



CHAPTER 3

EARTH'S NATURAL HERITAGE

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Convention on
Biological Diversity

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TITLE PAGE PHOTO

Giraffe (*Giraffa camelopardalis*), Kruger National Park, South Africa. The giraffe is the world's tallest living terrestrial animal, standing up to 5 to 6 metres in height with its unmistakable long neck and legs. It is a native of African dry savannahs and open woodland and browses higher than any other mammal. It is a remarkable species and part of the rich natural heritage of Earth.

Source: Graeme L. Worboys

Introduction

Earth is a very special place. It may seem large, maybe even infinite in size, but when viewing images captured by remote robots from Mars early in the 21st century, we quickly appreciate how Earth is just one bright dot in a vast expanse of space. From Mars, Earth is dwarfed by an immensity of the Milky Way Galaxy and the Universe beyond, and images like these are what help us appreciate that Earth really is a finite ark of life. Earth hosts extraordinary natural wonders, formed over 4.5 billion years of geological and evolutionary change. It is a dynamic world exhibiting breathtaking geological events; oceanic and atmospheric turbulence and turmoil; a relentlessness of forces of weathering, erosion and landform development; and of course, it hosts a remarkably rich assemblage of life forms with their own dynamics of adaptation, evolution and critical contributions to a healthy, liveable planet.

For all of these reasons Earth is a unique planet. It is in the interests of humans and all other species on Earth that its intrinsic values are understood, respected, and its life-support systems are protected and sustained. Securing Earth's natural heritage reinforces the role and importance of protected areas and conservation practice on Earth at a global scale. These areas and such action help to conserve Earth's natural heritage and the essential ecosystem processes, habitats and species that help support life. The moderating influence provided by protection and conservation is essential, given the voracious capacity of Earth's expanding human population to consume and alter natural resources at a rate that threatens the very planetary life-support systems (MEA 2005).

For professionals tasked with managing protected areas, it is imperative that they have a broad understanding of the intrinsic natural values of our planet. In this chapter, we provide this overview. We describe some of Earth's natural processes and its exceptional geodiversity and biodiversity. Then we briefly introduce, at a global scale, the impacts that humans are having on Earth's natural heritage early in the 21st century. This helps to emphasise why protected areas of all types, including governmental, non-governmental, private, and Indigenous Peoples' and Community Conserved Territories and Areas (ICCAs) are needed and why the efforts of each individual manager or ranger working in support of their local protected area or protected area system are so critical. Fundamentally, it is the sum total of these individual and local conservation efforts that is contributing to the retention of life on Earth.

This chapter will also provide an ecoregional context for these individual conservation contributions. It will reinforce how the conservation and protection efforts of each individual protected area professional, each protected area organisation and each nation are in effect part of a much larger global effort of conserving the diversity of life. Park managers and rangers the world over strive to conserve iconic and threatened species while enhancing the viability of protected populations. This could include, for example, protected area managers in Australia helping to conserve the koala (*Phascolarctos cinereus*) and kangaroo (*Macropus* spp.); their counterparts in India and Nepal conserving the tiger (*Panthera tigris*) and rhinoceros (*Rhinoceros unicornis*); in Africa, the elephant (*Loxodonta africana*) and lion (*Panthera leo*); and in North America, the grizzly bear (*Ursus arctos*) and bison (*Bison bison*); and so on. The key point here is that it is a finite world and the conservation of biodiversity is benefiting from a great deal of professional protected area work. For many staff and organisations, there is also collaboration across borders to help conserve habitats for international migratory species.

This chapter includes short descriptions of 12 World Heritage properties to exemplify aspects of the Earth's outstanding natural heritage in conjunction with the primary text. The case studies represent major natural phenomena and ecosystem types in terrestrial, freshwater and marine environments (Figure 3.1). The World Heritage Convention, adopted in 1972, seeks to encourage the identification and protection of cultural and natural heritage of 'outstanding universal value'. Early in the 21st century, the Convention has almost universal adoption among the nations of the world and in 2014 it included 222 of the world's greatest protected areas on its prestigious World Heritage List. Together, the 222 natural and mixed (natural and cultural) properties cover 7 per cent of the total recorded terrestrial protected area and 19 per cent of the total recorded marine protected area (IUCN 2013a), representing a wide range of protected area governance types and management categories.

Earth's natural processes

Protected areas help to conserve nature, but the forces of nature directly affect protected areas and how they are managed. There is a basic expectation that protected area managers will be extremely knowledgeable about how nature, in all its dynamic manifestations, may interact with and affect their area of responsibility. Understanding and interpreting when nature is at work and what is not nature enhance decision-making and implementation of corrective human interventions.

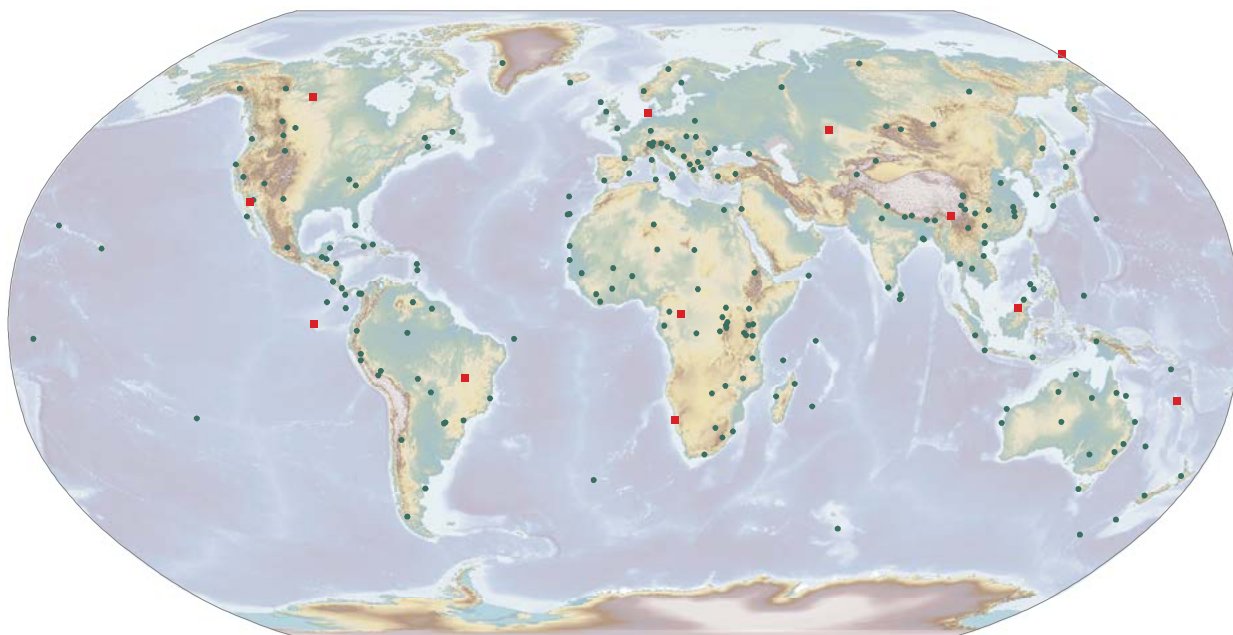


Figure 3.1 Distribution of the 222 natural and mixed World Heritage properties and case study locations (red markers)

Source: IUCN and UNEP-WCMC (2014)

Geological processes

The Earth's crust is the cool, brittle outer layer that includes oceanic crust and continental crust and is collectively referred to as the lithosphere. There are seven major tectonic plates covering the majority of this lithosphere and they are in constant motion. This movement is less observable on a yearly basis, but is clearly manifest over geological time, giving rise to the present-day continental distribution. The localised effects of a dynamic lithosphere may be witnessed in various global locations. Geological phenomena such as sea floor spreading, oceanic plate movement including downward movements below continents (subduction), mountain building, volcanism, earthquakes, weathering, erosion, solution and deposition are all processes affecting the Earth's crust. While these processes occur over geological time frames, protected areas may still be directly affected by them from time to time and especially by earthquakes, volcanism, weathering and erosion. Being prepared for potential geological effects and incidents by understanding the underlying causes for such events is paramount for managers responsible for such areas.

Many famous protected areas help to conserve geological evidence of Earth's dynamic crust (see Chapter 18). Outstanding examples of the effects of these geological processes are, for mountains, Mount Everest and the Dolomites; for karst, the immense caverns in Phong Nha-Ke Bang National Park in Vietnam; for grand, aesthetic waterfalls, Yosemite Falls, USA; and for volcanism, the active volcanoes on the Kamchatka Peninsula, Russia.



Sagarmatha (Mount Everest) National Park World Heritage Property landscape and site of ancient conservation practices

Source: Ashish Kothari

For managers in many of these areas the likelihood of such geological events may be small but in others it is an ever-present risk. For example, the Galápagos Islands World Heritage Property in Ecuador (Case Study 3.1) lies on the fastest moving plate on Earth, the Nazca Tectonic Plate. This plate is moving eastwards and southwards towards South America and has moved over a stationary volcanic thermal plume, triggering frequent volcanic eruptions (Constant 2004). These volcanic eruptions (over a considerable period) formed an archipelago of islands, with the youngest at the hotspot and the oldest, relocated by plate tectonic movements, closer to the South American mainland. The primary succession of increasingly younger islands, isolation and adaptation of species assisted one of the world's greatest naturalists, Charles Darwin, in formulating his theory of natural selection as an argument for evolution.

Case Study 3.1 Galápagos Islands, Ecuador: World Heritage property since 1978

Biogeographic realm: Neotropical; biome: deserts and xeric shrublands

An archipelago of 127 volcanic islands, islets and rocks located about 1000 kilometres off the Ecuadorian coast in the Pacific Ocean, the Galápagos Islands cover more than 140 600 square kilometres of land and ocean. The difference in age between the younger islands in the west and the older ones in the east reveals insights into ongoing geological and volcanic processes. The Galápagos Islands lie at the junction of three major tectonic plates, leading to continuous seismic activity. In fact, the two youngest islands, Isabela and Fernandina, are still being formed.

Charles Darwin was the first to spread the word about how extraordinary the biodiversity is on the Galápagos Islands. The evolutionary process of adaptive radiation can be observed not only on the isolated archipelago compared with the mainland, but also from one island to the next. Darwin's finches may be the world's best-known example

of this, but they are not the only one. Mockingbirds, marine iguanas, land snails, flightless cormorants, giant tortoises and several plant and insect groups have equally been found to demonstrate such evolutionary specialisation, and endemism levels are accordingly high.

The sea surrounding the islands is well protected in the Galápagos Marine Reserve and biodiversity in these waters is just as awe-inspiring as on land. Three oceanic currents meet here, supporting what is considered one of the richest marine ecosystems in the world. To date, more than 2900 marine species have been recorded, with endemism levels exceeding 18 per cent. As a consequence of all of the above, the Galápagos Islands are also known as a living museum and showcase of evolution.

Source: Adapted from UNESCO (2014)

Climate

We often take the Earth's atmosphere for granted and we may assume it has been and will always be the same. But we make this assumption at our peril, for the atmosphere is finite, it is dynamic and it has changed substantially over the 4.5 billion years of Earth's history. Most important is a realisation by humans that it is actually life on Earth that has created the conditions suitable for all other life forms dependent on oxygen. The oxygen in our atmosphere, the oxygen we breathe, has been produced by living organisms and it is this oxygen that continues to be sustained by life on Earth.

Atmospheric composition

In the 21st century, the atmosphere is dominated by nitrogen (about 78 per cent), oxygen (about 21 per cent) and argon (about 1 per cent), with a number of other gases including carbon dioxide and water vapour as well as dust and smoke particles. Oxygen was not present, however, on early Earth. About 3.8 billion years ago, the planet's early atmosphere was established by intense volcanic activity and outgassing that released nitrogen, carbon dioxide, water vapour, ammonia, methane and smaller amounts of other gases. There was no atmospheric oxygen, but water sourced from volcanic steam venting helped form the early oceans on Earth (Palmer 2009).

Living organisms such as blue-green algae used the sunshine, carbon dioxide and water of early Earth to produce carbohydrates and, importantly, oxygen as waste products (Biello 2009). The levels of oxygen gradually built up in the atmosphere, fluctuating over time but supporting the evolution of life. At some critical times,



Bartolome Island, Galápagos Islands World Heritage Property, Ecuador

Source: IUCN Photo Library © Imène Meliane

there has been insufficient oxygen. During the Permian-Triassic about 252 million years ago, for example, sudden and dramatic changes in the composition of the Earth's atmosphere occurred and resulted in a mass extinction event. Massive volcanism and the associated venting of sulphur dioxide and water vapour occurred in the Siberian Traps during this time and the oceans became starved of oxygen, with most marine species as well as many terrestrial plant and animal species becoming extinct (McNamara 2009).

David Beerling, in his book *The Emerald Planet* (2007:44), describes the role of atmospheric oxygen in more recent geological times (during the Phanerozoic) this way: 'Earth's atmospheric oxygen content is intimately linked to the evolution of plant life ... it begins with photosynthesising plants adding to the oxygen of the atmosphere as they manufacture biomass.'

He states that when plants (marine or terrestrial) die there are 'rich pickings for animals, bacteria and fungi that break down their remains, consuming oxygen in the process' (Beerling 2007:44). Beerling (2007:44) also identifies, however, that not all of the organic material is decomposed and

the gradual and continual burial of the fragmentary remains of plants on land and in the sea means that a fraction of the oxygen produced during its synthesis cannot be reclaimed by chemical or biological processes. Instead, it is free to accumulate, adding tiny amounts of oxygen to our atmosphere year by year.

Later, geological processes of uplift, weathering and erosion expose and breakdown these rocks, consuming oxygen in the process (Beerling 2007). During this oxidation, the balance of oxygen in the atmosphere is restored, and this process controls the oxygen content in the atmosphere over geological time, though 'the oxygen content of the air we breathe is not fixed at 21 [per cent]' (Beerling 2007:59)—it does vary.

The composition of the atmosphere is dynamic, oxygen levels are sustained by life on Earth and human activities such as habitat destruction do affect this balance and process. Protected areas help to maintain healthy ecosystems that directly benefit oxygen levels in the atmosphere, ecological processes and the life-supporting health of our atmosphere.

