STATUS AND TRENDS OF GLOBAL BIODIVERSITY

INTRODUCTION

The purpose of this chapter is to provide an overview of the changing status of the world's biological diversity. The first sections below provide general information on the nature and scope of biological diversity, and broad trends at genetic and species level. Subsequent sections outline the status of the general ecosystem types that are the subject of thematic programmes established by the Convention, and brief remarks are given on other important habitat types.

The Convention's approach to biodiversity

The key objectives of the Convention, as set out in Article 1, and outlined in chapter 2 below, are simple in summary but in practice all-encompassing: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from use of genetic resources. Article 2 of the Convention provides a short description of the term "biodiversity", which refers essentially to the diversity of living organisms, the genes they contain, and the communities to which they contribute.

In addressing the boundless complexity of biological diversity, it has become conventional to think in hierarchical terms, from the genetic material within individual cells, building up through individual organisms, populations, species and communities of species, to the biosphere overall.

The dimensions of biodiversity

This term is used by the Convention to refer to all aspects of variability evident within the living world, including diversity within and between individuals, populations, species, communities, and ecosystems. Differences in pest resistance among rice varieties, the range of habitats within a forest ecosystem, or the global extinction of species of lake fish, all illustrate different aspects of biological diversity. The term is commonly used loosely to refer to all species and habitats in some given area, or even on the Earth overall.

Genes provide the blueprint for the construction and functioning of organisms, and their diversity is thus clearly fundamental. The Convention puts due emphasis on genetic resources, i.e. the genetic diversity responsible for key properties of organisms used by humans, for food, medicine or other purposes, and which provides the potential for future modifications to these organisms. However, genes in nature are expressed only through the form and differential survival of organisms, and if attempts are made to manipulate genes, for example in bioengineering, it is important to focus on the requirements of whole organisms if this is to be undertaken successfully. Accordingly, the diversity of organisms tends to be central to biodiversity studies, and species diversity is a generally useful and practicable measure of biodiversity.

At the same time, in seeking to make management intervention as efficient as possible, it is essential to take an holistic view of biodiversity and address the interactions that species have with each other and their non-living environment, i.e. to work from an ecological perspective. By several of its decisions,[1] the Conference of the Parties has explicitly recognized the need for this approach. In particular, decision V/6 and its annex provide a description and discussion of the ecosystem approach, which in effect becomes the paradigm within which the Convention's activities are undertaken.[2]

It is often useful to address biodiversity issues in sectoral or other non-hierarchical terms. Agricultural biodiversity, for example, comprises those elements at all levels of the biological hierarchy, from genes to ecosystems, involved in agriculture and food production. The Convention has established a work programme on agricultural biodiversity, in recognition of the pivotal role this sector has in the complex area where biodiversity conservation and sustainable development intersect.

Attention may be focused on the biodiversity of a particular class of habitats, such as freshwaters, marine waters, mountains, soil or caves. The Convention has taken this approach in developing programmes of work on the biodiversity of inland waters, marine and coastal waters, forests, and dry and sub-humid lands.

The extent and occurrence of global biodiversity

The defining feature of the planet Earth is that it supports living organisms, and the entire space occupied by such organisms is termed the biosphere.

The biosphere

The part of the planet occupied by living organisms can be pictured as a thin and irregular envelope around the Earth's surface, at most just a few kilometres deep on the globe's radius of more than 6,000 km. Because most organisms depend directly or indirectly on sunlight, the regions reached by sunlight form the core of the biosphere: i.e. the land surface, the top few millimetres of the soil, and the upper waters of lakes and the ocean. Bacteria occur almost everywhere, even kilometres deep within the Earth's rocky crust. Active living organisms are usually absent where liquid water is absent, but the dormant spores of bacteria and fungi are ubiquitous, from polar icecaps to many kilometres above the surface of the Earth.

The living organisms in the biosphere are organized in discrete groups. Those that reproduce sexually typically exist as species, i.e. distinctive groups of similar populations that are isolated reproductively from other such groups. Bacteria and many plants spread and reproduce vegetatively, i.e. without sexual reproduction, and the classic species concept is difficult to apply in such cases. The diversity of species, broadly defined, is nevertheless a useful general measure of the biodiversity of an area, country or the world. Globally,

[1] Full information on the decisions adopted by the Conference of the Parties can be found in the *Handbook of the Convention on Biological Diversity* published simultaneously with the *Global Biodiversity Outlook*.

[2] See Table 3.4 in chapter 3.

around 1.75 million species have been described and formally named to date, and there are good grounds for believing that several million more species exist but remain undiscovered and undescribed (Table 1.1).[3]

Table 1.1 **Estimated numbers of described species, and possible global total**

Kingdoms	Described species	Estimated total species
Bacteria	4,000	1,000,000
Protoctists (algae, protozoa, etc.)	80,000	600,000
Animals	1,320,000	10,600,000
Fungi	70,000	1,500,000
Plants	270,000	300,000
TOTAL	1,744,000	ca.14,000,000

Notes: The "Described species" column refers to species named by taxonomists. These estimates are inevitably incomplete, because new species will have been described since publication of any checklist and more are continually being described; most groups of organisms lack a list of species and numbers are even more approximate. Most animal species, including around 8 million of the more than 10 million animal species estimated to exist, are insects. Almost 10,000 bird species and 4,640 mammals are recognized, and probably very few of either group remain to be discovered. The "Exstimated total" column includes provisional working estimates of described species plus the number of unknown and undescribed species; the overall estimated total figure may be highly inaccurate.
Source: UNEP-WCMC, adapted from tables 3.1-1 and 3.1-2 of the *Global Biodiversity Assessment*.

Nearly three quarters (71%) of the Earth's surface is covered by marine waters. These have an average depth of 3.8 km, and the whole of this region, comprising virtually all the water on the planet, is theoretically capable of supporting active life. Oceans and seas thus make up the vast majority of the volume of the biosphere and by far the most extensive, if most poorly known, main ecosystem type. However, the amount of living material in most of the sea, i.e. that part of the open ocean below the upper hundred or so metres, is low compared with many terrestrial habitats.

Only two to three percent of the total world water volume is non-saline: around two thirds of this is locked away as ice and around on -third is groundwater in the upper layers of the Earth's crust. Surface freshwaters, i.e. the world's lakes, rivers and wetlands, hold the vanishingly small volume of water remaining, but this supports an important sector of global biodiversity. For example, about 40% of the more than 25,000 fish species known in the world occur in freshwaters, and many isolated water systems, large old lakes in particular, have a large number of species found nowhere else. Land, bearing the wide diversity of terrestrial ecosystems that humans are most familiar with, as well as surface freshwaters, covers less than one third (29%) of the Earth's surface. About half of this is below 500 m elevation and the global average elevation is only about 800 m. Most of the world land surface is situated in the northern hemisphere, and the amount north of the Tropic of Cancer slightly exceeds that in the rest of the world combined.

[3] See UNEP (1995) *Global Biodiversity Assessment* (henceforth *Global Biodiversity Assessment*), chapter 3.

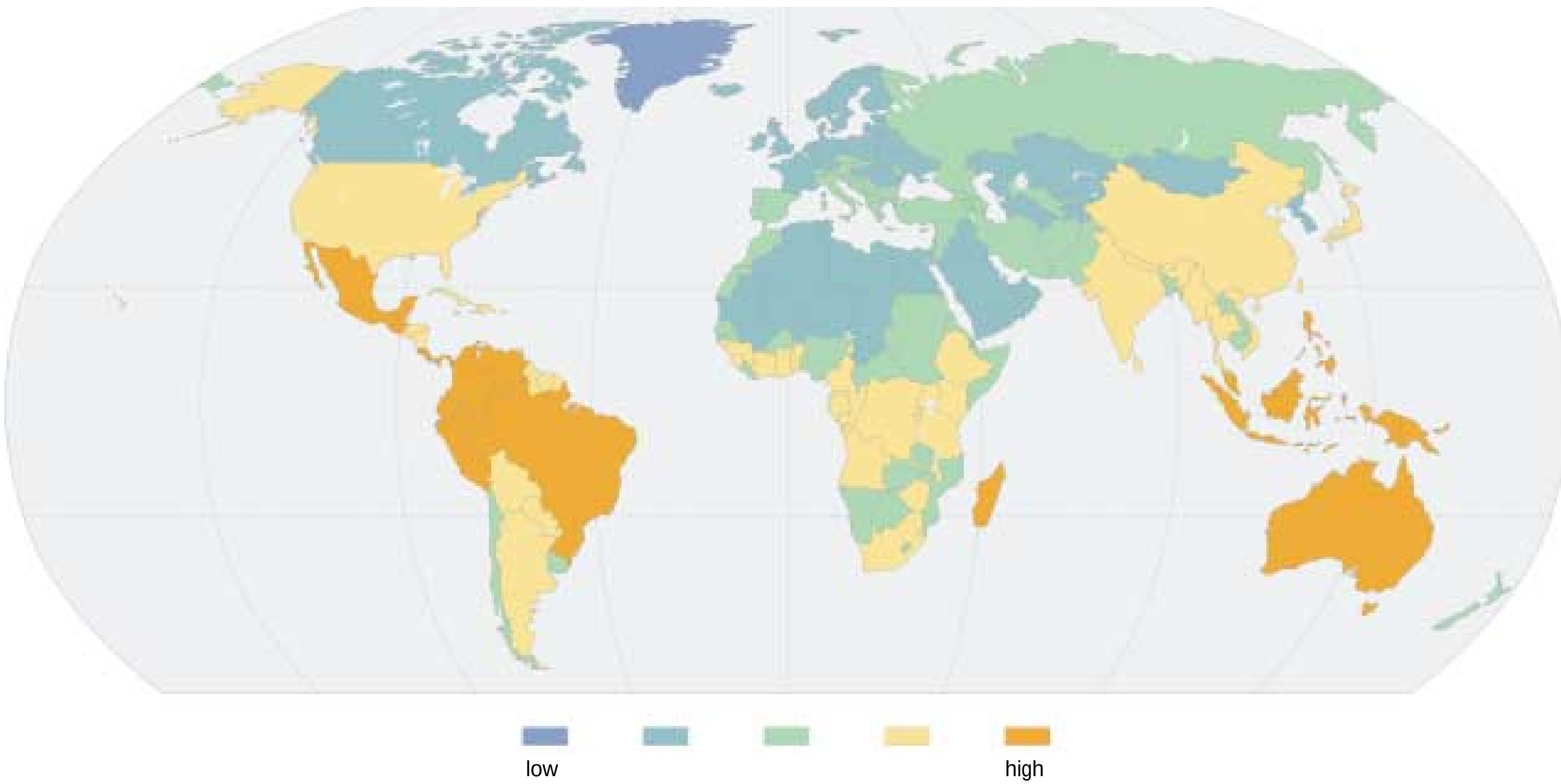
A familiar but important feature of biodiversity is that species are not evenly distributed over the planet. Although the information available on the distribution of the world's species is uneven and incomplete, the single most obvious pattern in global biodiversity is that overall species richness tends to increase toward the equator. At its simplest, this means that there are more species in total and per unit area in the tropics than in temperate regions, and more here than in polar regions. This variation in species number is strongly correlated with global variation in incident energy and water availability. These factors potentially lead to increased net primary production (NPP) by photosynthetic organisms, and a possible explanation for variation in species number is that this broader resource base may allow more species to coexist.

Species-rich habitats

Moist forests in the tropics are in general the most species-rich environments on Earth. If recent estimates of the number of as yet unknown species, mainly insects, in tropical forests are accepted, these regions, which extend over perhaps 7% of the world's surface, may hold up to 90% of the world's species. If tropical forest small insects are discounted, then coral reefs and, especially for flowering plants, areas of Mediterranean climate in South Africa and southwest Australia, may be similarly rich in species.

Map 1 represents an index of diversity based on richness and endemism in the four terrestrial vertebrate classes and vascular plants in most countries of the world. Further details of this National Biodiversity Index are provided in Annex 1. Map 2 shows selected regions of importance for both birds and plants.

MAP 1



Biodiversity at country level

This map represents an index of diversity derived from a database of richness and endemism in the four terrestrial vertebrate classes and vascular plants in most countries of the world, adjusted according to country area. Countries at the high end of the scale have more diversity than expected on area alone. The index is less reliable for the smallest countries.

Source: UNEP-WCMC National Biodiversity Index.

MAP 2

endemic bird areas | centres of plant diversity | areas of overlap

Selected regions of high biodiversity value

Many studies have attempted to define areas high in biodiversity, partly to guide investment in conservation. The BirdLife International study of restricted-range birds generated the first comprehensive and quantitative map of endemic-rich areas (Endemic Bird Areas) in a large group of organisms. The WWF/IUCN Centres of Plant Diversity project collated information on areas of special importance for plant diversity. This map shows in simplified form the areas identified by these two studies, and highlights regions apparently of importance for both birds and plants.

Source: data originally provided by BirdLife International and WWF/IUCN.

TRENDS IN GENETIC DIVERSITY

Genetic diversity is based on variation between genes, i.e. in the functional units of heredity in organisms. Not all the genetic material has a role in heredity, and in some organisms a large proportion of DNA is highly repetitive in sequence and has no known function. The features of an organism are determined fundamentally by the genes received from the previous generation, by the way these genes are expressed and interact, and to an extent by environmental effects on the organism.

The gene

A gene is a sequence of DNA (deoxyribonucleic acid) that constitutes the coded information for manufacture of proteins and other key substances in cells. This genetic material is copied and passed on between generations and copied to all cells of an organism, and the substances produced are responsible for the organization, development and maintenance of structure and life processes. Different genes are active at different phases and, in multicellular organisms, in different kinds of cell. Different forms of a gene are termed "alleles." The complete set of genes in an organism is "the genome."

New genetic diversity arises when chromosomes are not copied with absolute accuracy (i.e. undergo mutation) and through reassortment of genes on chromosomes when sex cells (sperm and egg cells) are being produced. In this latter process, different forms of genes at corresponding positions on maternal and paternal chromosomes can become exchanged, and entire chromosomes of maternal and paternal origin become sorted into different combinations. If the features determined by new mutations and new permutations of genetic material improve survival of individuals bearing them, the frequency of these genes in the population will increase.

Genetic diversity is important as it provides the raw material of evolution and because it enables adaptation and change in organisms. High levels of genetic diversity should allow species to be flexible in the face of environmental change, whereas low genetic diversity, for example in a small isolated population, tends to increase the risk of extinction.

Genetic diversity is also critically important for the continuing ability of human societies to derive economic and social benefits from biodiversity. The variability is an insurance policy that protects against risks that could reduce such benefits, for example widespread pest outbreaks or fluctuations in crop production from year to year.

Complex biochemical techniques can be used to measure the frequency and distribution of different gene products in species' populations, or genetic diversity may be assessed at organism level, for example in terms of the measurable production or pest resistance qualities of different crop varieties.

Bacteria differ from other organisms in that they can reproduce at a very high rate by dividing in two. They also exchange genetic material, but this sexual process is not associated with reproduction as it is in other organisms; instead, two bacteria in contact may directly exchange genetic material, or a single bacterium may take in DNA deposited in the environment by another bacterium. These exchanges, the latter in particular, are not always constrained by the kind of barriers that in higher organisms restrict exchange of genetic material to members of the same species. Genetic material can also be passed

Botswana*

"In recent years, declines have been observed in the numbers of many wildlife species. There is widespread replacement of diverse crop varieties by homogeneous modern cultivars that has resulted in genetic vulnerability."

between bacteria by viral infection. The apparent frequency with which genes move between populations of bacteria means that these organisms are able to generate high levels of new genetic diversity for natural selection to act upon, and favourable genetic material can spread very quickly in rapidly reproducing populations. This explains why resistance to antimicrobial substances can arise so readily in bacteria.

Declining genetic diversity

Human activities readily lead to change in the genetic diversity of populations of wild or domestic organisms. In extreme cases, genetic diversity is reduced to zero when a species is rendered extinct. More usually, it is reduced to some extent when populations of species are reduced in abundance or distribution. Such loss of genetic diversity, particularly if brought about by human activity, is often termed *genetic erosion.* The extent of reduction depends on the amount of diversity in the declining population and the way it is distributed geographically. Although levels of genetic diversity within such species would in some circumstances be expected to recover over time, particular genetic material that might be important for future adaptation may well be lost completely.

It would be possible, although not practicable routinely, to demonstrate genetic erosion at gene level. More usually it is evident at the species level, when measurably distinct populations (perhaps some local variety of crop plant) are lost or reduced in abundance, or is simply assumed to have occurred when an area of species-rich habitat is cleared. Because of the prevailing high rate of habitat modification, it can safely be assumed that genetic erosion is a very common and widespread phenomenon; however, not every loss of a local population is an instance of genetic erosion, because that population may have held no elements or combinations of genetic diversity not found elsewhere.

Manipulating genetic diversity

Human activity can also increase genetic diversity in species populations. By a process of artificial selection, humans have been indirectly but purposefully promoting genetic change in species during a period of more than 10,000 years, resulting in the current world diversity of domesticated crops and livestock.

Artificial selection involves managing the reproduction and survival of individuals within populations of useful plants and animals so as to preserve and make abundant those lineages that possess particularly useful features, such as high pest resistance or milk yield. The process is indirect in that it is focused on tangible features rather than on the genetic material from which such features originate.

* The quotations in the page margins have been taken from the first national reports on the implementation of the Convention (available at http://www.biodiv.org/world/reports.asp).

Biotechnology

Biotechnology
...is the general term applied to the use of living organisms or their components in agricultural, industrial or medical production processes. The role of selected strains of yeast in brewing and bread making is familiar, but micro-organisms are also used, for example, in the industrial-scale production of antibiotics, vitamins, and enzymes for food and drink manufacture.

Genetic Engineering
...or genetic modification, is a special form of biotechnology in which a section of DNA from one organism is introduced into another, in which it does not naturally occur, in order to produce a genetically modified organism (GMO) with favourable properties based on the new combination of genes. The new genes in the transgenic organism may be from an entirely different type of organism, or from a closely related lineage.

The activities collectively known as *genetic engineering* also involve manipulation of existing genetic material, creating new gene combinations with the aim of improving key features of organisms used by humans (see Table 1.2 for some examples). Genetic engineering is in one sense only an extension of traditional breeding practices, in that it relies on naturally occurring elements of diversity. However, it is fundamentally different in other important respects. Not only does it involve making direct modifications to the actual genetic material of organisms, but also genetic material from different kinds of organism usually isolated reproductively from each other, can be brought together and perpetuated in new lineages.

The more radical forms of genetic engineering have only been developed during the 1990s but already have had considerable social impact. The techniques may have great potential to improve efficiency, volume or quality in agricultural and other production processes, and these potential benefits could be of particular value to countries at risk of food insecurity. However, they also raise significant ethical and practical concerns, which have been expressed by scientists and by public opinion in both developed and developing countries.

Among the practical concerns, attention has focused on the possible effects of genetic material moving from genetically modified (GM) sources, particularly field crops, into other organisms. Regarding plants, the risk of this occurring depends partly on whether the crop is an inbreeding or outbreeding species (whether plants are self-fertile, for example rice and soya, or must be fertilised by pollen from another individual, for example oilseed rape), and whether wild relatives of the crop are grown in the area (for example maize or potatoes grown in the UK have no close wild relatives in the country).
The evidence available on possible effects at other levels in the food chain, for example on plant-feeding insects, is sparse but indicates that concern may be warranted. The use of genes conferring resistance to antibiotics as marker genes (to confirm presence of target genes) has caused concern because of the potential for increasing resistance in naturally occurring bacteria.

