sharing of benefits from biodiversity to people, including those benefits derived from bioprospecting, represents a particular challenge not completely addressed by the Antarctic Treaty System (Chown *et al.* 2017).

6.7 Responses

A broad spectrum of governance approaches and policy instruments are used to help address biodiversity loss. Their effectiveness and specific examples are explored in Chapter 13.

6.7.1 The Convention on Biological Diversity (CBD)

The CBD has been the key global convention on biodiversity in recent decades and it has three central goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. With 196 Parties in 2018, it establishes international norms and provides a forum for states to cooperate and share information and coordinate policy. In 2010 member states adopted the Strategic Plan for Biodiversity 2011-2020, as well as the more specific Aichi Biodiversity Targets, a comprehensive and ambitious array of goals subsequently reflected in many of the United Nations Sustainable Development Goals (SDGs). The midterm assessment of progress towards the Aichi Biodiversity targets concluded that, while progress has been made, it was insufficient to achieve them by 2020 (SCBD 2014).

The CBD's Cartegena Protocol on Biosafety deals with the international transfer of living modified organisms (LMOs), demanding advanced and 'informed' agreement from the importing country prior to the exchange of any LMOs, which includes genetically modified organisms (GMOs) such as seeds. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity establishes a framework for access to genetic resources and the sharing of benefits arising from their utilization, including the transfer of relevant technologies, which directly aims to curb biopiracy and promote equity in future bioprospecting agreements. It has been ratified by 105 countries as of May 2018. The Secretariat of the CBD plays a key role in raising awareness and organizing regional workshops and other capacity-building exercises.

An important mandatory requirement of Parties to the CBD is a commitment to produce National Biodiversity Strategies and Action Plans (NBSAPs) with associated targets (see Chapter 13.1). The Global Environment Facility (GEF), through its enabling activities window, provides support to eligible Parties which focuses on revising/updating their NBSAPs considering the CBD Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. This support is routed through the United Nations Development Programme (UNDP) and UN Environment (UNEP) as the key implementing agencies (Pisupati and Prip 2015). The CBD also supports the creation of subnational biodiversity strategies and action plans and regional (supranational) plans, and collaborates with the other key multilateral environmental agreements that have biodiversity-related mandates such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (see **Box 6.8** and Annex 6-1).

6.7.2 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

In 2012, IPBES was officially established with a stated mission "to strengthen the science-policy interface for biodiversity and ecosystem services/nature's contributions to people for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development." IPBES is organized under the auspices of four United Nations agencies – UNEP, United Nations Educational, Scientific

Box 6.8: The international wildlife trade and CITES

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) came into force in 1975 and had 183 Parties by 2018. International trade of flora and fauna is worth billions of dollars and includes hundreds of millions of species and species parts, including food products, artistic ornaments and many traditional medicines (Broad, Mulliken and Roe 2003; Rosen and Smith 2010). Today, the agreement assigns various degrees of protection to over 35,000 species of plants and animals (CITES 2018).

Species listed in CITES that are traded across borders are subject to controls through a licensing system managed by member countries. CITES species are listed in three Appendices attached to the Convention: Appendix I provides the highest degree of protection, effectively banning all commercial trade in wild-taken alive or dead specimens of the species; trade in specimens on Appendix II is strictly regulated; Appendix III indicates a country has unilaterally asked for the help of other Parties in controlling trade in the species, subject to regulation within its jurisdiction.

The CITES agenda is ambitious, and the Convention is not self-executing: parties must implement and enforce its provisions under national law. This is a difficult task requiring significant educational and enforcement resources, and corruption can be problematic (Bennett 2015).

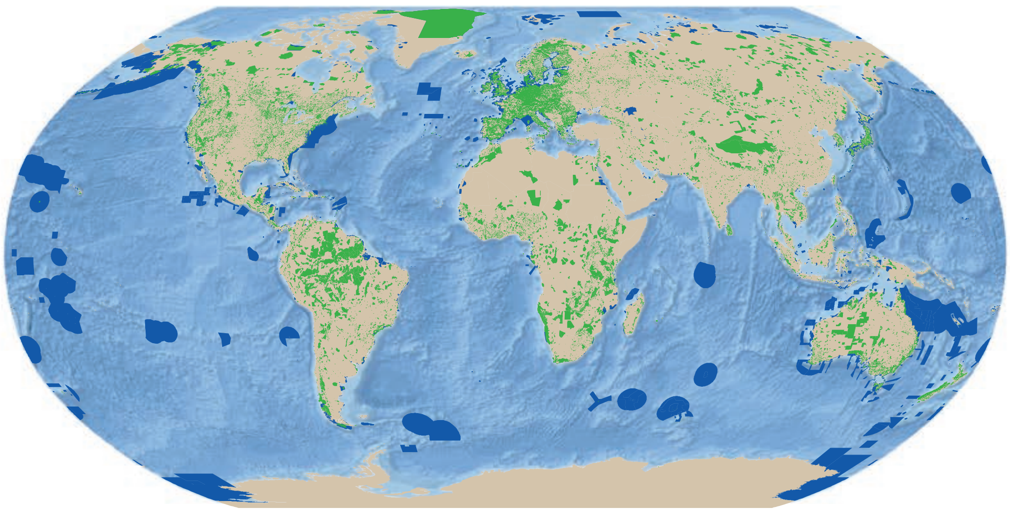
and Cultural Organization (UNESCO), Food and Agriculture Organization of the United Nations (FAO) and UNDP – and is administered by UNEP. By June 2018, its membership comprised 130 governments as well as a number of major stakeholder groups.

