CHAPTER 4

Changes in biodiversity

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Summary

By the year 2000, about 73% of the original global biodiversity on land was left. The largest declines have occurred in the temperate and tropical grasslands and forests, the biomes where human civilizations developed first. There is a projected further biodiversity loss on land of about 11% worldwide between 2000 and 2050. The global annual rate of loss increased dramatically in the twentieth century, especially in Europe, in comparison to previous centuries. The expected loss rate for Europe seems to decrease but does not halt, while the global average still increases. By 2050, for the world as a whole, biodiversity is lost corresponding with an area of 1.5 times the USA changing from entirely natural to asphalt. With these loss rates, the global and European 2010 targets will not be met, not in 2010, and not in 2050. The number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area. However, the biomes represented in that coverage are uneven and global figures mask significant regional disparities.

Fishing pressure has been such in the past century that the biomass of larger high-value fish and those caught incidentally has been reduced to 10% or less of the level that existed before industrial fishing started. The loss of biomass and fragmented habitats has led to local extinctions. Those scenarios that used current trends or increased effort whether for commercial or recreational fisheries all indicated collapses in stocks and ecosystems; they differed only in their rates of decline and mankind is increasingly relying on fish that originate from the lower part of marine food webs. Different scenarios for depletion of fish stocks between year 2007 and 2047 all produce negative global mean values, indicating a further depletion of the marine biodiversity. There has been a substantial loss of estuaries and associated wetlands globally. Over the last 25 years, 3.6 million hectares of mangroves, about 20 percent of the total extent found in 1980, have disappeared worldwide In 1999, it was estimated that approximately 27% of the world’s known reefs had been badly degraded or destroyed in the last few decades. While conversion to agricultural land was the major factor in historic biodiversity loss, the major increase between 2000 and 2050 in the respective contributors to the biodiversity loss are to found in the expansion of infrastructure and climate change.

4.1 Introduction

The COPI analysis is aimed at an estimate of the economic consequences of biodiversity loss. In this Chapter we present a qualitative and quantitative assessment of the expected future changes in biodiversity in ecosystems around the world, both terrestrial and marine. The assessment is based on three sources: (1) the projected changes in mean species abundance calculated with the GLOBIO model, based on the OECD Baseline scenario calculations about the land use changes and other pressures (Chapter 3), (2) scenario studies with the EcoOcean model and (3) a wide variety of case studies, many already extensively reviewed in the MA project (MA, 2005b) and selectively summarised here, alongside a number of more recent examples. The assessment provides an essential input to the analysis of subsequent changes in ecosystem service levels and economic value to society (see the next chapters).

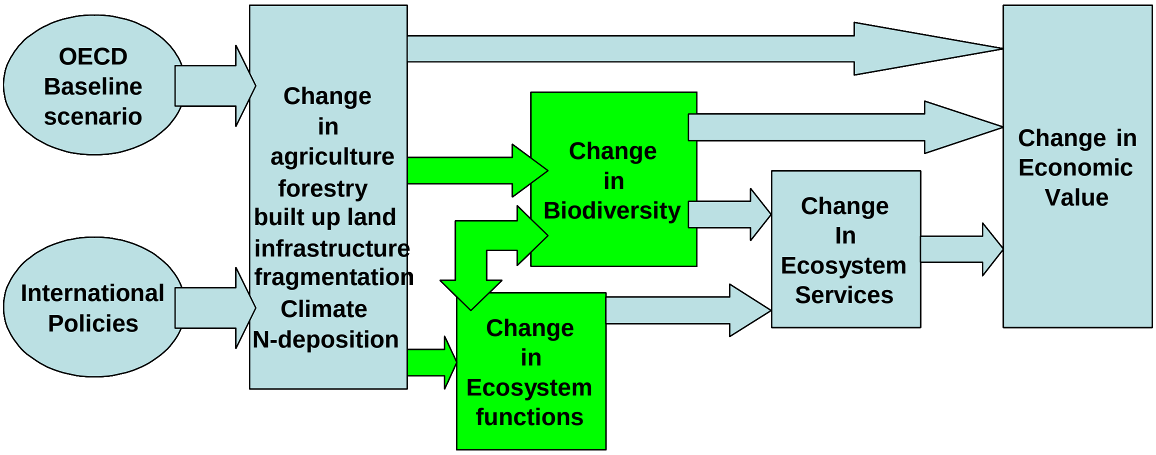


Figure 4.1 Chapter 4 in the conceptual model of the COPI-analysis

The information presented in the global assessments of the past decade, e.g. Global Environment Outlook-3 (2002) and GEO-4 (2007), the Millennium Ecosystem Assessment (MA, 2005a), the Global Biodiversity Outlook 2 (CBD, 2006; Ten Brink et al., 2007) and the OECD Environmental Outlook (2008), has made clear that the rates of loss of biodiversity have accelerated dramatically over the past century. Current rates of species extinction are at least 2 orders of magnitude above background rates and are expected to rise to at least 3 orders above background rates while 20% of all species in those groups that have been comprehensively assessed are believed to be threatened with extinction in the near future (MA, 2005b). Even among species not threatened with extinction, the past 20–40 years have seen substantial declines in population size or the extent of range in most groups monitored. Rates of biodiversity decline vary. Some species and species groups are more vulnerable to change than others. Some generalist species are expanding their ranges, either naturally or as invasive aliens, whereas many ecological specialists are in decline.

The drivers of loss are changing: invasive species and overexploitation were the predominant causes in historic times, while habitat conversion, especially from natural systems to agricultural use, is the most significant driver currently. Climate change is expected to develop into a major threat in the near future. Interactions within ecological communities mean that changes in the abundance of one species will often have effects through the community. It is also quite clear that ecosystems show both gradual changes, when perceived in the time frame of humans, but at the same time respond non-linearly to external changes, with threshold-based dramatic collapses. Changes are presented at the global level, by world regions, by biome and landscape types and at the species level. The changes are partly calculated with the IMAGE – GLOBIO model framework (for terrestrial systems; see Box 3.1

and Box 4.1 respectively) and the EcoOcean model (for the marine biomes; see Box 4.5), and partly derived from extrapolation of historic trends in case studies at various geographical levels. The changes are expressed in a number of CBD 2010-indicators, some of which are used in the models (ecosystem extent and species abundance).

4.2 Indicators of biodiversity change

4.2.1 Biodiversity measures and indicators

Biodiversity as defined by the Convention on Biological Diversity encompasses the diversity of genes, species and ecosystems. Given this complexity, biodiversity dynamics can only be described by a set of complementary indices (see *table 2.1* in Chapter 2). Several focal areas and indicators have been identified and accepted for measuring the progress towards the 2010 CBD target '*to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth*'. Well known indicators for the status and trends in terrestrial biodiversity are the Red List Index (IUCN), the Living planet index (WWF and UNEP-WCMC), the coverage of Protected Areas (UNEP-WCMC) and the Ecological Footprint (Global Footprint Network and WWF). Each of the indicators has strengths and weaknesses, as summarized in *figure 4.2*.

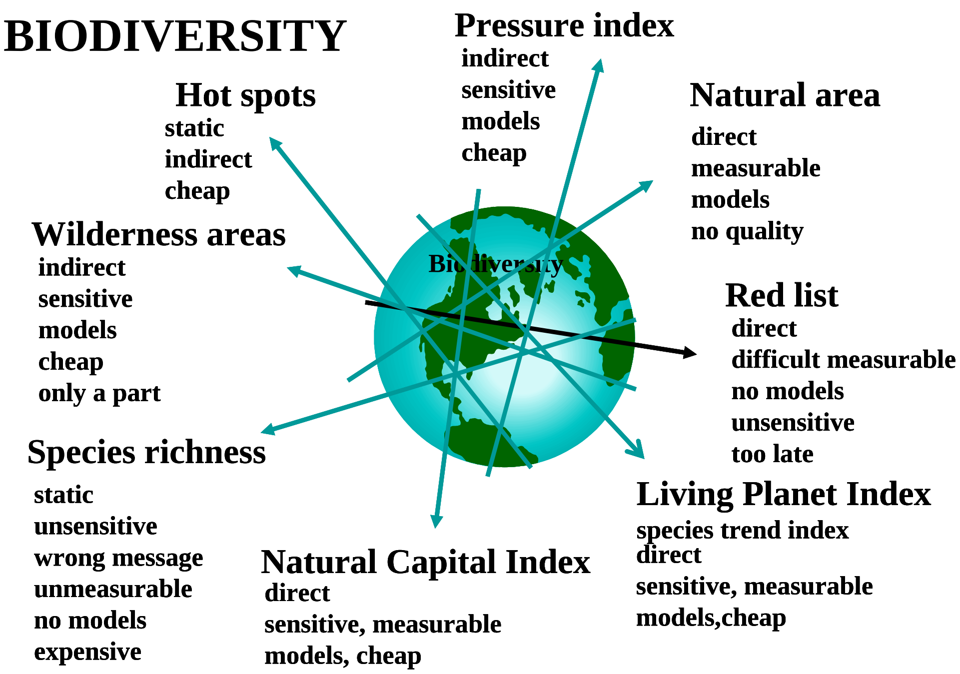


Figure 4.2 An overview of aggregated biodiversity indicators. **B. ten Brink, 2000, 2006**

In decision VII/30 the Conference of the Parties of the CBD in 2004 adopted a framework to assess and communicate progress towards the 2010 target at the global scale. The framework includes seven focal areas, each of which encompasses a number of indicators for assessing progress towards, and communicating, the 2010 target at the global level. In total, 22 indicators were indentified by the Conference of the Parties (see Chapter 2, *table 2.1*). These indicators are in the process of being developed at the global scale by a wide range of organizations, including UN agencies, research institutes and universities, and non-governmental organisations, brought together by the 2010 Biodiversity Indicators Partnership project. The EEA is developing a set of indicators derived from the CBD set, to monitor progress in Europe (EEA, 2007). Several of the CBD biodiversity indicators have also been included as indicators under MDG Goal 7 (ensuring environmental sustainability; *Table 4.1*). Proportion of land covered by forest, proportion of land in protected areas (terrestrial and marine), proportion of threatened species (the Red List Index) and proportion of fish stocks managed sustainably are all now official MDG indicators of biodiversity and sustainable use of environmental resources.

Table 4.1 Biodiversity in the Millennium Development Goals (MDGs)

Goal 7: Ensure environmental sustainability (biodiversity related aspects only)	
Target 7.A: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	7.1 Proportion of land area covered by forest 7.2 CO_2 emissions, total, per capita and per $1 GDP (PPP) 7.3 Consumption of ozone-depleting substances 7.4 Proportion of fish stocks within safe biological limits 7.5 Proportion of total water resources used
Target 7.B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss	7.6 Proportion of terrestrial and marine areas protected 7.7 Proportion of species threatened with extinction

4.2.2 - The Mean Species Abundance (MSA) indicator

In the COPI study, a model framework and biodiversity indicator were used for assessment of terrestrial biodiversity dynamics which are able to reflect the impacts of the most important direct and indirect drivers: the extent of biomes and ecosystems, trends in abundance and distribution of species, protected areas, nitrogen deposition, climate change and fragmentation. The biodiversity indicator chosen for use in the COPI study is the Mean Species Abundance (MSA), as used in the GLOBIO model (*Box 4.1*), and the IMAGE framework (see Chapter 3, *Box 3.1*). This measure of mean species abundance (MSA) is similar to the Biodiversity Intactness Index (Scholes and Biggs, 2005) and is a composite of CBD's 2010-indicator 'the abundance and distribution of a selected set of species' (*table 2.1*). The numerical values of the MSA in the COPI study represent the biodiversity impacts of the drivers and pressures in the OECD Baseline Scenario.

The loss of biodiversity we are facing in modern times is the –generally unintentional- by-product of increasing human activities all over the world. The process of biodiversity loss is generally characterised by the decrease in abundance of many original species and the increase in abundance of a few other -opportunistic- species, as a result of human activities. Extinction is just the last step in a long degradation process. Countless local extinctions ("extirpations") precede a potentially final global extinction. As a result, many different ecosystem types are becoming more and more alike, the so-called homogenisation process (Pauly *et al.*, 1998; Ten Brink, 2000; Scholes and Biggs, 2005; MA, 2005b). Decreasing populations are as much a signal of biodiversity loss as rapidly expanding species populations, which may sometimes even become plagues in terms of invasions and infestations. F*igure 4.3* showing this process of changing abundance (indexed) of the original species from left to right. Until recently, it was difficult to measure the process of biodiversity loss. "Species richness" appeared to be an insufficient indicator. First, it is hard to monitor the number of species in an area, but more important it may sometimes increase as original species are gradually replaced by new human-favoured species. Consequently the Convention on Biological Diversity (VII/30) has chosen a limited set of indicators to track this degradation process, including the "change in abundance of selected species".