Table 1.2 **A selection of genetically modified living organisms**

Modified organisms	Source or property of added gene	New features in GMO	Scale of field use
Soya	Gene from *Salmonella* bacteria for enzyme EPSP (enolpyruvyl shikimate phosphate synthase) insensitive to glyphosate.	EPSP is essential for amino acid synthesis but inhibited by glyphosate, the active ingredient in Roundup herbicide. New enzymes confer herbicide resistance by disabling inhibition.	Major commercial significance in USA.
Maize	Gene for protein toxins *(Cry 1Ac and Cry 2Aa)* from *Bacillus thuringiensis* inserted by *Agrobacterium* Ti-plasmid.	Toxins confer insect resistance on host plants, e.g. to Stem Borer in maize.	Major commercial significance in USA.
Tomato	DNA modified to inhibit production of enzyme polygalacturonase (PG) responsible for plant cell wall breakdown.	Fruit life prolonged by slowing natural softening and ripening, without interrupting development of desirable flavour and colour.	Sold since 1995 in Canada, Mexico and USA. Cleared or sale in UK in 1996 but withdrawn by 1999 due to consumer pressure.
Rice *japponica* variety T309	Two genes from a daffodil and one from a bacterium.	Develop a variety of rice rich in beta-carotene, which is most common source for vitamin A.	Trials, much interest in developing countries in Asia.
Oilseed Rape	Gene for enzyme thio-esterase from bay laurel.	Increases level of lauric acid in oil by inhibiting synthesis of longer-chain fatty acids.	Important in detergent manufacture.
Atlantic Salmon	Gene from other fishes (flounder or ocean pout) prolongs period of hormone secretion.	Increased growth rate.	Research project in USA, other work in Canada, New Zealand, Scotland.

It is widely believed that some movement of genetic material from GM sources into other organisms is inevitable in the long term; the level of risk that can be tolerated depends on the balance of benefits and costs. These questions of responsible management of GM resources and technology have given rise to the new field of "biosafety."

Biosafety

Article 8(g) of the Convention calls on Parties to establish or maintain means to regulate, manage or control risk to the conservation and sustainable use of biodiversity associated with the use and release of living modified organisms produced by biotechnology, and to take account of risk to human health. The objective of the Convention's Cartagena Protocol on Biosafety is to ensure an adequate level of protection in the safe transfer, handling and use of such living modified organisms, specifically focusing on transboundary movements. The Protocol was adopted in January 2000 and will enter into force once it has been ratified by fifty countries (see chapter 2).

Human activity has also unintentionally led to increased genetic diversity, particularly among bacteria. In such cases a form of artificial selection is imposed on bacterial populations when they are exposed to antibiotics. It has been shown, for example, that routine use of antibiotics as prophylactic or growth promoting agents in intensive agriculture, i.e. not just for therapeutic purposes, has led to emergence of bacterial strains that are resistant to antibiotics, and these strains can infect humans. Table 1.3 provides selected examples.

Table 1.3 **Examples of human-induced antibiotic resistance in pathogenic bacteria**

Bacterial pathogen	Resistance	Emergence
Salmonella typhimurium DT 104	Multidrug resistant	Recorded 1988 in cattle in England and Wales, increased in humans during 1990s in North America and UK, drug resistance broadening.
Enterobacter & Campylobacter	Flouroquinolone resistant	Resistant strains emerged after flouroquinolone approved for veterinary use.
Escherichia coli O157:H7	Multidrug resistant	Increased occurrence in humans in North America and Europe linked with therapeutic and sub-therapeutic veterinary use and phytosanitisation on fruit farms.

TRENDS IN SPECIES DIVERSITY

Austria

"Nearly 3000 animal species (2300 are insects) are listed as being threatened. Approximately 40% of ferns and angiosperms have been classified as being threatened to one degree or another."

Belarus

"Since the 1800s, 238 species of terrestrial vertebrates have either vanished from Belarus or can no longer be detected on its territory."

Despite the fundamental practical importance of trends in genetic diversity, biodiversity change has mainly been assessed in terms of declining populations and species, either individually, or collectively, when manifest as loss of habitats or reduction in area of ecosystems. Historically, the impetus for much conservation activity has been the drive to prevent the decline and extinction of individual species, with significant emphasis on species that are large and charismatic. The primary benefit of this approach may be that large organisms, terrestrial vertebrates in particular, generally require large areas of suitable habitat, and if such areas can be managed to minimise risk, other species in the system may be safeguarded.

Extinction

There has always been special concern about extinction because of its irreversibility, and the loss of a species will entail loss of unique elements or combinations of diversity at gene and organism level. In this regard, the fossil record demonstrates two important facts. Firstly, that although relative rates have varied greatly, over geological time as a whole there has been a net excess of species originations over species extinctions (i.e. biodiversity has increased). Secondly, that virtually all the species that have ever existed are now extinct, and the extinction of every species is a natural and expected event. Self-evidently there must always have been species at risk of extinction, i.e. "threatened species."

It is difficult for many reasons to keep track of species extinction in recent time. The species involved may be unknown; it may be unclear whether some population represents a separate species or not; the individuals may be too small to be noticed without special sampling procedures; and the entire process of decline and extinction may extend over much more than an average human lifespan. Positive evidence of extinction (i.e. direct observation of the death of the known last individuals) is unlikely to be available; typically, negative evidence (i.e. failure to find the species despite repeated searches) accumulates to the point where extinction is the most probable explanation.

In other words, unless circumstances are exceptional, monitoring of recent extinction events has a resolution limit measured in decades, and it is thus impossible to state with precision how many species have gone extinct in any given period or to predict exactly how many species are going to become extinct by some point in the future.

From the imperfect evidence that is available, it appears that around 300-350 vertebrates and nearly 400 invertebrates have become extinct during the past 400 years (see Table 1.4 and Map 3). The number of plant extinctions is thought to be in the hundreds, although some believed to be extinct in the wild have survived in botanic gardens and seed collections. Because mammals and birds tend to be relatively well recorded, and leave recognizable skeletal remains, it is principally among these groups that known extinctions may be reasonably representative of actual extinctions. In these two groups the known rate of extinction over the past 400 years averages around 20-25 species per hundred years.

[4] For further discussion and for sources, see WCMC (2000) *Global Biodiversity: Earth's living resources in the 21st Century* (henceforth *Global Biodiversity*), chapter 3. See also *Global Biodiversity Assessment*, chapter 4.

Finland

"One in eight species of plant and animal in Finland are endangered."

Zambia

"Elephant population have fallen from 100,000 in 1980 to less than 22,000 in 1993. Rhino populations have also declined from 15,000 in 1980 to less than 100 by 1993."

The key question then is: how does this compare with the average "normal" extinction rate indicated in the fossil record? Extinction rates have varied greatly, and species that are rare or otherwise prone to extinction must be poorly represented by fossils and so bias the record, but the average lifespan of a fossil species appears to be about four million years. Given this average, if 10 million species existed at any one time, the extinction rate would have been about 2.5 species annually. Applying this factor to recent birds and mammals (numbering about 10,000 and 5,000 living species respectively) the expected background extinction rate would be around one species every four hundred years and eight hundred years, respectively. The known recent extinction rate appears to be some 100 or 200 times higher than background. Bias inherent in the fossil record makes it difficult to achieve greater precision in such estimates, but the general direction of the trend is well supported.[4]

Because scientific knowledge of the world's species is incomplete and highly vertebrate-centred, it is virtually certain that more extinctions are occurring than currently known. Most predictions of the contemporary extinction rate are based on combining estimates of species richness in tropical forest with estimates of rate of loss of these forests; species extinction is then predicted on the basis of the general species-area relationship, under which species richness will decline as area declines. Projections of this sort suggest the contemporary extinction rate is very high. On a direct numerical basis, most extinctions predicted by calculations based on forest area reduction should involve beetles, because these species make up the great majority of all species in tropical forests. As a cautionary note, it should be observed that very few extinctions have to date been recorded in continental tropical moist forests, although monitoring species in these habitats presents great difficulty.

Most known animal and plant extinctions have occurred on islands, and most known continental extinctions have been among freshwater organisms (most of these being river-endemic molluscs and lake-endemic fishes). From the incomplete information available on the timing of extinction, it appears that the extinction rate (in molluscs, birds and mammals) has risen overall since about 1600 AD to near the middle of the past century (i.e. 1930-1960) and declined thereafter. The apparent decline after mid-century is probably caused in part by the time lag inherent in recording extinction, and in part by the conservation measures that many countries have taken during the latter half of the 20th century. It could also be due to the fact that extinction-prone species in the well-known groups (birds and mammals) have now been lost.

MAP 3

Vertebrates extinct since 1600 AD

Size of symbol indicates number of extinct vertebrate species. Numbers are approximate because of differences in taxonomy and criteria. In many cases, including most islands and lakes, the position of the symbol indicates former range or last record. Where several species ranged more widely over a country, the symbol is positioned at the centre of that country.

Source: UNEP-WCMC. 2000. *Global Biodiversity: Earth's living resources in the 21st century.*

Armenia

"Between 100 and 700 plant species are supported by steppe ecosystems, however after intensive overgrazing the number drops to around 15."

Australia

"Many species are no longer found throughout their former ranges, and may only occur in reduced numbers. Elephant seals, southern blue-fin tuna, whales and some native fishes and frogs have drastically declined in numbers."

Threatened species

Various national and international programmes have developed methods to assess the relative severity of risks faced by living species, and to label species with an indicative category name. Conservation activities can then be prioritised on the basis of relative risk, taking account of other relevant factors, such as feasibility, cost and benefits, as appropriate. The system developed by IUCN–The World Conservation Union and collaborators in conjunction with its Red Data Book and Red List programme provides a standard at the global level.[5] To be classified as threatened with extinction, a species is assessed against a set of five quantitative criteria that form the heart of the system. These criteria are based on biological factors related to extinction risk and include: rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation. Maps 4 and 5 represent threatened birds and mammals at global and country level.

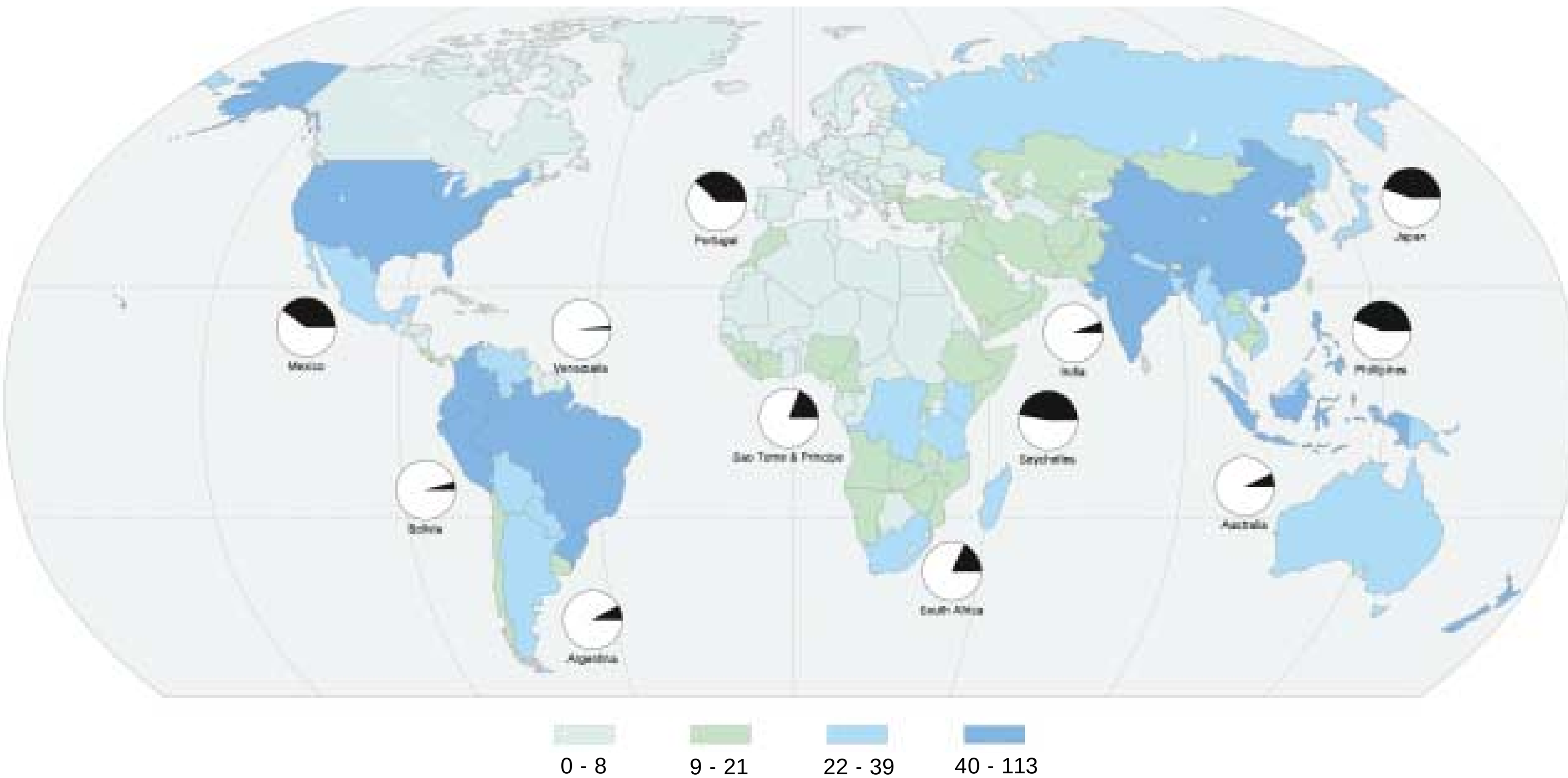
Extinct and threatened species: some key points

- Every species will become extinct at some point; virtually all species that have existed are extinct.
- In geological time, origination of species has proceeded at a higher rate than extinction of species, i.e. biodiversity has increased.
- In recent time, the known rate of extinction among mammals and birds is far higher than the estimated average rate through geological time.
- It is possible to estimate the relative risk of extinction among recent species on the basis of demography and distribution.
- All mammals and birds have been assessed for extinction risk: 24% of mammal species and 12% of birds were considered globally threatened in 2000.

In general, small isolated populations will be more sensitive than larger connected ones to demographic factors (for example random events affecting the survival and reproduction of individuals) or environmental factors (for example hurricanes, spread of disease, changes in food availability). Human activities tend to promote fragmentation of natural and often species-rich habitats (for example primary tropical forest or temperate meadow grassland), and the spread of highly managed species-poor habitats (for example teak plantations or cereal croplands). As a result, many species occur in just the kind of fragmented pattern that increases the risk of extinction.

[5] There are eight categories in the IUCN Red List system: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Lower Risk, Data Deficient, and Not Evaluated. Species that fall into the categories of Vulnerable, Endangered or Critically Endangered are classified as threatened species. The Red List is produced by the IUCN Species Survival Commission (SSC) – a worldwide network of some 7,000 species experts, and data from a number of partner organisations. So far, countries have not used a standard set of criteria to assess levels of threat to species at country level, with the consequence that it is not straightforward to compare trends in species diversity between countries. It is anticipated that the IUCN/SSC system, used initially at the global level, will increasingly be applied at national level.

MAP 4

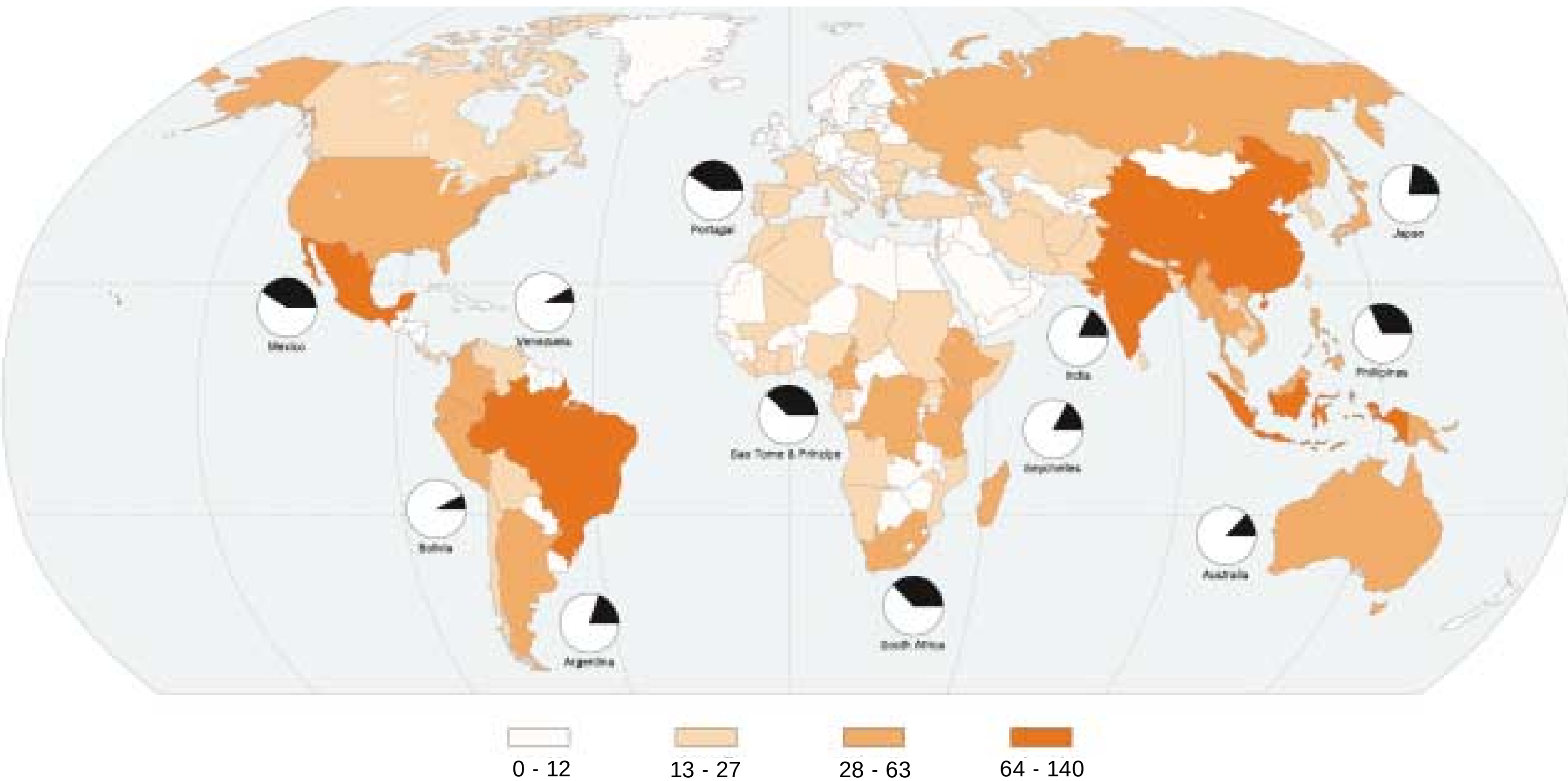


Threatened birds at global and country level

Colour represents number of globally threatened bird species in each country in 2000. Pie charts represent the proportion of the bird fauna assessed as threatened at national level in a small sample of countries. This is a highly generalised comparison because of differences in status assessment.

Source: global data from 2000 *IUCN Red List of Threatened Species*, country data from selection of national Red Data Books.

MAP 5



Threatened mammals at global and country level

Colour represents number of globally threatened mammal species in each country in 2000. Pie charts represent the proportion of the mammal fauna assessed as threatened at national level in a small sample of countries. This is a highly generalised comparison because of differences in status assessment.

Source: global data from 2000 *IUCN Red List of Threatened Species*, country data from selection of national Red Data Books.

The conservation status of most species is not known in detail, and this certainly applies to the many million as yet undescribed species, but two large animal groups – the mammals and birds – have been comprehensively assessed. Approximately 24% (1,130) of the world's mammals and 12% (1,183) of the world's bird species are regarded on the basis of IUCN criteria as globally threatened. Proportions are much lower in other vertebrates, but none of these has been assessed fully. Empirical observations such as these give grounds for serious concern for biodiversity maintenance, regardless of any hypotheses that have been proposed regarding the contemporary and future rate of extinction.