Carbon dioxide, a powerful greenhouse gas, is another gas whose concentration in the atmosphere varies, especially in recent times as a consequence of human activity. This change in concentration through human-caused pollution has serious consequences for the climate (see Chapter 17), and retaining and managing natural carbon stocks and sinks is an important part of the human response to this threat. Protected areas, for example, help conserve natural forests—the world's largest terrestrial carbon sink—so that they may continue to sequester carbon. Maintaining natural forests is one critical 'natural solution' to the Earth's deepening climate change challenge (Dudley et al. 2010) (see Chapter 17). Some key marine environments such as seagrass meadows are

also important carbon sinks (see Chapter 20). Protected areas have the potential to be a key element in our efforts to reduce carbon dioxide pollution to minimise the negative effects of global warming. Protected areas also help to reduce dust and aerial contaminants and achieve a healthier chemical composition of the atmosphere.

Atmospheric circulation

Air is constantly moving and atmospheric circulation simplistically may be described as warm air moving to higher latitudes and cold air moving towards the tropics, though of course this is complicated by the Coriolis effect and the effects of the jet stream. Ancient sailors took advantage of Earth's prevailing winds, just as seasonal shifts in wind direction herald the arrival of monsoons and the life-giving rains required for agriculture. Such changes in seasonal wind conditions may also reflect the onset of the dry season.

The overall atmospheric circulation influences the climate experienced by any protected area. It influences the nature of seasons, the daily weather and the condition and change in condition of species and their habitats. Climate change-caused higher average air temperatures may result in higher evaporation, greater water moisture in the atmosphere, higher energy levels and more frequent high-energy storm events in some areas. In other areas, dryness and droughts have been enhanced. In a 21st-century climate change world, the nature of the atmospheric circulation is changing and protected area managers need to understand the implications of this dynamic in terms of the weather events that the changes may trigger as well as any consequent changes to the natural environments of the protected areas for which they are responsible.

Climates of the world

Climate is the average pattern of weather determined over a very long time by measures such as temperature, precipitation, wind and atmospheric pressure. For any given protected area, the climate will also be influenced by the latitude, altitude, terrain, proximity to mountains and proximity to large water bodies. The broad climates of the world have been mapped using the Köppen-Geiger system of climate classification, which recognises 12 distinct climates for Earth (Table 3.1).

Table 3.1 Twelve distinct climates of Earth

Tropical rainy climates	
For tropical rainy climates, the average annual temperatures are above 18°C, there is no winter season and annual rainfall is large and exceeds annual evaporation. They include:	
	Hot climates with year-round rain (the rainfall of the driest month is > 6 cm)
	Hot climates with monsoon rain (the rainfall of the driest month is < 6 cm)
	Hot climates with seasonal rains—tropical savannah climates (the rainfall of the driest month is < 6 cm and the dry season is strongly developed)
Dry climates	
For dry climates, evaporation exceeds the precipitation on average throughout the year. These climates include:	
	Steppe climates—characterised by grasslands (this is an intermediate climate between desert climates and more humid climates)
	Desert climates (these are arid areas where the annual precipitation is < 40 cm)
Mild humid climates	
Mild humid climates have both a summer and a winter, with the coldest month being less than 18°C but above –3°C and at least one month is above 10°C. These climates include:	
	Mild humid climates with no dry season (precipitation in the driest month is > 3 cm)
	Mild humid climates with a dry winter (where 70 per cent of the precipitation falls in the warmer six months)
	Mild humid climates with a dry summer (where 70 per cent of the precipitation falls in the six months of winter)
Snowy-forest climates	
The average temperature of the coldest month is less than –3°C and the warmest month average temperature is above 10°C. These climates include:	
	Snowy-forest climate with a moist winter (no dry season)
	Snowy-forest climate with a dry winter
Polar climates	
The average temperature of the warmest month is below 10°C and there is no true summer. These climates include:	
	Tundra climate (where the mean temperature of the warmest month is above 0°C but below 10°C)
	Perpetual frost climate (where the mean monthly temperatures of all months are below 0°C)

Source: Strahler (2011:260–2)

The climates of Earth do change. Meteorologists have used models enabling them to forecast changes in climates based on increased concentrations of carbon dioxide and they have identified broad patterns that include enhanced temperatures, more or less rainfall, enhanced droughts, and more frequent severe storm events. These climate change effects will challenge protected area managers and their conservation management of biodiversity as these climatic shifts may bring shifts in species distributions that cannot be captured by static protected area boundaries (see Chapter 17).

Oceans

The five great oceans covering more than 70 per cent of Earth's surface are a remarkable part of dynamic Earth. They are perpetually in motion, whether this is caused by tides, surface water circulation, wind effects and waves, local currents, deep-water currents, upwellings

or by other means. Adding to this are the influences of severe storms and their associated storm surges as well as earthquakes and their potential tsunami phenomena. The relative sea-level has also changed over geological time and these fluctuations have helped shape our coastal environments. The Pleistocene and Holocene sea-level lows, for example, influenced the movement of humans out of Africa and the colonisation of other continents (see Chapter 4). As a result of human-caused climate change, the world today is witnessing rising sea-levels due to the thermal expansion of sea water and the melting of glaciers around the world—notably, the Greenland ice cap and Antarctic ice cap (IPCC 2013).

The higher carbon dioxide levels in the atmosphere and their consequential higher temperatures are affecting both the average temperatures of the world's oceans and their acidity (given greater amounts of dissolved carbon dioxide and the formation of a mild acid). This in turn has affected life in the oceans including bleaching of

coral reef systems and acidification impacts such as the rate of calcification or dissolution of marine organisms like corals, crustaceans and molluscs (see Chapters 17 and 20).

The recent rate of human-caused atmospheric changes has been a catalyst for enhancing natural phenomena. Increased sea-levels and greater energy in storm systems will bring the transformation of coastal landforms that have been stable for at least 8000 years as well as the creation of new landforms. This could include the erosion of coastal sand deposits such as beaches, sand spits, foredunes and dune barrier systems; the drowning of low-lying salt marshes, wetlands, low-lying river valleys and deltas; and the enhanced and more energetic erosion of headlands and barrier reef systems due to more frequent high-energy storm events (Short and Woodroffe 2009).

Protected area managers need to understand these dynamic marine processes in addition to the conservation needs of the world's marine and coastal biodiversity. Many coastal and marine protected areas will feel the full force of climate-affected and turbocharged nature in the future. Anticipating and responding to these inevitable situations will require managers to integrate their knowledge of these forces and associated impacts using the prevailing science as well as their experience of local circumstances. Undoubtedly, these strategies will also be influenced by variable sociopolitical regimes and global attitudes to climate change.

Managers also need to anticipate the high probability that there may be reactive political responses to protected area issues when the full effects of climate change are finally acknowledged. One enemy that managers face is the seemingly 'quick-fix' political response, with such responses potentially being harmful to their protected areas. The manager needs to anticipate inevitable issues and bring forward, well in advance, carefully considered solutions based on rigorous science. Managers should constantly and clearly present such cases for adaptive responses (see Chapter 17).

Geodiversity

Geodiversity is the term used to describe the geological component of abiotic nature and is defined by Gray (2004:8) as '[t]he natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems.'

For managers, a fundamental understanding of geodiversity and more specific concepts such as geoheritage and geoconservation is an integral part of conserving protected areas. All of these terms have been defined in this book (see Chapter 18), and the importance of geodiversity as a foundation for life and as a key determinant of biodiversity for a protected area is also presented.

The geodiversity of Earth is in a dynamic state. New rocks are formed through plutonic (below the Earth's surface) and volcanic (above the Earth's surface) processes, through sedimentary deposition and compaction, and through metamorphism and metasomatic effects. These rocks, when exposed on the surface, are affected by physical, chemical and biological weathering as well as erosion. The erosion may be by water, wind and ice (glaciation) and the subsequent deposition of eroded material may produce water-borne, wind-borne and glacial deposits. Volcanic eruptions produce ash, *nuée ardente* (ultra-hot, rapidly downward-moving volcanic ash flow) and aerosol deposits. Rare meteorite impacts create unique craters and potentially ring structures.

The mass movement of material on steep slopes may generate avalanches of rock debris, the movement of unconsolidated soil and debris and rapidly moving lahars (water-saturated rock and mud flows). Landslides, cliff collapses, solifluction (movement caused by freeze and thaw) and slumping on steep slopes are all part of these dynamic erosion processes. New landforms are also generated. Tectonic activity can give rise to new mountain or basin structures; it can precipitate landslides and the damming of rivers and can cause tsunamis in marine environments. New volcanoes may be formed, geothermal areas with their geysers produce sinter deposits; carbonate-charged rivers generate travertine and tufa deposits; and waterfalls and sediment-charged river systems create levees, islands and deltas. The geodiversity of Earth is indeed rich in dynamic natural processes for protected area managers to consider when planning and managing the geoheritage of their area (Gray 2004). There is a level of technical detail that managers may need to appreciate, as illustrated by the following examples.

- **Rock type:** The presence of serpentinite and other ultramafic rocks often includes elevated concentrations of chromium and nickel that are toxic to some plants and influence the composition of vegetation.
- **Suitability of rock types as track and road materials:** The chemical make-up of different volcanic and plutonic rocks, especially the type of feldspar(s)

Case Study 3.2 Gunung Mulu National Park, Malaysia: World Heritage property since 2000

Biogeographic realm: Indo-Malayan; biome: tropical and subtropical moist broadleaf forests

Located on the island of Borneo, Gunung Mulu National Park covers almost 530 square kilometres of land and includes the world's most researched tropical karst area. With its deep canyons, wild rivers, waterfalls and rainforest-covered mountains, the highest of which reaches almost 2380 metres, Gunung Mulu's landscape features spectacular natural beauty. In addition, underneath its surface, the site features some of the world's largest caves. Sarawak Chamber, 600 metres long and 415 metres wide with a height of 80 metres, is considered one of the largest cave chambers discovered globally. The world record for the largest cave passage and the longest cave in Asia can be found here. The site is also significant as an extraordinary example of major changes in Earth's history. Three major rock formations made of shale, sandstone and limestone occur, and their terrestrial alluvial deposits, jointly with

the subterranean geomorphology and hydrology, reveal important information about the tectonic and climatic evolution of Borneo.

Gunung Mulu's biodiversity is also exceptional. Within 17 different vegetation types, the site supports as many as 3500 species of vascular plants, and with 109 species is among the richest sites in the world for palms. More than 200 species of cave fauna have been identified and Deer Cave supports the largest bat species richness recorded in a single cave. It is also home to one of the world's largest colonies of free-tailed bats (*Chaerephon plicata*), exceeding three million individuals. Another cave hosts the world's largest colony of cave swiftlets (*Aerodramus* sp.). Many species occurring here are endemic and 41 are considered endangered.

Source: Adapted from UNESCO (2014)

(a rock-forming mineral) present, influences the suitability of the rock type as track construction material and whether a track or road should be constructed within such geological parent material. It will also influence the cost of track construction.

- Limestone and dolomite karst: The need to manage for subterranean water flows, troglobitic fauna and the conservation and protection of caves, speleothems, sub-fossil deposits and cave-based human cultural values such as at the World Heritage property of Gunung Mulu National Park in Malaysia (Case Study 3.2).
- Geothermal areas: The need to deal with visitor safety in environments of superheated water and mud and rare extremophile fauna and flora.
- Mountains and cliff areas: Considerations for the safety of people for potential cliff edge collapse and landslides.

Protected area management teams may include geologists or geophysicists or they may seek such expertise to assist with decision-making for a range of these dynamic Earth processes.

Biodiversity

Life on Earth is precious, reflecting ancient beginnings with the simplest of life forms billions of years ago to the past 600 million years of extraordinary evolutionary development. Life has endured five major extinction events and may be on the verge of a sixth—the first to be caused by humans (Box 3.1). From the poles to the equator, from continent to continent, there is an immense diversity of life. The distribution of plants, animals and



Gunung Mulu National Park, Borneo, Malaysia

Source: IUCN Photo Library © Jim Thorsell

other organisms is not even and is influenced by dynamic geological processes, the world's climates, its geodiversity and its geographical-based evolutionary development. In this section, we introduce this rich biodiversity including Earth's species and their major habitats.

For the establishment and management of effective protected areas it is essential to have at least a basic understanding of an area's biodiversity features, including key species and ecosystems, their conservation status and the conservation actions required to maintain or improve their status. Information on the area's global or national irreplaceability for the conservation of specific biodiversity features, if available, can also help guide protected area establishment and management (Ricketts et al. 2005; Langhammer et al. 2007; Le Saout et al. 2013).

Defining biodiversity

So, what is biodiversity? The term biological diversity, or biodiversity, refers to the variety of life on Earth. This includes plants, animals, fungi and micro-organisms, the genetic information they contain, the ecosystems they form and the ecological processes that bind them across multiple scales. Biodiversity has been defined in Article 2 of the UN Convention on Biological Diversity (CBD) as the 'variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (CBD 1992:3).

A species is widely defined as a group of organisms with a shared, closed gene pool (for example, the giant panda, *Ailuropoda melanoleuca*, is a species), although speciation can also occur without genetic isolation. Genes hold the information to develop and maintain an organism's cells and pass this information to offspring. A habitat is the natural environment in which a particular organism lives (for example, temperate montane forests with dense stands of bamboo in China are the habitat of the giant panda), and an ecosystem is a community of living organisms together with their non-living environment (for example, a forest with its soils, a lake or river with its bed, or a coral reef ecosystem with its surrounding waters).

Major divisions of species

Almost all species are directly or indirectly dependent on primary production through photosynthesis or chemosynthesis. Plants are multicellular organisms in the taxonomic kingdom Plantae and include, for example, all flowering plants (angiosperms), conifers

and other gymnosperms, ferns and mosses. Using energy from light (photosynthesis), most plants produce oxygen and organic compounds such as carbohydrates from inorganic molecules such as carbon dioxide and water. Plants are the primary producers in most terrestrial ecosystems and form the basis of the food web in those ecosystems. Algae and phytoplankton fulfil the same function in marine and other aquatic ecosystems. Some micro-organisms such as bacteria can also use the energy released by chemical reactions (chemosynthesis) to produce organic matter.

Animals are multicellular organisms in the taxonomic kingdom Animalia and include, for example, mammals, birds, reptiles, amphibians, fish, insects, corals and sponges. Animals function as consumers in terrestrial, marine and other aquatic food webs and obtain organic carbon by eating primary producers or other animals. Unlike plants, most animals are able to move spontaneously and actively in a purposeful manner, at least at some stage of their life.

Fungi form their own taxonomic kingdom, for they are neither plants nor animals, and can be both unicellular (for example, yeasts) and multicellular (for example, moulds and mushrooms). They perform an essential role in the decomposition of organic matter and, together with all other organisms, play an important role in nutrient cycling and recycling, and the functioning of ecosystems.