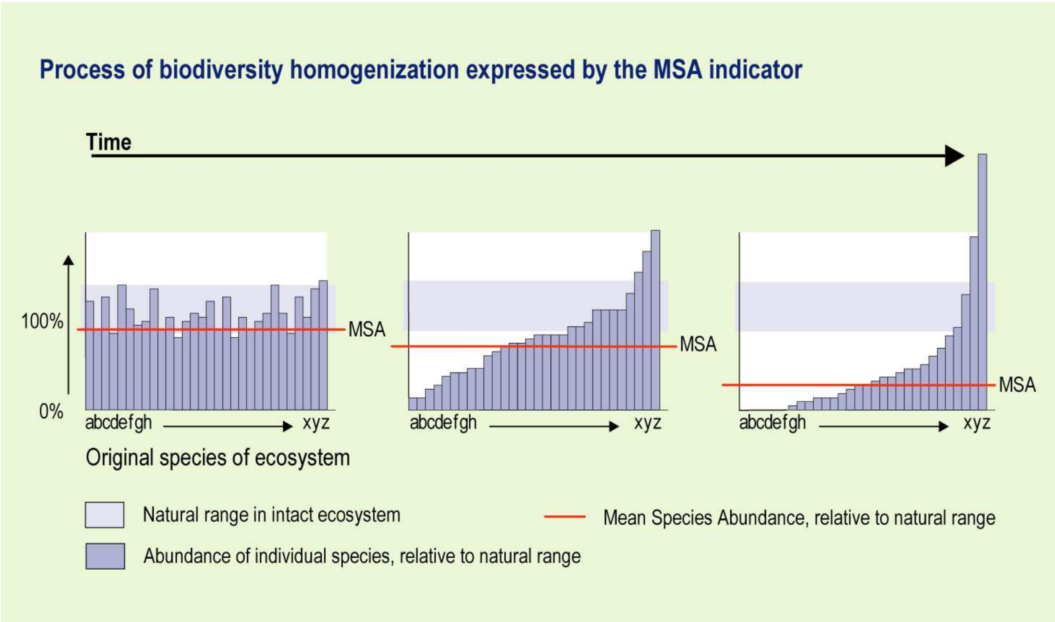
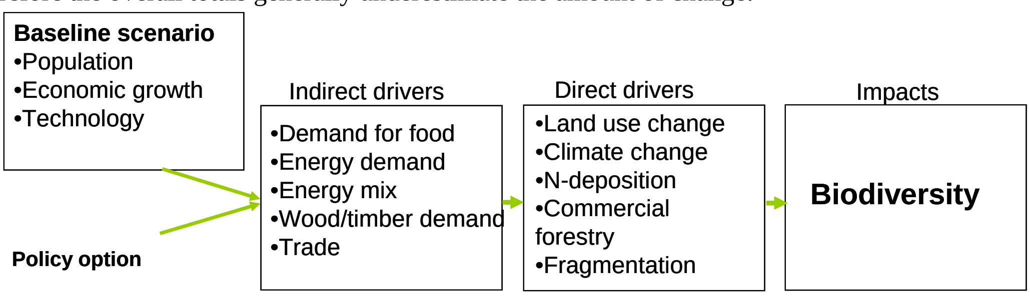


Figure 4.3 Species dynamics during the homogenisation process, and the response in the MSA biodiversity indicator.

This indicator has the advantage that it measures the key process, is universally applicable, and can be measured and modelled with relative ease. In the GLOBIO/MSA framework biodiversity loss is calculated in terms of the *mean species abundance of the original species (MSA) compared to the natural or low-impacted state*. This baseline is used here as a means of comparing different model outputs, rather than as an absolute measure of biodiversity. If the indicator is 100%, the biodiversity is similar to the natural or low-impacted state. If the indicator is 50%, the average abundance of the original species is 50% of the natural or low-impacted state and so on. The range of MSA values and the corresponding land-use and impact levels are visualised for grassland and forest systems in *Box 4.2* The *mean species abundance (MSA)* at global and regional levels is the sum of the underlying biome values, in which each square kilometre of every biome is equally weighted (ten Brink, 2000; UNEP, 2003, 2004).

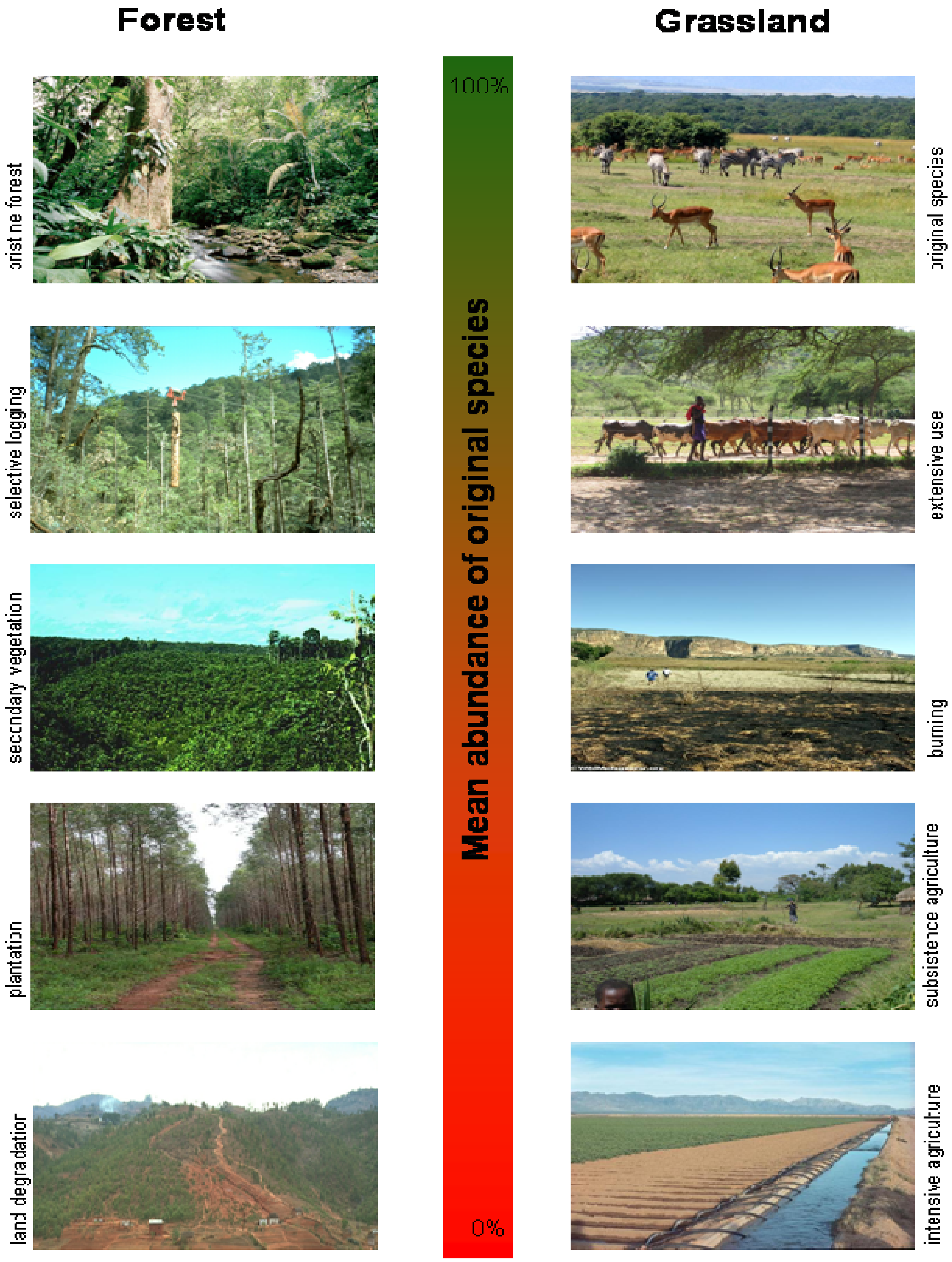
Box 4.1 GLOBIO: The Global Biodiversity model

The GLOBIO 3 model (Alkemade et al., 2006) contains generalised cause-effect relationships between a selection of pressure factors and the mean species abundance (MSA). The core of GLOBIO 3 is a set of regression equations describing the impact on biodiversity of the degree of pressure using dose–response relationships. These relationships are derived from a database of observations of species responses to change, derived from more than 700 peer reviewed publications. The database includes separate measures of MSA, each in relation to different degrees of pressure exerted by various pressure factors or driving forces. The pressures considered in GLOBIO 3 include land-cover change (agriculture, forestry, built up area), land-use intensity, atmospheric nitrogen (N) deposition, infrastructure development, fragmentation and climate change. The current version of the GLOBIO model does not capture that biodiversity is typically lost quickly and regained or restored only slowly. Therefore the overall totals generally underestimate the amount of change.



Box 4.2: Visual impressions of mean species abundance scale

A photographic impression of the gradual changes in two ecosystem types (landscape level) from highly natural ecosystems (90-100% *mean abundance of the original species*) to highly cultivated or deteriorated ecosystems (around 10% mean abundance of the original species).



4.3 Change in terrestrial biodiversity

4.3.1 Global developments

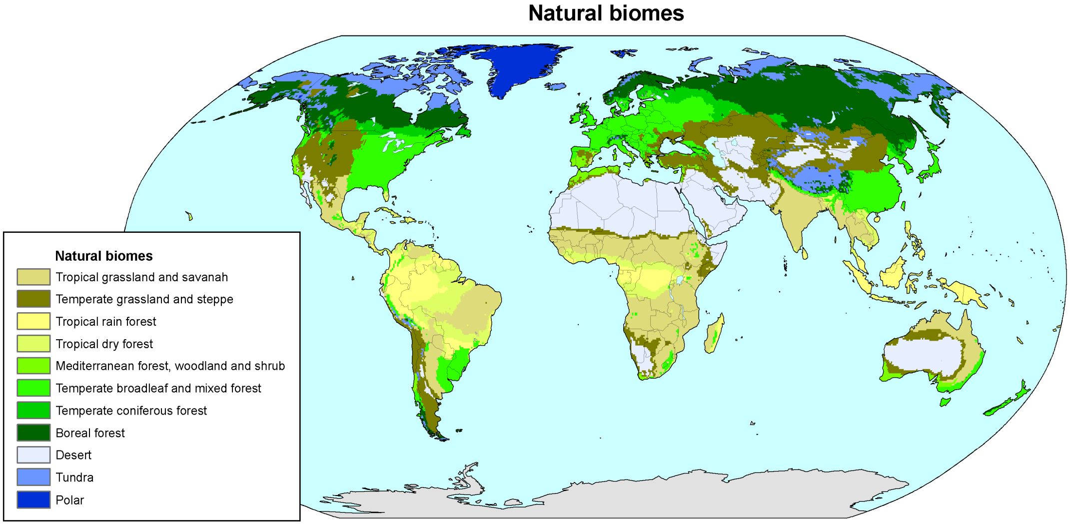


Figure 4.4 Geography of the major world biomes, as used in the IMAGE and GLOBIO model framework.

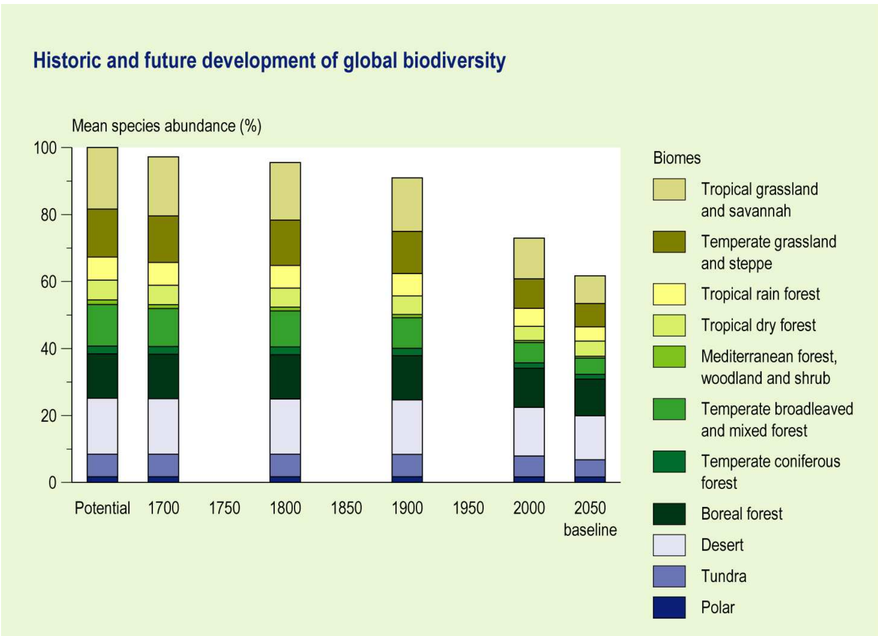


Figure 4.5: Global terrestrial biodiversity development by major biomes, from 1700 to 2050

Anthropogenic biodiversity loss in natural terrestrial biomes (see map in *figure 4.4*) started many centuries ago (see *figure 4.5*). By the year 2000, about 73% of the original global natural biodiversity was left. The strongest declines have occurred in the temperate and tropical grasslands and forests, the biomes where human civilizations developed first (McNeill & McNeill, 2003). Natural habitats were converted to cropland and pasture already more than 10,000 years ago in Southwest Asia, 6,000 – 9,000 years ago in China and 4,000 – 6,000 years ago in Mexico and South America. The most intact biodiversity is therefore found in those biomes that are less suitable for human development, such as desert, tundra and polar areas.