Colombia

"103 species of animal are considered threatened to some degree."

Fiji

"116 species have been categorized as potentially rare, threatened or endangered."

Table 1.4 **Threatened and extinct species**

	Number of species in group	Approx. proportion of group assessed	Threatened species in 2000	% of total in group threatened	Extinct species
Vertebrates					
Mammals	4,763	100%	1,130	24%	87
Birds	9,946	100%	1,183	12%	131
Reptiles	7,970	<15%	296	4%	22
Amphibians	4,950	<15%	146	3%	5
Fishes	25,000	<10%	752	3%	92
Invertebrates					
Insects	950,000	<0.1%	555	0.06%	73
Molluscs	70,000	<5%	938	1%	303
Crustaceans	40,000	<5%	408	1%	9
Others	>100,000	<0.1%	27	0.02%	4
Plants					
Mosses	15,000	<1%	80	0.5%	3
Conifers, cycads, etc.	876	72%	141	16%	1
Flowering plants	138,000	<9%	5,390	3.5%	86

Note: The two groups that have been comprehensively assessed (mammals, birds) are shown in bold. The plant data refer to the relatively small number of species that have been assessed using the current IUCN system of threat categorisation; the 1997 plants Red List covered approximately 20% of plant species using the former (pre-1994) IUCN system under which 30,827 taxa (11%) were regarded as threatened. The "Extinct" column includes species believed to have become total extinct since around 1500 AD, and species extinct in the wild but extant in captivity or cultivation; overall the "extinct in the wild" species form about 6% of the total numbers shown in this column.
Source: adapted from Table 5.2 in *Global Biodiversity* using revised data from Hilton-Taylor, C (Compiler). 2000. *2000 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland and Cambridge.

Oman

"Many high value fish have shown considerable declines. Kingfish contributed only 15% of the large pelagic catch in 1995, compared with 39% in 1988."

Japan

"A survey in 1993 showed that 38% of the 19,134 km coastline of the four main islands in Japan are artificial coastline. Since 1978, 3875 hectares of tidal flat have disappeared."

Biodiversity of Marine and Coastal Ecosystems

The major zones of the oceans

The area of the ocean most influenced by human activity, and best known scientifically, is the continental shelf – the area of shallow water lying around the major landmasses that may be anything from a few kilometres to several hundred kilometres wide. The most landward part of this is the intertidal or littoral zone, where the bottom is periodically exposed to air and water depth varies from zero to several metres. Seaward of this the shelf slopes gently from shore to depths of one hundred to several hundred metres, forming the sublittoral or shelf zone. At the outer edge of the shelf there is an abrupt steepening of the sea bottom, forming the continental slope, which descends to depths of 3-5 km. At this level there are immense abyssal plains, which form the floor of much of the world's oceans. The plains are punctuated by numerous submarine ridges and seamounts, which may break the sea surface to form islands. The deepest parts of the ocean are ocean trenches, which are seismically highly active, and reach depths of from 7,000 to 11,000 metres.

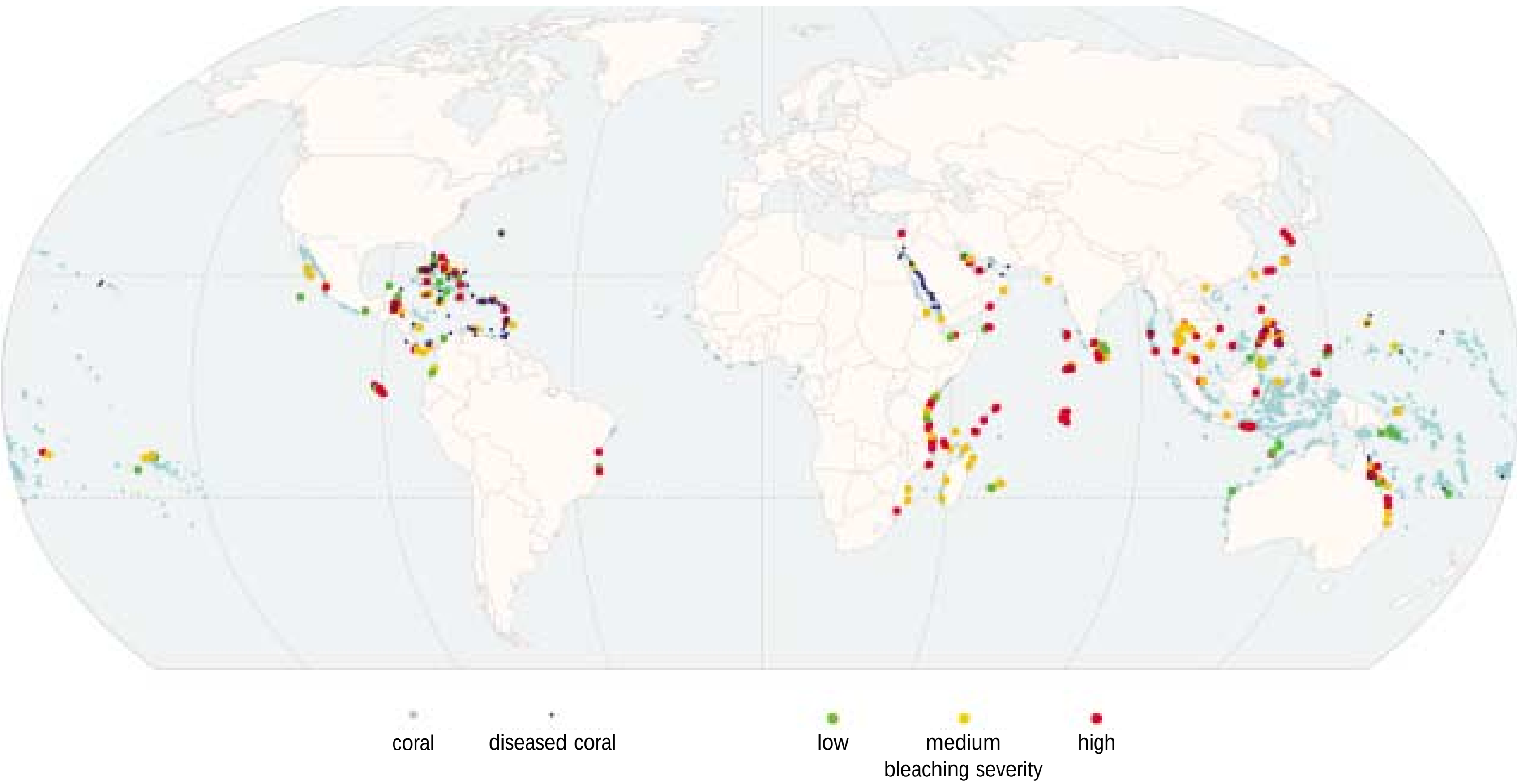
In the sea, as on land, photosynthesis based on sunlight is the driving force behind the maintenance of life. Because seawater absorbs sunlight strongly, photosynthesis is limited to the topmost layers of the sea, the so-called euphotic zone, which rarely reaches depths of more than 200 m in the open ocean, although at depths between 200 m and one kilometre blue light may still penetrate sufficiently to allow limited photosynthesis. Primary producers, largely in the form of photosynthesising bacteria and algae, are effectively confined to this zone. The few exceptions include bacteria living around hydrothermal vents associated with rift zones in the ocean floor. These bacteria use hydrogen sulphide as an energy source and support a unique community of other organisms. They are scientifically of enormous interest, but make a negligible contribution to overall productivity in the oceans. Areas of high productivity are associated with upwelling zones, where nutrient-rich bottom water is brought to the surface.

Major marine communities

Mangroves or mangals are truly hybrid terrestrial/marine ecosystems. They are a diverse collection of shrubs and trees (including ferns and palms) which live in or adjacent to the intertidal zone and are thus unusual amongst vascular plants in that they are adapted to having their roots at least periodically submerged in sea water. Mangrove communities are predominantly tropical and are rarely found beyond the latitudes 30°N and 30°S. They are only able to grow on shores that are sheltered from wave action. Diversity in mangrove ecosystems is usually relatively low, particularly when compared with other tropical ecosystems such as tropical moist forests and coral reefs. The most diverse mangrove systems are found in Southeast Asia (Map 12).

Coral reefs are calcium carbonate structures developed very largely by stony corals in the order Scleractinia of the phylum Cnidaria. They are essentially tropical, shallow water ecosystems largely restricted to the area between latitudes 30°N and 30°S and most abundant in shallow, well flushed marine environments characterised by clear, warm, low-nutrient waters that are of average oceanic salinity (Map 6). It is difficult to measure the global area of coral reefs, although it is believed to exceed 600,000 km^2. Near-surface reefs (the most productive and diverse) are estimated to cover around 255,000 km^2. They are among the most productive and diverse of all natural ecosystems, although it appears that their diversity is generally lower than that of the tropical moist forests often regarded as their terrestrial analogues. As with mangroves, the centre of diversity of reef-building corals is Southeast Asia, with an estimated minimum of 450 species of corals found associated with reefs around the Philippines, Borneo, Sulawesi and associated islands.

MAP 6



Coral reefs

This map represents the general occurrence of coral reefs and the relative severity of observed coral bleaching, a process associated with high temperature and other stressors in which algal symbionts in coral are killed leading to coral death or growth reduction.

Source: compiled from multiple sources.

United Kingdom

"Many fish stocks are at worryingly low levels because of over-exploitation."

Thailand

"The recorded number of fishing vessels in Thai waters has increased from 4000 vessels in 1972 to 13,000 vessels in 1980. The reduced harvests of demersal and pelagic fishes would indicate that the fisheries have long since reached their carrying capacity and can no longer support any more vessels."

Seagrasses are flowering plants (not true grasses) that are adapted to live submerged in seawater. There are approximately 48 species found in shallow coastal areas between the Arctic and Antarctic, down to depths of around 60 m. The most extensive areas are on soft substrates. Seagrass beds have high productivity and contribute significantly to the total primary production of inshore waters, being an important source of food for many organisms. The total global area is unknown.

Algae are the major large photosynthesising organisms in marine environments. There are three main groups: the red algae or Rhodophyta with around 4,000 marine species, the green algae or Chlorophyta with around 1,000 species, and the brown algae or Phaeophyta with about 1,500. In many of the colder regions of the world, hard subtidal substrates are occupied by very large brown algae collectively known as kelps (order Laminariales), which form extensive kelp beds or forests. The cooler regions of the world are rich in algal species.

Pelagic or open-ocean communities occupy a greater area than any other major community type on Earth. They are dominated by the activity of plankton in the euphotic zone near the surface. The plankton support a large number of free-swimming organisms or nekton, predominantly fishes but also cetaceans and cephalopod molluscs (squid). The marked vertical gradients within the pelagic zone – of light, temperature, pressure, nutrient availability and salinity – lead to strong vertical structuring of pelagic species assemblages. This vertical stratification is not static, but fluctuates seasonally and, often, daily, with variations in the physical and chemical characteristics of the seawater and vertical migrations of mid-water organisms. Until recently it was assumed that biomass in the pelagic zone everywhere below the euphotic zone was low. Recent studies have indicated that in some areas (for example the northern Indian Ocean), biomass of tropical mid-water or mesopelagic animals may be surprisingly high.

Deep-sea communities are prevalent on around half of the world's surface area, where the ocean is over 3,000 m deep. All such areas are in permanent darkness (other than light generated by bioluminescence and tectonic activity). Biomass is very low but new sampling techniques indicate that the diversity of small organisms in or on the sea bottom is often relatively high.

Major values and uses of marine and coastal ecosystems

The world ocean plays a crucial role in the regulation of climate and in the carbon cycle and other biogeochemical cycles. Much of this role can be ascribed to the ocean as a physical entity, that is as a vast, circulating body of water whose high specific heat capacity buffers atmospheric changes in temperature and which is capable of dissolving very large amounts of carbon dioxide. It does seem however that marine organisms also play a very important role in the major biogeochemical cycles, although one which is difficult to quantify.

Marine fisheries provide by far the largest source of wild protein, this being of critical importance to many subsistence communities around the world, making use of fin fishes, crustaceans and molluscs, with marine algae increasing in importance in Asia. Mangroves and seagrass beds fulfil an important function as nursery areas for juvenile fish and shellfish.

Belize

"Concerns that fisheries stocks are being affected by overfishing of commercial species, and coastal based development related activities that may permanently damage mangroves and reef ecosystems which the fisheries rely on."

Marine capture fisheries have increased in volume nearly five-fold in the past 50 years, rising to nearly 90 million tonnes in the late 1990s, this making up more than 70% of the total world production of aquatic resources (Map 7). Analysis by FAO and others indicates that marine stocks are widely overexploited and in urgent need of remedial management. Other major uses of the marine sphere include:

- waste disposal;
- recreation, chiefly in coastal zones;
- coastal stabilisation;
- transportation.

Major impacts on marine and coastal ecosystems

Impacts can be grouped into five main categories:

- chemical pollution and eutrophication;
- fisheries operations;
- global climate change;
- alterations of physical habitat;
- invasions of exotic species.

Chemical pollution with eutrophication is a widespread problem, most pronounced in semi-enclosed seas such as the Mediterranean and the Black Sea.

In addition to the potential for over-fishing, fishery operations can have a destructive physical impact on the seabed, and affect population levels of non-target species through incidental catch, such problems being of particular significance for cetaceans, sea turtles and seabirds such as albatross, in different parts of the world. All commercial bottom fishing disturbs sea-floor organisms and the seabed, with impacts on both habitats and species.

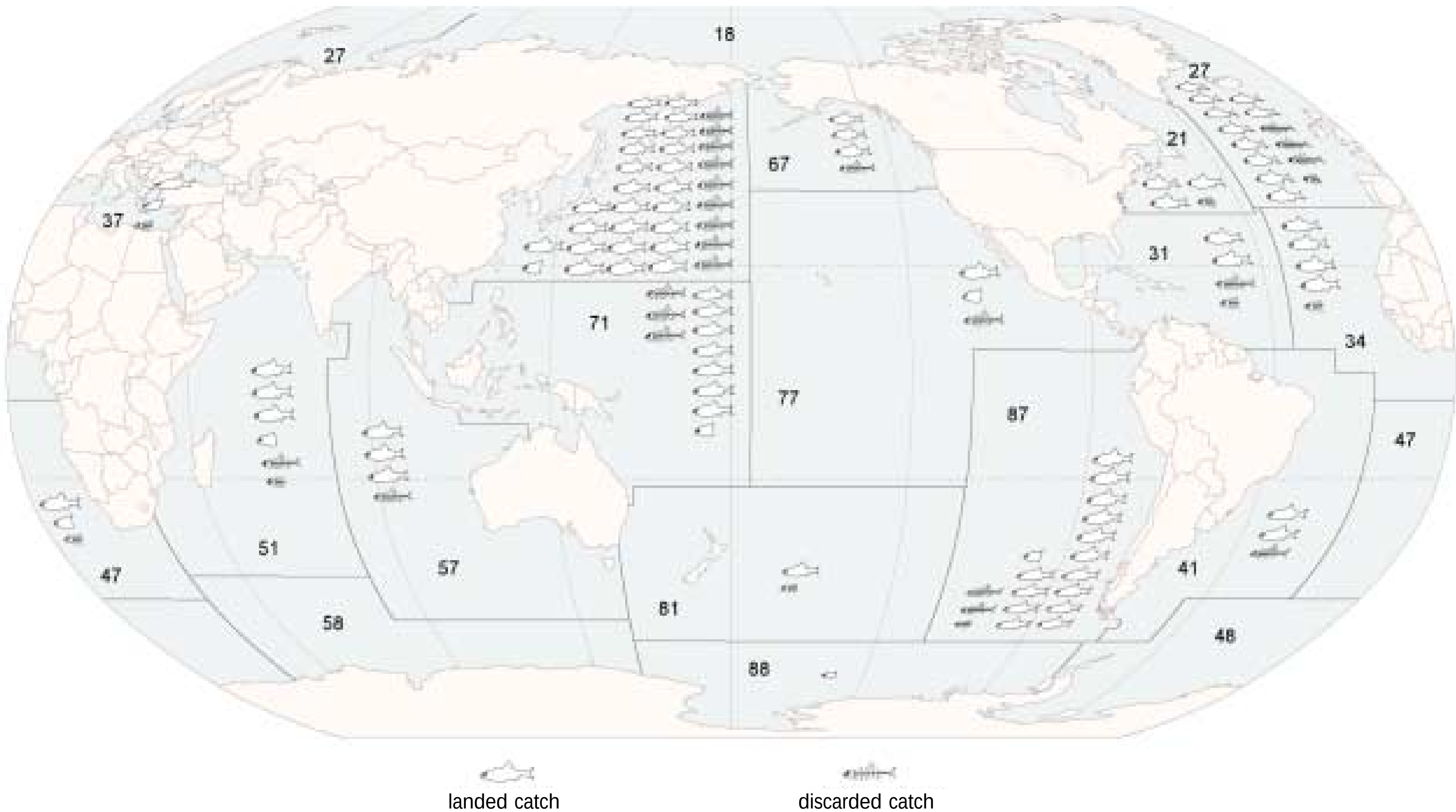
Coral bleaching related to periodic climatic events is the primary threat to coral reefs on the global scale. The increase in sea-surface temperature associated with the major El Niño and La Niña climate switches in 1997-1998 resulted in extensive coral bleaching and mortality over large portions of the Indian Ocean and Southeast and East Asia. On some reefs, there were mortality levels greater than 90% leaving some reefs almost bare of corals and with early indication of major shifts in the population structures.

The critical feature of recent coral-bleaching events is that areas have been struck indiscriminately, irrespective of the status of reef health; impacts have been felt both on pristine, remote reefs and on reefs already under major human-induced stresses. Some of the changes recently caused by periodic climate events, including coral bleaching, are not necessarily permanent, however human-induced stresses causing physical degradation and destruction to coral-reef organisms often exacerbate the effects of these events or limit the recovery capability of reef ecosystems.

Status and trends of species in marine and coastal ecosystems

As a gross generalisation, marine species appear to be somewhat less prone to extinction than inland water or terrestrial ones. Certainly, available information indicates that far few marine species are known to have become extinct since 1600 than either terrestrial or freshwater ones. Part of this difference may be because marine species are in general much less readily observable than those in terrestrial habitats, and, to a lesser extent, inland water species. It is possible therefore that a higher proportion of marine than terrestrial or inland water species has become extinct without our knowing. However, it seems likely that the difference is in large part a real one, and can be ascribed to two main factors. First, because of the size of the oceans, and the fact that people do not live permanently in them, they are as a whole considerably more buffered from human impacts than terrestrial or

MAP 7



Marine fisheries catch

This map represents the volume of landed catch and discarded catch in each Fishery Area as defined for statistical purposes by the FAO. Each symbol represents approximatery one million tonnes.

Source: data from the FAO relating to 1995, as represented in UNEP-WCMC. 2000. *Global Biodiversity: Earth's living resources in the 21st century.*

Mozambique

"Current estimates indicate that mangroves cover 396,080 hectares of coastline, which represents a reduction of 3.9% since 1972."

inland water areas. Second, marine species appear on the whole to be more widespread than terrestrial or inland water ones. This makes them generally less vulnerable to extinction. There are, of course, many exceptions to this.

Notes on a selection of the marine species that are categorised as Critically Endangered in the 2000 IUCN Red List, i.e. at highest risk of extinction, are provided in Table 1.5 below.