Measuring biodiversity

Biodiversity can be measured in many different ways (Gaston 2000; Purvis and Hector 2000; Groombridge and Jenkins 2002; Hoekstra et al. 2010). From a 'compositional' perspective, one of the most commonly asked questions is: how many species are there on Earth? Global species estimates vary greatly and, in the past, have ranged from three million to more than 100 million species. One recent estimate arrives at 9.9 million eukaryotic species—that is, 'higher life forms' that have a membrane-bound cell kernel, of which 19 per cent have been described (Chapman 2009; Table 3.2). Another recent study estimates there are 8.7 million (± 1.3 million) eukaryotic species globally, of which some 14 per cent have been described (Mora et al. 2011). Estimating the number of prokaryotic species, which do not have a membrane-bound cell kernel (for example, bacteria), is difficult and recent estimates still vary from as little as 10 000 to more than one million (Chapman 2009; Mora et al. 2011).

Table 3.2 Described eukaryote species and possible total number of species

Kingdom	Estimated number of described species	Estimated total number of species
Animalia (animals)	1 424 153	6 836 330
Plantae (plants)	310 129	390 800
Fungi	98 998	1 500 000
Other eukaryotes (for example, algae)	53 915	> 1 200 500
Total	1 887 195	9 927 630

Source: Adapted from Chapman (2009)

Many of the species described so far are considered threatened—that is, they are facing a higher risk of extinction as a result of human-derived or natural impacts. The IUCN Red List of Threatened Species provides a global standard for assessing and recording the conservation status of species, the threats affecting them and the conservation actions in place or required (Rodrigues et al. 2006; Mace et al. 2008; Salafsky et al. 2008). At the beginning of the 21st century, 41 per cent of the world's amphibians, 25 per cent of the mammals and 13 per cent of the birds are recognised as being 'critically endangered', 'endangered' or 'vulnerable' (IUCN 2013b). Plant groups with a high proportion of such threatened species include cycads (63 per cent), conifers (34 per cent) and cacti (31 per cent) (IUCN 2013b). Recent extinction rates have been estimated to be 100 to 1000 times higher than in prehuman times (Pimm et al. 1995), and this has led to suggestions that the sixth major extinction event in Earth's history may be underway (Leakey and Lewin 1992; Box 3.1).

Major divisions of ecosystems

An ecosystem is defined as a biotic community (an association of interacting species populations) and its abiotic environment (for example, climate, water, soil and sunlight), and these ecosystems can be at various scales, with larger-scale ecosystems synonymous with a landscape or seascape (Sinclair et al. 2006). The most basic classification of ecosystems distinguishes terrestrial, freshwater and marine ecosystems. Within each of these broad classes, a number of major ecosystem types can be distinguished, each characterised by fairly similar climatic conditions and ecological communities (for example, tropical and temperate forests, mountains, lakes, rivers and coral reef ecosystems). These major ecosystem types (or biomes) are described in the next section. Similar to species, ecosystems can also be threatened, and a corresponding IUCN Red List of Threatened Ecosystems is currently under development (Rodríguez et al. 2011).

Box 3.1 The sixth major extinction event: triggered by humans?

The number of species alive has probably never been greater than today, although up to 99 per cent of all species that ever lived on our planet have become extinct. Extinction is a widespread natural process that usually occurs slowly, affecting only small numbers of species over long periods (Barnosky et al. 2011). As a result of human activities, however, populations of many species are likely to go extinct in the near future, or have already gone extinct in prehistoric and historical times (Barnosky et al. 2011; Dullinger et al. 2013; Duncan et al. 2013).

Due to various natural causes, Earth has experienced five mass extinctions in the past, each time losing more than 75 per cent of all species in a geologically short period (several hundred thousand to several million years) (Barnosky et al. 2011). The most famous of these is the Cretaceous event around 65 million years ago, which was most likely triggered by a meteorite impact and subsequent rapid global cooling, which ended the 'age of the dinosaurs'.

Based on recent extinction rates, which are already substantially higher than in prehuman times (Pimm et al. 1995), and the extinction risk of extant species recorded in the IUCN Red List of Threatened Species (IUCN 2013b), it has been estimated that Earth could again lose 75 per cent of all species within as little as three centuries (Barnosky et al. 2011). This suggests that the sixth mass extinction is under way—for the first time caused by an individual species: humans.

As human societies begin to respond to the ongoing biodiversity extinction crisis, conservation actions—including area-based conservation measures such as protected areas—can help to prevent extinctions, or reduce the extinction risk of species and populations (for example, Butchart et al. 2006, 2012). The Alliance for Zero Extinction (AZE), for example, is coordinating work to identify and protect centres of imminent extinction where highly threatened species are confined to single sites (Ricketts et al. 2005; Figure 3.10).

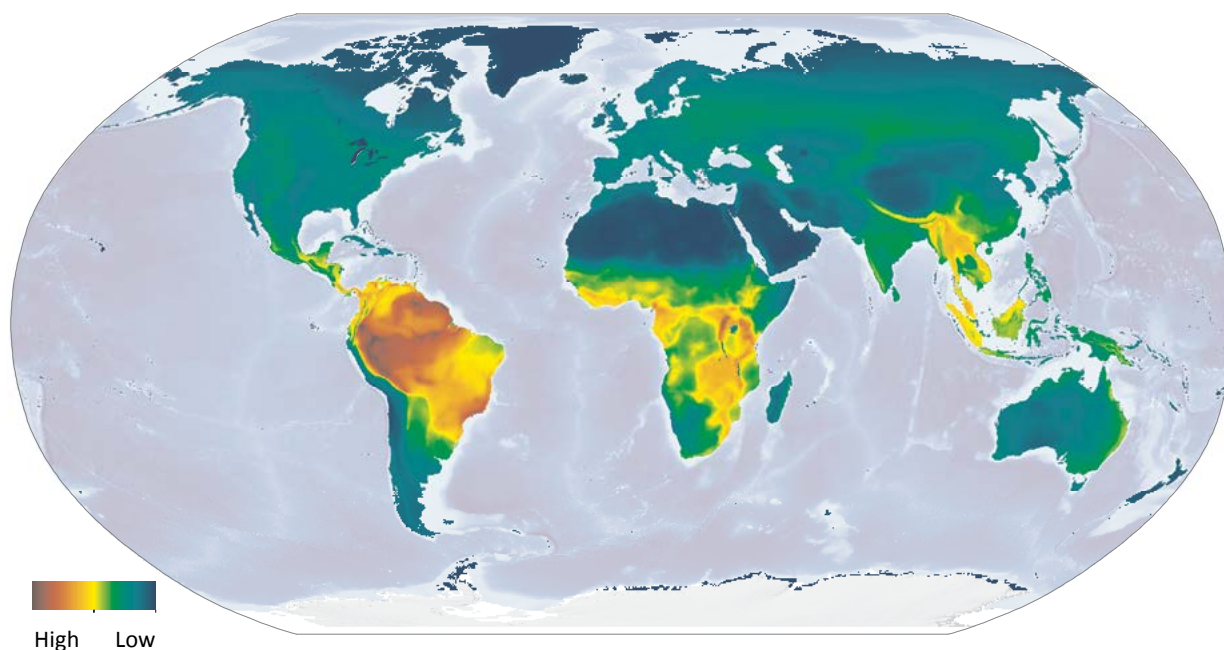


Figure 3.2 Global diversity of mammal, bird and amphibian species

Source: Modified from SavingSpecies and Globaia (2012), based on data provided by IUCN, BirdLife International and NatureServe

All ecosystems together make up the world's biosphere—that is, all the places from the top of the atmosphere to the bottom of the ocean and into the Earth's rocks and soils that are occupied by living organisms. The biosphere is an intricately interconnected system, and ultimately sets the rules for the survival of species of all sorts, including humans (White 2003). The biosphere has evolved over billions of years in interaction with the non-living environment (atmosphere, hydrosphere and lithosphere) and this has determined the natural distribution of biodiversity on Earth.

Distribution of biodiversity

Biodiversity is not evenly distributed across the Earth. The number and type of species and ecosystems present change with factors such as climate, altitude, latitude, available space, time and energy (Gaston 2000). Overall species richness, for example, increases from polar regions to temperate regions to the tropics (Figure 3.2). This also applies within most of the taxonomic groups (for example, there are more bird species in the tropics than in temperate regions) and within most similar ecosystems (for example, there are more species in tropical forests than in temperate forests) (Gaston 2000).

Biogeography is the study of the distribution of species and ecosystems in space and time. Biogeographic classification systems seek to delineate distinct ecological areas based on their biotic and abiotic characteristics, including the Earth's broad climate zones. They help to understand Earth's natural heritage and are widely viewed

as essential tools for biodiversity conservation science, policy, planning and management. Global classification systems are used by biodiversity related conventions such as the CBD, Ramsar Convention and World Heritage Convention to guide the identification, classification and conservation of important biodiversity sites, and to establish and manage ecologically representative networks of protected areas. The CBD also has several thematic programs that deal with specific 'biomes', including marine and coastal ecosystems, inland waters, mountains, islands, forests and drylands. In addition to the global classification systems, many national and regional classification systems exist, informing conservation policy and practice.

Different approaches to biogeographic classification of the world's terrestrial, freshwater and marine environments have been developed and refined over time, serving different purposes, and all of them have limitations (Ladle and Whittaker 2011; Whittaker et al. 2013). Some recent approaches make use of our ever-increasing but still imperfect knowledge of species distributions and the phylogenetic relationships of species to delineate biogeographic regions (Kreft and Jetz 2010; Holt et al. 2013). Other approaches subdivide the world into major biomes and ecoregions based on the distribution of ecological communities.

Several of the last approaches have been developed specifically for, and found wide application in, the field of biodiversity conservation. These include the biogeographical provinces defined by Udvardy (1975)

Table 3.3 Selected biogeographic classification systems for terrestrial, freshwater and marine areas

System	Description	Units	References
Terrestrial ecoregions of the world (TEOW)	Provides a classification of the world's terrestrial ecosystems. Based on review of existing information and expert knowledge. Overlaps with freshwater ecoregions	Nested system of 8 realms, 14 biomes and 827 terrestrial ecoregions	Olson et al. (2001)
Freshwater ecoregions of the world (FEOW)	Provides a classification of the world's freshwater ecosystems. Based on the distributions and compositions of freshwater fish species and major ecological and evolutionary patterns. Overlaps with terrestrial ecoregions	426 freshwater ecoregions	Abell et al. (2008)
Marine ecoregions of the world (MEOW)	Provides a classification of the world's coastal and shelf waters (< 200 m depths). Based on review of existing information and expert knowledge of pelagic and benthic biotas. Closely aligns with the pelagic provinces of the world	Nested system of 12 realms, 62 provinces and 232 marine ecoregions	Spalding et al. (2007)
Pelagic provinces of the world	Provides a classification of the world's off-shelf surface waters (< 200 m depths). Based on review of existing information and expert knowledge of pelagic biota. Closely aligns with the marine ecoregions of the world	Nested system of 4 realms, 7 biomes and 37 pelagic provinces	Spalding et al. (2012)
Deep-sea benthic provinces of the world	Proposes global biogeographic provinces for the lower bathyal and abyssal benthos (> 800 m depths). Based on oceanographic proxies and location data for select benthic marine species	Proposed system includes 14 lower bathyal (800–3500 m) and 14 abyssal (3500–6500 m) provinces	Watling et al. (2013)

under IUCN auspices, and the more recent terrestrial, marine and freshwater ecoregions of the world (Table 3.3; Olson et al. 2001; Spalding et al. 2007; Abell et al. 2008). These systems have been used, for example, in ecological gap analyses of the global protected area network and to measure progress towards the protected area targets of the CBD (Brooks et al. 2004; Chape et al. 2005; Spalding et al. 2008; Jenkins and Joppa 2009; CBD 2010a; Bertzky et al. 2012). Additional systems have recently been developed to cover the high seas (Table 3.3; Spalding et al. 2012; Watling et al. 2013). These systems can be used for conservation science, policy, planning and management (Hoekstra et al. 2010).

Terrestrial biomes

The 'terrestrial ecoregions of the world' system of Olson et al. (2001) is used here to describe in more detail the natural distribution of terrestrial ecosystems on Earth. It recognises eight biogeographic realms—large areas within which organisms have been evolving in relative isolation over long periods—and 14 vegetated biomes (Figure 3.3). While the realms are characterised by the related evolutionary history of the organisms they contain, the biomes represent major ecosystem types that are characterised by fairly similar climatic conditions and

ecological communities. Major biomes such as forests, grasslands and deserts are easily recognised, including from space, and influence the distribution of species on Earth.

Key characteristics of each of the 14 biomes are summarised below based on Olson et al. (2000). Mountains are briefly described as a separate biome as recognised by Udvardy (1975). Throughout this section, we use World Heritage case studies to showcase a selected sample of the world's most widespread biomes.