The total biodiversity loss resulting from land conversion and other pressures between 2000 and 2050, representing the projections of the driving forces and environmental pressures as described in the OECD Baseline scenario is 11% points (73 to 62%). This corresponds with an area of 1,300 million ha (about 1.5 times the United States) which would loss its entire original biodiversity, for example changing from pristine to asphalt. The relative loss is greater when the desert, tundra and polar biomes are excluded from the equation: 12 %-point in 50 years.

The global annual rate of loss increased dramatically in the twentieth century, especially in Europe, in comparison to previous centuries. The expected loss rate for Europe seems to decrease, while the global average still increases (see *figure 4.6*).

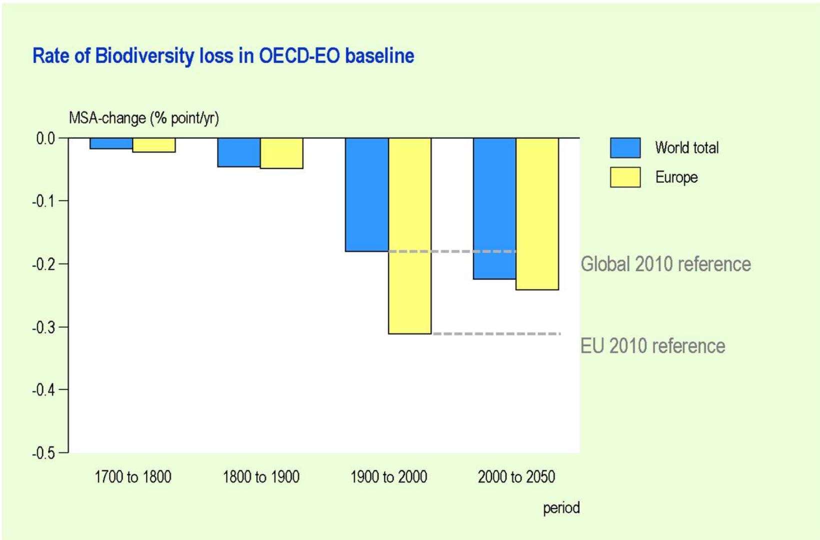


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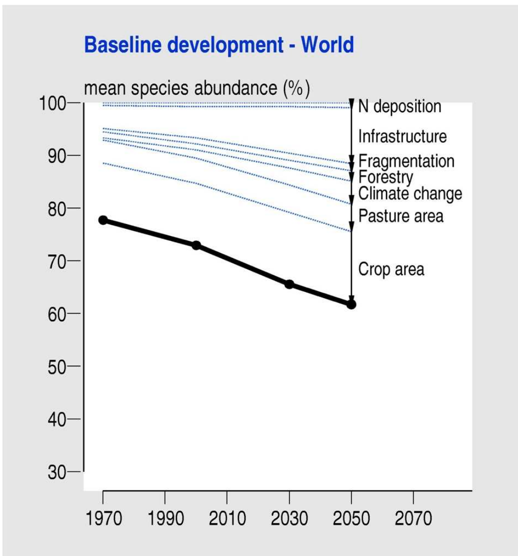
Fig 4.6 Rate of annual terrestrial biodiversity loss (MSA %-points) for different periods.
(*a change from 80% MSA to 40% MSA = absolute decrease of 40%-point and relative change of 50%.)*

The role of agricultural land-use (crops and pastures) remains the largest of all the pressure factors, which is a logical consequence as the total crop area continues to grow in the Baseline scenario (see figure 4.7a). While conversion to agricultural land was the major factor in historic biodiversity loss, the major contributors to the *additional* biodiversity loss between 2000 and 2050 are expansion of infrastructure and climate change (*Figure 4.7b*). The influence of nitrogen deposition and fragmentation are not expected to increase, even though these factors share similar indirect drivers as the other factors. But through the expansion of agriculture, less natural biome area is left where these stresses can exert their influence.

Figure 4.7a Contribution of different pressures to the global biodiversity loss between 2000 and 2050 in the OECD baseline.



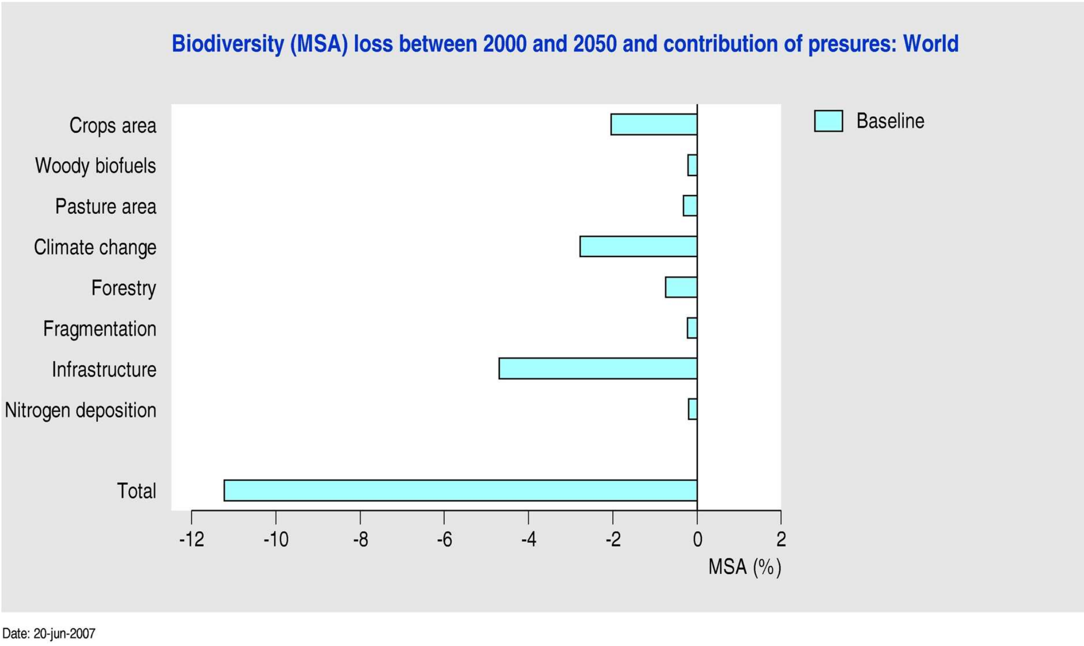


Figure 4.7b ***Contribution of different pressures to the global biodiversity loss between 2000 and 2050 in the OECD baseline.***

4.3.2 Biodiversity change by world region

The results for the main groups of OECD-countries, transition economies (BRIC) and the developing countries (Rest-of-World) are generally similar to the global average. However, there are strong differences in biodiversity levels between regions within the groups (see maps in *figure 4.9*), both in the rate of decline and in the breakdown over the various stress factors (*figure 4.8*).

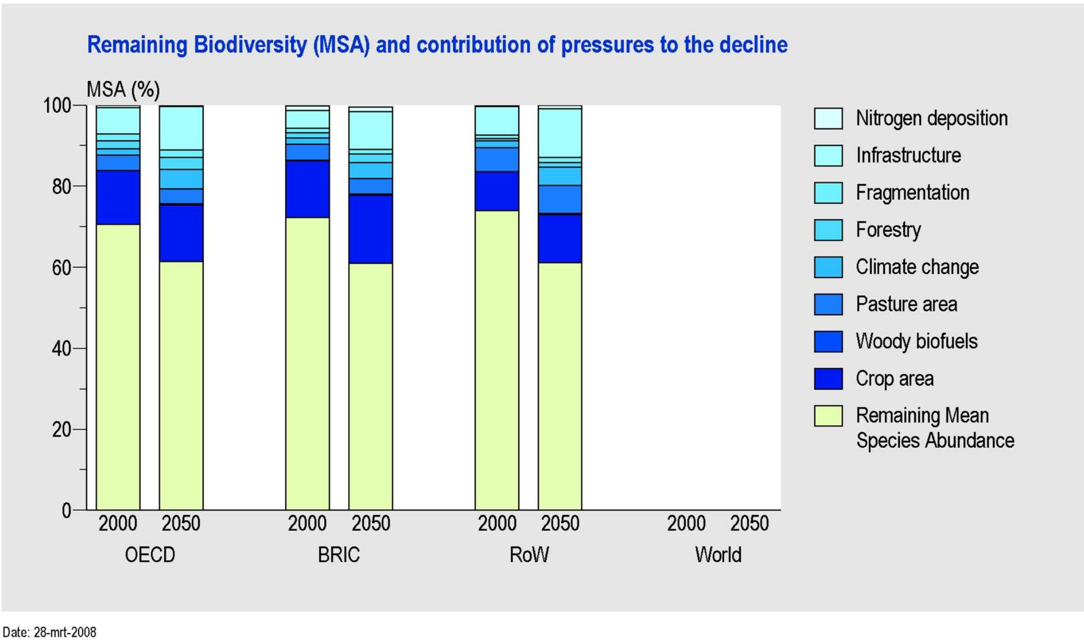
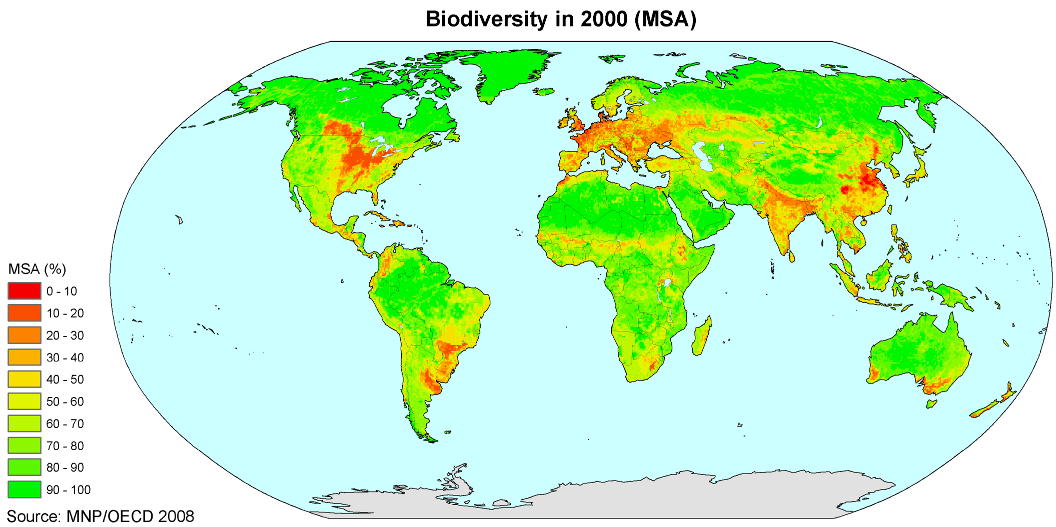
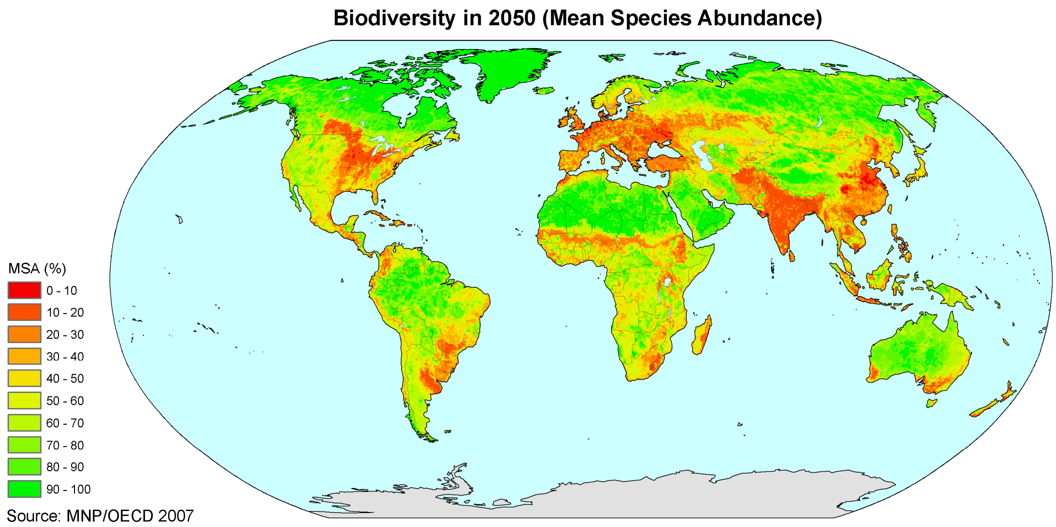


Figure 4.8 ***Remaining biodiversity (MSA) in 2000 and 2050 and contribution of pressures to the loss, for the different country clusters of the OECD baseline.***





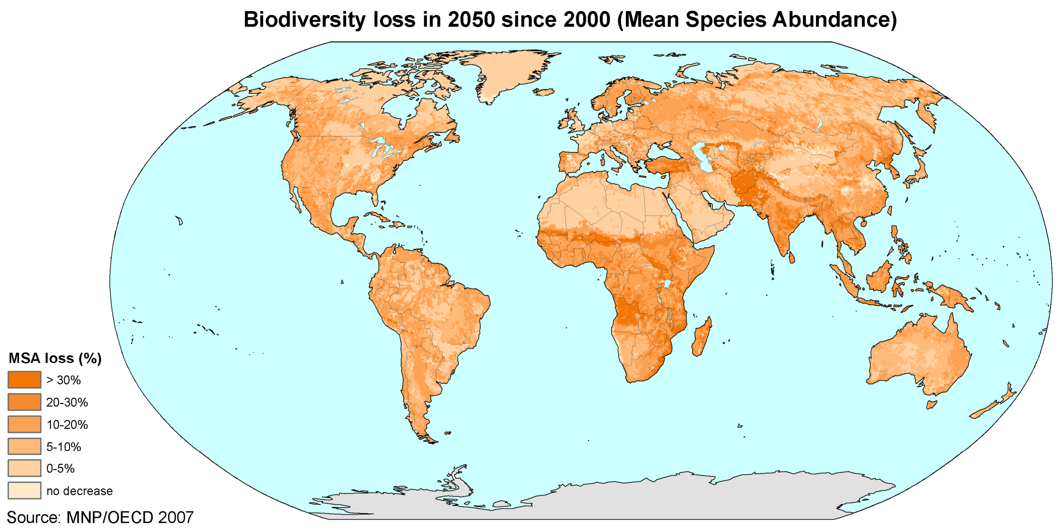


Figure 4.9 Global biodiversity (MSA) in 2000 and 2050 (top maps) and change in global biodiversity (bottom map), according to OECD Baseline development.