6.7.3 Protected areas

Protected areas have been successful in reducing habitat loss (Aichi Biodiversity Target 5) and have helped in lowering extinction risk for some target species (Aichi Target 12) (UNEP-WCMC and IUCN 2018). However, despite clear evidence that investment in conservation can help reduce biodiversity loss (Geldmann *et al.* 2013; Waldron *et al.* 2017), less than 15 per cent of the world's terrestrial and inland waters, less than 11 per cent of the coastal and marine areas within national jurisdiction, and less than 4 per cent of the global ocean is covered by protected areas **(Figure 6.20)** (UNEP-WCMC and IUCN 2018; Sala *et al*. 2018). In addition, a third of the land area within protected area boundaries is already degraded by human impacts (Jones *et al.* 2018).

While providing biodiversity benefits, protected areas can have potentially negative effects on livelihoods in local communities due to decreased access to natural resources or the lack of support for the development of cultural, social, financial, natural, human, physical and political capital assets (Bennett and Dearden 2014). This can result in ineffective management,

Figure 6.20: Protected areas of the world



Protected Areas of the World
- Terrestrial protected areas
- Marine and coastal protected areas

Source: UNEP-WCMC and IUCN (2018).

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Box 6.9: Biodiversity conservation and poverty

It is increasingly accepted that biodiversity loss and poverty are closely coupled problems, though seeking to solve one does not automatically address the other (SCBD 2010; Suich, Howe and Mace 2015). Indeed, some approaches to protecting particular species or natural areas have exacerbated existing uneven access to natural resources and placed disproportionate burdens on already-vulnerable populations (Dowie 2009; Sylvester, Segura and Davidson-Hunt 2016). Intergenerational justice is also an important theme, since loss of biodiversity will impoverish future generations in a variety of ways, including reducing their ability to rely upon and connect with a biodiverse natural world.

Biodiversity conservation is likely to be more effective in programmes that successfully integrate social and ecological support, and the benefits from conservation are more likely to be directly accessible by local human populations (Figurel, Durán and Bray 2011; Persha, Agrawal and Chhatre 2011; Fischer *et al*. 2017).

equity issues, lack of accountability or conflict (Halpern *et al*. 2014; Watson *et al.* 2014; Di Minin and Toivonen 2015; Eklund and Cabeza 2017; see also **Box 6.9**). The active engagement of indigenous and local communities in the decision-making process has proven highly effective at addressing these imbalances **(see Box 6.10)**. Analysis of deforestation rates indicate that these can be significantly lower in community-managed forests in comparison to strictly protected areas (Porter-Bolland *et al*. 2012). The development of a more inclusive and integrated approach linking communities with national, divisional and provincial governments for sustainable development has proved highly efficient (see Locally Managed Marine Areas case study in Fiji in Section 13.2.1). Increasingly, indigenous and local communities' contributions and collective actions have the potential to be scaled up and to inform national and international practice and provide a practical governance approach as an alternative to top-down policy-setting.

6.7.4 Other approaches

Many other approaches have evolved to confront biodiversity loss and respond to related drivers. Biodiversity offsets create biodiversity benefits to compensate for losses (Gordon *et al.* 2015; Apostolopoulou and Adams 2017). Controversially based on the monetization of nature (Adams 2014; Costanza *et al.* 2017), offset programmes have been developed in numerous countries within the last ten years. Monetary valuation can serve as a useful tool in underpinning policy instruments such as socioeconomic assessments of public policies and investments, and economic incentives such as payment for ecosystem services, permits and taxation schemes (Bateman *et al.* 2013; Gaworecki 2017). Another economic instrument is the United Nations System of Environmental-Economic Accounting (Experimental Ecosystem Accounting), developed in 2012. Examples of ecosystem accounting have been prepared (e.g. Victoria in Australia, Uganda, and the United Kingdom of Great Britain and Northern Ireland; Eigenraam, Chua and Hasker 2013; UNEP-WCMC and Institute for Development of Environmental-Economic Accounting [IDEEA] 2017; United Kingdom Office for National Statistics 2018), and initiatives to encourage its use in planning have been launched (see https://www.wavespartnership.org and https://naturalcapitalcoalition.org/).