Table 1.5 **Some Critically Endangered marine species**

Mammals	
Vaquita *Phocoena sinus*	A small porpoise restricted to the Gulf of California, Mexico. The vaquita is threatened by accidental entanglement and drowning in fishing nets.
Mediterranean Monk Seal *Monachus monachus*	Formerly widespread throughout the Mediterranean and North African coast; now mostly restricted to islands in the Aegean Sea and the coast of Mauritania. Threatened by entanglement in fishing nets, disturbance of breeding sites and illegal killing.
Birds	
Amsterdam Albatross *Diomedea amsterdamensis*	A large seabird nesting only on Amsterdam Island in the Southern Indian Ocean. The small population (approximately 70 individuals in 1990) was previously threatened by habitat loss, and is at risk from entanglement in fishing gear.
Fiji Petrel *Pseudobulweria macgillivrayi*	Until 1984 known from a single specimen collected in 1855 from Gau Island, Fiji. Nesting is believed to occur in mature forest on the island, though nests have yet to be located. Feral cats are a potential threat to this little-known seabird.
Galápagos Petrel *Pterodroma phaeopygia*	Breeds only in the highlands of the Galápagos Islands, Ecuador. Destruction of nest sites and predation by introduced animals have resulted in a steady population decline.
Reptiles	
Kemp's Ridley *Lepidochelys kempii*	Mainly occurs in the waters of the western Atlantic and nests almost exclusively at a single beach in Mexico. Predation of eggs, illegal catch of adults and entanglement in fishing gear have led to the species decline. The species is now recovering through intensive conservation measures.
Fishes	
Spotted Handfish *Brachionichthys hirsutus*	Endemic to the Derwent estuary, Tasmania, Australia. Causes of decline not clear but predation of handfish eggs by an introduced starfish species and increases in soil runoff from surrounding agricultural land may be the principal factors.
Totoaba *Totoaba macdonaldi*	A large fish restricted to the Gulf of California, Mexico. Threatened by excess fishing, mortality of juveniles in shrimp fishery bycatch and possibly by a reduction of freshwater discharge into the Gulf.
Largetooth Sawfish *Pristis perotteti*	These large unusual fish occur mainly in the shallow estuarine waters of the Atlantic, eastern Pacific and possibly the Mediterranean. Decline of this slow maturing species attributed to excess fishing.

Finland

“In southern Finland 23.4% of various natural-state spruce mires survived in the 1950s, but by 1985 only 3.8% remained in its natural state.”

Biodiversity of Inland Water Ecosystems

Freshwaters make up less than 3% of the total volume of water on Earth. They consist largely of water in the form of polar ice (mostly Antarctica) and groundwater, i.e. water below the Earth’s surface held within rocks or between rock strata and constituting perhaps 30% of global freshwater resources. Water in lakes and rivers constitutes less than one hundredth of one percent (<0.01) of the world’s total water volume, and around a quarter of one percent (<0.27) of global freshwater volume. Lake water is the largest component in this vanishingly small subtotal.

The more superficial groundwater deposits are linked to the global water cycle, and are used for human consumption or agricultural purposes, whereas the deeper layers tend to be somewhat saline and do not (except over geological time scales) participate in exchanges with other parts of the system.

Table 1.6 **The world water resource**

	Area million km²	% total area	Volume million km³	% total water	% fresh water
Earth surface	510				
Land	149	29			
World ocean	361	71	1,338	97.5	
Fresh water:	–	–	35	2.5	
Ice	16	–	24	1.75	69
Ground water	–	–	10.5	0.75	30
Wetlands *	2.6	–	0.01	0.0008	0.03
Lakes **	1.5	–	0.09	0.007	0.26
Rivers	–	¬	0.02	0.0002	0.006

Note: all estimates are approximations and vary according to the methods used to derive them; for consistency we have taken data from a single source. * in the traditional sense, i.e. marshes, swamps, mires, lagoons, floodplains etc; ** excluding saline lakes.
Source: Anon. (USSR Committee for the International Hydrological Decade) 1978.

Inland aquatic habitats show far more variety in their physical and chemical characteristics than marine habitats. They range from vast, permanent lakes and rivers to geothermal springs, temporary puddles and minute pools and from almost pure water to highly concentrated solutions of mineral salts, toxic to all but a few specialised organisms.

Inland aquatic habitats can be divided into running or *lotic* and standing or *lentic* systems. They may also be divided into permanent water bodies, periodically (usually seasonally) inundated and transient or ephemeral. There is no rigid dividing line between an inland aquatic habitat on the one hand and a terrestrial or marine habitat on the other. Seasonally inundated areas, such as river floodplains, are effectively hybrid or transitional systems. There are also many areas that consist of shifting mosaics of land and shallow water, or areas of saturated vegetation, such as sphagnum moss bogs, that are neither strictly land nor water. There areas are often termed “wetlands.”

Uzbekistan

"Between 1992 and 1995 there has been a significant decline in fisheries production, approximately 51%."

Major inland water systems

Rivers and other lotic systems are essentially linear bodies of water draining under the influence of gravity from elevated areas of land toward sea level. River systems typically branch into ever smaller and more numerous channels with increasing elevation. The volume of water and speed of flow usually varies greatly from one part of a river system to another. These factors also vary seasonally; in some arid areas rivers flow for only part of the year, or in extreme cases only once in several years. Variations in water flow and in underlying geology create a wide range of habitats within any river, often within a short distance. Large river systems may also span many degrees of latitude and pass through a wide range of climatic conditions within their catchments. This variation creates a wide range of niches for different organisms within any given river system. Although river systems are constantly changing their courses, sometimes radically, through deposition and erosion of channels and the uplift and erosion of watershed uplands, evidence suggests that many larger river systems are extremely old, with some having been in continuous existence for tens of millions of years.

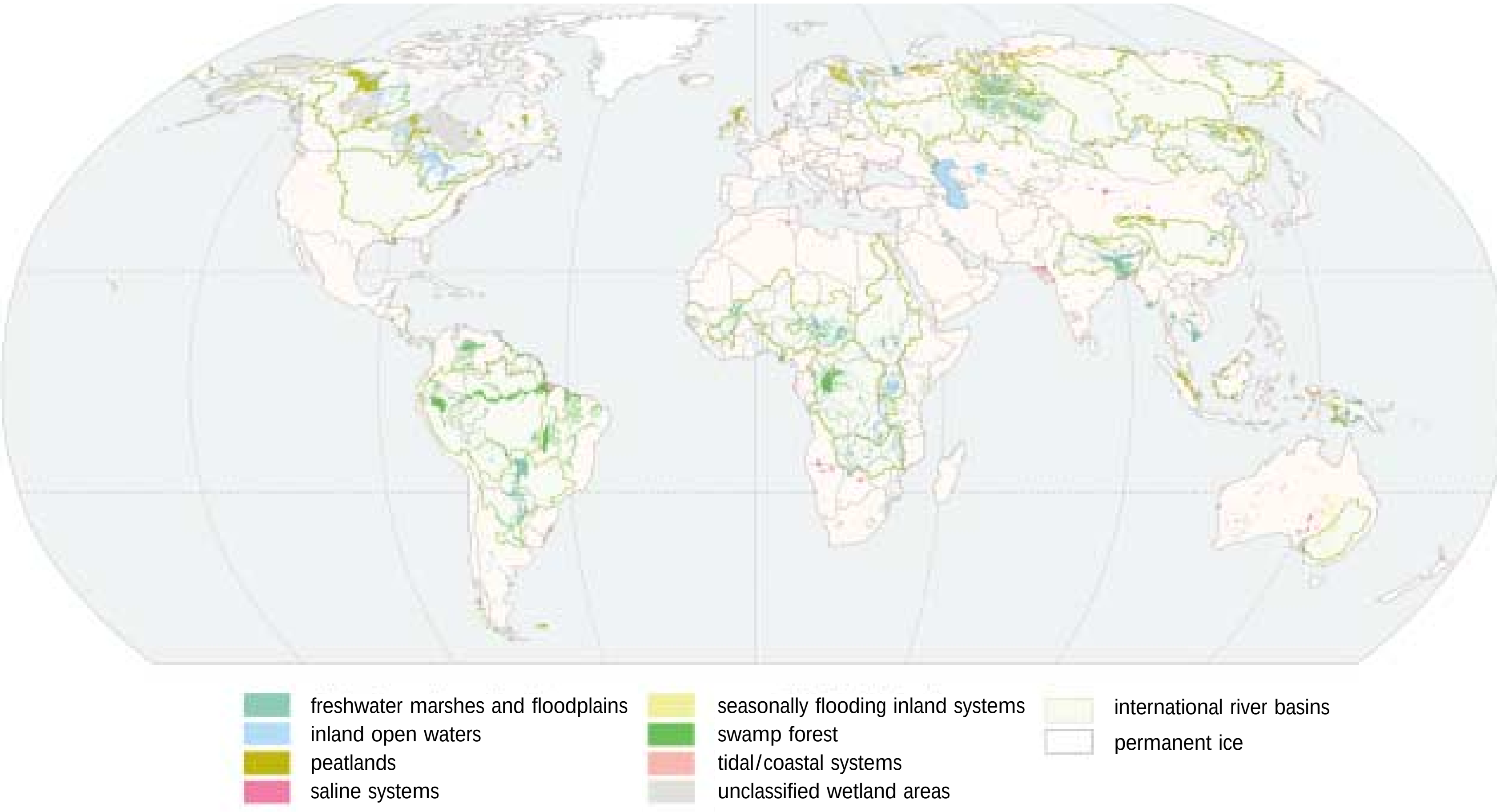
Lakes, of which around 10,000 exceed 1 km^2 in extent, are mainly glacial in origin and geologically very young, dating from the retreat of the continental ice-sheets at the start of the Holocene, some 11,500 years before present. All such lakes are expected to fill slowly with sediment and plant biomass and to disappear within perhaps the next 100,000 years, along with any isolated biota. Most other lakes are caused by tectonic activity, either through faults caused by deep crustal activity or through vulcanism. Lakes may also be formed by dissolution of soluble rocks (for example limestone in karst regions) or by changes in the course of rivers in floodplain regions. Only around ten existing lakes are known with certainty to have origins much before the Holocene. Most of these occupy basins formed by large-scale subsidence of the Earth's crust, dating back to at most 20 million (Lake Tanganyika) or 30 million (Lake Baikal) years before present.

Wetlands are traditionally understood as heterogeneous habitats of permanent or seasonal shallow water dominated by large aquatic plants and broken into diverse microhabitats. The four major habitat types are:

- Bogs, which are peat-producing wetlands in moist climates where organic matter has accumulated over long periods. Water and nutrient input is entirely through precipitation. Bogs are typically acid and deficient in nutrients and are often dominated by sphagnum moss. They are also important habitats for carnivorous plants. In many places they are endangered by the extraction of peat for horticulture.
- Fens are peat-producing wetlands that are influenced by soil nutrients flowing through the system and are typically supplied by mineral-rich groundwater. They are usually more productive and less acidic than bogs.
- Marshes are inundated areas with herbaceous emergent vegetation, commonly dominated by grasses, sedges or reeds. They may be either permanent or seasonal and are fed by ground or river water, or both.
- Swamps are forested wetlands on waterlogged or inundated soils where little or no peat accumulation occurs. Like marshes they may be either seasonal or permanent.

Map 8 portrays the major inland water areas of the world.

MAP 8



Inland waters

This map portrays in highly generalised form the occurrence of major water bodies and wetlands. The river basins shown are the twenty largest only.

Source: compiled from multiple sources, from UNEP-WCMC. 2000. *Global Biodiversity: Earth's living resources in the 21st century.*

Belarus

"Since the 1950s the total area of bogland in Belarus has decreased from 4.13 million ha to 2.3 million ha."

Germany

"Between 1950 and 1985, 57% of all wetlands disappeared in West Germany."

Diversity in inland water ecosystems

At higher taxonomic levels, the diversity of organisms in inland waters is considerably lower than on land or in the sea. The number of species overall is also low compared with marine or terrestrial habitats; however, species richness compared to habitat extent may be very high. For example, of known fish species around 40% (ca 10,000) are freshwater forms and 60% marine, despite the fact there is around 10,000 times as much seawater as there is water in inland water habitats. This high diversity of inland water fishes relative to habitat extent is undoubtedly promoted by the extent of isolation between inland water systems. As is the case with terrestrial habitats, species richness overall increases strongly toward the equator, so that there are far more species in tropical than in temperate or polar regions (Map 9). Among river systems, the Amazon-Ucayali is both by far the largest river catchment in the world, holding the greatest volume of water, and is also wholly within the tropics. Unsurprisingly, it is the major repository of the world's inland water biodiversity, although it remains very incompletely catalogued. Among lentic systems, the most diverse are the large African rift valley lakes, notably Tanganyika, Victoria and Malawi.

Major values and uses of inland water ecosystems

Freshwater – as precipitation, groundwater or in inland water ecosystems – is essential for human survival, chiefly because humans must drink and also because it is needed, in far greater quantity, to produce food. Inland fisheries, particularly in land-locked less-developed countries, are extremely important to human nutrition, and fish protein may be critical in times of food stress (Map 10). The relative contribution of inland fisheries is, however, impossible to assess accurately because so much of the catch is consumed locally and not reported in official statistics.

Major uses of inland waters include:

- provision of freshwater for drinking, agriculture, industrial production, cleaning and other purposes;
- harvest of species for food, clothing, medicines, building material, horticulture and live animal trade;
- waste disposal;
- transportation;
- generation of hydroelectric power;
- recreation.

Major impacts on inland water ecosystems

Inland waters have in many areas suffered as a result of the conflicting interests of different sectors. Physical change to freshwater habitats is a prime cause of decline and extinction of fish species, but may provide benefits, such as hydroelectric power, to human populations. Dam construction is the chief cause of extinction in the formerly large gastropod fauna in Mobile Bay (USA), for example. The introduction of alien species is a second prime cause of decline: the impact of Nile Perch on the native cichlid fauna in Lake Victoria is well documented. Overall, the major kinds of impact on inland waters are:

- physical alteration and destruction of habitat through abstraction of water, drainage, canalisation, and flood-control systems;
- construction of dams and reservoirs;
- sedimentation;
- introduced species;
- pollution, including: eutrophication, acid deposition, salinisation, heavy metals.

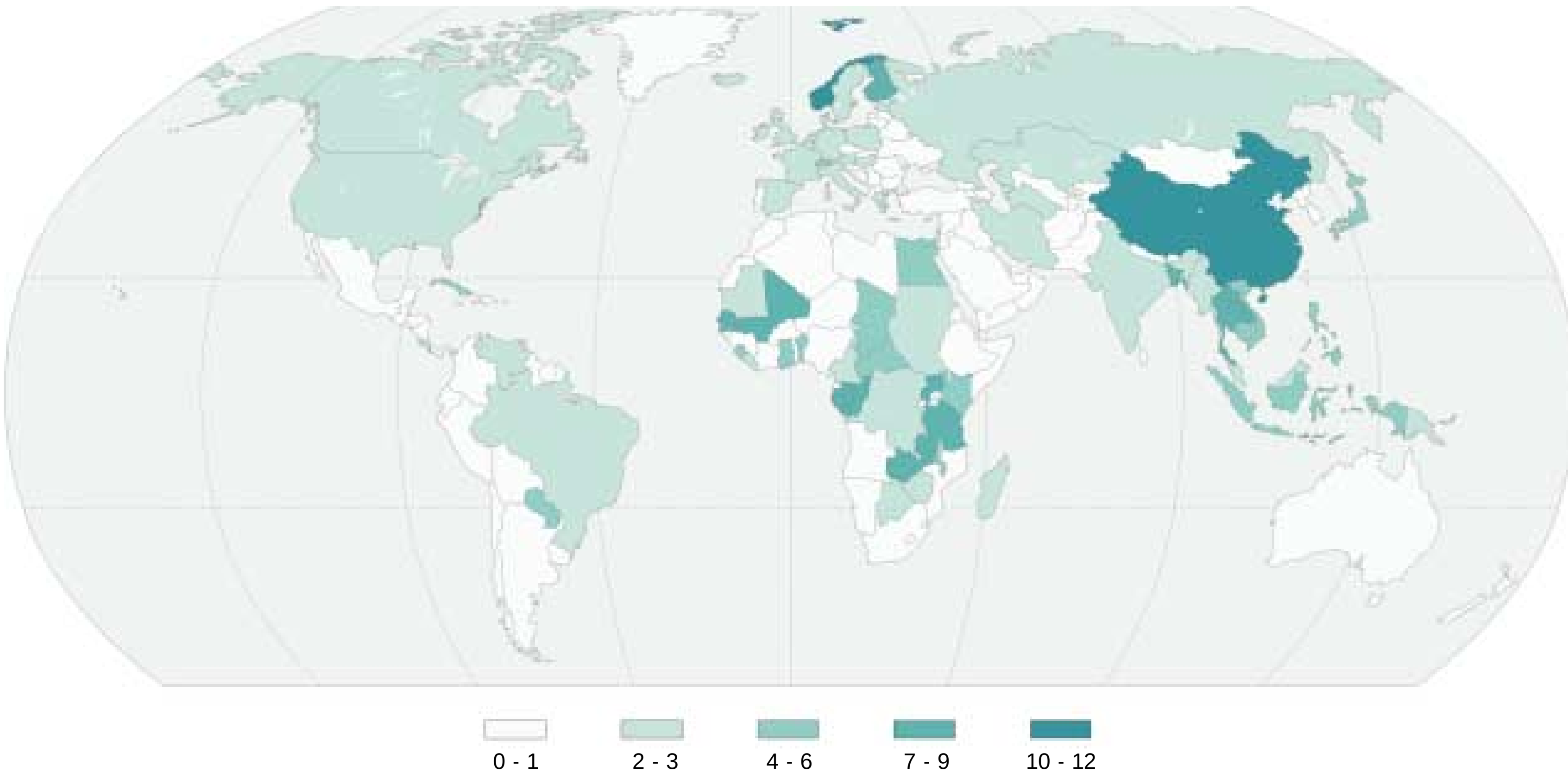
MAP 9

Freshwater fish biodiversity

This map represents an informal synthesis of documented expert opinion on globally important areas for freshwater fish diversity, taking into account species richness and endemism. Two categories are shown: discrete areas and systems known to be of high diversity, and areas where diversity is globally important but less concentrated.

Source: compiled with the help of members of relevant IUCN/SSC Specialist Groups; from UNEP-WCMC. 2000. *Global Biodiversity: Earth's living resources in the 21st century.*

MAP 10



Freshwater fish food supply

This map indicates approximate per capita annual supply (kg) of freshwater fish for food purposes.

Source: FAOSTAT statistical database, December 2000.

Ireland

"Irish bogs once covered approximately 1.3 million hectares, or 16% of the land area of the country. Presently only 19% (220,000 ha) of the original area remains intact. There has been a 92% loss of raised bogs and an 82% loss of blanket bog."

Israel

"Lake Hula was drained in the 1950s causing the destruction of a unique wetlands ecosystem."

Status and trends of species in inland waters

In those relatively few cases where detailed studies have been carried out, it has been found that the status of inland water faunas has been considerably worse than originally suspected. Of the 20 or so countries that have been reasonably comprehensively assessed, on average just under 20% of the inland water fish fauna has been found to be threatened. The proportion of inland water chelonians (tortoises and turtles) threatened is even higher, with more than 30% of species having been assessed as critically endangered, endangered or vulnerable. Amongst birds and mammals the proportions are considerably lower, probably because many semi-aquatic species are able to disperse relatively easily from one inland water body to another.

The two major documented extinction events in the 20th century both took place in inland water ecosystems. Lake Victoria, shared by Kenya, Tanzania and Uganda, was until recently the home of a species flock of around 300 halpochromine cichlid fishes, of exceptional scientific interest, as well as of a number of other fish species. Following introduction of the Nile Perch *Lates niloticus*, and possibly also as a result of a range of other factors, at least half and up to two thirds of the native species are now believed extinct or nearly so, with virtually no chance of recovery. In the Mobile Bay drainage in the USA, dam construction has had a catastrophic impact on what was probably the most diverse freshwater snail fauna in the world. Nine families and around 120 species were known from the drainage basin. At least 38 species are believed to have become extinct in the 1930s and 1940s following extensive dam construction in the basin: the system now has 33 major hydroelectric dams and many smaller impoundments, as well as locks and flood control structures. These patterns are likely to have been repeated at a smaller scale in many other less well-documented parts of the world.