The strongest increase in crop area can be seen in the BRIC group, whereas in the OECD group agricultural influence even declines from 2030 to 2050. Pastures are not expanding, so their impact stays more or less the same. Impacts of infrastructure development are considerable in all regions, which is the consequence of increasing economic and agricultural activities. Through the global effects of temperature rise, all groups show a similar and increasing climate change effect.

The OECD group
The lowest further loss is seen in the OECD group (- 9 %-point). The overall biodiversity level in the OECD group is strongly influenced by the vast natural areas in USA, Canada and Oceania with relatively high biodiversity levels. By contrast, remaining biodiversity in the densely populated regions Japan and especially Europe is much lower. The further decline to 2050 for the OECD group is mostly due to infrastructure expansion (additional 4 %-point loss) in the densely populated countries of this group and to global effects of climate change (additional 3 %-point loss).

The BRIC group
The main causes for the further decline of 11 %-point to 2050 in the BRIC group are agricultural expansion (additional 3 %-point), expanding infrastructure (additional 5 %-point) and climate change (additional 2,5 %-point). The differences within the BRIC group are also large. The vast natural and sparsely populated areas in Russia and Brazil have a large influence on the total BRIC group biodiversity level. At the other extreme are the densely populated and strong developing countries in South Asia. These have the lowest biodiversity of the BRIC group, and the mean species abundance declines through further growth in already important agricultural activities.

The Rest-of-the-World group
The highest further loss is found in the Rest-of-the-World group (-13 %-point). Again, large differences in both levels and trends are found between regions. The main cause for the further decline in the ROW-group to 2030 is the strongly expanding infrastructure (additional 5 %-point) through economic development. In all regional clusters in Rest-of-World the influence of climate change on biodiversity increases (additional 3 %-point). The last important cause is agricultural expansion (additional 2 %-point). The Other Asia and East and Central Asia regions show the lowest biodiversity values, with large additional losses due in particular to strong expansion of infrastructure. Infrastructure development is also a significant factor on the vast African continent, which exerts a large influence on the total Rest-of-World group. This development is caused by growth in population and GDP, and natural resource exploitation. In the Middle East, original biodiversity levels remain relatively high, due to the widespread arid and desert biomes that are not easily converted to human activities. Agricultural expansion plays an important role in Other Asia and Africa.

4.3.4 Changes by Biome

The major changes in the different biomes can be described with land-use developments and changes in the total biodiversity of each biome. The total area of a biome[1] does not change in the 2000-2050 period (due to only slowly changing boundaries), but major shifts in land-use occur within each biome. This is mostly from natural and extensively used areas to intensive agricultural use. The total biodiversity in a biome (expressed by the biodiversity indicator MSA) is changing due to the land-use shifts and to changing environmental conditions.

[1] By definition, a biome is an area with suitable conditions (climate, temperature, rainfall) for development of certain natural vegetation types, given undisturbed development. In the IMAGE model framework, biomes are modeled according to Prentice *et al.*, (1992).

Box 4.3 Historic changes in biomes and landscapes around the world
(adapted from the MA, 2005b)

Forests

- *Forest ecosystems are important refuges for terrestrial biodiversity, a central component of Earth's biogeochemical systems, and a source of ecosystem services essential for human well-being. Forests, particularly those in the tropics, provide habitat for 50% or more of the world's known terrestrial plant and animal species.*
- *In the last 300 years, global forest area has been reduced by approximately 40%. Forests have completely disappeared in 25 countries, and another 29 countries have lost more than 90% of their forest cover.*

Dry-lands

- *Depending on the level of aridity, dry-land biodiversity is relatively rich, still relatively secure, and is critical for the provision of dry-land services. Of 25 global ''biodiversity hotspots'' identified by Conservation International, 8 are in dry-lands. The proportion of dry-lands designated as protected areas is close to the global average, but the proportion of dry-land threatened species is lower than average. At least 30% of the world's cultivated plants originated in dry-lands and have progenitors and relatives in these areas.*
- *Transformation of rangelands to cultivated systems (approximately 15% of dry-land grasslands, the most valuable dry-land range, were converted between 1950 and 2000), in combination with inappropriate dry-land irrigation and cultivation practices has led to soil salination and erosion.*

Polar

- *Important changes include: the reduction of top predators in Antarctic marine food webs, increased shrub dominance in Arctic wetlands, which contributes to summer warming trends and alters forage available to caribou, changes in insect abundance that alter food availability to wetland birds, energy budgets of reindeer and caribou, or productivity of forests; increased abundance of snow geese, which are degrading Arctic wetlands; overgrazing by domestic reindeer in parts of Scandinavia, Russia, and sub-Antarctic islands; and a rapid increase in the occurrence and impact of invasive alien species, particularly in previously isolated sub-Antarctic islands.*

Inland waters

- *It is estimated that 50% of inland water habitats were lost during the twentieth century. Inland water habitats and species are in worse condition than those of forest, grassland, or coastal systems. Inland water systems encompass habitats such as lakes and rivers, marshes, swamps and floodplains, small streams, ponds, and cave waters. All inland aquatic habitats,-whether fresh, brackish, or saline—as well as inland seas are considered. More than 50% of inland waters (excluding lakes and rivers) have been lost in parts of North America, Europe, and Australia. In addition to the loss of inland water systems, degradation is widespread. The species biodiversity of inland waters is among the most threatened of all ecosystems.*

Mountains

- *Because of the compression of climatic life zones with altitude, and small-scale habitat diversity caused by different topo-climates, mountain regions are commonly more diverse than lowlands. They support about one quarter of terrestrial biodiversity, with nearly 50% of the world's biodiversity hot spots concentrated in mountains. 32% percent of protected areas are in mountains (9,345 mountain protected areas covering about 1.7 million square kilometres).*

Land-use changes (in terms of ha)

The remaining part (in terms of ha) of each biome that still has a natural character is getting smaller for all biomes. Changes are strong in the savannah biome, where only 700 million ha of natural area will be left in 2050, compared to 900 million ha in 2000 (*figure 4.10a*). This leads to increases for intensive agriculture or grazing (*some managed forest is also found within the savannah biome, due to boundary effects and spatial mismatch between biome and actual land-use maps*). Extensive agriculture also disappears as agricultural productivity is expected to increase in the coming decades. Similar changes are projected for the grassland and steppe biome, with a large share for grazing and intensive agriculture. The vast areas with boreal forest still have a large share with relatively unaffected natural areas, but forestry and agricultural practices are developing here as well towards 2050. A similar development takes place in the tropical forests and woodlands.

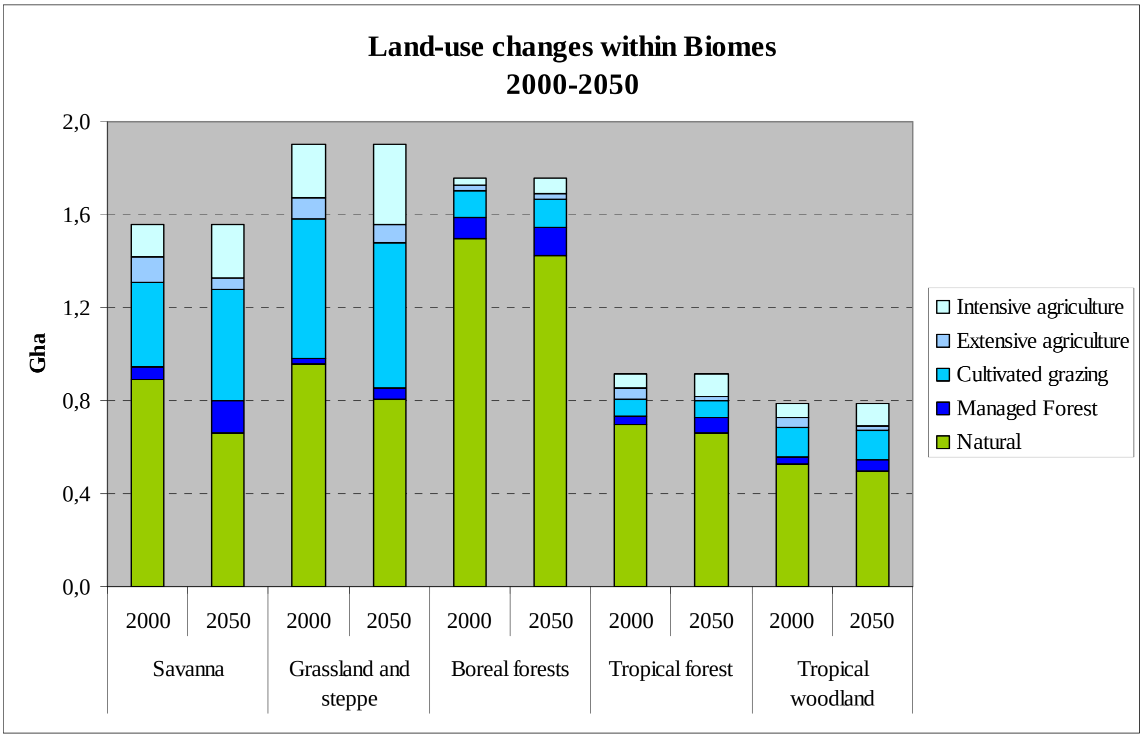


Figure 4.10a Land-use changes within the biomes (in Gha) between 2000 and 2050 (according to OECD Policy inaction scenario).

Biodiversity changes (in terms of MSA)

The future changes in biodiversity (in terms of MSA) between 2000 and 2050, both absolute and relative, are projected to be most dramatic in the Savannah Biome (270 million MSA-ha, and ca. 17 % of original natural area in the biome; *figure 4.10b***)**. MSA-ha is the product of area and remaining % biodiversity (MSA %)[2]. The Grassland & Steppe biome (ca 220 million MSA-ha, 11%) and the Boreal Forest Biome (160 million MSA-ha, almost 9%) are hit hard as well. The tropical forest and woodland biomes together lose more than 200 million MSA-ha or ca 13% of their original biodiversity. Surprisingly at first sight, the desert biome also loses quite a lot of biodiversity, but that is mainly the result of its large area (just 8% relative loss). In the savannah, grassland and steppe biomes, the biodiversity had already dropped to about 70% of the pristine situation in 2000, and declines to about 50% by 2050. The decline is mostly due to the much smaller natural area, while grazing area expands. For the forested systems, the areas still natural make up a very large part of the remaining biome biodiversity. Only in tropical woodlands is some biodiversity present in grazed areas.

[2] If 100 ha intact biodiversity (100% MSA) deteriorates in 100 ha of 40% MSA, then 100 MSA-ha changes into 40 MSA-ha (area x quality).