Efforts to address deforestation and forest degradation in developing countries culminated in international agreement under the United Nations Framework Convention on Climate Change (UNFCCC) on methodological guidance for implementing activities relating to reducing emissions from deforestation and forest degradation (REDD) and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries – known as REDD+ (UNFCCC 2018). Forest certification, such as that promoted by the Forest Stewardship Council (https://www.fsc.org/) and the Programme for the Endorsement of Forest Certification (https://www.pefc.org/) provides greater information flow to consumers, encompassing not just logging and extraction but also the social and economic well-being of workers and local communities (e.g. forest management certification

Box 6.10: Female rangers in South Africa

In 2015, a South African ranger group consisting mostly of women, the Black Mamba Anti-Poaching Unit, was one of the winners of the top United Nations environmental prize. The unit was formed in a bid to engage local communities outside conservation parks in protecting biodiversity inside the fences. Initially comprising 26 unemployed female high-school graduates, the unit has reduced snaring by 76 per cent since its launch in 2013, removed more than 1,000 snares, and put five poachers' camps and two bushmeat kitchens out of action (United Nations 2015).

http://www.blackmambas.org/uploads/8/3/5/5/83556980/screen-shot-2016-07-18-at-4-34-38-pm_orig.png

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in Indonesia; Miteva, Loucks and Pattanayak 2015), and transparency and inclusiveness in decision-making. In the European Union (EU) Common Agricultural Policy, some mechanisms have been developed to address environmental problems through protecting and promoting biodiversity in the European countryside.

Within urban settings, a movement towards 'green cities' is gathering pace, especially, but not only, within developed countries (Hegazy, Seddik and Ibrahim 2017), which highlights the protection and expansion of urban forests and green spaces and parks, and the recreational and air quality benefits they provide to people (Salbitano *et al.* 2016), including increased exposure to microbial biodiversity, important for healthy immune responses (Lax, Nagler and Gilbert 2015). Public engagement in urban agriculture, and specific programmes on beekeeping and bird conservation can facilitate human contact with nature in an urban setting. Urban and peri-urban agriculture, when guided by principles of agroecology, with wastes (or by-products) reused as raw materials, promotes self-sufficiency, gender equality, disaster resilience, water and soil conservation and environmental sustainability (FAO 2001; van Veenhuizen 2012).

More generally, ecosystem-based adaptation (EbA) promotes the conservation, sustainable management and restoration of natural ecosystems to help people and communities adapt to climate change (Cohen-Shacham *et al.*2016). However, the effective integration of EbA is challenged by scientific uncertainty at the international scale and disputes over criteria for prioritization (Ojea 2015; Bourne *et al*. 2016).

Ocean governance is particularly complex. Current efforts are focused on the elaboration of the text of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (ABNJ).

6.8 Conclusion

Our understanding of the natural world and the threats posed to its integrity has never been greater. New technologies have allowed us unparalleled insight into the different dimensions of biodiversity, from genomes to biomes. The major pressures on biodiversity are increasingly well-understood – habitat transformation/land-use change, invasive species, pollution, overexploitation including the illegal wildlife trade and climate change – though each of the world's biomes faces distinct challenges, reflecting particular geographic, ecological and socioeconomic contexts. Biodiversity loss is exacerbated where there is significant inequality in wealth and is a major threat to intergenerational justice. But the political and social will necessary to preserve biological diversity has been lacking. While certain policy responses have demonstrated effectiveness in promoting biodiversity conservation, persistent negative trends in almost every aspect of biodiversity indicate the need for more concerted action. Wildlife populations are thinning, reducing their adaptive potential; current rates of species extinctions are estimated to be orders of magnitude greater than background rates, with some scientists suggesting that we may be entering a sixth mass extinction event, and ecosystems are becoming increasingly degraded.

Increased investment in conservation on a global scale is urgently required. Greater focus on strengthening governance systems; improving policy frameworks through research; integration, implementation and effective enforcement; and encouraging partnerships and participation, are all measures that have the potential to address the greatest pressures on biodiversity. Efforts to combat biodiversity loss must also address poverty eradication, gender inequality, systemic corruption in governance structures and other social variables. The path to conserving global biodiversity and to finding solutions for sustainable use is a long but critical journey; humankind depends on it to support nature's contributions to people and the flourishing of health and development.

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