A common finding among global assessments of the status and trends of biological diversity is that inland waters are those suffering the greatest deleterious impact from human activities at present. Notes on a selection of the species that occur in inland waters and are categorised in the 2000 IUCN Red List as Critically Endangered, i.e. at highest risk of extinction, are provided in Table 1.7.

Colombia

"The Magdalena river has lost about 78% of its production over the last 20 years – the catch being down from 78,847 tons in 1974 to 16,998 tons in 1994."

Table 1.7 **Some Critically Endangered inland water animal species**

Mammals	
Baiji *Lipotes vexillifer*	A freshwater dolphin endemic to the Yangtze River, China. The fewer than 200 remaining individuals are threatened by entanglement in fishing gear, collisions with boats, pollution, and hydroelectric schemes.
Birds	
Brazilian Merganser *Mergus octosetaceus*	This little-known duck inhabits shallow, fast flowing rivers of eastern South America. Occurs in a few widely scattered populations, threatened by deforestation, hydroelectric development and hunting.
Reptiles	
Orinoco Crocodile *Crocodylus intermedius*	Restricted to the middle and lower reaches of the Orinoco River. Severely affected by commercial exploitation for skins from the 1930s through the 1960s; threatened by illegal hunting, pollution and loss of habitat.
Striped Narrow-headed Softshell Turtle *Chitra chitra*	Restricted to the Mae Klong River basin (Thailand). Only a single population of 16 turtles is now believed to exist. Threatened by the domestic pet trade.
Amphibians	
Mount Glorious Torrent Frog *Taudactylus diurnus*	Known only from few mountain rainforest streams in southeast Queensland, Australia. Not found in recent searches, possibly extinct. Reason for decline not known.
Fishes	
Common Sturgeon *Acipenser sturio*	A large anadromous fish previously widespread in large European river basins. Following habitat loss, pollution and overfishing the species now spawns only in the Gironde-Garonne-Dardogne basin of France and the Rioni basin of Georgia.
Cave Catfish *Clarias cavernicola*	Endemic to Aigamas Cave lake, near Otavi, Namibia. The small population of catfish (<400 individuals) is threatened by a decrease in water level resulting from the depletion of local aquifers.
Lake Victoria cichlid *Macropleurodus bicolor*	One of the many cichlid fishes endemic to Lake Victoria, east Africa. The introduction of the predatory Nile Perch, together with intensified fishing efforts appear to be responsible for the decline in this particular species.
Crustaceans	
Shasta Crayfish *Pacifastacus fortis*	A small crayfish limited to the Pit River basin, California, USA. The few remaining populations are threatened by introduced crayfishes, stream modification and pollution.
Molluscs	
Rough Pigtoe *Pleurobema plenum*	Formerly present in larger river systems of the eastern United States, this mussel is now restricted to a few sites in Alabama, Kentucky and Tennessee. Decline attributed to pollution and habitat loss.

Armenia

"8% forest cover has been destroyed between 1992 and 1995. A number of regions in Armenia are now totally deforested. Between 1930s and 1950s around 450,000 m^3 of wood was extracted from Armenian forests."

Poland

"In 1945 forest covered just under 6.5 million hectares of Poland, since then the forest cover has increased to 8.78 million hectares. The amount of forest under State protection has also risen from 22.5% in 1957 to 47.3% in 1996."

Biodiversity of Forest Ecosystems

Forests are ecosystems in which trees are the predominant life forms. A more precise definition than this remains surprisingly elusive, because trees occur in many different ecosystems, at different densities and in different forms. Most definitions of forest refer to canopy or crown cover, which is essentially the percentage of ground area shaded by the crowns of the trees when they are in full leaf.

Clearly, estimates of the area of forest both globally and in any given place must vary enormously depending on the definition of forest adopted. In this discussion a threshold of 30% canopy cover is generally used as defining a forest.

What is a forest?

The FAO has defined natural or semi-natural forests as "ecological systems with a minimum of 10% crown cover of trees and/or bamboo, generally associated with wild flora and fauna and natural soil conditions and not subject to agricultural practices." This is an extremely wide definition, and includes many open vegetation systems that would not normally be regarded as forests. A more rigorous definition, which accords much more closely with wider perceptions of what constitutes a forest, is that of closed-canopy forest. Thresholds for defining closed-canopy forest range from as low as 30% to as high as 75% crown cover.

Where are forests?

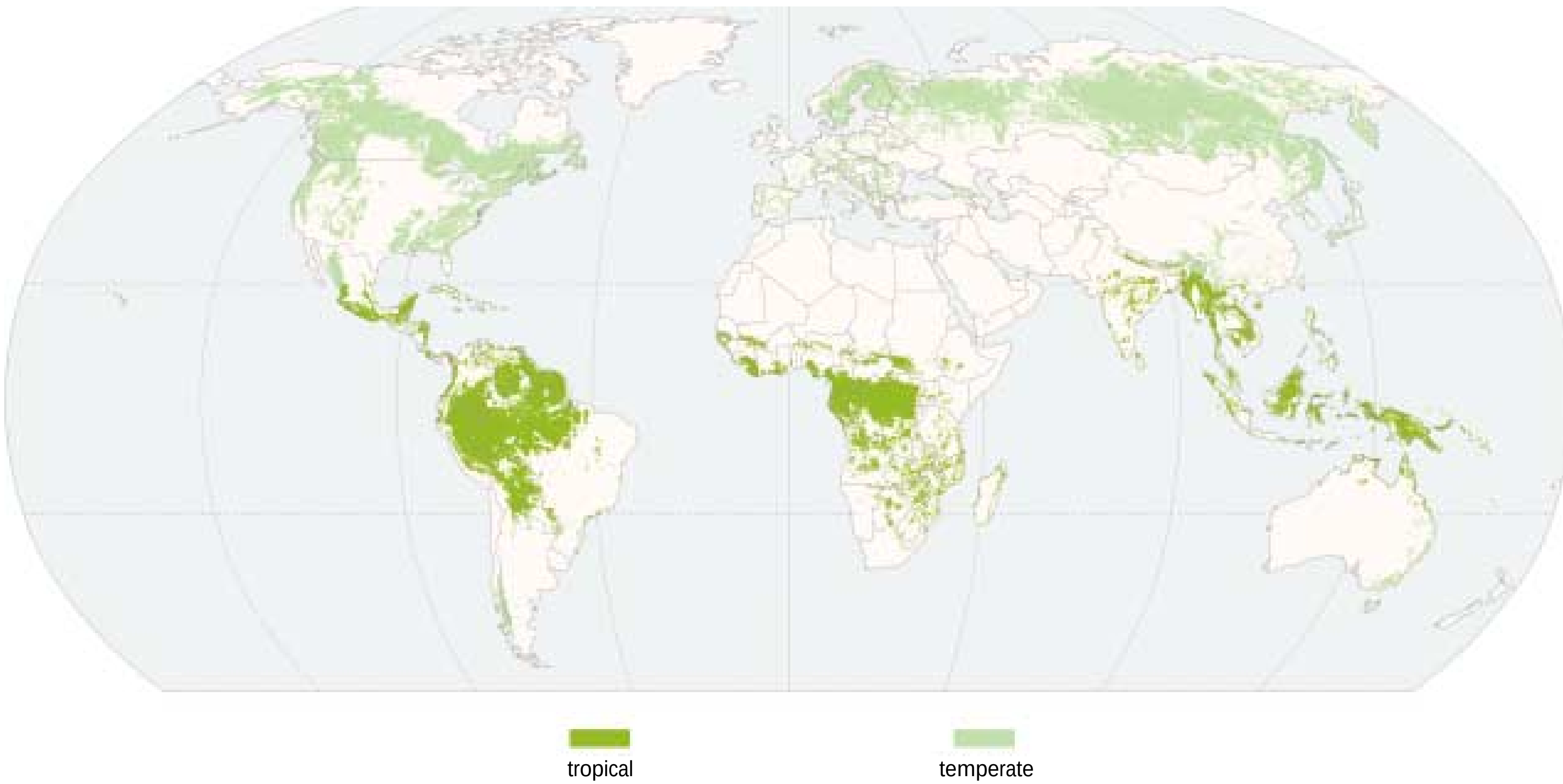
The factors determining the distribution of forests are largely climatic: tree establishment and growth requires a minimum number of days in the year with adequate moisture and warmth for active growth. Substrate characteristics are also important as trees require access to enough soil for supply of nutrients and water, and to provide anchorage. Trees are therefore absent from areas that are too dry, or too cold or have inadequate soil cover. Other natural factors that may limit the distribution of forests include fire, flooding, the presence of toxic minerals in the substrate, and the impact of large herbivores. Around one half of the Earth's land surface is climatically suitable for forest, but as a result of human actions, around one half of this area is not forested, so that current forest cover amounts to just under 40 million square kilometres (Map 11).

Major forest types

Classifying forests is in some ways an even more difficult task than defining forest. A number of global classification systems have been proposed, some extremely complex, but as yet none has gained universal acceptance. All such systems are more or less artificial as in nature forests rarely form homogenous units clearly separable from other such units; instead species composition and forest structure tend to change gradually or irregularly with, for example, changing altitude, exposure and latitude.

Nevertheless simplified global level classification systems can be a useful guide to the world's major forest types. Table 1.8 provides a breakdown of 22 forest types in five major categories: temperate needleleaf; temperate broadleaf and mixed; tropical moist; tropical dry; and sparse trees and parkland. Map 12 shows forest types broadly classified by ten types.

MAP 11



Present forest cover

This map provides an overview of the global distribution of forest, including plantation and other secondary types, at the end of the 20th century.

Source: compiled by UNEP-WCMC from numerous national and international sources.

Bhutan

"Bhutan has the highest fraction of land in protected areas and the highest proportion of forest cover of any Asian country. 8% of the forest is considered degraded. Bhutan has managed to increase the area under forest cover from 64% in the early sixties to 73%. Most ecosystems remain substantially intact."

Brazil

"About 15% of the Amazon forest has been destroyed. There has been a 40% loss of native Cerrado vegetation. The Caatinga has lost 50% of its native vegetation. Only 8.75% of the Atlantic Forest remains."

Table 1.8 **Global areas of 22 main forest types**

Forest Type	Area (km^2)
Boreal and Temperate Needleleaf	12,511,062
Evergreen needleleaf	8,894,690
Deciduous needleleaf	3,616,372
Temperate Broadleaf and Mixed	6,557,026
Mixed broadleaf/needleleaf	1,803,222
Broadleaf evergreen	342,892
Deciduous broadleaf	3,738,323
Freshwater swamp forest	126,963
Sclerophyllous dry forest	485,093
Disturbed	60,533
Tropical Moist	11,365,672
Lowland evergreen broadleaf rainforest	6,464,455
Lower montane forest	620,014
Upper montane forest	730,635
Fresh water swamp	516,142
Semi-evergreen moist broadleaf	1,991,013
Mixed needleleaf and broadleaf	17,848
Needleleaf	61,648
Mangrove	121,648
Disturbed	842,269
Tropical Dry	3,701,883
Deciduous/semideciduous broadleaf	3,034,038
Sclerophyllous	405,553
Thorn	262,292
Sparse Trees and Parkland	4,748,694
Temperate	2,407,735
Tropical	2,340,959
TOTAL	**38,808,671**

Source: Global Biodiversity, table 7.4

Boreal and temperate needleleaf forests cover a larger area of the world than any other forest type. They occur mostly in the higher latitudes of the northern hemisphere as well as high altitude zones and some warm temperate areas (particularly on soils poor in nutrients or otherwise unfavourable). Conifer canopies are efficient light absorbers, so limiting opportunity for extensive development of lower strata of vegetation, and the structure of these forests is often fairly simple. Species diversity is usually relatively low, and vast expanses of such forest in the northern hemisphere are dominated by a very small number of tree species. However, diversity amongst some groups of organisms, such as mosses and lichens, may be surprisingly high. These forests are of great importance in the carbon cycle, acting as major reservoirs of organic carbon both above and below ground.

Temperate broadleaf and mixed forests are generally characteristic of the warmer temperate latitudes but extend to cool temperate ones, particularly in the southern hemisphere. These forests tend to be structurally more complex than needleleaf forests, and to have considerably higher species diversity. Aboveground biomass tends to be lower than in temperate needleaf or tropical moist forests, while that below ground tends to be intermediate.

Tropical moist forests include many different forest types. They are without doubt overall the most diverse ecosystems on earth. Some estimates suggest that at least 60% of all species (and possibly near 90%) occur in them, despite the fact that they cover little more than 7% of the world's land surface, and around 2% of the surface of the globe. Diversity is usually extremely high at all spatial scales; in some parts of the western Amazon and of the Atlantic coastal forest of Brazil

Fiji

“An estimated 11-16% (90-140,000 ha) of the nations forest have been converted to non-forest landuse.”

Greece

“Coastal and lowland forests have been degraded to a significant extent due to urbanisation and conversion to agricultural land as the Mediterranean region has become exposed to human activities.”

(*Mata Atlântica*) there may be as many as 300 tree species per hectare. Notable exceptions are mangrove ecosystems, which have low tree species diversity, and forests on very nutrient-poor soils. Diversity also tends to decrease with increasing altitude and with increasing seasonality of climate. Lowland tropical moist forests can have very high aboveground biomass, although not as high as some needleleaf forests. Belowground biomass, however, with the exception of some peat-swamp forests, tends to be relatively low. Tropical moist forests are estimated to account for nearly one third of global terrestrial annual net primary production.

Tropical dry forests are characteristic of areas in the tropics affected by seasonal drought. Seasonality of rainfall often results in a largely deciduous forest canopy; however, under some conditions, such a low fertility soils or unpredictable rainfall regimes, the canopy may become dominated by evergreen sclerophyllous species (i.e. those with typically small, thick-skinned leaves). On very poor soils and especially where fire is a recurrent phenomenon, woody savannas may develop. In general dry tropical forests have lower species diversity than tropical moist forests; however they appear to be characterised by high levels of local endemism.

Sparse trees and parkland are forests with open canopies of 10-30% crown cover. They occur principally in areas of transition from forested to non-forested landscapes. The two major zones where these formations occur are the boreal region (i.e. at very high latitudes) and the seasonally dry tropics.

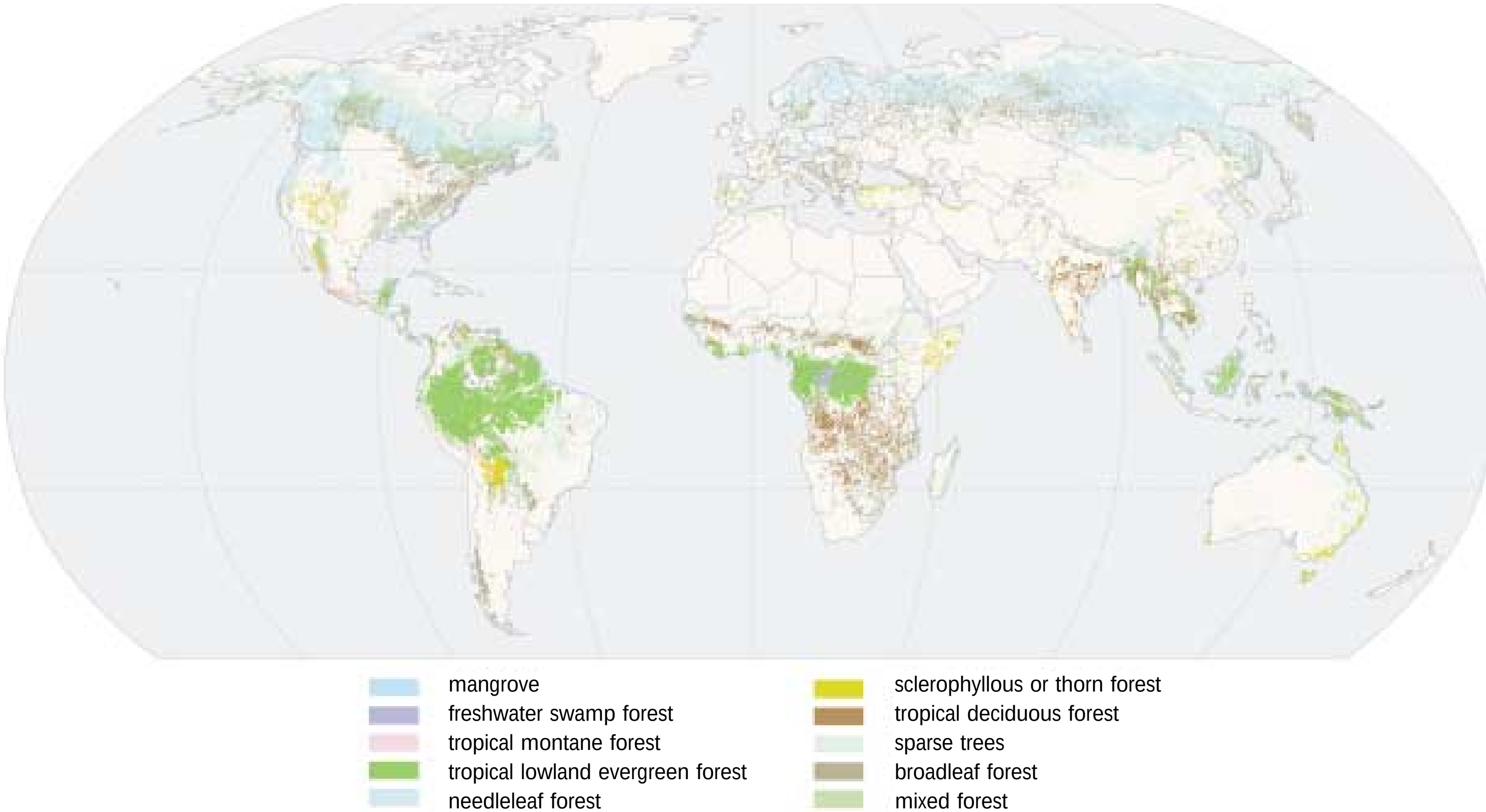
Forest plantations, generally intended for the production of timber and pulpwood, are believed to cover well over one million square kilometres worldwide. Commonly composed of only one species, often non-native, plantations are not generally important as habitat for native species. However, they can be managed in ways that enhance the role they play in maintaining biodiversity. They may also be important providers of ecosystem services, such as maintaining nutrient capital and soil structure as well as protecting watersheds. They may also alleviate pressure on natural forests for timber and fuelwood production.

Changes in forest cover

The Earth’s climate has been extremely unstable for the past two million years and for most of this time much colder than today’s. The extent and distribution of forests during the cold periods were very different from today, not least because much of the northern hemisphere was covered in thick ice, but also because the climate in much of the tropics was apparently drier.

The beginning of the Holocene, which followed the last major glacial period between 11,000 and 12,000 years ago, would undoubtedly have been a period of major forest expansion as the ice retreated and wetter conditions began to prevail in much of the tropics. However, it also evidently marked the emergence of agriculture and the spread of humans through almost all the habitable world, including the Americas. Human impact on forest cover undoubtedly dates back at least to this period, but because these impacts started at a time when forest extent and distribution would have been rapidly changing also for climatic reasons, it is extremely difficult to determine just how much land has been permanently deforested by human hands. In other words, it is very difficult, and perhaps of little value, to seek a precise global baseline of “original forest cover” against which to measure human impact. Such a baseline could theoretically be established before the start of the Pleistocene ice ages, over two million years ago, but the climate at that time is not sufficiently well known to make this feasible.

MAP 12



Present forest types

This map shows forests broadly classified by type.

Source: compiled by UNEP-WCMC from numerous national and international sources.