Tropical and subtropical moist broadleaf forests

This biome occurs around the world mostly along the equatorial belt and between the Tropics of Cancer and Capricorn as large, discontinuous patches of semi-evergreen and evergreen forests. Their largest stretches can be found in the Amazon Basin, the Congo Basin (Case Study 3.3) and the Indo-Malayan archipelagos. Low variability in annual temperature combined with high levels of rainfall (> 2000 millimetres annually) is characteristic for this biome. Tropical and subtropical moist broadleaf forests harbour the highest number of species of any terrestrial biome—estimated to account

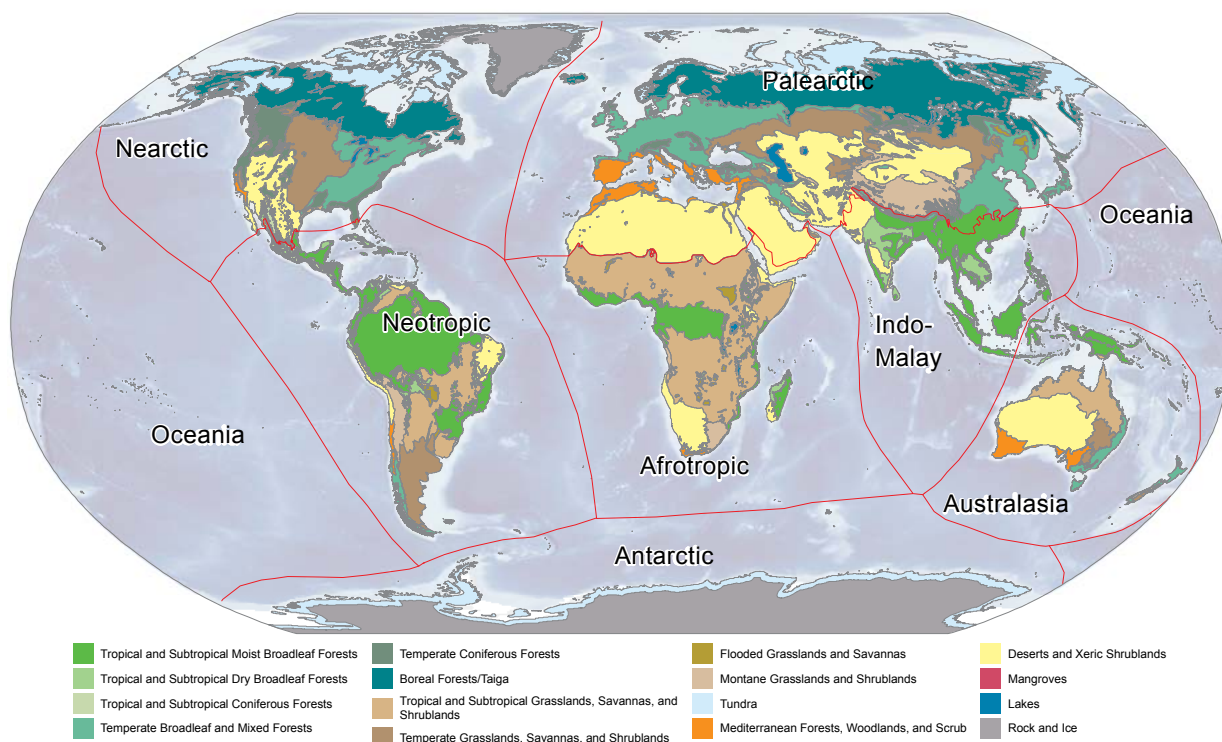


Figure 3.3 The eight biogeographic realms and 14 biomes of the world

Source: Modified from Olson et al. (2001)

for up to half of the world's known species (Figure 3.2). Species richness is highest in the forest canopies, while a lack of sunlight makes life on the forest floor less varied. Still, one square kilometre of these forests can host as many as 1000 different species of trees. With a total of 50 ecoregions, tropical and subtropical moist broadleaf forests include more ecoregions than any other biome, further emphasising their diversity and complexity.

Tropical and subtropical dry forests

Just as in rainforests, in this biome temperature varies little, and there is enough rainfall for forests to grow. There is, however, a dry season lasting several months, causing deciduous instead of evergreen tree species to dominate the forest. When the trees shed their leaves to conserve water during the dry season, sunlight can reach the forest floor, supporting the growth of dense understorey vegetation. Tropical and subtropical dry forests provide important habitat for wildlife, including monkeys, large cats, parrots and ground-dwelling birds. Overall biodiversity, however, is lower than in tropical and subtropical moist broadleaf forests. The biome can be found in southern Mexico, valleys of the northern Andes, coastal Ecuador and Peru, eastern Bolivia and central Brazil, the Caribbean, south-eastern Africa, Madagascar, central India, Indochina, the Lesser Sundas and New Caledonia.



Sangha Trinational, Cameroon, Central African Republic and Republic of the Congo

Source: IUCN Photo Library © Charles Doumenge

Case Study 3.3 Sangha Trinational, Cameroon, Central African Republic and Republic of the Congo: World Heritage property since 2012

Biogeographic realm: Afrotropic; biome: tropical and subtropical moist broadleaf forests

Combining three national parks in the Congo Basin—Parc National de Lobéké in Cameroon, Parc National de Dzanga-Ndoki in the Central African Republic and Parc National de Nouabalé-Ndoki in the Republic of the Congo—this trans-boundary World Heritage property covers about 7500 square kilometres of land. The property's diverse ecosystems include tropical evergreen forests, swamp forests and periodically flooded forests, as well as various types of forest clearings, all of which are connected at a landscape level.

The property is outstanding due to the maintenance of ecological and evolutionary processes in a mostly

intact forest landscape at huge scale, and a large buffer zone surrounding the property in all three countries helps conserve this status. The property supports viable populations of many forest species such as the critically endangered tree species mukulungu (*Autranella congolensis*), critically endangered western lowland gorilla (*Gorilla gorilla*), endangered chimpanzee (*Pan troglodytes*), the endangered antelope species sitatunga (*Tragelaphus spekii*) and bongo (*Tragelaphus eurycerus*), and forest elephants (*Loxodonta cyclotis*). The numerous types of forest clearings are also home to unique plant assemblages.

Source: Adapted from UNESCO (2014)

Tropical and subtropical coniferous forests

Characterised by different species of conifers, these forests occur in semi-humid climates in tropical and subtropical regions. They are areas with limited rainfall and moderate annual temperature variability. The cover of tropical and subtropical coniferous forests is dense, allowing little sunlight to reach the forest floor. Fungi and ferns dominate the understorey, together with some shrubs and small trees. Tropical and subtropical coniferous forests are important for biodiversity as they are often used as winter refuges for migratory birds or butterflies. Local endemism can be high, especially where the forest occurs in more humid areas or on unusual soils. The most diverse forests falling into this category are in Mexico. The largest extents can be found in North and Central America, but the biome also occurs in some parts of Asia.

Temperate broadleaf and mixed forests

These are forests in temperate climates, where variation in rainfall and temperature over the year is much larger than in tropical and subtropical regions. Where rainfall is more evenly distributed, deciduous species can occur together with broadleaved species. Oak (*Quercus* spp.), beech (*Fagus* spp.), birch (*Betula* spp.) and maple (*Acer* spp.) are commonly found in northern temperate forests, and the southern beeches (*Nothofagus* spp.) in the Southern Hemisphere. Unlike tropical rainforests, in these forests biodiversity is much higher towards the forest floor compared with the canopy. Important areas of temperate broadleaf and mixed forests are in eastern North America, south-western South America, Europe, Russia, the Caucasus, the Himalaya, East Asia, Australia and New Zealand.

Temperate coniferous forests

Warm summers and cool winters support this type of evergreen forest, which is typically found in coastal areas with mild winters and heavy rainfall, further



Three Parallel Rivers of Yunnan Protected Areas, China

Source: IUCN Photo Library © Jim Thorsell

inland where climates are drier or in mountainous areas. Pine (*Pinus* spp.), cedar (*Cedrus* spp.), fir (*Abies* spp.), juniper (*Juniperus* spp.), spruce (*Picea* spp.), podocarpus (*Podocarpus* spp.) and redwood (*Sequoia*, *Sequoiadendron* and *Metasequoia* spp.) are among the common tree species. Needle-leaf species do not always dominate this biome; in some places the forest is composed of broadleaf evergreen species or a mixture of both broadleaf and needle-leaf species. Temperate coniferous forests store the highest levels of biomass of all terrestrial ecosystems and trees can reach an average height of 50–85 metres (*Sequoiadendron giganteum*). These forests can be found, for example, in western and south-eastern North America and many mountain ranges of the Palearctic realm (Case Study 3.4).

Case Study 3.4 Three Parallel Rivers of Yunnan Protected Areas, China: World Heritage property since 2003

Biogeographic realm: Palaearctic; biome: temperate coniferous forests

Spanning a total of 17 000 square kilometres, the Three Parallel Rivers of Yunnan Protected Areas in Yunnan Province, southern China, combines 15 protected areas grouped into eight geographical clusters. As its name indicates, this serial (multi-part) property includes upper sections of three of the great rivers of Asia—the Yangtze, Mekong and Salween—which run roughly parallel from north to south through the incorporating Three Parallel Rivers National Park. The landscape is stunning, with the rivers running through gorges up to 3000 metres deep flanked by snow-covered peaks of up to 6000 metres in altitude. The mountains display a range of different rock types and landforms, including alpine karst, granite monolith and Danxia sandstone, reflecting the property's varied geological history. Dense forests, lakes and meadows dominate the landscape between the rivers.

The combination of a wide range of altitudes, climates and habitats close to the intersection of three major biogeographic realms (East Asian, South-East Asian and Tibetan Plateau) favours very high biodiversity. Nowhere in China is biodiversity richer than in the north-west of Yunnan Province, and compared with other temperate regions this property may be the most biologically diverse. About 6000 plant species have been identified to date, and up to 25 per cent of the world's animals are believed to occur here, many of which are endemic, relict or endangered. Well-known examples include the red panda (*Ailurus fulgens*), Chinese grouse (*Bonasa sewerzowi*) and Asiatic wild dog (*Cuon alpinus*).

Source: Adapted from UNESCO (2014)

Boreal forests and taiga

This biome occurs where annual temperatures are low and precipitation, falling mostly as snow, ranges between 400 and 1000 millimetres per year. Soils can be under permafrost and drainage consequently is poor, leading to low nutrient levels. Many tree species are not able to grow on such soils, but there are exceptions, including coniferous and broadleaf tree species such as fir (*Abies* spp.), spruce (*Picea* spp.), larch (*Larix* spp.), pine (*Pinus* spp.), birch (*Betula* spp.) and poplar (*Populus* spp.). Mosses and lichens typically dominate the ground layer. While less rich in species numbers and endemism, this biome is an important stage of large-scale migrations of caribou (*Rangifer tarandus*). In addition, some places still harbour intact assemblages of predators with large home ranges. These species depend upon vast expanses of boreal forests and taiga, or at least large-scale linkages of natural habitat, to allow movements in response to natural disturbance regimes. This vast biome is restricted to the northern Palaearctic and Nearctic, with the largest expanses occurring in central and eastern Russia, followed by Canada (Case Study 3.5).

Tropical and subtropical grasslands, savannahs and shrublands

This biome is characterised by little annual temperature variation, rainfall between 900 and 1500 millimetres, and distinct wet and dry seasons. Drought conditions and frequent natural fires during the dry season lead to a landscape dominated by grasses and scattered trees. Grasslands, savannahs (wooded grasslands) and shrublands typically form a transitional biome between forests and deserts. While grasses are dominant, the trees and shrubs that exist are often drought, fire or



Wood buffalo or wood bison (*Bison bison athabasca*), Wood Buffalo National Park, Canada

Source: © Jim Thorsell

browse-resistant. Large herbivores traversing these lands are characteristic and in some regions they are in large numbers. No other biome harbours so many hoofed animals and in such density, which in turn support large predator populations. The largest and richest of these ecosystems can be found in Africa, where the most intact species compositions occur in the East African acacia (*Acacia* spp.) savannahs and Zambezian savannahs. The Llanos in Colombia and Venezuela is one of the best examples of this biome in South America due to its floristic and habitat diversity, but larger expanses can be found in Brazil (Case Study 3.6). The biome is also important in northern Australia and southern Papua New Guinea. Australian savannahs reflect the dominance of termites as herbivores and support distinctive marsupial communities.

Case Study 3.5 Wood Buffalo National Park, Canada: World Heritage property since 1983

Biogeographic realm: Nearctic; **biome:** boreal forests and taiga

Located in the north-central region of Canada, the 44 807 square kilometre Wood Buffalo National Park contains huge tracts of boreal forest as well as the largest extent of North America's Great Plains boreal grassland ecosystem. It also includes the world's largest inland delta, formed by the three rivers Peace, Athabasca and Slave, and associated ecosystems such as floodplains and mudflats.

North America's largest population of threatened wood bison (*Bison bison athabasca*) roams the plains of Wood Buffalo National Park and it is one of the few places in the world where the relationship between predator and

prey—here, grey wolf (*Canis lupus*) and wood bison—has remained undisturbed. It is also globally unique in providing precious breeding habitat for the endangered whooping crane (*Grus americana*). The inland river delta is a popular stopover point for migratory waterbirds. Overall, 46 mammal species and 227 bird species have been recorded, including Arctic fox (*Vulpes lagopus*), moose (*Alces alces*), black bear (*Ursus americanus*), snowy owl (*Bubo scandiacus*) and boreal chickadee (*Parus hudsonicus*).

Source: Adapted from UNESCO (2014)

Case Study 3.6 Cerrado Protected Areas—Chapada dos Veadeiros and Emas National Parks, Brazil: World Heritage properties since 2001

Biogeographic realm: Neotropical; **biome:** tropical and subtropical grasslands, savannahs and shrublands

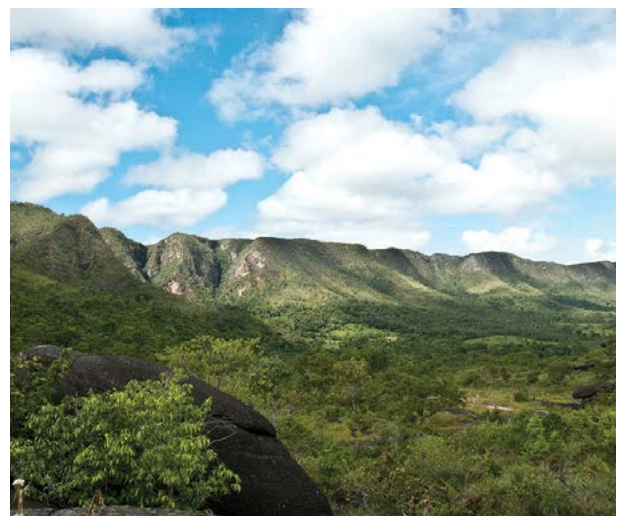
The Cerrado Protected Areas cover about 3670 square kilometres and contain exceptional examples of one of the world's oldest and most diverse tropical savannah ecosystems. The property spans two national parks, Chapada dos Veadeiros and Emas. The first forms part of central Brazil's highest plain and includes wide plateaus, waterfalls and springs as well as deep rocky canyons and valleys. Emas National Park forms part of the Serra dos Caiapós plateau, a gently rolling plain that serves as the divide between the La Plata and Amazon rivers.

The Cerrado has provided key species refuges during past climatic changes and the altitudinal ranges and vast undisturbed habitats will continue to do so for species adjusting to recent change. More than 60 per cent of all Cerrado plant species and almost 80 per cent of its vertebrate species are represented within the property, including most of its threatened mammals, such as the giant armadillo (*Priodontes maximus*) and marsh deer (*Blastocerus dichotomus*). Emas National Park also hosts a number of bird species specialised to living in these grasslands, some of which are endemic, including the endangered white-winged nightjar (*Eleothreptus candicans*) and the marsh seedeater (*Sporophila palustris*).