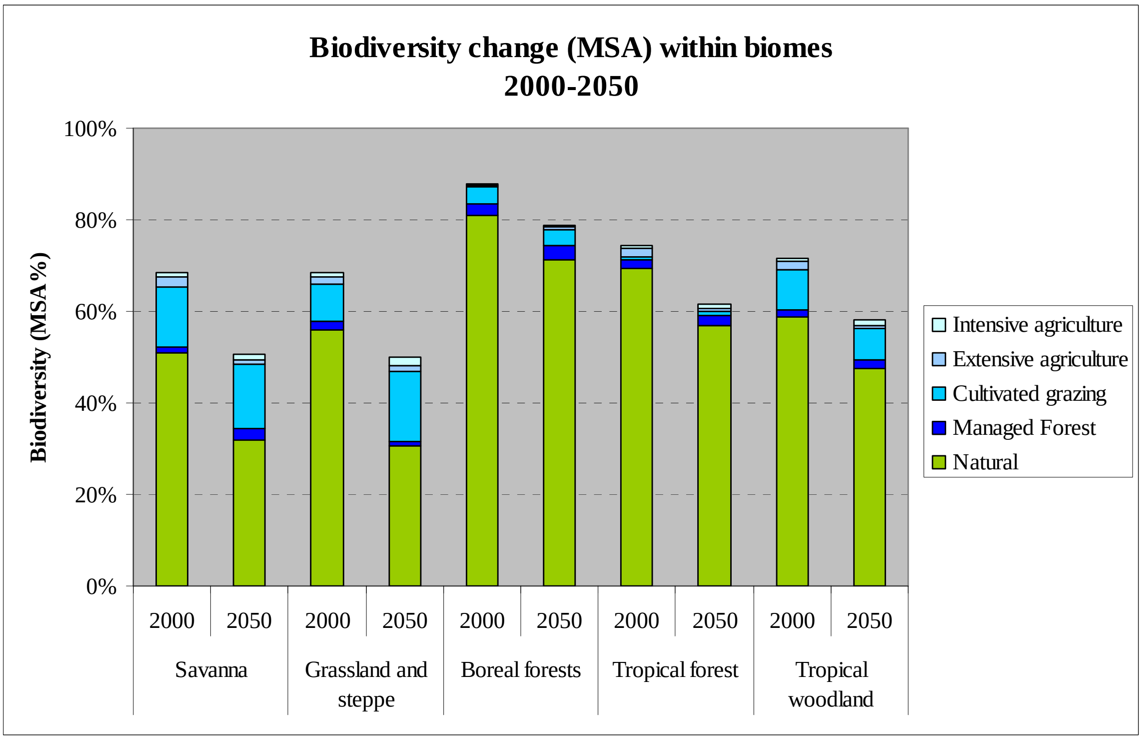


Figure 4.10b** **Biodiversity changes (in MSA% of the original biome) within biomes between 2000 and 2050 (according to OECD Policy inaction scenario).

4.4 Protected areas

The number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area. However, the biomes represented in that coverage are uneven. Marine areas are under-represented in all categories of protected areas. Protected areas represent the cornerstone of efforts to conserve biological diversity, and the CBD has set a target of conserving 10% of the earth's surface in formally protected areas. Currently some 19.3 million km^2 of terrestrial area and 2.4 million km^2 of marine area are protected, representing 12.9% of terrestrial area 9.8% of territorial waters (0.7% of total marine area) and 12.4% overall. This is an increase from 8.45% in 1990, and suggests that, globally, targets are beginning to be met (see *figure 4.11*).

However, global figures mask significant regional disparities. Moreover, not all biodiversity is included in protected area networks – some 20% of threatened species do not occur in any protected area, with birds and amphibians being particularly under-represented (Rodrigues *et al.*, 2004). Countries with the greatest proportion of un-protected species included China, India, Sri Lanka and Madagascar, the last being a conservation hotspot of threatened biodiversity. Nevertheless, improvements are underway. For example, the government of Madagascar has pledged to increase its protected area network from 2.9% in 2002 to 10% in 2010. By 2006 the Protected Areas network in Madagascar had been expanded to cover 6.3%, and recent priority-setting analyses are helping to identify where to establish a further 3.7% to ensure greatest inclusion of endemic biodiversity (Kremen *et al.*, 2008).

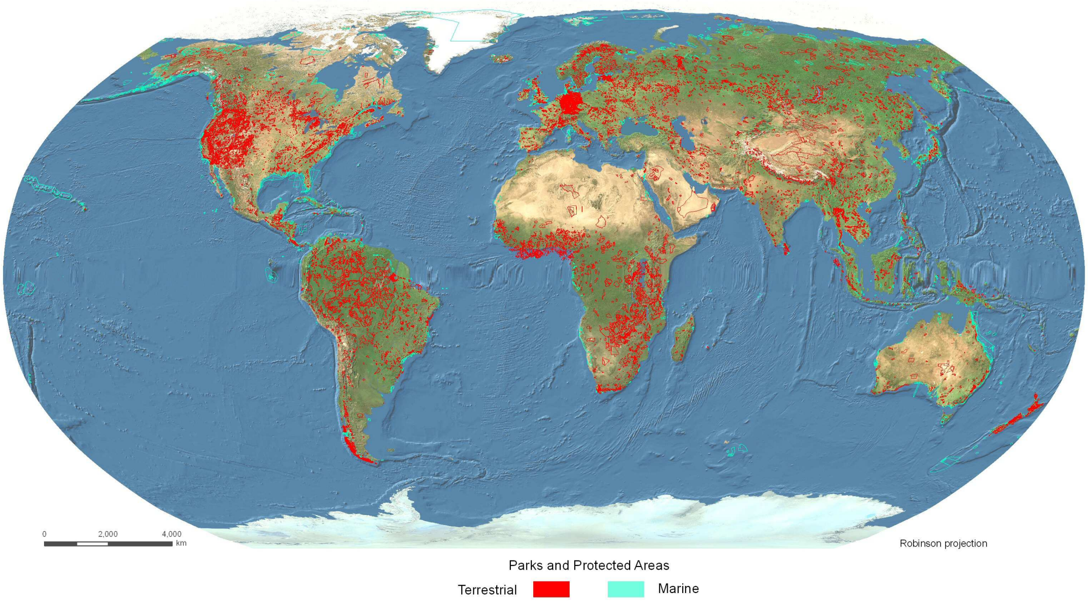


Figure 4.11 Global distribution of Terrestrial and Marine Protected Areas.
For display purposes, only protected areas with spatial (GIS) boundaries are shown.

Source: Data extracted from the World Database on Protected Areas (WDPA), produced by UNEP-WCMC and the IUCN World Commission on Protected Areas working with governments and collaborating NGOs, January 2008.

Of course, protected areas are not a guarantee to maintain biodiversity unless they are managed effectively. Whilst degradation is usually less within protected areas than in surrounding unprotected zones, many protected areas are nothing more than ‘paper parks’, and many of the world’s flagship protected areas, such as those inscribed on the UNESCO World Heritage List, are threatened by external pressures and lack of adequate protection. For example, all five of the natural World Heritage Sites in DRC are listed as ‘in danger’ by UNESCO due to the conflict in that region. In China, deforestation within Wolong Nature Reserve was higher than in surrounding areas, and appeared to increase after the Reserve was established, leading to a significant decline in the resident Giant Panda population (Liu *et al*., 2001). Yet it is still the case that in general the ecosystem service benefits from protected areas outweigh the management costs by at least an order of magnitude (Balmford *et al*., 2002).

4.5 Changes in marine biodiversity

4.5.1 Introduction

The Ocean biomes
In a similar way as on land, biomes can be distinguished in the marine part of Earth. A short orientation is presented in this section (adapted from MA, 2005b; see *figure 4.12*).

The *Coastal Boundary Zone biome* (10.5% of the world ocean) consists of the continental shelves (0–200 meters) and the adjacent slopes. This biome is the most significant source of marine fish landed globally, and it also bears many of the impacts of fishing on ecosystems and of other human activities.

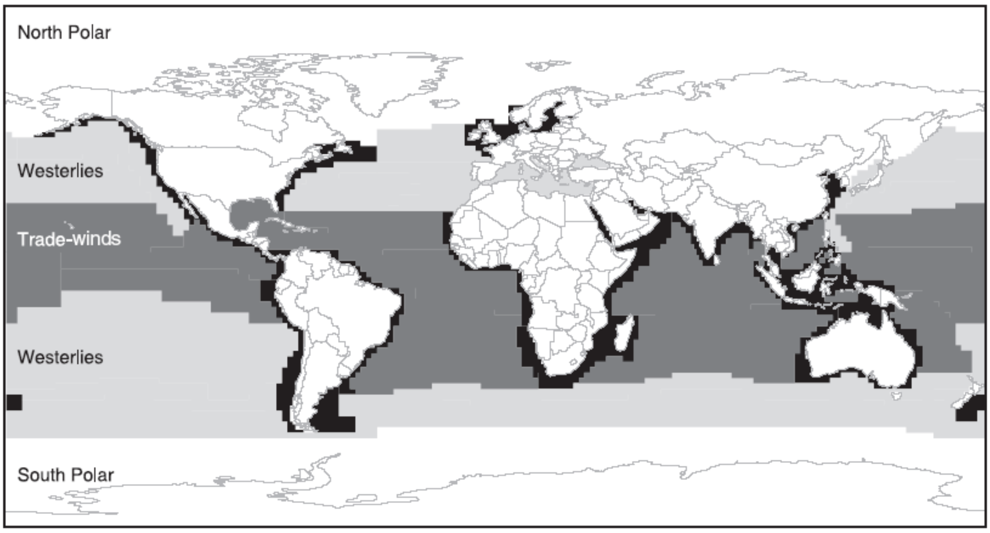


Figure 18.1. Classification of World's Oceans. Four "Biomes" were identified: Polar, Westerlies, Trade-winds, and Coastal Boundary (Longhurst et al. 1995; Longhurst 1998). The Coastal Boundary is indicated by a black border around each continent. Each of these Biomes is subdivided into Biogeochemical Provinces. The BGP of the Coastal Boundary Biome largely overlaps with LMEs identified by K. Sherman and coworkers (see Watson et al. 2003).

Figure 4.12 The Marine Biomes

The *Polar biome* (15% of the world ocean) accounts for 15% of global marine fish landings. Its vertical density structure is determined by low-salinity waters from spring melting of ice. The bulk of annual primary production occurs in ice-free waters during a short intense summer burst. However, primary production under lighted ice occurs over longer periods, especially in Antarctica.

In the *Westerlies biome* (35.7% of the world ocean), seasonal differences in the depth of the mixed layer result from seasonality in surface irradiation and wind stress, inducing strong seasonality of biological processes, including a spring bloom of phytoplankton. Overall, the Westerlies biome contributed 15% of the world's marine fisheries catch in 2001.The marine environment in this biome is relatively unaffected by human use other than fishing.

The *Trade-winds biome* (38.5% of the world ocean) lies between the northern and southern sub-tropical convergences, where a strong water density gradient hinders nutrient recycling between deep layers and upper surface layers. The resulting low levels of new primary production make these zones the marine equivalent of deserts. Therefore, fisheries in this biome rely mainly on especially tunas, capable of migrating over the long distances that separate isolated food patches. Overall, the trade-winds biome contributed 15% of the world's marine fisheries catch in 2001. One exception to the general low productivity of the trade-winds biome is around islands and seamounts, where physical processes such as localized upwelling allow for localized enrichment of the surface layer.

Like on land, mountain ranges in the oceans, seamounts, are areas with relatively high biodiversity. They are increasingly under pressure, both from the inhabited mountain tops (islands) and from long range fishing industries. The map in *figure 4.13* illustrates the location and share of the seamounts in Exclusive Economic Zones.

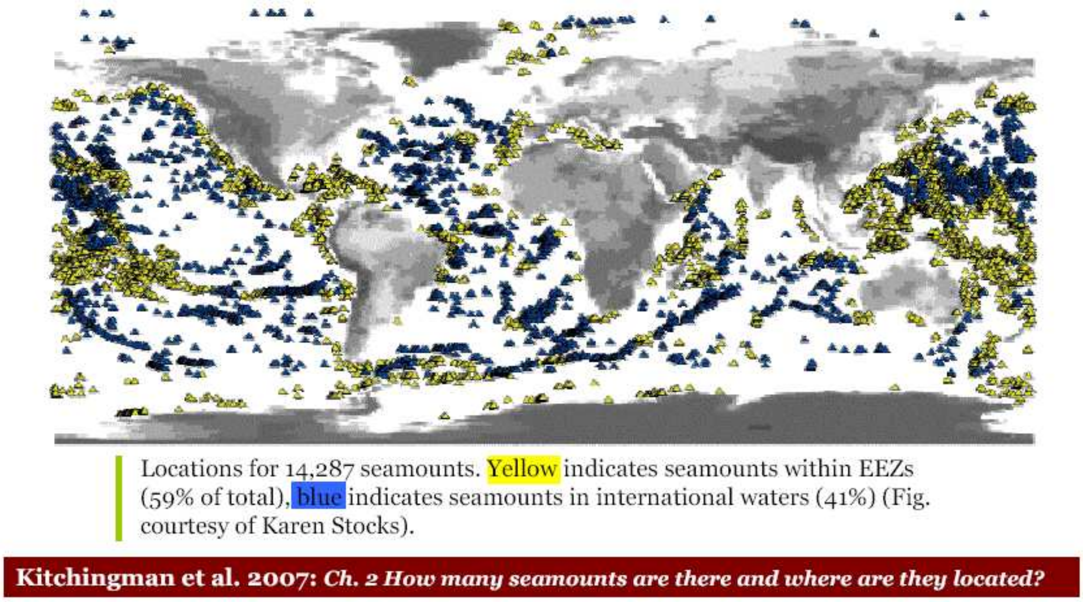


Figure 4.13 Seamounts around the world

4.5.2 Global trends in Marine biodiversity

Fishing pressure has been such in the past century that the biomass of larger high-value fish and those caught incidentally (the ‘by-catch’) has been reduced to 10% or less of the level that existed before industrial fishing started[3]. The loss of biomass and fragmented habitats have led to local extinctions. The percentage of stocks which are not yet completely exploited has declined steadily, while the proportion of stocks exploited beyond maximum sustainable yield levels has increased steadily[4] (see *figure 4.14*).