Iran

"During the last 30 years 40% of Iran's deciduous temperate forest has been destroyed, almost 1.2 million hectares. Today forest areas cover 12.4 million hectares of the country, 40 years ago the figure was estimated at 18 million hectares. Caspian broadleaf deciduous forest has lost 1.5 million hectares in the last 45 years. Only 60,000 hectares of the original 500,000 hectares of Arasbaran broadleaf deciduous forest remain. Zagros broadleaf deciduous forest has been reduced from 12 million hectares to 5.5 million hectares in the last 50 years. Irano-Touranian evergreen juniper forest has been reduced from 3.4 million hectares to 500,000 hectares in the last 50 years."

Despite these problems, it is possible to make some general observations on the history of forest loss, which differs markedly between different regions and different forest types. In Western Europe it seems that forest clearance has an extremely long history, with, for example, much of the British Isles deforested in the Neolithic, between 7,000 and 5,000 years ago. In Europe as a whole, forest cover continued to decline until the 19th century when it stabilised. Since the early 20th century, forest cover in Europe has expanded, often through the establishment of conifer plantations although latterly also through reestablishment of mixed and broadleaf forests. Similarly, in eastern North America, forest cover reached a minimum around 1860, but has since expanded. Forests west of the Appalachians in North America suffered the most severe impacts in the late 19th and early 20th centuries, but are still under pressure from demand for timber and pulp.

It has been widely assumed that large-scale forest clearance outside of Europe had only taken place following European colonisation. However, there is increasing evidence that indigenous peoples in some areas (for example the Yucatan region of Central America, parts of the Andes in South America and present day Cambodia in Southeast Asia) may have had major impacts on forest cover before the arrival of Europeans. Nevertheless, in most areas European colonisation undoubtedly precipitated a major phase of deforestation, which appears to have reached unprecedentedly high levels in the last half-century or so. Table 1.9 shows that rates of deforestation continue to be high in the developing countries of the tropics, in both absolute and proportional terms. In contrast, temperate (mostly developed) countries are losing forests at lower rates, or indeed showing an increase in forest area.

Table 1.9 **Estimated annual change in forest cover 1990-1995**

Region	Annual change (km^2)	Annual change rate (%)
Africa – tropical	-36,950	-0.7
Africa – non-tropical	-530	-0.3
Asia – tropical	-30,550	-1.1
Asia – non-tropical	1,540	0
Oceania – tropical	-1,510	-0.4
Oceania – temperate	600	0.1
Europe	5,190	0
North America	7,630	0.2
Central America, Mexico and Caribbean	-10,370	-1.3
South America – tropical	-46,550	-0.6
South America – temperate	-1,190	-0.3

Source: FAO 1999. Note – forest cover change data are not available for the former USSR.

Kenya

"Average annual forest loss is approximately 5,000 hectares per year. The Mau forest has been degraded by 30% in the last 10 years"

Norway

"The area of virgin forest has been reduced to less than 0.5% of the total forested area of the country."

France

"Since the early 1980s forest coverage has increased by 3%."

Major values and uses of forests

Goods

- Timber and other wood products
- Fuelwood and charcoal
- Non-wood forest products (bushmeat, rattans and fibres, honey, edible plants, medicinals, aromatics, dyes)

Services

- Climate amelioration
- Regulation of local and regional hydrological cycles
- Mediators in the carbon cycle, chiefly as carbon sinks
- Soil stabilisation and watershed protection
- Cultural values (aesthetic, spiritual, recreational)

Major impacts on forests

- Conversion, chiefly to cropland (including plantation forestry) but also for a range of other purposes, including road building, mining, urban and industrial development,
- Fragmentation,
- Changing fire regimes,
- Invasive alien species,
- Logging,
- Extraction of non-timber forest products,
- Fuelwood extraction,
- Hunting,
- Unsustainable shifting cultivation,
- Climate change,
- Pollutants, including acid rain.

Status and trends of species in forests

Because forests occur over such a wide area and encompass such a wide range of ecological conditions, it is difficult to generalise about the status of forest species as a whole. Most temperate and boreal forest species in the northern hemisphere are widespread and generally not highly threatened with extinction. Forests of warmer temperate and subtropical areas have a higher diversity of species, many of which are localised and therefore in general more vulnerable to extinction. A higher proportion of these is threatened. Similarly, southern hemisphere temperate forests are generally isolated from each other and have a high proportion of localised and threatened species. For those groups, namely mammals and birds, that have been analysed in any detail, far more tropical forest species are considered threatened than species from any other habitat. It is unclear, however, whether this is merely a reflection of the fact that tropical forests contain far more species in these groups than any other habitat, or whether a higher proportion of these species is threatened than of temperate and boreal forest species. In tropical and subtropical regions, there are clear differences between insular and continental biotas. The former appear far more extinction-prone and have a far higher proportion of threatened species than the latter.

Notes on a selection of the species that occur in forest, mainly in the tropics, and that are categorised as Critically Endangered, i.e. at highest risk of extinction, are provided in Table 1.10.

Philippines

"Forest cover has been reduced from more than 50% to less than 24% over a 40 year period.."

Slovenia

"Forest area has increased from 47% in 1961 to 53% in 1990. 85% of the forests regenerate naturally, thus supporting conservation of native populations of tree species and enhancing genetic diversity."

Table 1.10 **Some Critically Endangered forest species**

Mammals	
Black-faced Lion Tamarin *Leontopithecus caissara*	Discovered early 1990 on Superagüi island, south Brazil, where restricted to around 300 km^2 of forest, with a total population of about 300 individuals.
Golden Bamboo Lemur *Hapalemur simus*	Discovered in 1987. Patchily distributed in a few areas of rainforest in southeast Madagascar. The small population of a few hundred animals is threatened by deforestation.
Sumatran Rhinoceros *Dicerorhinus sumatrensis*	Formerly widespread in upland forests of Southeast Asia. Reduced by deforestation and hunting to a few hundred animals, mostly in Indonesia and Malaysia.
Birds	
Djibouti Francolin *Francolinus ochropectus*	Restricted to forests of the Goda and Mabla Mountains, Djibouti. Fewer than 1,000 birds, and declining because of habitat degradation and hunting.
Philippine Eagle *Pithecophaga jefferyi*	A large eagle endemic to the Philippines. Remains mostly on Luzon and Mindanao, where threatened by forest loss, hunting and trapping.
Reptiles	
Jamaican Iguana *Cyclura collei*	Believed extinct until rediscovered in 1990. Restricted to the Hellshire Hills where threatened by predation from mongooses, dogs and cats and habitat loss through deforestation.
Amphibians	
Peppered Tree Frog *Litoria piperata*	Recorded from a few localities in the eucalypt forest of the New England Tableland, NSW, Australia. Reasons for decline not clear.
Eleutherodactylus karlschmidti	Endemic to the mountain forests of Puerto Rico. Not recorded for a number of years and possibly now extinct.
Crustaceans	
Tree Hole Crab *Globonautes macropus*	Restricted to closed canopy rainforest in the Upper Guinea region of West Africa. Estimated to total less than 250 mature individuals in several fragmented populations.
Plants	
Chisos Oak *Quercus graciliformis*	A small isolated population exists in riparian oak woodland in the Chisos Mountains, Texas, USA. The locality is threatened by the activities of tourists and occasional drought.
Saucos *Sambucus palmensis*	Known from a few scattered individuals in cloud forest of the Canary Islands, Spain. With a very poor regenerative capacity, the few remaining populations are threatened by fire, grazing and exploitation of the medicinal bark.
Palm *Ptychosperma bleeseri*	Scattered in the lowland rainforests near Darwin, Australia. The entire population consists of approximately 500 mature individuals and is believed to have stabilised since feral pigs and water buffaloes were excluded.

Source: UNEP-WCMC

Syria

"Wind and water erosion has degraded 2,678 thousand hectares of land. Desertification has encroached on 480,000 hectares and salting of irrigated land has spoiled a further 125,000 hectares of land. Causing losses in biological diversity."

Biodiversity of Dry and Sub-humid Land Ecosystems

All life requires water. On land the abundance and diversity of life as well as the kinds of life-form that exist in any given area are overwhelmingly influenced by two major factors: the amount of available moisture and the temperature. Variability in these factors, on daily, seasonal and inter-annual scales, is as important as long-term averages. Aridity is defined on the basis of the ratio of rainfall (and other precipitation) per unit area to the potential loss of water from that area through plant use and evaporation (see Box).

What is a dryland?

Some 60% of the world's land surface may be considered as arid to some degree. In such areas shortage of available liquid water is a major constraint on living systems. Aridity may be defined, and measured, in a variety of ways. Probably the most useful at a global level is a measure of the ratio of precipitation – rain, snow, fog, dew, etc. – (P) to potential evapotranspiration (PET). The latter is essentially a function of temperature and number of daylight hours and represents the potential rate of loss of water from a unit area though evaporation from the soil and transpiration by plants. P/PET ratios are typically calculated on a monthly basis and then averaged over a year to produce a single P/PET ratio, known as an aridity index (AI). AI values greater than 0.65 are generally counted as humid.

Humid areas, defined by an aridity index of 0.65 or above, extend over more than 39% of the Earth's land surface. The remaining non-humid 61% is made up of the cold regions, and the drylands. The former include polar and tundra areas, and certain high mountains and plateaus, together covering nearly 14% of the land. They differ ecologically from other non-humid areas, mainly by having temperatures below freezing for a period long enough to restrict or prevent plant growth, although they are "dry" in the sense that liquid water is unavailable for a significant part of the year. The true drylands extend over nearly half (47%) of the Earth's land surface, and can be subdivided into a number of zones on the basis of the aridity index (Table 1.11).

The hyperarid regions have very low biological productivity, and little or no opportunity for human occupation and human-induced land degradation. The less extreme and more productive arid, semiarid and dry sub-humid areas are liable to become degraded by human activity, and are collectively known as the susceptible drylands.

Drylands contain a very wide range of natural habitats, including barren desert with virtually no visible signs of life, semi-desert dominated by succulents and other xerophytic plants, grassland, savannah, and many different kinds of scrub- or shrubland, woodlands and forests. However, in contrast to humid areas, where the dominant natural vegetation is usually forest, many drylands are characterised by sparse or absent tree cover. This may be because the climate is simply too dry to support closed forest ecosystems, or because the area is too severely affected by fire or grazing.

Dry and sub-humid ecosystems are the centres of origin of many major crops. Some of the most important categories are described briefly below and presented in Map 13.

Egypt

"Land reclamation for agriculture and the development of desert tourism has led directly to habitat destruction of numerous species of wild plants and animals."

Table 1.11 **World dryland areas**

Aridity zone zone	AI	Area (million km²)	% global land area	
Hyperarid	<0.05	9.7	7.5	True deserts. Rainfall irregular, may not rain at all for period of several years. The Sahara forms near 70% of the global hyperarid total.
Arid	<0.20 >0.05	15.7	12.1	Annual average rainfall is almost invariably less than 200 mm, although there is considerable variation between years.
Semiarid	<0.50 >0.20	23.0	17.7	Highly seasonal rainfall regimes, with maximum average annual rainfall of 800 mm and considerable variation between years.
Dry sub-humid	<0.65 >0.50	12.9	9.9	Typically have highly seasonal rainfall regimes with relatively little variation between years.

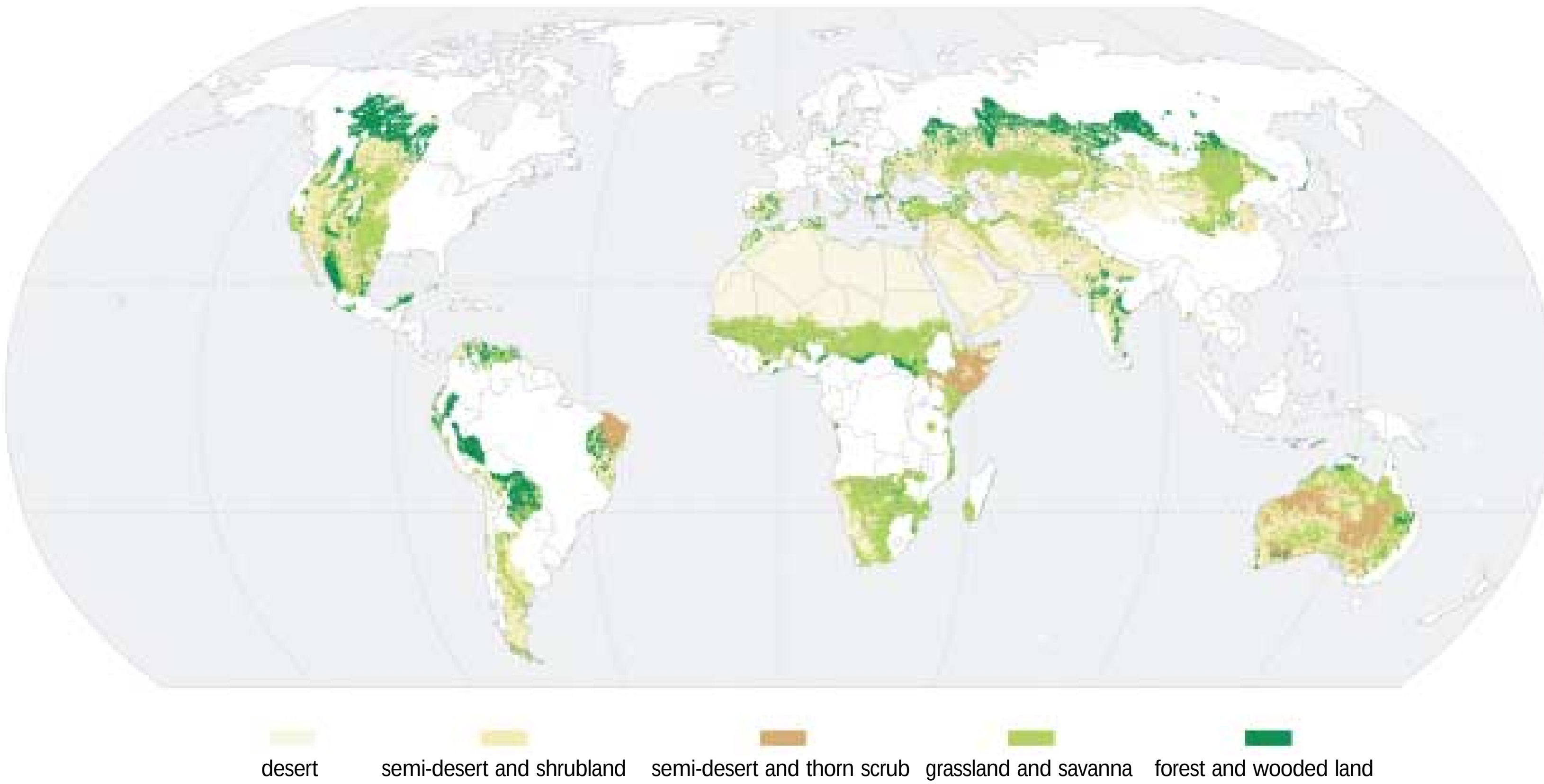
Source: UNEP-WCMC

Major types of dry and sub-humid lands

Mediterranean ecosystems are typified climatically by generally cool, wet winters and warm or hot dry summers. However, no single climatic or bioclimatic definition of a Mediterranean ecosystem has yet been established. Mediterranean ecosystems encompass a wide range of habitat types including forest, woodland and grassland, but are typified by a low, woody, fire-adapted sclerophyllous shrubland (variously known as *maquis, chaparral, fynbos, mallee*) on relatively nutrient-poor soils. These systems occur in five distinct parts of the world: the Mediterranean basin, California (USA), central Chile, Cape Province (South Africa), and southwestern and south Australia. Each of these regions occurs on the west side of a continent and to the east of a cold ocean current that generates winter rainfall. They cover around 2.5 million km² in total, or between 1% and 2% of the Earth's surface (according to definition), more than three quarters of which is within the Mediterranean basin. They are disproportionately rich plant species compared with most other parts of the world. In most parts of the world where they are found, a proportion of ecosystems generally classified as Mediterranean occur within dryland areas according to the definition given above. Elsewhere, including those regions generally associated with the typical Mediterranean high diversity sclerophyllous vegetation, Mediterranean-type ecosystems occur in humid climatic zones and are therefore not classifiable as drylands.

Grassland ecosystems may be loosely defined as areas dominated by grasses (members of the family Gramineae excluding bamboos) or grass-like plants with few woody plants. Natural grassland ecosystems are typically characteristic of areas with three main features: periodic drought; fire; and grazing by large herbivores. In addition, they are often associated with soils of low fertility. The relative importance of different factors in maintaining grasslands varies locally and regionally.

MAP 13



Land cover in world drylands

This map shows a simplified classification of land cover types within the world's drylands. Drylands here include dry sub-humid, semiarid, arid and hyperarid zones, defined by an aridity index (AL) calculated as the ratio of precipitation to potential evapotranspiration. Drylands have an AL of <0.65.

Source: compiled by UNEP-WCMC; dryland boundary from UNEP-GRID, land cover from USGS EROS Data Centre.

Spain

"18% of Spain is affected by serious erosive problems."

Savannas are tropical ecosystems characterised by dominance at the ground layer of grasses and grass-like plants. They form a continuum from treeless plains through open woodlands to virtually closed-canopy woodland with a grassy understorey.

Most, but by no means all, of the world's natural grasslands and savannas are found in dryland regions. Around 20% of the Earth's land surface (excluding Antarctica) supports grasslands of varying degrees of naturalness; temperate grasslands make up approximately one fourth of this area, and savannas the remainder.

Seasonally flooded grassland areas are found in many river basins and may be of considerable ecological and biotic importance. Such areas may be considered grassland ecosystems or inland water (wetland) ecosystems; there is no clear dividing line between the two.

Major values and uses of drylands

Drylands are home to over 2 billion people, or around 35% of the global population, a high proportion of whom are subsistence farmers or fishers. Major uses of dryland biological diversity include:

- Existing crops and livestock and their wild relatives. Drylands, grasslands and Mediterranean ecosystems are centres or origin of a significant proportion of the world's major crop plants. Populations of wild relatives of many existing crops are potentially very valuable genetic resources.
- Potential new crops, for example salt-tolerant or halophytic species, such as *Salicornia* spp. and some *Atriplex and Distichlis* spp.
- Wild foods, particularly as famine foods.
- Medicinals.
- Aromatics and stimulants. Drylands have a high diversity of plants rich in secondary compounds such as terpenes, which may have aromatic properties (for example frankincense *Boswellia* sacra and myrrh *Commiphora* spp.) and may be of considerable economic importance.
- Ornamentals. Arid and semi-arid, and Mediterranean-type, ecosystems have proven important sources of ornamental plants, with many thousand species now in cultivation outside their natural ranges.
- Pastoralism. Grazing of domestic or semi-domestic livestock is a major land use in most of the world's drylands; extensive pastoral systems generally have negligible artificial inputs in the form of fertilisers or other chemicals, and are therefore reliant on natural ecosystem productivity and resilience.
- Soil stabilisation and prevention of erosion. Dryland soils are particularly prone to erosion, which is one of the major causes of land degradation. Natural vegetation cover plays a major part in reducing the erodibility of soils and in preventing or mitigating land degradation.
- Wildlife tourism. Grassland and savannah areas with major concentrations of large, wild mammals include many of the most important sites globally for wildlife-based tourism.