Source: Adapted from UNESCO (2014)

Temperate grasslands, savannahs and shrublands

Precipitation levels in this temperate biome are generally too low for trees to grow in abundance, and annual temperature variation, usually with hot summers and cold winters, is much greater than in the tropics and subtropics. Additionally, strong winds often blow over these areas, exacerbating evapotranspiration and hence drought conditions. The species composition of temperate grasslands, savannahs and shrublands is consequently very different from that of their tropical and subtropical counterparts. Trees are almost entirely absent, with only a few exceptions such as riparian or gallery forests occurring along streams and rivers. A number of large grazing mammals are characteristic, together with associated predators, and numerous species of birds and insects. Natural fire regimes are important to sustain this biome, and vast expanses of land are required for



Cerrado Protected Areas: Chapada dos Veadeiros and Emas National Parks, Brazil

Source: © Bruno Poppe

Case Study 3.7 Saryarka–Steppe and Lakes of Northern Kazakhstan, Kazakhstan: World Heritage property since 2008

Biogeographic realm: Palaearctic; biome: temperate grasslands, savannahs and shrublands

Saryarka comprises two protected areas—Naurzum State Nature Reserve and Korgalzhyn State Nature Reserve—located some 350 kilometres apart in the Kazakh Uplands. They jointly cover an area of about 4500 square kilometres, of which 44 per cent is Central Asian steppe with the remainder consisting mainly of fresh and saltwater lakes and associated wetland ecosystems.

The steppe in Saryarka is home to more than half of the typical floristic species found in this region's steppe ecosystem. Every year when the grass begins to sprout, large herds of the critically endangered saiga antelope (*Saiga tatarica*) migrate across the steppe from south to

north. The species occurs nowhere else but in the Central Asian steppe and Saryarka is important for their survival. The property's wetlands and lakes are of global significance for migratory waterbirds along the Central Asian flyways. Species from Africa, Asia and Europe visit the Saryarka lakes on journeys to their breeding grounds in western and eastern Siberia. Jointly, the lakes in Saryarka support up to 850 000 nesting waterfowl. Many globally threatened species are among the migrants, including the critically endangered Siberian white crane (*Grus leucogeranus*) and the vulnerable Dalmatian pelican (*Pelecanus crispus*) and Palla's fish eagle (*Haliaeetus leucoryphus*).

Source: Adapted from UNESCO (2014)

species to escape such disturbance, or to move between seasonal or patchy resources. This biome is widespread and known under different names from one continent to the next, such as prairie in North America, pampas in South America and steppe in Asia (Case Study 3.7).

Flooded grasslands and savannahs

Usually located in temperate-warm to tropical-hot climates, these grasslands and savannahs are flooded seasonally or year-round, creating wetland mosaics across the landscape. They are often referred to as swamps. The soil is very moist to water-saturated and typically nutrient rich. A large variety of uniquely adapted plants and animals can be found in these habitats, which harbour numerous bird species, including many migrants. The biome is found on four continents—North America, South America, Africa and Asia—with the Everglades in North America one of the best-known examples. Other well-known examples include the Pantanal in South America and the Sahelian and Zambezan flooded savannahs, including the Okavango Delta, in Africa.

Montane grasslands and shrublands

Occurring in high-elevation areas of the tropics, subtropics and temperate regions on five continents, this biome is characterised by cool, often wet conditions and intense sunlight. Ecosystems within this biome have often evolved as virtual islands, separated from similar montane ecosystems by areas of lower elevation and warmer climate. Consequently, their flora and fauna are not only well adapted to the specific climatic conditions (such as through waxy surfaces and hairy leaves), but also support local or regional endemics. Giant rosette plants from different families, including lobelia in Africa and puya in South America, are typical for tropical montane grasslands and shrublands and can grow in altitudes of up to 4600 metres. Tropical and subtropical montane



Saryarka–Steppe and Lakes of Northern Kazakhstan, Kazakhstan

Source: IUCN Photo Library © Jim Thorsell

grasslands and shrublands can be found in the northern Andes, where the ecosystem is called *páramo*, mountains and highlands in eastern and southern Africa, Mount Kinabalu in Borneo, and mountain areas in Papua New Guinea. Drier, temperate montane grasslands and shrublands can be found, for example, on the Tibetan Plateau and in the Altai Mountain Range.

Tundra

Long, dry winters with months of darkness and very low temperatures characterise this biome, which is typical of polar regions north of the taiga belt. Precipitation levels are very low and most rain falls during the summer months, while it tends to be windy all year round. Soils, if not permanently frozen, are saturated with water and are acidic. During the summer months, where the permafrost melts, the tundra is covered by marshes, lakes, bogs and streams.

Case Study 3.8 Natural System of Wrangel Island Reserve, Russian Federation: World Heritage property since 2004

Biogeographic realm: Palaearctic; biome: tundra

Located in the high Arctic between the Chukchi and the East Siberian seas, Wrangel Island Reserve consists of Wrangel Island and Herald Island and their surrounding waters, overall covering about 9160 square kilometres of land and water.

Wrangel Island Reserve has evolved self-sustained and uninterrupted by the glaciation in the Quaternary. This fascinating natural history is visible in many ways. Mammoth tusks and skulls discovered here have been found to be so recent (some only 3700 years old) that Wrangel Island is considered the last place in the world where mammoths lived. The range of terrain types and geological formations and the rapid succession and mosaic of tundra types create a variety

of different habitats for flora and fauna. The result of all this is remarkably high biodiversity and endemism. For example, the numbers of identified vascular plant species are double those of other Arctic tundra ecosystems of similar size and include 23 endemics. About 100 migratory bird species use the islands as their northernmost nesting ground, and many of them are endangered. The world's largest population of Pacific walrus (*Odobenus rosmarus divergens*) resides on Wrangel Island, Asia's only snow goose (*Chen caerulescens*) population breeds there, and it is also where the highest density of ancestral polar bear dens can be found. The waters around the islands, which are low in salinity but high in oxygen, are an important feeding ground for migrating grey whales (*Eschrichtius robustus*).

Source: Adapted from UNESCO (2014)

In general the landscape is barren, often covered with rocks and patches of low-growing vegetation, including heath, sedges and dwarf shrubs, mosses and lichens. Only in some places do trees occur, but they are scattered. Biodiversity in these areas is generally low, however, millions of migrating birds visit the tundra every year to breed in the marshes. Additionally, the tundra is an important habitat for caribou (*Rangifer tarandus*) migration. Tundra occurs primarily in Alaska, Canada, Russia (Case Study 3.8), Greenland, Iceland and Scandinavia, as well as on Antarctica and several sub-Antarctic islands.

Mediterranean forests, woodlands and scrubs

Long, hot and dry summers and mild and rainy winters characterise this biome, resulting in diverse vegetation types, ranging from forests and woodlands to savannahs, shrublands and grasslands. Quite often several of these vegetation types occur in a heterogeneous mosaic, depending on soil characteristics, topography, exposure to sun, wind and rain, and fire history. Fauna and flora are well adapted to water scarcity and many species are also adapted to fire. For some, their persistence depends on natural fire regimes. Biodiversity is typically very rich, and regional and local endemism common. The fynbos in South Africa's Cape Floristic Region is an important example of this biome. Here, 68 per cent of the 8600 known vascular plant species that occur in an area of only 90 000 square kilometres are endemic. Globally, this biome is relatively rare, restricted to only five regions where the specific Mediterranean climatic conditions occur: the Mediterranean, south-central and south-western Australia, the fynbos of southern Africa, the Chilean matorral and the Mediterranean ecosystems of California.

Deserts and xeric shrublands

Deserts and xeric shrublands are located in tropical, subtropical and temperate regions that receive a maximum of 250 millimetres of rainfall per year.



Natural System of Wrangel Island Reserve, Russian Federation

Source: © Gabrielle and Michelle Therin-Weise

Evaporation usually exceeds rainfall, sometimes by far. Extreme temperature variation between day and night is typical, with searing daytime temperatures dropping steeply in the night due to the lack of insulation that is provided elsewhere by humidity and cloud cover. Soils are often sandy or rocky and organic material content tends to be low. Where vegetation occurs, it consists of woody-stemmed shrubs and plants specialised to minimise water loss. Animals are well adapted to these harsh climatic conditions and many of them are nocturnal to avoid moisture loss. The diversity of plants and animals can be quite high, especially the reptile fauna, and local endemism can be high in some places. Deserts and xeric shrublands are the largest of all the biomes, covering an estimated 19 per cent of the world's land area. Floristically, the most diverse ecosystem falling into this biome is the Namib-Karoo in south-western Africa (Case Study 3.9), closely followed by the Chihuahuan Desert and central Mexican deserts in the Neotropics.

Case Study 3.9 Namib Sand Sea, Namibia: World Heritage property since 2013

Biogeographic realm: Afrotropic; biome: deserts and xeric shrublands

The Namib Sand Sea is a hyper-arid desert covering 30 000 square kilometres of land along the Namibian coastline entirely within the Namib-Naukluft Park. The property contains gravel plains, rocky hills, a coastal lagoon and ephemeral rivers, but is mainly composed of different types of shifting sand dunes whose only source of water is fog. It is the only coastal desert in the world where this is the case. While most other dunes are composed of *in situ* eroded bedrock, the Namib Sand Sea is composed of sand originating from inland Africa. It is transported to the coast over thousands of kilometres by rivers, ocean

currents and wind. Wind-driven sand transport processes have subsequently shaped the site's geomorphology and ecology, creating a 'sea of sand dunes' landscape.

Fauna and flora are remarkably well adapted to the climatic conditions, as reflected in species' behaviour, morphology and physiology, leading to large numbers of endemics. More than 50 per cent of the plant and insect species in the sand sea are endemic, and for arachnids (spiders, scorpions and ticks) this figure exceeds 80 per cent. Some fascinating adaptations include ways to filter moisture out of the air to minimise species' dependency on other water sources.

Source: Adapted from UNESCO (2014)

Mangroves

Mangroves are a vegetation type dominated by salt-tolerant tree species that grow between the intertidal zone and the high-tide mark of tropical and subtropical coastlines. About 60 tree species from 12 different genera make up 'mangrove' communities. Soils are waterlogged, salty and oxygen poor, and mangroves are often exposed to tidal movements and seasonal weather fluctuations. A variety of different adaptations to cope with these special conditions can be observed: a massive root system helps mangroves gain a foothold in the soft ground, aerial roots absorb oxygen from the air and the leaves of mangroves can excrete excess salt. Together with a variety of other associated aquatic and saline plants, mangroves provide important habitat, especially nursing grounds, for numerous marine animal species, such as oysters, shrimp and mud lobster. Mangrove biodiversity is highest in South Asia, and the Sundarbans mangroves shared by Bangladesh and India represent the world's largest expanse of this vegetation type.

Mountains

Mountains are sometimes considered a separate biome (Udvardy 1975) due to their special characteristics although they support a wide range of major ecosystem types including deserts, grasslands, forests and alpine tundra. Mountains are major Earth features found on every continent (Hamilton and McMillan 2004) and in 197 of the world's 237 countries (Rodríguez-Rodríguez et al. 2011). Mountains defy precise definition but many mountain scholars use the definition developed by UNEP-WCMC (2002), which considers elevation, slope and local elevation range, bringing into the fold some of the 'low' mountains of the world (Figure 3.4). Using this definition, mountains cover 27 per cent of the Earth's surface (UNEP-WCMC 2002). We explore the special values of mountains further in Box 3.2.



Namib Sand Sea, Namibia

Source: IUCN Photo Library © Peter Howard

Marine and freshwater biomes

In contrast with the 'terrestrial ecoregions of the world' system, the corresponding systems for marine and freshwater ecoregions (Spalding et al. 2007; Abell et al. 2008) do not differentiate major ecosystem types such as those examples shown in Table 3.4. The 'pelagic provinces of the world' system (Spalding et al. 2012) recognises the following seven major biomes in the world's off-shelf surface waters:

- polar
- gyre
- eastern boundary currents
- western boundary currents
- equatorial
- transitional
- semi-enclosed seas.

Case Studies 3.10, 3.11 and 3.12 highlight the diversity of coastal and marine ecosystems.

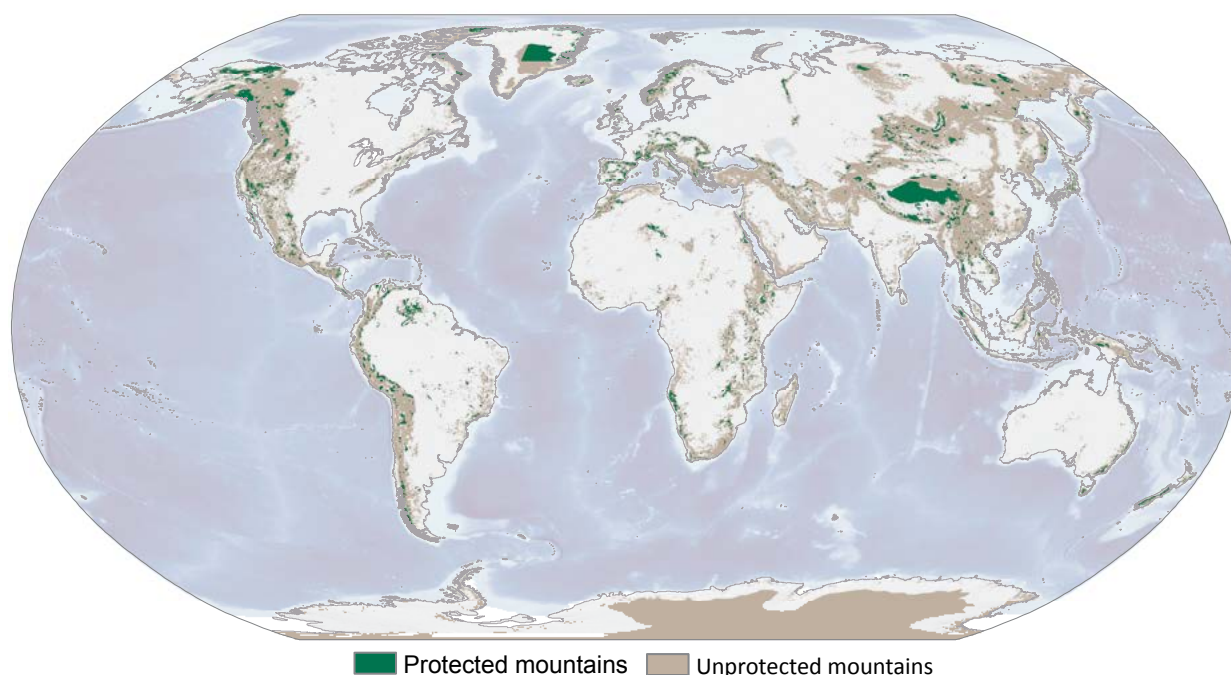


Figure 3.4 Mountain areas and mountain protected areas of the world

Sources: UNEP-WCMC (2002); IUCN and UNEP-WCMC (2014)

Box 3.2 The special values of mountains and mountain protected areas

Mountains are critical for biodiversity, ecosystem services and human wellbeing. Much of the world's native biodiversity is found in mountains. Their species and ecosystem richness is due largely to the extreme heterogeneity of environments (climates and soils), resulting from the rapid altitudinal changes, variable orientation (aspects) and abundant microhabitats of rough topography. Moreover, a great share of the world's endemic species is found in mountains due to the isolated island nature of mountain massifs, which are often the last bastions of wild nature.