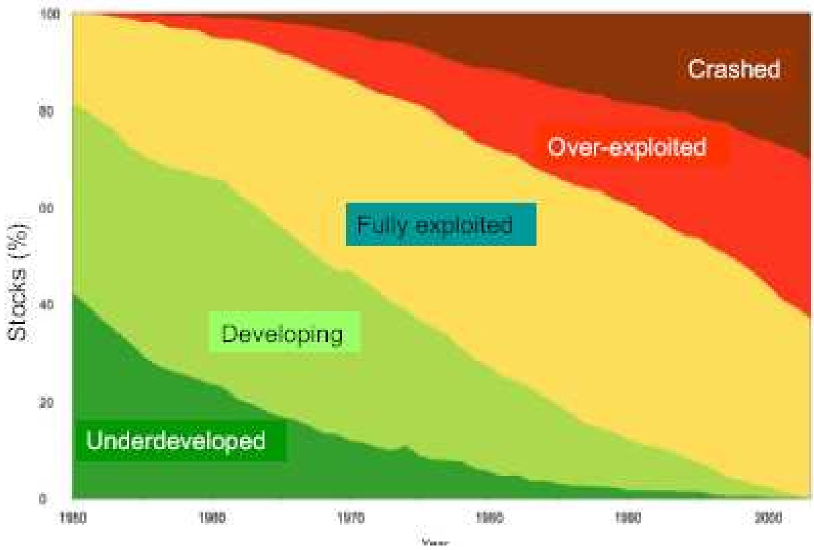


Figure 4.14 ***Changes in degree of exploitation of stocks of marine fish species (source: Alder, Trondheim/UN conference on Ecosystems and people, October 29-November 2, 2007; original source: Sea Around Us project, 2007)***

[3] *Add reference*
[4] *Add reference*

Trophic level decline is the change through time in the composition of the catch from a mixture of “top predatory fish such as sharks, mid-trophic level fish such as cods and herrings, and a few lower trophic level animals such as shrimp” to a catch of “a few mid-trophic species such as whiting and haddock and many low-trophic species such as shrimp” (*see figure 4.15*). This change is a result of three phenomena:

- the expansion of fisheries from benthic coastal areas to the open ocean;
- the expansion of fisheries from the Northern Hemisphere (dominated by large shelves and bottom fish) to the Southern Hemisphere (dominated by upwelling systems and pelagic fish); and
- over-fishing, leading to a local replacement of depleted large predators by their prey.

This change in catch composition is sometimes called ‘‘fishing down marine food webs.’’

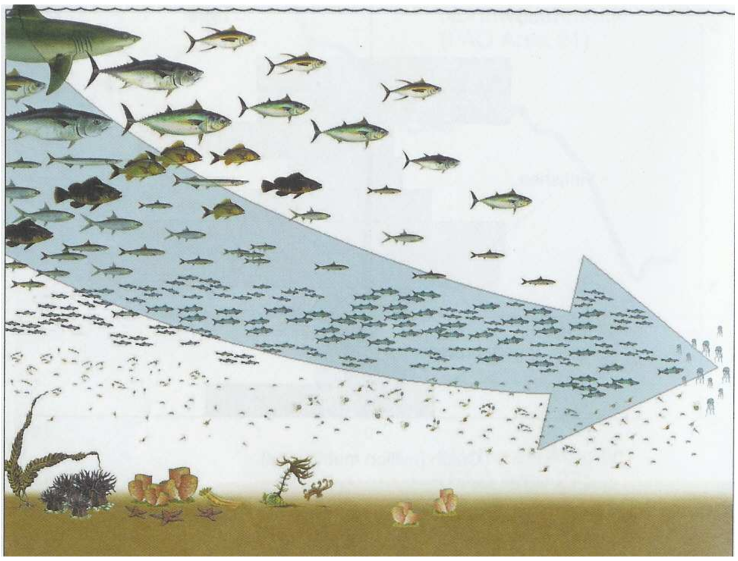


Figure 4.15 Fishing down the foodweb (source: Pauly et al., 1998.)

Figure 4.16 illustrates the actual decline in average trophic level in the catch for North Atlantic and coastal areas, which implies that we are increasingly relying on fish that originate from the lower part of marine food webs (MA, 2005b).

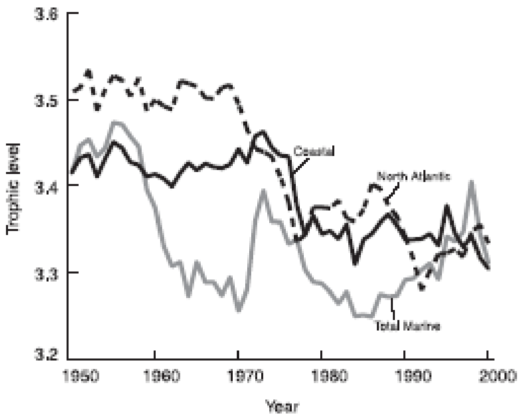


Figure 18.9. Changes in Trophic Level in North Atlantic and Coastal Areas at Less Than 200 Meters Depth, and Total Marine Landings, 1950–2000 (SAUP 2005)

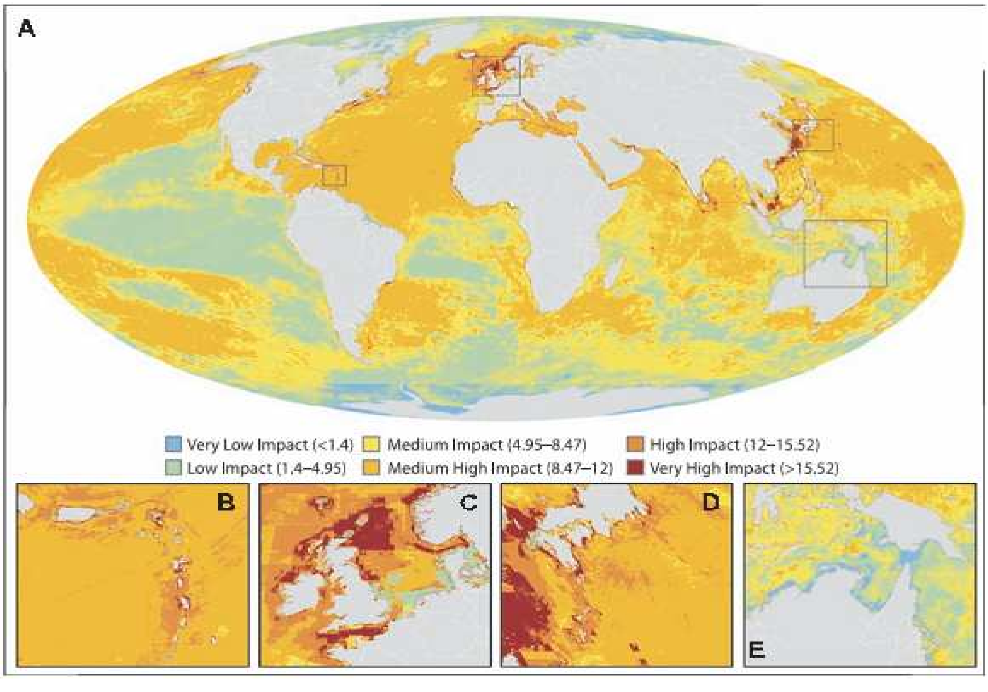
Figure 4.16 Changes in trophic level (source MA, 2005b)

Box 4.4 Case examples of trends in marine biodiversity (adapted from MA, 2005 b, Alder et al. 2007)

- Shark declines are believed to be occurring as a result of increased by-catch from pelagic long-line fisheries and direct exploitation for shark fins. Most recorded shark species have experienced a decline of more than 50% in the past 1990's. Sharks grow and reproduce slowly, so even if exploitation were stopped, recovery would be slow.
- Trends in Caribbean corals reveal that there has been a significant decline over the past three decades and although the decline has slowed, the trend persists. The average hard-coral cover on reefs has been reduced by 80%, from around 50% to 10% cover, in three decades. These data support the notion that coral reefs are globally threatened.
- The sudden switch in 1983 from coral to algal domination of Jamaican reef systems followed several centuries of overfishing of herbivores, which left the control of algal cover almost entirely to a single species of sea urchin, whose populations collapsed when exposed to a species-specific pathogen. As a result, the reefs shifted to a new low diversity, algal-dominated state with very limited capacity to support fisheries.
- The major stock collapses of the last few decades have been a surprise, even to those involved in monitoring and managing these stocks. One well known example is Newfoundland's northern cod. Almost the same scenario was re-enacted 10 years later, in 2001, in Iceland, which very nearly lost its cod stock in spite of the Icelandic government's commitment to sound fisheries management.

4.5.3 The current state of marine biodiversity

Figure 4.17 presents an image of the current, impacted, state of the biodiversity of the global marine system. The highest impact regions are the North Sea and North-eastern Atlantic, the North-western Atlantic coast and the coastal seas of South-East Asia, the areas with historically intensive fisheries.



Source: Salman Hussein presentation at the Workshop: ***The Economics of the Global Loss of Biological Diversity 5-6 March 2008, Brussels, Belgium***

Figure 4.17 The impact of human use of the oceanic biomes (source: National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara.)

4.5.4 Marine biodiversity futures

A global crisis in marine fisheries is included in the COPI analysis since the world's fisheries contributes to addressing food security as well as assisting in economic development for many countries, especially for developing coastal countries (Pauly *et al.*, 2005). The EcoOcean model (see *Box 4.5*) was developed as a tool to explore fisheries and marine policy options. The development of EcoOcean was in response to requests from three global assessment projects: the GEO4, which has a strong environment focus; the IAASTD, which has a strong focus on knowledge development and transfer and includes fisheries from a capture and aquaculture perspective; and the GLOBIO project (applied in the OECD Environmental Outlook 2008 study) which is exploring global changes in biodiversity. All three assessments are using scenarios. GEO4 is based on scenarios developed from GEO3 (UNEP, 2002) with weightings for optimization based on input from regional representatives of the GEO4 process. The IAASTD and OECD/GLOBIO are using variations around a baseline which is not necessarily a business as usual scenario, but using current trends that are modified by key drivers such as subsidies.

Box 4.5 The EcoOcean MODEL (adapted from Alder et al, 2007)

A stratified global model, EcoOcean, was developed for quantitatively assessing the future of fisheries under different scenarios. A series of 19 marine ecosystem models representing the 19 FAO (Food and Agriculture Organization of the United Nations) areas of the world's oceans and seas was constructed. The models account for the biomass of each functional group, their diet composition, consumption per unit of biomass, natural and fishing mortality, accumulation of biomass, net migration, and other mortality. The principle behind this modelling approach is that biomass and energy are conserved on a yearly basis, i.e. that future biomass can be estimated from current biomass plus change in biomass due to growth, recruitment, predation, fisheries, etc. (Walters et al., 1997).

The models were quantified using global datasets of catches, ex-vessel prices, biomass and distant water fleets from the Sea Around Us Project and the fleet statistics from the FAO from 1950 to 1998, the last year for which data are available. The model distinguishes 43 functional ecological groups that are common to the world's oceans. The groups were selected with special consideration for exploited fish species but include all major groups in the oceans. Fishing effort is the most important driver for the ecosystem model simulations. Five major fleet categories (demersal, distant water fleet, baitfish tuna (purse seine), tuna long-line and small pelagic) are used to distinguish different fishing effort based on historical information. For current purposes, the oceans should be considered as spatially-separated production systems.

The aggregated global model produces results within 10% of the reported total for any given year. This gave confidence that the models are providing plausible results for different scenarios. EcoOcean was developed using the most up-to-date and best available global data, and while it does simulate many of the processes that occur, it is however not a full representation of the world's oceans as it contains several sources of uncertainties. The development of EcoOcean also provided the opportunity to look at the future of marine biodiversity using a **depletion index** (*Box 4.6*) as a proxy for changes in species composition and abundance under the different scenarios.