Major impacts on drylands

Humans have had enormous impact on dryland, grassland and Mediterranean ecosystems, often with major negative impacts on biological diversity (Map 14). These impacts are often complex and interrelated. The following are among the major categories of activities that have or can have an adverse impact:

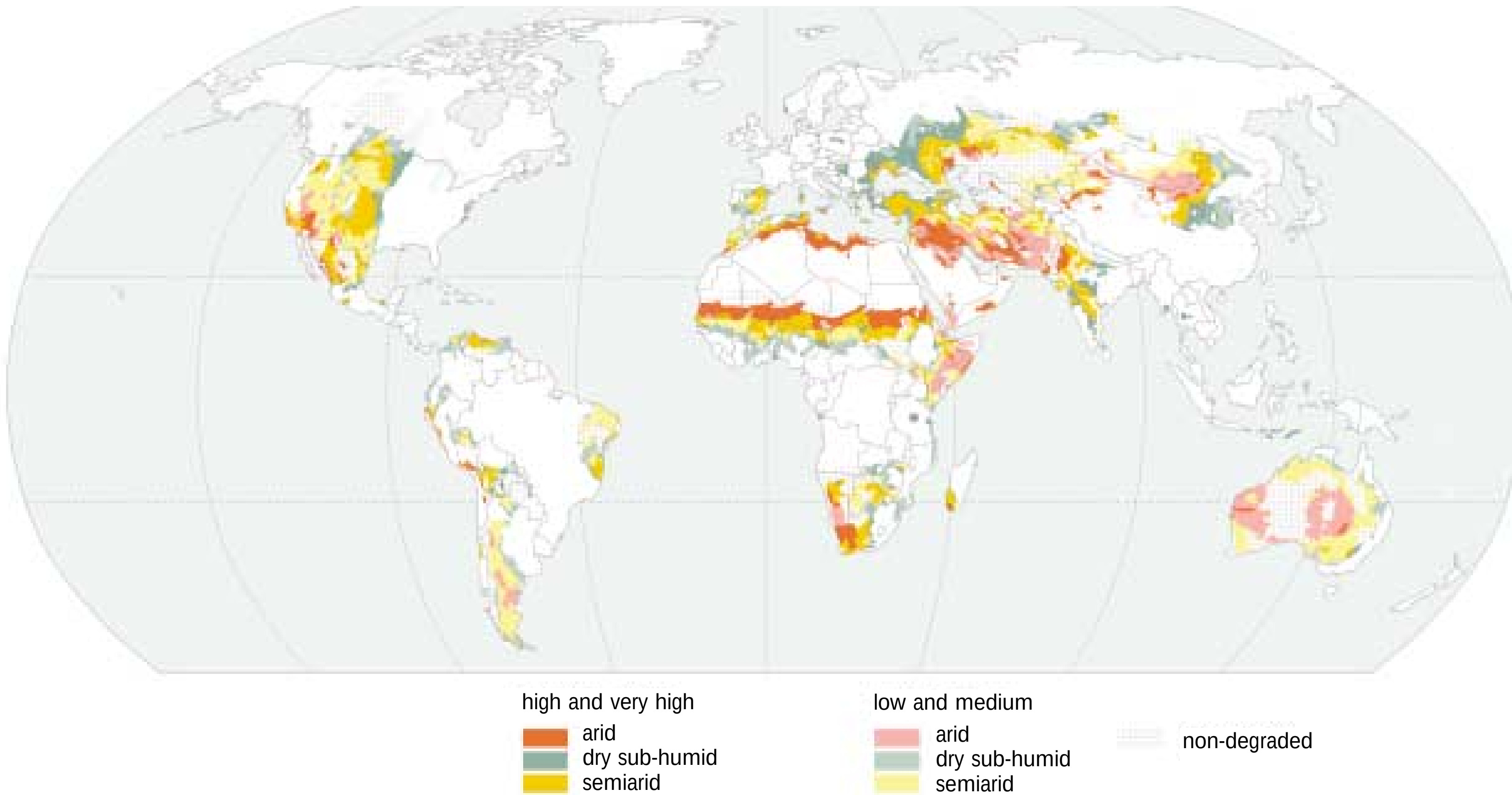
- Conversion, particularly to cropland. Large-scale transformation to cropland in drylands is dependent on availability of freshwater, either as surface waters (lakes, rivers, reservoirs) or in aquifers. In many areas, conversion is followed by abandonment as soil becomes degraded, often through salinisation or waterlogging.
- Changing fire regimes. Many dryland ecosystems are naturally adapted to some degree to fire. However, in many areas fires caused by humans (often as deliberate burning to produce new growth for livestock) are far more frequent and extensive than natural fires, and have very different impact on ecosystems and their biodiversity.
- Impact of introduced herbivores, particularly livestock, through trampling, removal of plant biomass, introduction of pathogens and alteration of plant species composition through selective grazing and competition with native species.
- Introduction of non-native plants. Grassland ecosystems have been routinely modified by deliberate introduction of non-native species, particularly other grasses and leguminous plants.
- Water. By definition, water is a limiting resource in dryland ecosystems. Human use of existing water resources in these systems therefore has often a disproportionately extreme impact. Abstraction of water for irrigation from freshwater systems such as lakes and rivers has an often extreme impact on the biodiversity of these ecosystems. Depletion of groundwater resources may have a less obvious direct impact but is likely to affect natural ground-fed springs and deep-rooted vegetation where the aquifer is relatively near the surface. Creation of artificial water sources for livestock leads to the creation of virtually barren "sacrifice zones" around the water source as a result of extremely heavy trampling by livestock.
- One of the most significant human impacts in natural or semi-natural dryland and savannah ecosystems in developing countries is through harvest of wood for fuel. Quantifying this, and assessing its long-term impact on ecosystems, has proved problematic, although in some areas the impact is undoubtedly severe.
- Overharvest of wild species. Excess hunting of wildlife and collection of plants, whether for subsistence use or national or international trade, can have severe impacts, in some cases driving species to extinction. Because dryland species tend to have relatively low population growth rates, and in the case of plants, individual growth rates, they may be particularly sensitive to overharvest.
- Chemical inputs. In many grassland ecosystems, highest biological diversity seems to be associated with poorer soils. Artificial enrichment of grasslands, particularly through application of nitrogenous fertiliser, generally leads to a very marked decrease in plant species diversity.
- Long-term impacts of climate change. The potential impacts on dryland ecosystems of human-induced climate change remain to be quantified but are likely to be significant.

These various impacts interact in a complex and sometimes unpredictable way. In drylands, the collective effect of factors, mainly of human origin, leading to land degradation make up a process often termed *desertification*. According to the United Nations Environment Programme (UNEP), desertification directly affects some 36 million km^2 of the world's drylands, i.e. about 70% of the total dryland area, and one-sixth of the world's people. The effects of desertification

Belarus

"Since 1750 forest cover has decreased from 80% to 35%."

MAP 14



Land degradation in susceptible drylands

A preliminary expert Global Assessment of the Severity of Soil Degradation (GLASOD), emphasising human impacts, was released in 1990. This map summarises the data within the limit of susceptible drylands (ie. excluding hyperarid regions by definition not subject to degradation).

Source: World Map of the Status of Human-Induced Soil Degradation; an Explanatory Note (October 1990), available at UNEP-GRID.

Brazil

"Between 1977 and 1994 deforestation rates in the Brazilian Amazon showed a tendency to stabilize at around 0.4%. It peaked in 1994 but has since fallen. In 1995/96 deforestation rate was 18161 km^2 a year."

promote poverty among rural people, and by placing greater stress on natural resources, poverty tends to reinforce any existing trend toward desertification.

Desertification

Under the UN Convention to Combat Desertification, desertification is defined explicitly as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities."

Land degradation is further defined as "reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

- soil erosion caused by wind and/or water;
- deterioration of the physical, chemical and biological or economic properties of soil;
- long-term loss of natural vegetation."

Status and trends in species in dry and sub-humid lands

Summary analysis of the habitat distribution of globally threatened mammals and birds shows clearly that while the majority of species occupy forest habitats (particularly lowland tropical moist forest), dryland, scrub and grasslands made up the second most important group of habitats (being somewhat more critical for mammals than for birds, in which group wetlands were significant). There are generally insufficient data overall at present to determine whether species in the ecosystem types under discussion are relatively more or less prone to extinction than those elsewhere – that is whether a higher or lower than average proportion of species in these ecosystems can be classified as threatened. However, for some groups and some ecosystems there is more detailed information.

With respect to mammals, a high percentage of continental (as opposed to island or marine) species believed or known to have become extinct since 1600 occurred in dryland ecosystems, most notably in Australia. In general, dryland mammals tend to be relatively wide-ranging but to occur at low population densities because of the low primary productivity of these areas. Larger species are also more conspicuous (and in the case of ungulates more gregarious) than forest dwelling species and thus more vulnerable to overhunting. These factors have meant that a notable number of large dryland mammals are either highly endangered or extinct in the wild.

The Mediterranean-type ecosystems in general have a relatively high proportion of their species categorised as threatened. This is in part a consequence of human land-use development in agriculture, industry and housing, and, especially in Cape Province (South Africa) and in California, of the spread of non-native plant species (some 10% of the flora in parts of California consists of naturalised alien species, and some perennial grasslands have been replaced by annual alien-dominated grassland). The Cape flora, largely within a Mediterranean-type ecosystem, occupies only 4% of the land area of southern Africa, but accounts for nearly 70% of the region's threatened species. Around 10% of the California flora is considered threatened (equivalent to approximately one quarter of all threatened plants in the USA). The main threats are: urban coastal development, pollution, agriculture, tourism, water shortages and fire.

Forests and woodlands, and inland water ecosystems within drylands tend to be placed under disproportionate pressure. This is chiefly because they are inherently scarce resources but also, in the case of forests and woodlands, because they tend to be found in areas within drylands with somewhat more favourable conditions (microclimate and soil fertility) than normal. These areas are therefore most likely to be settled by people and suffer extensive habitat conversion. Mediterranean ecosystems in particular are noted for their amenable climates and therefore come under particular pressure for permanent settlement and tourism.

Notes on a selection of dryland species that are categorised as Critically Endangered, i.e. at highest risk of extinction, are provided in Table 1.12.

Colombia

"Timber production affects 40,000-68,000 ha of wood each year."

Table 1.12 **Some Critically Endangered dryland species**

Mammals	
Addax *Addax nasomaculatus*	Formerly occurred through much of the Sahara. Reduced by uncontrolled hunting to a few remnant populations in inaccessible areas.
Northern Hairy-nosed Wombat *Lasiorhinus krefftii*	Restricted to a single colony of some 70 animals at Epping Forest Station, Queensland, Australia. Decline attributed to habitat loss and competition with introduced grazing animals.
Birds	
Bulo Burti Bush-shrike *Laniarius liberatus*	Discovered during the late 1980s in fragmented acacia scrub of central Somalia. Despite searches, known only from a single individual.
Night Parrot *Geopsittacus occidentalis*	An extremely rare bird from central Australia, probably threatened by habitat degradation, predation by introduced species and loss of available water.
Reptiles	
Anegada Rock Iguana *Cyclura pinguis*	Formerly present on several islands of the Puerto Rico Bank, now restricted to Anegada (British Virgin Islands). Threatened by predation and grazing pressure from introduced species.
Bulgar Dagh Viper *Vipera bulgardaghica*	Restricted to open grassland and thorn habitats in the Cilician Taurus mountains of southern Turkey. Susceptible to habitat change and excess collection of specimens.
Fishes	
Cachorrito de Mezquital *Cyprinodon meeki*	A desert fish endemic to the upper Rio Mezquital drainage, Mexico. Threatened by pollution, introduction of exotic species and habitat modification.
Insects	
Prairie Sphinx Moth *Euproserpinus wiesti*	A moth confined to high prairies of central USA threatened by insecticide use and perhaps collection.
Plants	
Sicilian Fir *Abies nebrodensis*	A coniferous tree known from a small population of fewer than 20 individuals in Sicily (Italy), most of which are non-reproductive.
Aloe helenae	A tree-like succulent known from two or three populations in southern Madagascar, potentially threatened by habitat loss and collection.

Republic of Korea

"74% of endemic crop species in Korea were lost in the ten years following 1985."

Biodiversity of Agricultural Ecosystems

What is agricultural biodiversity?

Agricultural biodiversity is the diversity at all levels of the biological hierarchy, from genes to ecosystems, that is involved in agriculture and food production.

The diverse range of organisms making up agricultural biodiversity can be divided into three major groups, based on the way they contribute to or affect agricultural production (Table 1.13).

such benefits from converted ecosystems will generally not exceed those provided by natural ecosystems. The cultural and spiritual benefits that are often associated with traditional agricultural landscapes provide an important exception to this generalisation.

Wild species and their products used for food are not usually regarded as part of agricultural biodiversity unless there is some degree of resource management involved, so, for example, species involved in coastal or inland fish farming come within the scope of agricultural biodiversity, but (for most purposes) high seas fishery species do not.

Table 1.13 **Agricultural biodiversity: functional groups**

Producers	the domestic, cultivated, farmed and semi-wild species (mainly flowering plants, fishes, birds and mammals) whose production provides human food, together with the varieties and wild relatives that expand the genetic resource base for future breeding improvements.
Support services	the wild and semi-managed species (mainly micro-organisms and invertebrates) that provide services supporting agricultural production, notably the soil biota, pollinators and the predators that affect pest species.
Pests, pathogens, predators	the wild species (mainly micro-organisms and invertebrates) that decrease agricultural production by causing disease or damage to producers.

The fundamental and distinct property of agricultural biodiversity is that it is largely created, maintained and managed by humans, originally by subsistence farming communities, but more recently also by biotechnologists, in part using material in *ex situ* genetic resource collections. In this regard, agricultural biodiversity stands in total contrast to wild biodiversity, which is most valued *in situ* and as a product of natural evolution.

Although agricultural ecosystems provide some of the environmental services provided by wild ecosystems, in that they can, for example, protect soil structure and affect air and water quality, the magnitude of

Where does agricultural biodiversity occur?

The components of agricultural biodiversity variously occur in protected areas, seed banks, laboratories, and the stores of industrial seed producers, but their primary habitat is land supporting agricultural production. Although most crop production is rainfed and based in the cool to warm humid regions of the world, production is extended into drylands by irrigation. Domestic livestock can thrive under a variety of climatic conditions. The ability of sheep, goats and camels to exist on sparse vegetation with little water allows humans to occupy marginal drylands, and the semi-domestic reindeer ranges into arctic regions.

At the close of the Pleistocene, some 11,500 years before present, domestication of plants and animals had just begun and the area of agricultural land would have been imperceptibly small. The history of agriculture is a history of experimentation with plant and animal genetic resources by human communities, and the dispersion of these resources by trade and the migration of peoples. Map 15 shows possible centres of origin of major crop plants. Map 16 presents the high dependence that most countries have on food crops that originated in distant centres of origin.

Agricultural land now forms a significant proportion, some 38%, of the world's total land area. Table 1.14 shows global level estimates of the recent area of land use types relating to agriculture, based on aggregated national data collated by the FAO. In this classification, permanent pastures, which include wild and cultivated forage crops, grassland and rangelands, make up the largest area of agricultural land. Land regularly cultivated for mainly annual crops, ranging from kitchen gardens to the cereal plains of industrial farming, i.e. arable lands in the usual sense, form 11% of the total.

Clearly, at global level, the habitat of agricultural biodiversity has increased enormously during the past ten millennia. Although some care is needed in interpreting these data, a graph of estimates of agricultural land area shows the rate of increase from the 1960s to the present (apart from an anomalous datum for 1970) (Figure 1.1). An increase in area attributed to one classification unit must entail a decrease in some other land cover type; in this case, the increase in agricultural land is accompanied by a decrease in forest and woodland area, and a decrease in the category "all other land."

Table 1.14 **Agricultural land in relation to total world land area**

	Area in 1998 (million km²)	% world land area
World land, excluding inland waters	130.5	100
Agricultural land:	49.4	38
Arable land (mainly annual crops)	13.8	11
Permanent crops (e.g. fruit and nut trees)	1.3	1
Permanent pasture (incl. rangeland)	34.3	26

Source: estimates rounded from FAO land-cover data for 1998, available at http://apps.fao.org

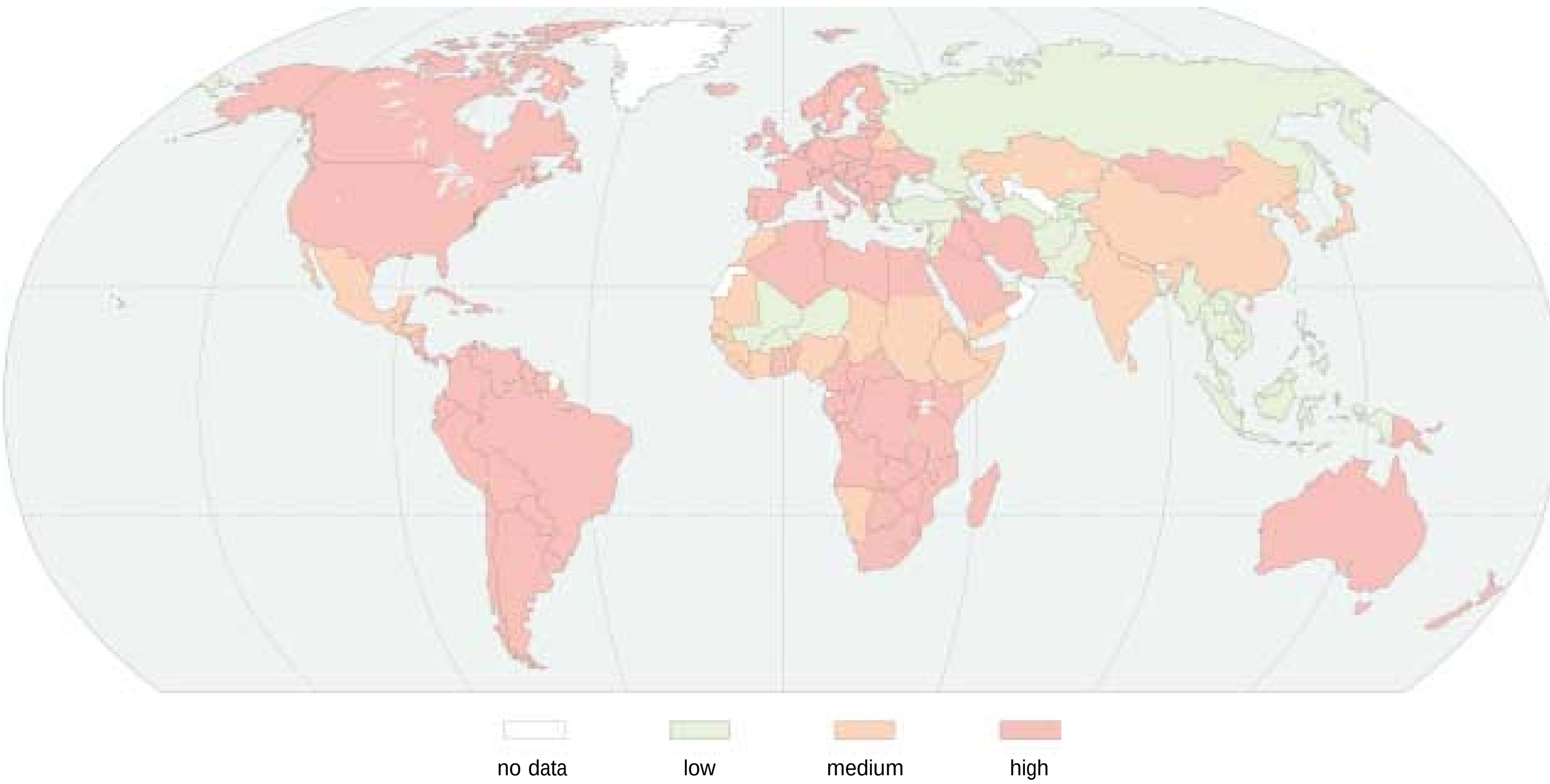
MAP 15

Centres of crop plant diversification

This map represents in simplified form the possible areas of origin of major crop plants (Vavilov centres), together with other regions of importance for crop diversification.

Source: based on multiple sources.