At the same time mountains are home to 12 per cent of the world's human population and 26 per cent of all humans live in or adjacent to mountains (Price 2004). More than half of humanity relies on the freshwater that emanates from mountains (Linniger et al. 1998), and mountain protected areas play a critical role in freshwater provision for many cities and communities. Many mountains are also special because they take on deep spiritual and cultural significance (for example, Mount Fuji in Japan). To some traditional peoples, mountains are held in awe or fear, or are sacred sites where religious ceremonies are held. On the other hand, mountain ranges frequently form national borders, and frontier conflict, even open warfare, has not been uncommon.

Mountain ecosystems are often fragile and face multiple threats to their natural and cultural values (Hamilton 2002). Half of the world's biodiversity hotspots are located in mountains (Kohler and Maselli 2009) and, of the 587 sites threatened with imminent species extinctions identified

by the Alliance for Zero Extinction (AZE), 81 per cent are mountainous (Rodríguez-Rodríguez et al. 2011).

Mountain protected areas can provide refuges for biodiversity. Nearly 17 per cent of the world's mountain area outside Antarctica falls in protected areas (not always well managed), but many priority mountain areas for conserving biodiversity remain unprotected, including 45 per cent of the mountains identified by AZE (Rodríguez-Rodríguez et al. 2011). To effectively conserve biodiversity, mountain protected areas need to be enlarged downslope and buffered by sustainably managed surrounding lands. Isolated mountain protected areas need to be connected to the lowlands to facilitate altitudinal species migration from these lower areas in response to climate change or continued land conversion. They also need to be connected where possible to other mountain protected areas. Fortunately, many mountain ranges provide natural connectivity for corridors of conservation (see Chapter 27).

Because of their outstanding natural and/or cultural values, many mountain areas have been included on the World Heritage List: 159 of the 222 natural and mixed (natural and cultural) World Heritage sites contain mountain areas (UNEP-WCMC 2002; IUCN and UNEP-WCMC 2014) (Figure 3.1). This includes many well-known sites such as the Canadian Rocky Mountains, Hawai'i Volcanoes, Mounts Huascarán, Kilimanjaro, Kinabalu and Sagarmatha (Everest), Swiss Alps Jungfrau-Aletsch, Mount Tongariro and the Volcanoes of Kamchatka.

Case Study 3.10 Islands and Protected Areas of the Gulf of California, Mexico: World Heritage property since 2005

Located in the Sea of Cortez in north-eastern Mexico, the Islands and Protected Areas of the Gulf of California consist of 244 islands, islets and coastal areas covering almost 6900 square kilometres. The natural beauty of this property contrasts the high cliffs and sandy beaches of the mostly barren mountainous or volcanic islands with the surrounding turquoise waters.

Almost all major oceanographic processes, such as upwelling and wind-driven currents and high tidal mixing, can be observed in these waters and contribute to the extraordinary marine productivity and biodiversity that characterise the Gulf of California. Almost 900 species of fish, 90 of them endemic, as well as 39 per cent of

the world's marine mammals occur here. Terrestrial biodiversity is equally high, supported by the combination of oceanic islands that were populated by air and sea and 'bridge islands' populated by land when ocean levels were lower during past glaciations. Floral composition reflects that of the Sonoran Desert, with almost 700 vascular plant species. Typical species include elephant tree (*Bursera microphylla*), desert ironwood (*Olneya tesota*), white bursage (*Ambrosia* spp.) and cacti such as the columnar cardon (*Pachycerus pringlei*), viejito (*Mammillaria capensis*) and prickly pears (*Opuntia* spp.).

Source: Adapted from UNESCO (2014)

Table 3.4 Examples of major ecosystem types in marine and freshwater environments

Marine	Freshwater
Open ocean	Lakes
Deep sea	Ponds
Sea floor	Rivers
Coral reefs	Streams
Seagrass beds	Springs
Salt marshes	Wetlands
Mangrove forests	



Islands and Protected Areas of the Gulf of California, Mexico
Source: IUCN Photo Library © David Sheppard



The Wadden Sea, Germany and the Netherlands
Source: IUCN Photo Library © Pedro Rosabal

Case Study 3.11 The Wadden Sea, Germany and Netherlands: World Heritage property since 2009

The Wadden Sea World Heritage Property combines the Dutch Wadden Sea Conservation Area with the German Wadden Sea national parks of Lower Saxony and Schleswig-Holstein and covers 9820 square kilometres of coastland. The site represents one of the few remaining temperate intertidal ecosystems where natural processes—such as the creation of barrier islands, channels, flats and gullies—continue almost undisturbed at such a large scale. It is also the world's largest unbroken system of intertidal sand and mud flats.

Habitat diversity is remarkable in the Wadden Sea, featuring tidal channels, sandy shoals, seagrass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches

and dunes. While coastal wetlands do not generally rank very high in terms of their faunal diversity, the Wadden Sea is different. The salt marshes are home to about 2300 plant and animal species, and another 2700 species inhabit the marine and brackish areas. The abundance of food attracts abundant birdlife. The Wadden Sea is among the world's most important places for migratory birds, playing a crucial role for species travelling the East Atlantic Flyway as well as for African–Eurasian migratory waterbirds. More than six million birds may be present at a single time and an estimated 10–12 million pass through every year.

Source: Adapted from UNESCO (2014)

Case Study 3.12 Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems, France—World Heritage property since 2008

The Lagoons of New Caledonia are vast, covering more than 15 700 square kilometres of mainly seascape in the French Pacific Ocean archipelago of New Caledonia. They represent all the main types of coral reefs and associated ecosystems, featuring tropical lagoons, coral islands, fringing reefs, double barrier reefs and atolls, as well as seagrass meadows and mangroves. As an additional specialty, the reef complex is 'freestanding' in the ocean, encircling New Caledonia, and as a consequence exposed to both cold and warm currents.

The barrier reefs and atolls are among the world's three most extensive reef systems and have at least the same

or higher coral and fish diversity as Australia's much larger Great Barrier Reef. The property's stunning underwater world contains reef fissures, arches and caves as well as impressive displays of coral structures and diversity. Its intact ecosystems support healthy populations of a variety of threatened fish, including top predators, but also marine turtles and the world's third-largest population of the vulnerable dugong (*Dugong dugon*).

Source: Adapted from UNESCO (2014)



Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems, France

Source: IUCN Photo Library © Dan Laffoley

Human impact on the distribution of biodiversity

Human alteration of the global environment has caused considerable changes to the natural distribution of biodiversity (Chapin et al. 2000; Ellis and Ramankutty 2008; Ellis et al. 2010; Barnosky et al. 2012). The human impact on the biosphere can be assessed in many ways. Recent estimates of the human appropriation of net primary production suggest, for example, that 24 per cent of the potential net primary productivity of the world's terrestrial ecosystems is consumed by humans (Haberl et al. 2007).

The level of human influence on the terrestrial biosphere can also be measured and mapped through the human footprint index (Figure 3.5; Sanderson et al. 2002). This index combines information on human population density, land transformation (for example, through agriculture or in built-up areas), human accessibility (for example, along roads, major rivers and coastlines)

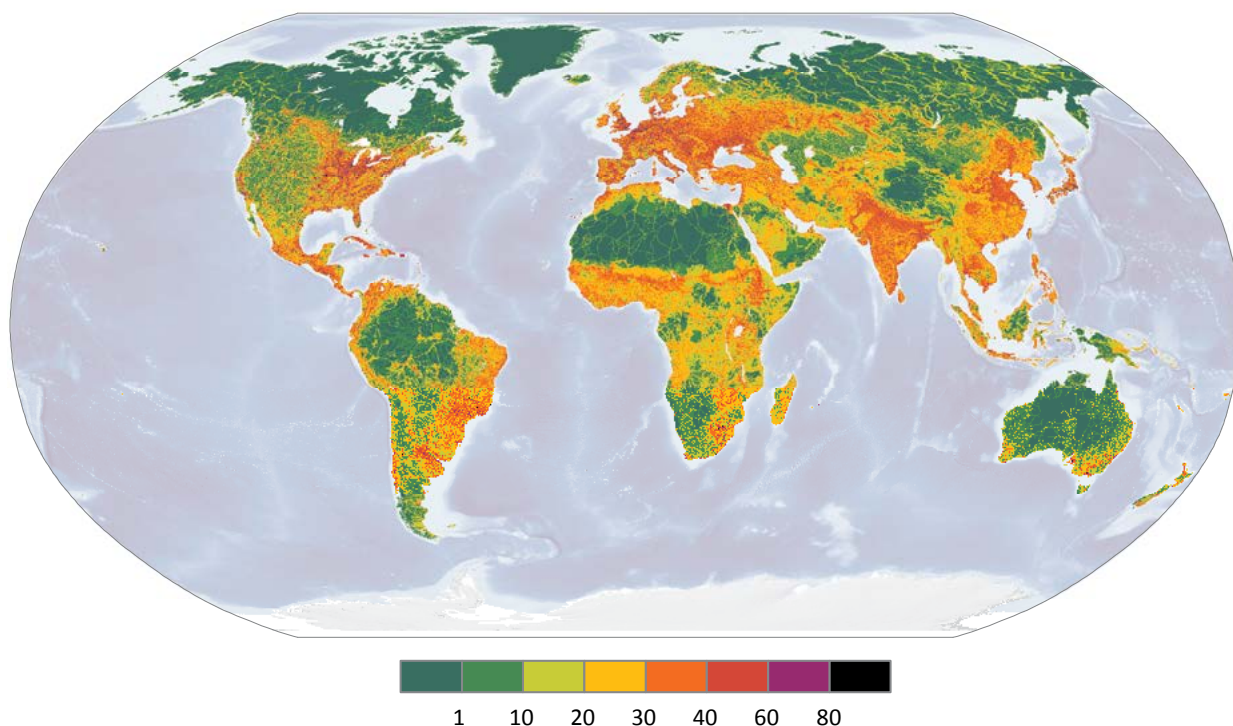


Figure 3.5 The human footprint on the global land area

Source: Modified from Sanderson et al. (2002)

and electrical power infrastructure (inferred from night-time lights). It measures the relative human influence in each terrestrial biome. A value of zero indicates the least-influenced part of the biome, and a value of 100 indicates the most-influenced part of the biome. So an index score of 10 in moist tropical forests in the Afrotropic realm indicates the area is among the 10 per cent least-influenced areas in its biome, the same as a score of 10 in the tundra of the Palearctic realm, although the absolute amount of influence in those two places may be very different (Sanderson et al. 2002).

Protected areas as safeguards for Earth's natural heritage

Effectively managed protected areas play a key role in the conservation of the Earth's natural heritage. Through associated ecosystem services, protected areas also support the livelihoods of more than one billion people worldwide (UN Millennium Project 2005), and contribute billions of dollars to local, national and global economies (Kettunen et al. 2011).

To be effective, however, protected areas need to be located in the right places, well governed and managed, and adequately planned and resourced (Lockwood et al. 2006). This has long been recognised in a number of international multilateral environmental agreements

such as the CBD, Ramsar Convention and World Heritage Convention. In 2010, the 193 parties to the CBD adopted the Strategic Plan for Biodiversity 2011–2020, including 20 headline targets collectively known as the Aichi Biodiversity Targets (CBD 2010b). Target 11 deals specifically with protected areas and sets an ambitious agenda for the years ahead:

By 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes. (CBD 2010b:9)

Global protected area coverage

By mid 2014, protected areas, comprising all nationally and internationally designated protected areas of all IUCN management categories and governance types (including 'unknown') except for UNESCO biosphere reserves recorded in the World Database on Protected Areas (WDPA), covered 15.4 per cent of the global land area (outside Antarctica) and 3.4 per cent of the global ocean area (Figure 3.6; IUCN and UNEP-WCMC 2014).

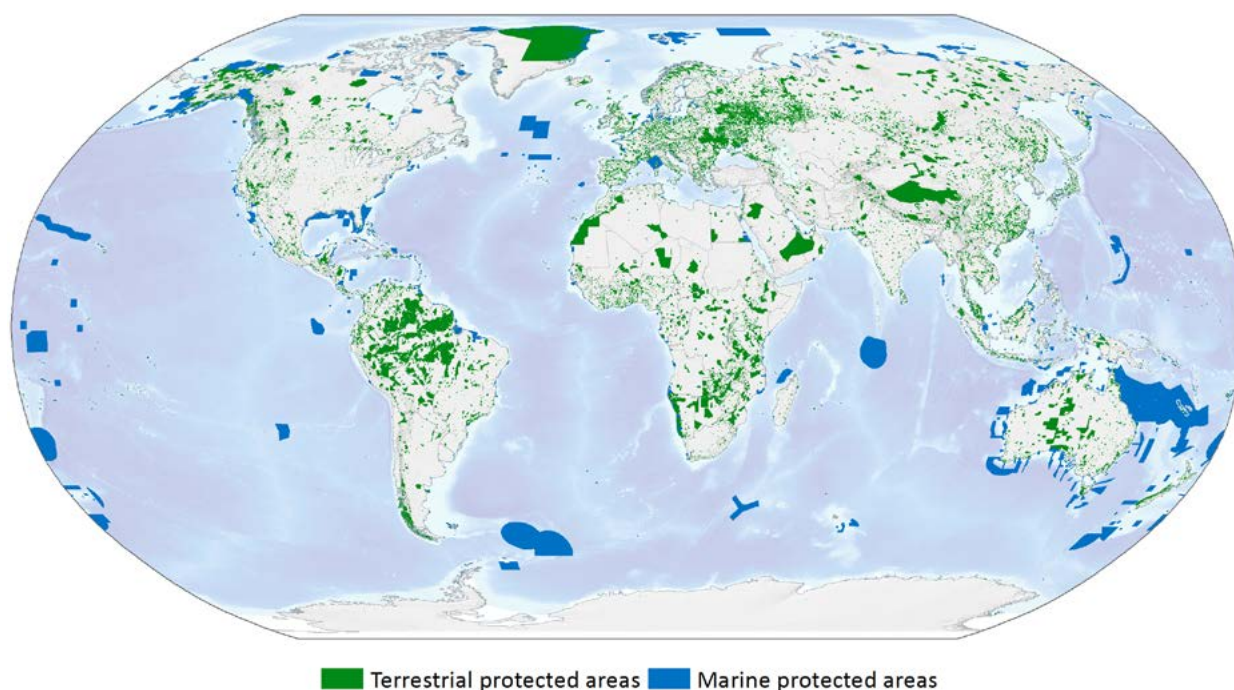


Figure 3.6 Protected areas of the world

Source: IUCN and UNEP-WCMC (2014)

Table 3.5 Protected area coverage of terrestrial realms

Terrestrial realm	Total land area (km ²)	Protected area (km ²)	Protected area (%)
Afrotropic	21 630 400	3 558 059	16.4
Australasia	9 268 092	1 375 024	14.8
Indo-Malayan	8 543 097	829 286	9.7
Nearctic	20 472 280	2 534 229	12.4
Neotropic	19 386 026	4 633 935	23.9
Oceania	49 199	4 552	9.3
Palaearctic	52 859 883	6 918 957	13.1

Coverage was calculated based on all protected areas shown in Figure 3.6, eliminating spatial overlaps of different protected areas.