Box 4.6 Indicators of Marine Biodiversity (adapted from Alder et al. 2007)

- A **biomass diversity index** can be used to synthesise information on the number of species or functional groups that compose the biomass of the ecosystem,. The biomass diversity index can be used to evaluate model behaviour, assuming that more stable ecosystems will tend to have a more even distribution of biomass across the functional groups.
- The **marine trophic index (MTI)** is calculated as the average trophic level of the catch and is used to describe how the fishery and the ecosystem may interact as a result of modelled policy measures (Pauly and Watson, 2005). The index is often used to evaluate the degree of "fishing down the food web" (Pauly et al., 1998). The MTI is one of the core indicators being used by the Convention on Biological Diversity.
- The indicator used in the scenario-analyses is the mean species abundance (MSA) of the original species belonging to an ecosystem, that is, the abundance of native wildlife in terrestrial systems. EcoOcean has been used to develop a marine equivalent to the MSA, the **depletion** index (DI) that is calculated as part of the overall assessment within EcoOcean. The **DI** was used to represent the different rates of decline of species that had been aggregated into functional groups. The DI was calculated from prior knowledge of the intrinsic vulnerability and the estimated changes in functional group biomasses. Intrinsic vulnerability to fishing of the 733 species of marine fishes with catch data available from the Sea Around Us Project database (www.seaaroundus.org) was included in the analysis.

The application of EcoOcean to GEO4 and the IAASTD resulted in plausible outcomes under the different policy scenarios, and the outcomes differed across geographic areas as well as across scenarios. In cases where effort increased, landings and therefore profits increased; however, any increase in landings was achieved by increases in groups that are not currently fished in large quantities. The groups that declined varied with each scenario and geographic area. In many cases increased landings resulted in declining marine trophic levels, and increased depletion risks. The fishing scenarios indicated that only those scenarios with significant reductions in effort and targeting fish at lower trophic levels would be effective in rebuilding depleted stocks and maintaining other stocks. Those scenarios that used current trends or increased effort whether for commercial or recreational fisheries all indicated collapses in stocks and ecosystems; they differed only in their rates of decline.

All GEO4 scenarios proposed an increase in effort, and as a consequence landings generally increased. Landings were increased by augmenting the proportion of secondary ground fish groups and the proportion of invertebrates. As a consequence, the marine trophic index (MTI) generally decreased in all oceans. The decline in MTI confirms that as demersal effort increased, landings increased, but usually at lower trophic levels. With the exception of the Mediterranean Sea and the Caribbean region, the biomass diversity index also decreased for the three main oceans. In the Mediterranean Sea and Caribbean region, the increase appears to be a result of the predation impact of a few top predators being lowered as their biomasses decrease, allowing for increase in dominance of lower trophic levels.

IAASTD Scenarios 1 and 2 proposed an increase in effort and, as a consequence, landings increased for the scenarios in the Atlantic and Pacific Ocean. For scenario 3, which emphasises ecosystem rebuilding, with a 2% annual effort increase over the last 25 years of the scenario, landings decreased for all areas for the first twenty years of the scenario run, while subsequently landings increased as effort increased. As a consequence, the marine trophic index (MTI) generally decreased in all oceans. An exception to this would be for scenario 4, where the 10% decrease in tuna longline and demersal fleet effort over the last 45 years of the scenario run resulted in a decrease in demersal and large tuna landings, and as a result the MTI increased or remained constant for all oceans.

Depletion index

By comparing the calculated DI of the ecosystems between year 2007 (present) and 2047 under different scenarios, we can predict changes in conservation status during this period (see *figure 4.18*. In all scenarios the global mean difference is negative, indicating a further depletion of the marine biodiversity.

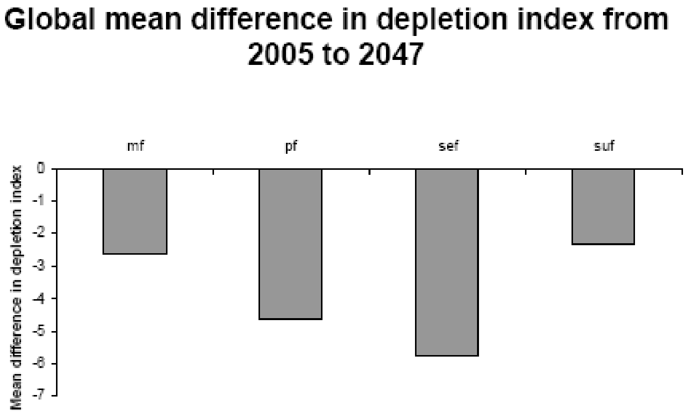


Figure 4.18 Global mean difference in Depletion index in the GEO4 scenarios (Alder et al., 2007)

Figures 4.19a and 4.19.b show the regional differences across the global marine ecosystem.

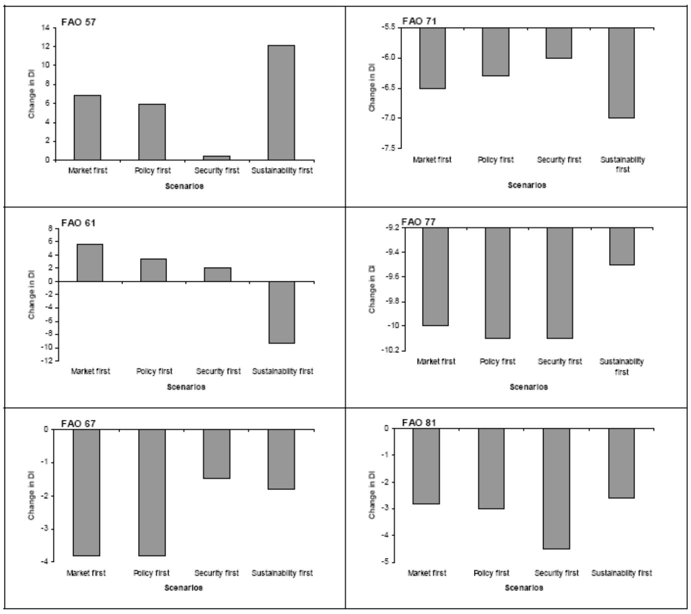


Figure 14b. Changes in the calculated depletion index (DI) from year 2007 to 2047 in FAO areas 57 to 81 and under different scenarios ("Market first", "Policy first", "Security first" and "Sustainability first"). Positive changes in DI indicate reduction in depletion risk while negative changes indicate increase in depletion risk.

Figure 4.19a Depletion index in 6 FAO marine regions in 4 GEO4 scenarios (Alder et al., 2007) FAO 57=East Indian, 61=Northwest Pacific, 67=Northeast Pacific, 71=Northwest Oceanic, 77=California Current, 81=Southwest Pacific

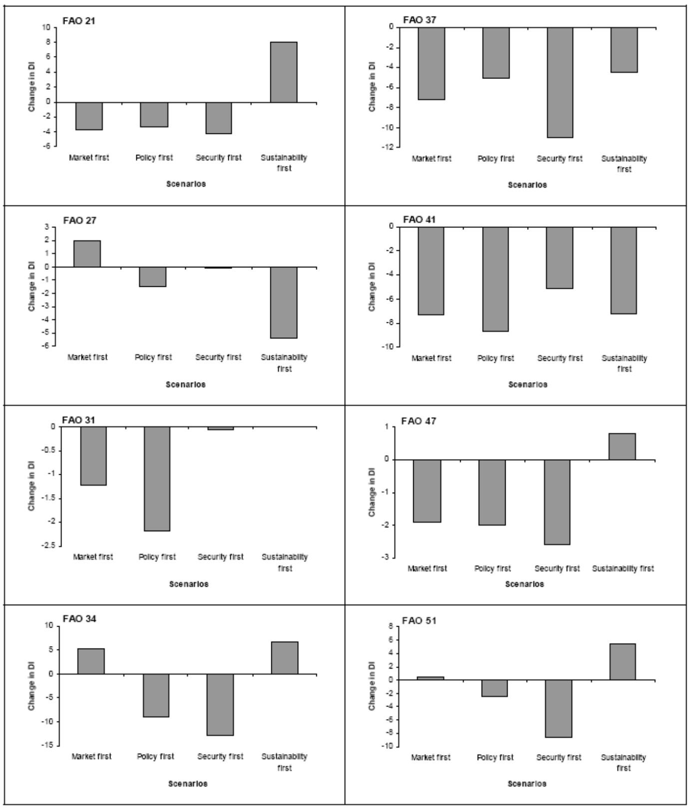


Figure 14a. Changes in the calculated depletion index (DI) from year 2007 to 2047 in FAO areas 21 to 51 and under different scenarios ("Market first", "Policy first", "Security first" and "Sustainability first"). Positive changes in DI indicate reduction in depletion risk while negative changes indicate increase in depletion risk.

Figure 4.19b Depletion index in 8 FAO marine regions in 4 GEO4 scenarios (Alder et al., 2007) FAO 21=Northwest Atlantic, 27=Northeast Atlantic, 31=Caribbean, 34=Northwest Africa, 37=Mediterranean, 41=Southwest Atlantic, 47=Southeast Atlantic, 51=West Indian

The graphs illustrate that only in the Sustainability First scenario in some FAO regions a positive development can be expected. In all other areas the future of marine biodiversity is very dismal.

4.6 Changes in coastal systems

4.6.1 Introduction

Coastal ecosystems are among the most productive ecosystems in the world. They include freshwater and brackish water wetlands, mangrove forests, estuaries, marshes, lagoons and salt ponds, rocky or muddy intertidal areas, beaches and dunes, coral reef systems, seagrass meadows, kelp forests, nearshore islands, semi-enclosed seas, and nearshore coastal waters of the continental shelves (see map in *figure 4.20*). They are highly dynamic, and are now undergoing more rapid change than at any time in their history. The changes are due to dredging of waterways, infilling of wetlands, and construction of ports, resorts, and housing developments, and biological, as has occurred with declines in abundances of marine organisms such as sea turtles, marine mammals, seabirds, fish, and marine invertebrates. Sediment transport and erosion deposition have been altered by land and freshwater use in watersheds. These impacts, together with chronic degradation resulting from land-based and marine pollution, have caused significant ecological changes and an overall decline in many ecosystem services (MA, 2005b).

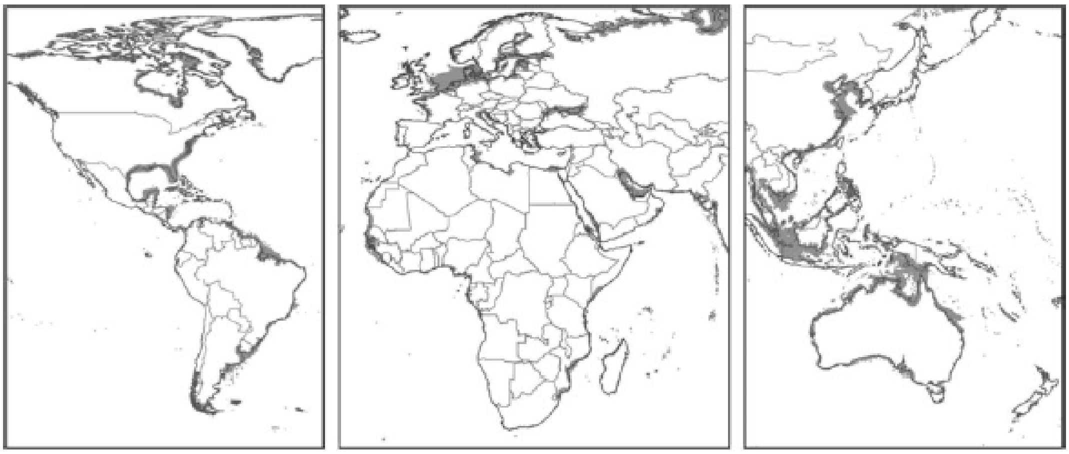


Figure 4.20 Costal ecosystems around the world

4.6.2 Trends in estuaries and salt marshes

Estuaries are areas where the fresh water of rivers meets the salt water of oceans. Worldwide, some 1,200 major estuaries have been identified and mapped, yielding a total area of approximately 500,000 square kilometers. The 1,200 largest estuaries, including lagoons and fiords, account for approximately 80% of the world's freshwater discharge (Alder 2003). There has been a substantial loss of estuaries and associated wetlands globally. In the United States over 50% of original estuarine and wetland areas have been substantially altered. In Australia, 50% of estuaries remain undamaged, away from current population centers.

Salt marshes and coastal peat swamps have also undergone massive change and destruction, whether they are within estuarine systems or along the coast. Salt marsh subsidence has occurred in part due to restricted sediment delivery from watersheds. Peat swamps in Southeast Asia have declined from 46–100% in countries monitoring changes. Since sea level is rising due to climate change as well as to land subsidence, and since freshwater diversion impedes delivery of sediments to estuarine systems, salt marshes will continue to be degraded and lost.

4.6.3 Trends in mangroves

Mangroves are trees and shrubs found in intertidal zones and estuarine margins that have adapted to living in saline water, either continually or during high tides. Mangroves grow under a wide amplitude of salinities, from almost fresh water to 2.5 times seawater strength; they may be classified into three major zones (Ewel et al. 1998): tide dominated fringing mangroves, river-dominated riverine mangroves, and interior basin mangroves.