MAP 16

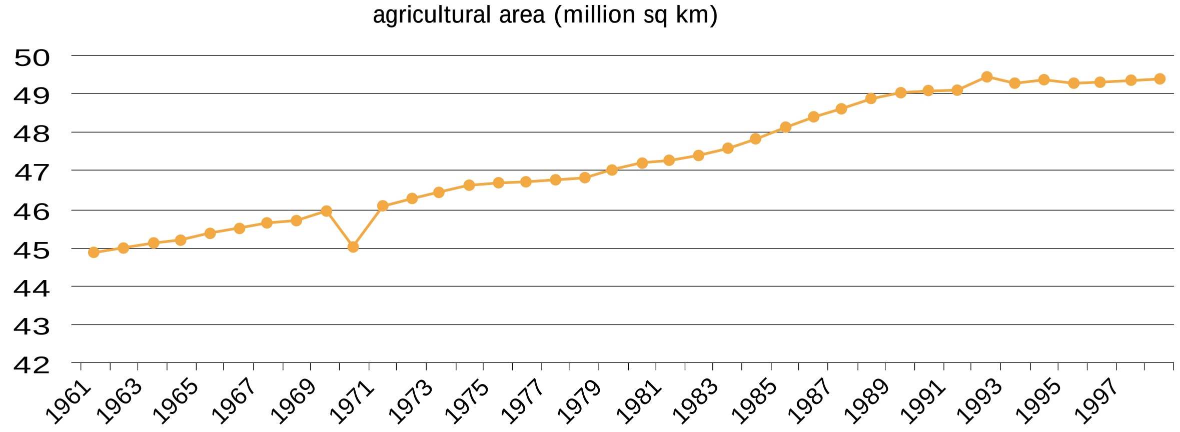


Food crop interdependence

The three classes represent in general terms the high dependence most countries have on food crops that originated in distant centres of diversity.

Source: from data in FAO Commission on Genetic Resources for Food and Agriculture. Background study paper No. 7. Rev. 1.
Contribution to the estimation of countries' interdependence in the area of plant genetic resources.

Figure 1.1 **World area of land classed as "agricultural" 1961-1998**



Source: FAO (FAOSTAT Agricultural database on www.fao.org)

El Salvador

"Forest originally covered 90 to 95% of the country. Today it has been reduced to less than 7%, half of which is degraded mangroves and pines."

Although the area of land used for agricultural purposes has increased during the latter half of the 20th century, by some measures the quality of that land has declined. According to the FAO's Global Assessment of the Status of Human Induced Soil Degradation (GLASOD), about 35 million km^2 of the world total land surface (26%) has suffered degradation severe enough to destroy its productive capacity. The majority of this degradation will have affected agricultural land, and on more than 12 million km^2 (9% of world land area) it is attributed to agricultural activities. At local level, however, it appears that previous global studies may have exaggerated the severity of degradation or its impact on productivity. It is expected that the rate of forest clearance for agriculture is likely to slow, but steep slopes and wetlands will increasingly undergo conversion to agricultural land, and this will have undesirable impacts on non-agricultural biodiversity.

The status of living agricultural resources

A very large variety of species are used for human food, some harvested directly from the wild, some subject to modest management intervention (for example replanting, predator protection, restocking), and some produced by intensive industrial-scale methods. There are few quantitative data available relating to the status of wild and low-management food resources, but indications are that they have in very many instances been adversely affected by land conversions, or by excess harvesting (many marine and some inland fisheries).

More information is available on the status of agricultural plant genetic resources, where a large number of varieties and landraces have been lost, although it remains difficult to derive a quantified view of the situation globally because the basic resource documentation is incomplete. There is, however, abundant evidence at national level of the enormous scale of genetic erosion in crop plants (Table 1.15).

Cuba

"From 1900s forest cover has been reduced by 53.2% due to expansion of agriculture. From 1959 deforestation was more drastic, and the forest was reduced to 14% cover. However now with afforestation 19% coverage by forest has been achieved."

There are far fewer livestock breeds, and documentation is more complete, so that among domestic mammals and birds it is possible to give numerical minimum estimates of the large number of varieties regarded as extinct or at risk of extinction (Table 1.16 and Map 17).

Although some locally distributed plant genetic resources, particularly among the wild relatives of crop plants, have been lost as a result of land conversion, many resources once actively used have been lost because other varieties have proved to have superior production qualities. The former is the second most frequently cited cause of genetic erosion in country reports collated by the FAO, while the latter is the predominant cause. Replacement by modern, genetically more uniform breeds specialised for intensive systems is the main cause of loss of livestock breeds.

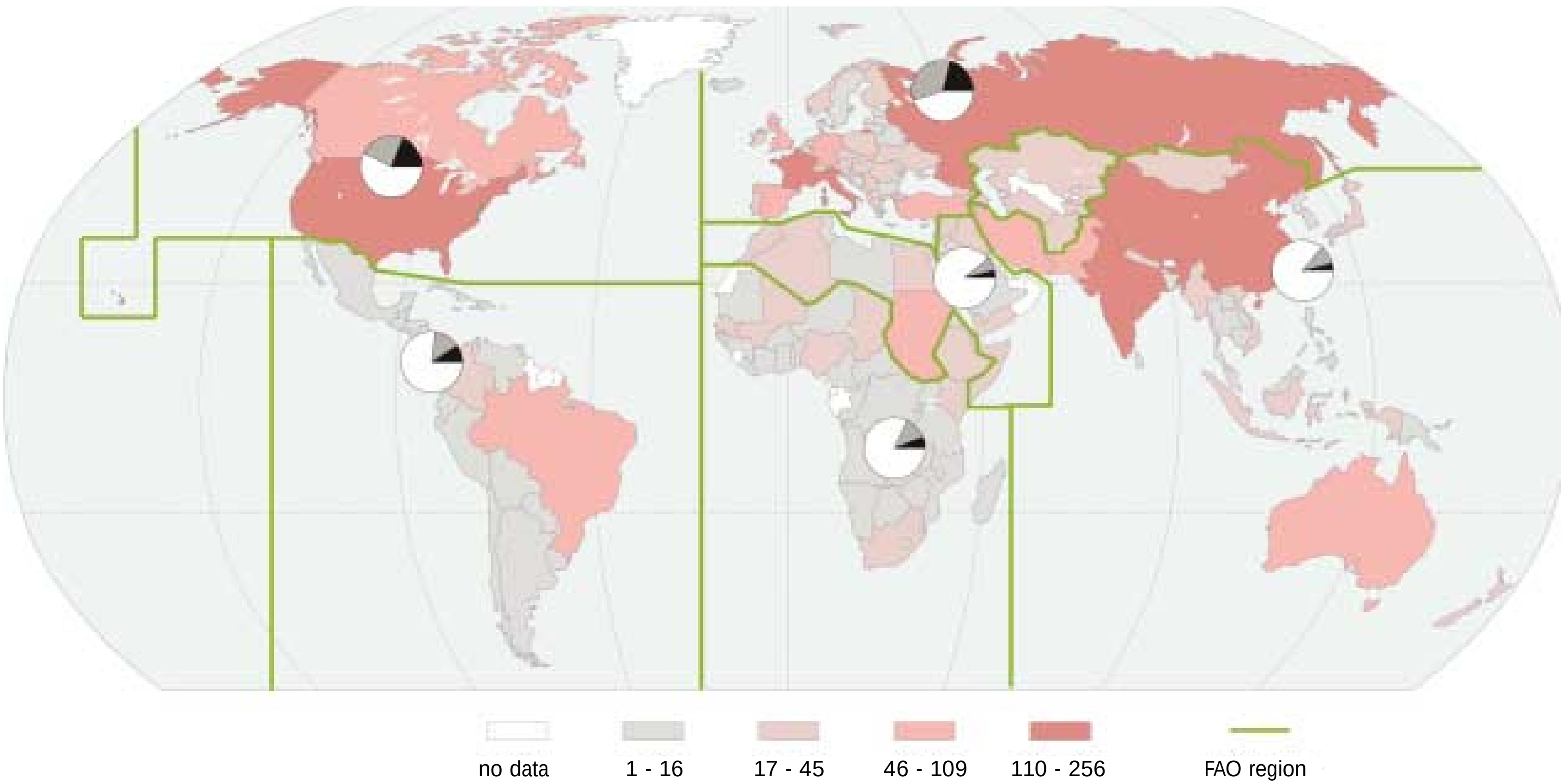
The full significance of the loss of varieties of crop plants and livestock, and their wild relatives, is difficult to evaluate. The loss of a cultivated plant variety might entail little or no loss of individual genes not present in other varieties although a particular pattern of gene regulation or interaction may be lost. It can be assumed, on the basis of much evidence, often anecdotal, that many local varieties possessed features of adaptive value in a local context, and their continued existence presents the opportunity for using the genes responsible in breeding improvements more generally. The precautionary principle implies that such diversity should be conserved.

Table 1.15 **Loss of crop plant genetic resources: examples at country level**

Country	resource	varieties lost	notes
China	wheat varieties	90% loss	of 10,000 varieties used in 1949 about 1000 (10%) remained in 1970s
Korea (S)	garden landraces	74% loss	of 14 crops in home gardens, 26% of landraces present in 1985 remained in 1993
Mexico	maize varieties	80% loss	only 20% of maize varieties planted in 1930s remain; maize being replaced by more profitable crops
USA	Varieties of apple, cabbage, field maize, pea, tomato	80-95% loss	percent loss comparing varieties grown 1804-1904 and present

Source: FAO. 1998. The state of the world's plant genetic resources for food and agriculture. FAO, Rome.

MAP 17



Livestock breeds

Colour represents the number of mammal breeds in each country. Recording of breeds is incomplete globally. Pie charts represent the proportion of all mammal breeds associated with each FAO region (green line) assessed as threatened (grey) or extinct (black).

Source: country-level data calculated from FAO *World Watch List for Domestic Animal Diversity* (2nd edition, 1995); charts calculated from data in 3rd edition (2000).

Germany

"Total forest cover in West Germany increased by 0.5 million hectares between 1960 and 1993."

Table 1.16 **The global status of major plant and animal genetic resources for food**

No. species known in total (approx.)	No. species domesticated (approx.)	Most important to global-level food supply	No. domestic breeds and varieties	No. domestic breeds and varieties at risk	No. domestic breeds and varieties extinct
Plants					
270,000	200	Bananas/plantains, beans, cassava, maize, millet, potatoes, rice, sorghum, soybean, sugar cane, sweet potatoes, wheat	Many thousands	Thousands	Not known
Mammals					
5,000	20	cattle, pigs	> 3,000	>500	238
Birds					
10,000	10	chickens	>860	>370	25

Source: data on livestock breed status from Scherf, B. D. 1995. World Watch List for domestic animal diversity. 2nd edition. FAO, Rome.

Soil degradation can include impairment of ecological services mediated by soil organisms, such as bacteria, fungi and small invertebrates, but there is little detailed information available on the overall status of soil biodiversity, or the resilience of these species following environmental change.

There is, however, an increasing amount of information relating to declines in abundance of some pollinators. It is estimated that twothirds of the world's species of agricultural crops require animals for pollination.[8] Species responsible for this service include birds, wasps, beetles, butterflies, bats, moths, giraffes, opossums and flies, but by far the greatest part is provided by bees. Although most estimates of the economic value of crop pollinators give credit to the honeybee (*Apis mellifera*), many other species of bee are involved.

However the numbers of native bees are dwindling. The losses are due mostly to the use of agrochemicals and monocultures, and to deforestation. The chemicals kill bees and, with the removal of wild vegetation and crop specialisation, the bees find neither places to nest nor alternative flowers while they wait for the crop to bloom.
In addition, honeybees in many parts of the world have contracted a serious disease and the numbers of honeybee colonies have decreased dramatically.

We have little or no information on most of the world's crops that will permit us to say whether they receive adequate visits of pollinators to effect maximum yields, yet research on numerous crops has demonstrated clearly that pollination can be a limiting factor to yields. The rapid development of transgenic crops raises additional causes for concern, as the employment of a herbicide or pesticide coupled with a variety of crop resistant to this could eradicate all alternative forage for pollinators, leading to devastation in their numbers.

[8] "The São Paulo Declaration on Pollinators" (see Annex 4).

IMPACTS OF GLOBAL ENVIRONMENTAL PROBLEMS ON BIOLOGICAL DIVERSITY

The strong scientific linkages between global environmental issues – such as loss of biological diversity, climate change, stratospheric ozone depletion, water degradation, or the accumulation of persistent organic pollutants – are becoming increasingly apparent.

The issue that may pose one of the greatest threats to biodiversity is climate change. For this reason, one of the most critical tasks is to identify the scientific and policy interlinkages between biodiversity loss and climate change. This section will look at those links.

Climate change

The weight of scientific evidence suggests that the observed changes in climate are caused, at least in part, by human activities, primarily the burning of fossil fuels and changes in land cover. These activities are modifying the concentration of CO_2 and other greenhouse gases which absorb heat radiating from the earth as well as the properties of the surface which absorbs or scatters radiant energy (the *albedo effect*).

Climate change may directly affect species through changes in phenology (e.g., earlier flowering of trees and egg-laying in birds), lengthening of the growing season, and changes in distribution (e.g. pole-ward and altitudinal shifts in insect ranges). In many cases the observed changes are consistent with well-known biological responses to climate. Changes in such characteristics of organisms may thus serve as indicators or early warnings of climate change.

Israel

“Over the last 50 years Israel has increased its forest area from less than 1% to nearly 10% of its territory. To date the Jewish National Fund has planted over 200 million trees.”

Climate change

Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is addition to natural climate variability observed over comparable time periods.

Adverse effects of climate change means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

United Nations Framework Convention on Climate Change, Article 1

Climate change is an additional stress on ecosystems and species that are, often, already under stress from other pressures such as: habitat change resulting from land-use change; overharvesting; pollution; and the effects of invasive species. Such pressures thus make biodiversity more vulnerable to climate change. For example:

- Habitat fragmentation poses barriers to dispersal, thereby reducing the possibility that species can adapt by moving as the climate changes. (Such barriers to dispersal may also exist naturally, in areas such as small islands or mountain tops.);
- Habitat fragmentation and overharvesting may result in small isolated populations with low genetic diversity. With low genetic adaptability such populations will be more vulnerable to extinction;

- Ecosystem degradation, which may result from unsustainable use of ecosystem components, pollution, pest outbreaks, or changes in fire regimes, can decrease the resilience of ecosystems to climate change.

Addressing such exacerbating factors may be an important component of adaptation to climate change.

The expected result of these interactions is that climate change will lead to reduced biological diversity. At the species level, those that are most likely to be adversely affected are those that can only tolerate a narrow range of climatic conditions and that have limited capacity to disperse. This is likely to include a significant proportion of already threatened species.

At the ecosystem level, established natural communities may be broken up as the constituent species shift at different rates in response to climate change. For example, a substantial fraction of the world's forested area is expected to undergo major changes in broad vegetation types with the greatest changes at high latitudes. New assemblages of species and hence new ecosystems may be established. As noted below, this may have major implications for the role of forests as carbon stores.

Differential responses to climate change by species in ecosystems may lead to disruption of important functional interactions, with potentially highly serious consequences for the provision of ecosystem services such as pest control, pollination, seed dispersal, decomposition and soil nutrient cycling. In addition to the effects on natural ecosystems, these could have socio-economic consequences for agriculture.

The impact of climate change on biological diversity is expected to be non-linear. The impact may be particularly severe when certain critical thresholds are crossed. Ecosystem types that are vulnerable to such thresholds include:

- Wetlands overlying permafrost. These are likely to be severely affected when the ice melts;

- Coral reefs. As already noted by the Conference of the Parties, there is significant evidence that climate change is a primary cause of the recent and severe extensive coral bleaching. Bleaching is reversible when the increases are short-term and of no more than 1-2ºC. However, sustained increases in water temperatures of 3-4ºC above normal maxima can cause significant coral mortality. Severe bleaching events were triggered, for example, by the El Niño events of 1982-83 and 1997-98.

Climate change may also increase threats from invasive alien species:

- Climate change may result in extension or changes in the ranges suitable to certain invasive species. An example may be the increased prevalence of vector-borne infectious diseases transmitted by blood-feeding mosquitoes and ticks;

- Environments may become more favourable to weedy species because of climate change induced ecosystem disruptions.

In short, and as the Intergovernmental Panel on Climate Change (IPCC) has concluded, ecosystems vital to human development and well-being are vulnerable to climate change. There are likely to be reductions in biological diversity and in the goods and services that ecosystems provide to society, e.g. sources of food, fibre, medicines, recreation and tourism, and ecological services such as controlling

Kenya

"Average annual forest loss is approximately 5,000 hectares per year. The Mau forest has been degraded by 30% in the last 10 years."

nutrient cycling, waste quality, water runoff, soil erosion, pollination services, detoxification and air quality. Additionally there may be an increased provision of ecosystem "bads" such as pests, diseases and other invasive species.

MONITORING TRENDS IN BIODIVERSITY

Present patterns in global biodiversity reflect the many and extensive changes brought about by the human species. No natural habitats are free from human impact, and large areas have been totally transformed. Many wild species have declined in distribution and abundance; some are known to have become extinct. With human help, domestic livestock and crops occupy large areas of land, along with introduced game animals and a host of accidental introductions, including many weeds and animal pests.

The objectives of the Convention are to conserve biodiversity, to use its components sustainably, and to ensure that benefits arising from the use of genetic resources are shared equitably. Core tasks, as set out in Article 7 of the Convention, are to identify important components of biodiversity and to monitor trends in their status. While it is usually feasible to assess national biodiversity at a general level in terms of species and broad ecosystem types, and this is evident in the national reports submitted to the Secretariat (see chapter 4), effective monitoring is a greater challenge.

Monitoring implies repeated assessment in order that change and long-term trends over time can be identified. All kinds of evidence may be admissible, but for scientific dialogue a quantitative and structured monitoring framework is preferred, and for comparative purposes, for example seeking to build a comprehensive continental or global picture from national data, it is desirable that similar parameters are measured in similar terms. Until recently, however, change in biodiversity at species and habitat level has very often been identified retrospectively on an *ad hoc* basis, by means of largely anecdotal evidence, and using terms and units of measurement that are highly case-specific.

Knowledge of biodiversity at local and regional levels is embedded in cultural practices and languages. The knowledge, innovations and practices of indigenous and local communities are key human components of sustainability. They are the result of long periods of use, observation and experimentation. The decline of cultural diversity brings with it the concomitant loss of biodiversity knowledge. This is especially the case when languages are lost.

During the past decade, considerable effort has been devoted to the assessment of change in the environment, often at national or regional level, and to the development of indicators to represent environmental change. An indicator is a value, perhaps an index derived from a set of observational data, that can be taken to represent some broader issue beyond the indicator value itself. The central purpose is to communicate real-world complexity in a simplified and readily understood numerical or graphic form.

Economic indicators rely mainly on time-series of quantitative numerical data, as do the most effective environmental indicators, for example those relating to trends in readily measurable factors such as temperature or carbon dioxide emissions. One of the principal obstacles to the development of good biodiversity indicators is that time-series of numerical data, especially if applicable above local or national level, are scarce. For this reason, most existing biodiversity indicators are based on static status assessments, for example the proportion of the mammal fauna that is threatened with extinction, the number of national-endemic species, or amount of protected forest.

Now that a large number of countries have begun to implement the Convention, and the period since relevant measures have been in place is lengthening, it is increasingly desirable to develop tools to monitor the actual on-the-ground impacts of compliance. The Parties have explicitly recognised this need in their several calls for development of a core set of biodiversity indicators, and in their efforts to improve and harmonise national reporting.

However, it is not yet possible to build a reliable and comprehensive picture of the effectiveness of measures adopted in compliance with the CBD, in terms of change in the status of the components of biodiversity. This is in part because insufficient time has passed since implementation of the Convention at national level began so that it is in many instances not realistic to expect a clear response, i.e. recovery or restoration of species and habitats is generally a protracted process. It is in part also because reliable monitoring tools, with the appropriate resolution, have not been developed and widely implemented.