Sources: Olsen et al. (2001); IUCN and UNEP-WCMC (2014)

This included 8.4 per cent of the marine areas under national jurisdiction, here defined as extending from the shoreline to the outer limit of the exclusive economic zone (EEZ) at 200 nautical miles (370 kilometres), and 10.9 per cent if only near-coastal areas (0–12 nautical miles, or 0–22 kilometres, from land) are considered.

The global protected area network does not yet meet the requirement of ecological representativeness stipulated in Target 11, and several biogeographic realms, in particular the Oceanian and Indo-Malayan realms, are underrepresented (Table 3.5; IUCN and UNEP-WCMC 2014). Greater coverage is also needed in a number of biomes, especially temperate grasslands, savannahs and shrublands, and tropical and subtropical

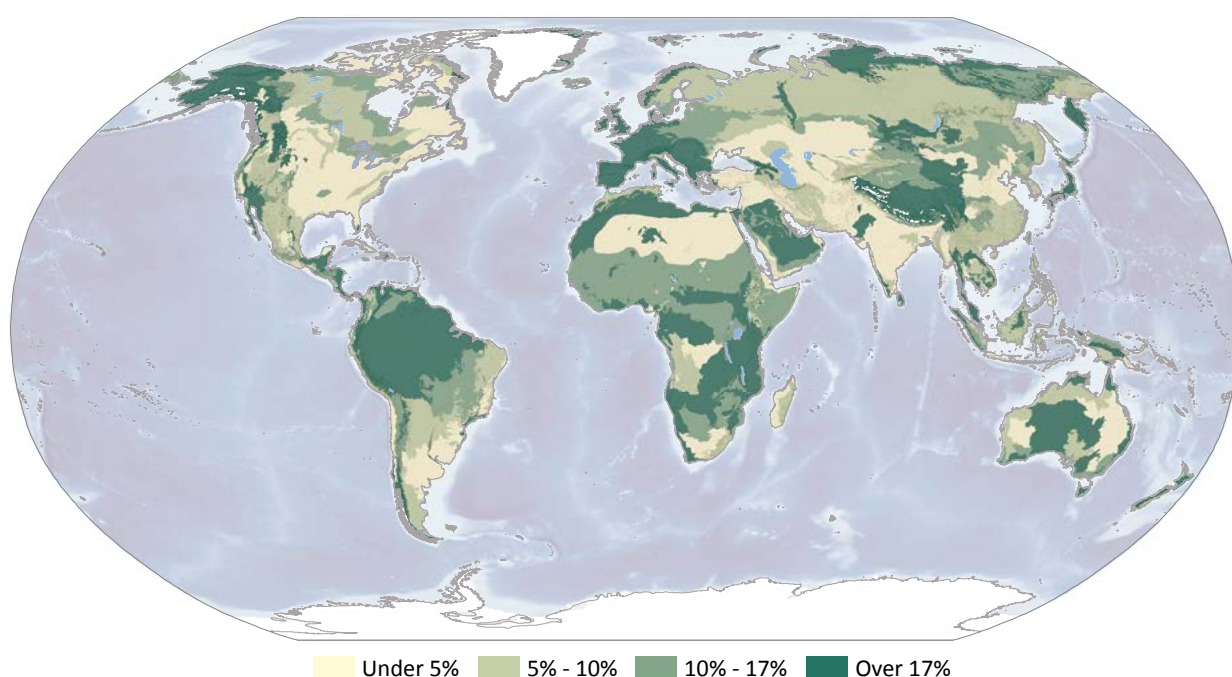
dry broadleaf forests (Table 3.6). At present, 350 (43 per cent) of the world's 823 terrestrial ecoregions outside the Antarctic mainland meet the 17 per cent target (Figure 3.7; IUCN and UNEP-WCMC 2014), and 78 (34 per cent) of the 232 marine ecoregions meet the 10 per cent target (Figure 3.8; see also Spalding et al. 2013).

Table 3.6 Protected area coverage of terrestrial biomes

Terrestrial biome	Total land area (km ²)	Protected area (km ²)	Protected area (%)
Tropical and subtropical moist broadleaf forests	19 896 257	4 712 331	23.7
Tropical and subtropical dry broadleaf forests	3 025 997	290 896	9.6
Tropical and subtropical coniferous forests	712 617	83 513	11.7
Temperate broadleaf and mixed forests	12 835 688	1 540 766	12.0
Temperate coniferous forests	4 087 094	687 694	16.8
Boreal forests/taiga	15 077 946	1 570 569	10.4
Tropical and subtropical grasslands, savannahs and shrublands	20 295 446	2 973 704	14.7
Temperate grasslands, savannahs and shrublands	10 104 108	456 517	4.5
Flooded grasslands and savannahs	1 096 130	339 170	30.9
Montane grasslands and shrublands	5 203 411	1 393 007	26.8
Tundra (excluding four Antarctic ecoregions)	8 313 849	1 812 734	21.8
Mediterranean forests, woodlands and scrub	3 227 268	512 190	15.9
Deserts and xeric shrublands	27 984 645	3 382 967	12.1
Mangroves	348 519	97 983	28.1

Coverage was calculated based on all protected areas shown in Figure 3.6, eliminating spatial overlaps of different protected areas.

Sources: Olsen et al. (2001); IUCN and UNEP-WCMC (2014)

**Figure 3.7 Percentage area of each terrestrial ecoregion covered by protected areas**

Sources: Olsen et al. (2001); IUCN and UNEP-WCMC (2014)

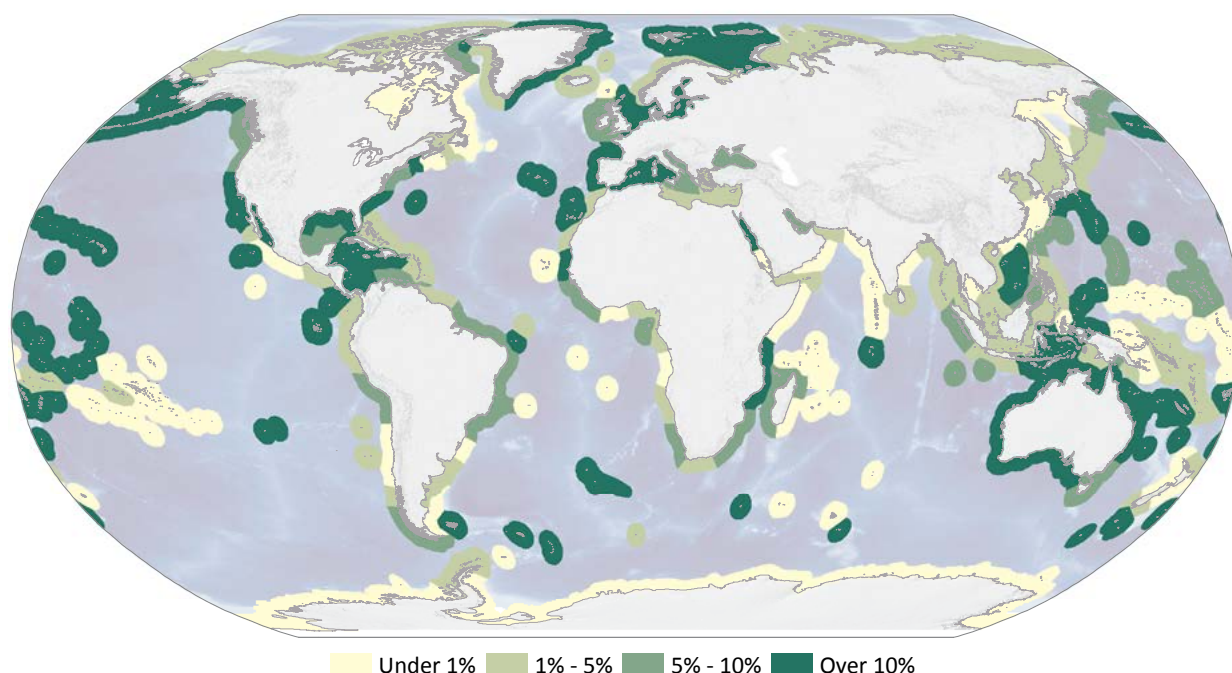


Figure 3.8 Percentage area of each marine ecoregion (out to 200m depth) covered by protected areas

Sources: Spalding et al. (2007); IUCN and UNEP-WCMC (2014)

Many studies have also shown that existing protected area networks, from national to global scales, do not yet provide adequate coverage of threatened species (for example, Rodrigues et al. 2004; Watson et al. 2011) and the key sites that support them (Butchart et al. 2012). It should also be noted, however, that a vast number of species is already entirely confined to protected areas and sometimes just a single protected area.

Coverage is just one of many indicators that can be used to evaluate the strengths and weaknesses of the existing protected area networks. Subsequent chapters in this book address protected area management effectiveness measures in detail, including good governance, competent management and the adequate planning and resourcing of different types of protected areas. Since resources for conservation will always be limited, conservation efforts need to be prioritised. This is the matter we discuss next.

Global biodiversity conservation priorities

Prioritising conservation action is necessary because the resources available for conservation are limited, and biodiversity and the threats to it are not evenly distributed (Brooks et al. 2006, 2010). In short, prioritisation helps to decide where, when and how to act, with effective protected areas one of the key tools in our toolbox of conservation actions.

Several major templates for the identification of global priority areas for biodiversity conservation have been developed to guide the allocation of resources and actions (Brooks et al. 2006, 2010). All these approaches, however, have their strengths and weaknesses—for example, with regard to their taxonomic or geographic coverage, criteria and thresholds used and practical value for designing effective and efficient protected area networks.

All the templates apply one or more of the following concepts to prioritise specific sites, (eco)regions or clusters of ecoregions for conservation (Margules and Pressey 2000; Brooks et al. 2006, 2010; Schmitt 2011):

- irreplaceability
- vulnerability
- representativeness.

Irreplaceability is about the spatial conservation options available—that is, the importance of an area for the conservation of specific biodiversity features such as species or ecosystems. Irreplaceability has often been measured based on the number of endemic species present in an area but other measures exist (Brooks et al. 2006). In contrast, vulnerability is an indicator of the temporal conservation options available, or the urgency for conservation action. This can be assessed, for example, based on the occurrence of threatened species, past or present habitat loss, land tenure and human population pressure (Brooks et al. 2006). Representativeness refers to the need to represent, or sample, the full variety

of biodiversity features, including both patterns and processes, within a network of priority areas or protected areas (Margules and Pressey 2000).

Most of the major templates prioritise high irreplaceability, but some prioritise high vulnerability and others prioritise low vulnerability (Brooks et al. 2006). Representativeness was an important consideration, for example, in the identification of Global 200 priority ecoregions (Olson et al. 2000; Olson and Dinerstein 2002; Schmitt 2011).

An overview of six selected biodiversity conservation priority templates is provided in Table 3.7. With the exception of the Global 200 priority ecoregions, which explicitly include 43 marine priority ecoregions, most of the well-known templates cover only terrestrial and

freshwater environments. In recent years, however, an increasing number of studies has also identified global priority areas in the marine environment (Tittensor et al. 2010; Selig et al. 2014), and some existing templates are also being expanded to include more and more marine sites (BirdLife International 2010).

A summary of broadscale approaches can be found in Brooks et al. (2006, 2010), while site-based approaches collectively known as key biodiversity areas (KBAs) are summarised in Langhammer et al. (2007). In the next subsections, we describe biodiversity hotspots and high-biodiversity wilderness areas as examples of broadscale approaches, and AZE sites as an example of site-based approaches. We close this section with information on the wider KBA standard that includes AZE sites.

Table 3.7 Selected methods for biodiversity conservation prioritisation

Template	Definition	Scale	Number of areas or sites	Total land area (million km ²)	Percentage of global land area (%)	References
Biodiversity hotspots	Biogeographically similar aggregations of ecoregions holding $\geq 0.5\%$ of the world's plants as endemics, and with $\geq 70\%$ of primary habitat already lost	Ecoregion clusters	35	23.6	15.9%	Myers et al. (2000); Mittermeier et al. (2004); Williams et al. (2011)
High-biodiversity wilderness areas	Biogeographically similar aggregations of ecoregions holding $\geq 0.5\%$ of the world's plants as endemics, and with $\geq 70\%$ of primary habitat remaining and ≤ 5 people per km ²	Ecoregion clusters	5	11.8	7.9%	Mittermeier et al. (2002, 2003)
Global 200 priority ecoregions	Aggregations of ecoregions within biomes characterised by high species richness, endemism, taxonomic uniqueness, unusual phenomena or global rarity of major ecosystem type	Ecoregion clusters	142 terrestrial (plus 53 freshwater and 43 marine)	55.1	37.0%	Olson et al. (2000); Olson and Dinerstein (2002)
Endemic bird areas	Sole area where ≥ 2 bird species with global breeding ranges of $< 50\,000$ km ² occur	Region or site	218	14.2	9.5%	Stattersfield et al. (1998)
Alliance for Zero Extinction sites	Site is sole area where an endangered (EN) or critically endangered (CR) species occurs (or contains $> 95\%$ of the EN or CR species' global population for at least one life history segment)	Site	588	0.6	0.4%	Ricketts et al. (2005); AZE (2012)
Important bird areas	Sites hold significant numbers of one or more globally threatened bird species; site is one of a set of sites that together hold a suite of restricted-range bird species or biome-restricted bird species; and/or has exceptionally large numbers of migratory or congregative bird species	Site	10,993	8.8	5.9%	Evans (1994); BirdLife International et al. (2012)

Sources: Brooks et al. (2006, 2010); Schmitt (2011); Bertzky et al. (2013)

Biodiversity hotspots and high-biodiversity wilderness areas

Both biodiversity hotspots and high-biodiversity wilderness areas (HBWAs) support exceptional concentrations of endemic species (Table 3.7). Each of these broadscale priority areas is home to at least 1500 endemic species of vascular plants—that is, more than 0.5 per cent of the world's estimated 300 000 vascular plant species (Myers et al. 2000; Mittermeier et al. 2002, 2004). While hotspots and HBWAs are comparable in terms of their overall irreplaceability, they differ in their vulnerability: hotspots have already lost more than 70 per cent of their primary vegetation while HBWAs retain more than 70 per cent of their primary vegetation and are sparsely populated (less than five people per square kilometre).

To date, 35 hotspots and five HBWAs have been identified around the world (Figure 3.9). Together, the hotspots and HBWAs have been estimated to support more than 50 per cent of the world's vascular plant species and terrestrial vertebrate species (mammals, birds, reptiles and amphibians), plus countless other species including invertebrates and fungi (Stork and Habel 2013), on 23.8 per cent of the global land area. Although these areas are clearly critical for the survival of the diversity of life on Earth, it should be noted that they do not encompass all known global priority areas even for vertebrates (Jenkins et al. 2013), let alone other taxonomic groups.

Alliance for Zero Extinction sites

AZE sites, on the other hand, are an example of site-scale priority areas. In short, these sites are of exceptional irreplaceability and vulnerability as they represent 'centres of imminent extinction, where highly threatened species are confined to single sites' (Ricketts et al. 2005:18497). The 588 AZE sites identified to date (Figure 3.10; Table 3.7) cover only 0.4 per cent of the global land area but are critical to the survival of 919 critically endangered or endangered vertebrate and conifer species (Butchart et al. 2012). More such sites are likely to exist for other taxa but have not yet been formally identified as AZE sites.

Protection of AZE sites remains inadequate although it has been shown that species occurring in AZE sites with greater protected area coverage tend to be better off. Butchart et al. (2012) showed that the increase in extinction risk over the past two decades was one-third lower for mammals, birds and amphibians restricted to AZE sites completely covered by protected areas compared with those restricted to unprotected sites or sites that are only partially protected. They also found, however, that only 22 per cent of the 588 known AZE sites were completely covered by protected areas, while 51 per cent remained entirely unprotected by 2008 (Figure 3.10). Green points in Figure 3.10 indicate sites that are completely covered by protected areas, yellow points partially covered sites, and red points unprotected sites.

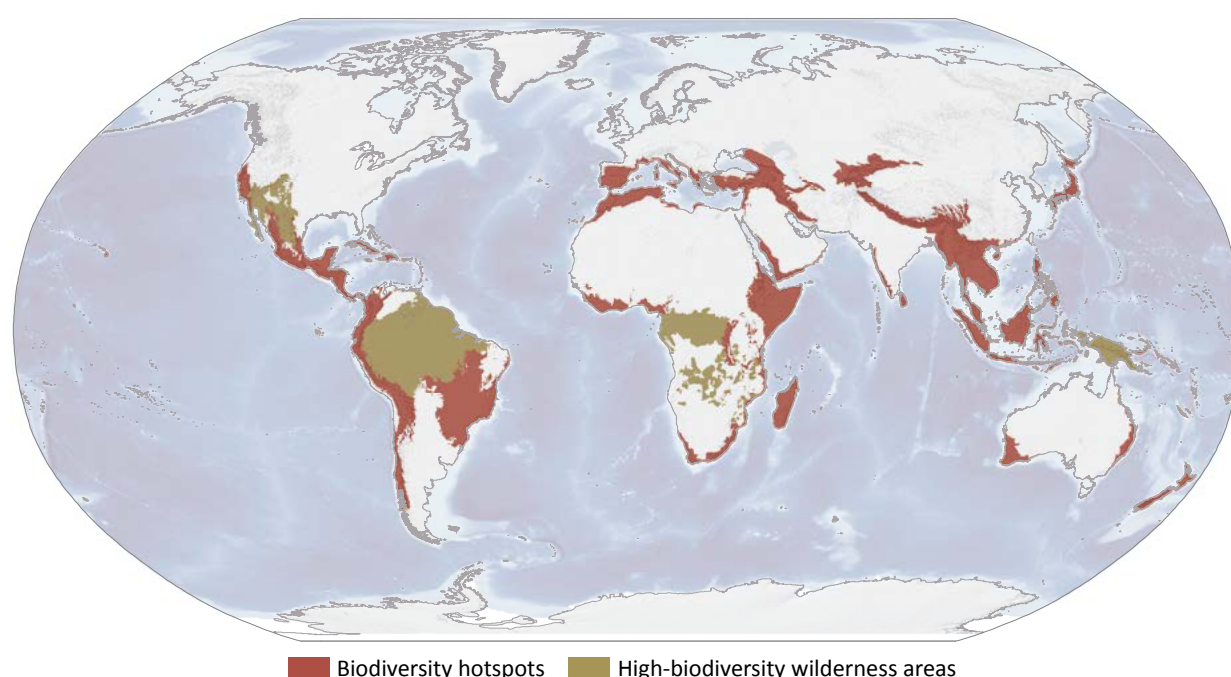


Figure 3.9 Biodiversity hotspots and high-biodiversity wilderness areas of the world

Sources: Modified from Mittermeier et al. (2002, 2004); Williams et al. (2011)

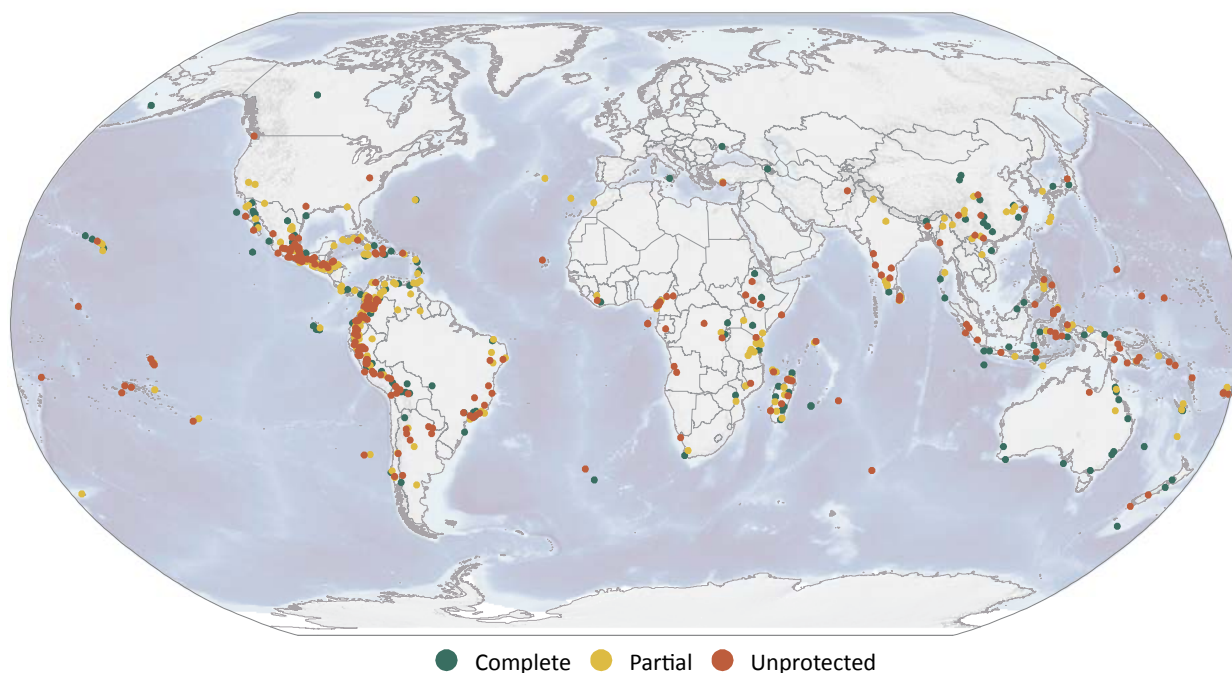


Figure 3.10 Protection status of Alliance for Zero Extinction sites

Source: Modified from Butchart et al. (in prep.)

Key biodiversity areas

AZE sites are the highest priority subset of KBAs—that is, sites that contribute significantly to the global persistence of biodiversity according to globally standardised criteria (Langhammer et al. 2007). Other well-known subsets of KBAs include important bird areas (IBAs) (Table 3.7) and important plant areas (IPAs), both representing priority areas identified within specific taxonomic groups. The KBA approach can also be applied in marine and freshwater environments (BirdLife International 2010; Holland et al. 2012) and, through the CBD, the complementary concept of ecologically or biologically significant marine areas (EBSAs) has been advanced in recent years.

The KBA inventories have ‘informed the selection of sites for protection under national and international legislation, are considered in international sustainability performance standards, and are included under multilateral environmental agreements’ (IUCN 2012:2). One example of the latter is the use of AZE sites and IBAs to achieve and measure progress towards the Aichi Biodiversity Targets of the CBD—for example, as priority sites for reducing species and habitat loss through the targeted establishment and management of protected areas.

The IUCN is currently leading a global consultation process to consolidate the different existing KBA criteria and thresholds into a new KBA standard. The

new standard is proposed to be launched in 2015, and is expected to find wide application in conservation planning and decision-making:

The final goal of this process is to provide an objective, scientifically rigorous methodology that is easy to apply, to identify KBAs across terrestrial, freshwater, and marine biomes. This new IUCN standard will guide decision-makers on areas that require safeguarding and will help a range of end users to define their conservation priorities, achieve their international commitments, and comply with their environmental policies. (IUCN 2012:2)

Systematic conservation planning

Knowledge about KBAs and other priority areas can also inform the important process of systematic conservation planning. This process can help to design effective and efficient protected areas and protected area networks that meet the overall goals of representativeness and persistence of biodiversity in the most cost-effective way (Margules and Pressey 2000). To achieve this, systematic conservation planning uses the best available data on biodiversity patterns and processes, including their irreplaceability and vulnerability, existing protected areas, the cost of establishing and managing new protected areas, and the opportunity costs of competing land

uses. In the words of Margules and Pressey (2000:243), the power of systematic conservation planning comes from its 'efficiency in using limited resources to achieve conservation goals, its defensibility and flexibility in the face of competing land uses, and its accountability in allowing decisions to be critically reviewed'. More information on systematic conservation planning can be found in Chapter 13.

Introducing ecosystem management

We have briefly introduced Earth's abiotic and biotic natural heritage in this chapter. Protected area managers are at the frontline of managing for the protection and conservation of major ecosystems that help support life on Earth. Once the important biodiversity areas identified have been formally protected, they need to be effectively managed.

This management may include responses to threats such as habitat destruction and fragmentation, overexploitation, invasive alien species, disease, disturbance, pollution and climate change (Sinclair et al. 2006) (see Chapter 16).

Protected area problems are, however, generally more complex than single issues. This complexity needs to be understood by managers and it is part of managing in a dynamic world (see Chapter 10). The root causes of threats to biodiversity need to be assessed and responded to strategically rather than in a reactive manner that may just deal with the symptoms of threats (see Chapter 16). One complex challenge is climate change. It is a major threat for all species (see Chapter 17), and strategic guidance has been provided for protected area management in the form of the following six guiding principles:

1. Maintain well-functioning ecosystems: 'Maintaining or enhancing the resilience of ecosystems is crucial to ensure the adequate functioning; but when, under climate change, does it become counter-productive and facilitation of new ecosystems become more important?' (Steffen et al. 2009:150). As climate change transformation becomes more common later this century, monitoring the functioning of these new ecosystems and their ability to deliver the services on which society depends will be critical (see Chapters 11 and 21).
2. Protect a representative array of ecological systems: 'All environments should be represented in regional reserve systems, and a diversity of landscape

architectures in terms of the arrangements of patches and connecting habitats should be represented in regional on and off-reserve landscapes' (Steffen et al. 2009:150) (see Chapters 13 and 27).

3. Remove or minimise existing stressors: '[W]ith particular attention to those that may benefit from climate change' (Steffen et al. 2009:150) (see Chapter 16).
4. Manage appropriate connectivity of species, landscapes, seascapes and ecosystem processes: 'This principle implies the need to reverse the trend towards simplicity and efficiency (loss of diversity) in landscapes and in the coastal zone and to build landscapes and ecosystems with more complexity, redundancy and resilience' (Steffen et al. 2009:151) (see Chapter 27).
5. Eco-engineering may be needed to assist the transformation of some communities under climate change: '[T]here will be cases where a passive "let nature adapt" approach can and should be augmented by more proactive measures to conserve biodiversity' (Steffen et al. 2009:151).
6. Genetic preservation must be considered in some cases: 'As a last resort approach, some species may need to be preserved outside of an ecosystem context, whether it is an existing or transformed natural ecosystem or a human engineered ecosystem' (Steffen et al. 2009:151) (see Chapter 17).

Conclusion

In this chapter, we have provided a global overview of critical matters for protected area managers from a natural heritage management perspective. We have emphasised that the Earth is a marvel of nature, but finite in size. The lithosphere that we occupy, the atmosphere we breathe and the biosphere and life forms we share Earth with are all finite. We have identified that the Earth is also a dynamic place, with geological processes constantly changing the nature of our planet's geodiversity, and how early life on Earth has helped to create the atmospheric conditions suitable for the organisms present today. We described how this, in turn, through evolutionary responses has culminated in a rich and biodiverse natural world. We introduced this diversity and described the major ecosystem types on Earth.

We also introduced how Earth's life-support systems have been affected by human activity and subsequent climate change. We have reflected on what this means for protected area managers in the 21st century and

what the challenges are for working in a dynamic natural world that has been impacted by humans. We have, in effect, introduced the nature, scope, complexity and enormity of the challenge for protected area managers, worldwide, in helping to conserve life on Earth and its

other natural treasures. We have also provided the basis for other chapters of this book that examine in more detail particular aspects of the profession of protected area management.



The New Holland honeyeater (*Phylidonyris novaehollandiae*) is a frequent, welcome and busy visitor to many southern Australian homes and gardens. It is one of Australia's 898 recorded bird species and is a native to habitats that include forests and woodlands, creek sides, and coastal scrubs and heathlands. It is shown here with one of its favoured nectar sources, the flower of a native *Grevillea* sp., a relic Gondwanan Proteaceae species (Gondwana is the ancient super continent that included Antarctica, Australia, Africa, India and South America). Some Australian birds illustrate convergent evolution to species elsewhere, with honeyeaters resembling northern hemisphere sunbirds.






Source: Graeme L. Worboys

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