About 15.2 million hectares of mangroves currently exist worldwide, with the largest extent found in Asia, followed by Africa and South America. The area of mangroves present in each country varies from a few hectares to more than 3 million, with close to half the global area found in just five countries: Indonesia, Australia, Brazil, Nigeria and Mexico. Many mangrove areas have become degraded worldwide, and habitat conversion of mangrove is widespread. Over the last 25 years, 3.6 million hectares of mangroves, about 20 percent of the total extent found in 1980, have disappeared worldwide. Estimates of the loss of mangroves from countries with available multiyear data show that 35% of mangrove forests have disappeared in the last two decades—at the rate of 2.1%, or more than 2,800 square

kilometers, per year. In some countries, more than 80% of original mangrove cover has been lost due to deforestation.
Mangroves have been converted to allow for aquaculture and for agriculture, including grazing and stall feeding of cattle and camels. The leading human activities that contribute to mangrove loss are aquaculture (38% shrimp plus 14% fish), 26% forest use, and 11% freshwater diversion. Although alarming, the rate of net loss of mangroves is showing signs of slowing down. From about 185 000 ha lost annually in the 1980s (-1.03 percent per annum), it dropped to some 105 000 ha/year (-0.67 percent) during the 2000–2005 period. This may reflect an increased awareness of the value of mangrove ecosystems, which has led, in turn, to the preparation of new legislation, better protection and management and, in some countries, to an expansion of mangrove areas through active planting or natural regeneration (Global Forest Resources Assessment, 2005) Restoration has been successfully attempted in some places, but this has not kept pace with wholesale destruction in most areas.

4.6.4 Trends in intertidal habitats, deltas, beaches, and dunes

Rocky intertidal, nearshore mudflats, deltas, beaches, and dunes provide ecosystem services such as food, shoreline stabilization, maintenance of biodiversity (especially for migratory birds), and outdoor recreation. In the United States, the rocky intertidal zone has undergone major transformation in the last few decades: Similar trends have been observed elsewhere in the world. Along the Yellow Sea coast, China has lost around 37% of habitat in intertidal areas since 1950.

Intertidal mudflats and other soft-bottom coastal habitats play pivotal roles in ocean ecology, even though research and public interest have not historically focused on these habitats. Soft bottom coastal habitats are highly productive and can be extraordinarily diverse, with a species diversity that may rival that of tropical forests. Mudflats are critical habitat for migrating shorebirds and many marine organisms. Unfortunately, mudflats are commonly destroyed during port development or maintenance dredging, and coastal muds in many areas are highly contaminated by heavy metals, PCBs, and other persistent organic pollutants.

Coastal deltas are extremely important microcosms where many dynamic processes and human activity converge. Deltas, estuaries, and small islands are the coastal systems most vulnerable to climate change and sea level rise. Deltas are high population and human land use areas and are dynamic and highly vulnerable (e.g. New Orleans, The Netherlands, Bangla Desh).

Beaches and sandy shores also provide very important and economically valuable ecological services and are being altered worldwide. Sandy shores have undergone massive alteration due to coastal development, pollution, erosion, storms, alteration to freshwater hydrology, sand mining, groundwater use, and harvesting of organisms. Dune systems occur inland of the intertidal zone but are commonly found in conjunction with beaches and sandy shores. These habitats are often highly dynamic and mobile, changing their form in both the short and long term. Dunes support high species diversity in certain taxonomic groups, including endangered bird, plant, and invertebrate species. Encroachment in dune areas often results in shoreline destabilization, resulting in expensive and ongoing public works projects such as the building of breakwaters or seawalls and sand renourishment.

4.6.5 Trends in coral reefs and atolls

Coral reefs exhibit high species diversity and are valued for their provisioning, regulating, and cultural services. Reef-building corals occur in tropical coastal areas with suitable light conditions and high salinity and are particularly abundant where sediment loading and freshwater input is minimal. Reef formations occur as barrier reefs, atolls, fringing reefs, or patch reefs, and many islands in the Pacific Ocean, Indian Ocean, and Caribbean Sea have extensive reef systems occurring in a combination of these types. Coral reefs occur mainly in relatively nutrient-poor waters of the tropics, yet because nutrient cycling is very efficient on reefs and complex predator-prey interactions maintain diversity, productivity is high. However, with a high number of trophic levels the amount of primary productivity converted to higher levels is relatively low, and reef organisms are prone to overexploitation. The fine-tuned, complex nature of reefs makes them highly vulnerable to negative impacts from overuse and habitat degradation— when particular elements of this interconnected ecosystem are removed, negative feedbacks and cascading effects occur. Many coral reefs are transformed from productive, diverse biological communities into depauperate ones, along with similar cascading effects caused by technological, economic, and cultural phenomena. Coral reefs are at high risk from many kinds of human activity, including coastal construction that causes loss of habitat as well as changes in coastal processes that maintain reef life. In 1999, it was estimated that approximately 27% of the world's known reefs had been badly degraded or destroyed in the last few decades, although the latest estimates are of 20% of reefs destroyed and more than a further 20% badly degraded or under imminent risk of collapse.

Of all the world's ecosystems, coral reefs may be the most vulnerable to the effects of climate change. Although the mechanisms are not clear, warming seawater triggers coral bleaching, which sometimes causes coral mortality. Climate change also has other detrimental impacts on coral. For example, rising carbon dioxide levels change the pH of water, reducing calcium carbonate deposition (reef-building) by corals. Climate change also facilitates the spread of pathogens leading to the spread of coral diseases. It has been suggested that climate change will reduce the world's major coral reefs in exceedingly short time frames—one estimate suggests that all current coral reefs will disappear by 2040 due to warming sea temperatures, and it is not known whether the reefs that take their place will be able to provide the same level of services to humans and the biosphere.

4.7 Changes at the species level.

4.7.1 The Red List Indicator

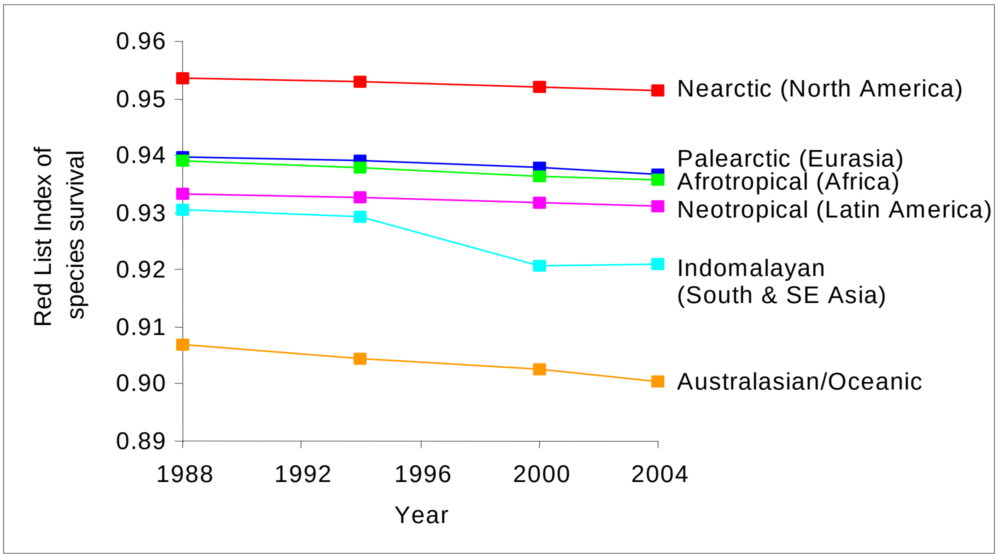


Figure 4.21 Changes in the Status of Species, as shown by the IUCN Red List Index for birds in different biogeographic realms (ecological regions) (approximate equivalent regional listings are provided in parentheses). The IUCN RLI tracks changes over time in the status of species. An IUCN RLI value of 1.0 equates to all species being categorised as Least

Concern, and hence that none are expected to go extinct in the near future; a value of zero indicates that all species have gone Extinct (Butchart et al., 2007)

The changes in the "Status of Species" indicator, as shown through the IUCN Red List Index (RLI; *figure 4.21*), provides both a widely accepted indicator of changes in overall biodiversity, and an indicator with strong connections to the socio-economic context of the links between biodiversity and development. The focus on species is relevant for some ecosystem services, e.g. those species that are harvested for food, medicines and fibres, that are domesticated for agriculture, that play a role in regulating local and global environments, and that hold cultural and other societal benefits for rich and poor people alike. The IUCN RLI can be calculated for any set of species for which species threat status assessments have been carried out at least twice. To date, an IUCN RLI has been developed for all bird species for 1988–2004 and a preliminary IUCN RLI has been developed for all amphibian species for 1980–2004. These indices show ongoing deterioration in the status of birds and amphibians worldwide, even after improvements in the status of certain species as a result of conservation action have been taken into account. Regional and national trends in the status of species will be important in formulating conservation responses to biodiversity loss, and measuring the success of these responses at these sub-global scales.

Birds in the Australasian/Oceanic region, for example, are showing a continual decline in the status of the species. The status of birds declined much faster in the Indo-Malayan realm than in other biogeographic realms during the 1990s. This was directly attributable to the increased rate of deforestation in the Sundaic lowlands during that period. When a graph line of the IUCN RLI is increasing, it means that the expected rate of species extinctions from that region is abating (i.e. the rate of biodiversity loss is decreasing), but this does not mean that biodiversity loss has stopped. To show that the global target of significantly reducing the rate of biodiversity loss has been met, an upwards trend is needed at the very least.

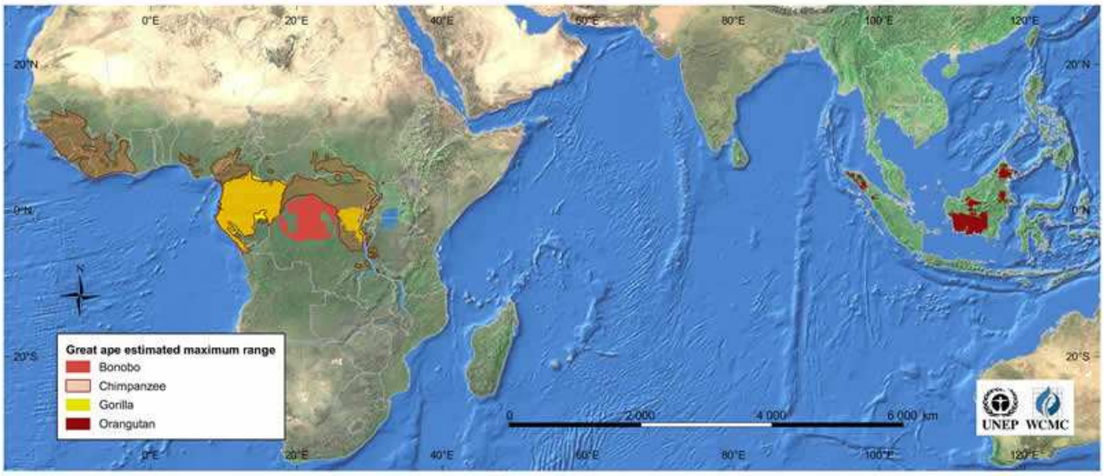
Data for calculating the IUCN RLI comes from the IUCN Red List of Threatened SpeciesTM (IUCN Red List, www.redlist.org). In 2006, the IUCN Red List contained 40,177 species, 16,119 of them threatened with extinction. Of the groups for which every species has been assessed globally, 12% of all birds are classified as threatened, 23% of mammals (see Box 4.5), 33% of amphibians, approximately 42% of turtles and tortoises, 25% of conifers and 52% of cycads. A set of quantitative criteria is applied to every species included in the IUCN Red List. These criteria place each species into one of seven categories on a continuum from "Extinct" to "Least Concern" (or into a "Data Deficient" category for species that are very poorly known). The movement of species up and down this continuum of Red List Categories over time is a measure of the extent to which their status is either improving or deteriorating. When these changes are measured for large number of species across taxa over a given time period, the index calculated reflects changes in the status of biodiversity overall.

The status of terrestrial vertebrates is relatively well documented, with roughly 76% of species assessed, but less is known about the status of biodiversity in marine and aquatic systems, or of species-rich groups like invertebrates, plants and fungi – which together comprise the overwhelming majority of the world's species. These gaps in knowledge are being addressed by more species being assessed for the IUCN Red List every year. As more is documented about the status of species, the longer the world's list of extinctions becomes. From known extinctions of birds, mammals and amphibians over the past 100 years, it is clear that the extinction rates of recent times exceed the natural rates of extinction determined from the fossil record by at least 2 to 4 orders of magnitude. Although most human-caused extinctions over the past several hundred years have taken place on oceanic islands, roughly half of extinctions over the past twenty years occurred on continents. The problem of continental extinctions is becoming much worse and as most terrestrial and aquatic species occur on continents they are facing growing threats to their survival and persistence.

BOX 4.5 Great Apes – habitat destruction and population decline

The great apes are our closest living relatives yet are among the most endangered species on the planet. All are listed on the IUCN/SSC Red List as endangered or critically endangered, and all are in decline. A recent survey of *24* protected areas on both continents revealed that great apes were declining in *96%* of them due to habitat loss/degradation and hunting. As flagships for conservation in these regions, and generating significant tourism revenues as a result of their charisma and rarity, they are rightly a global conservation priority (Nellermann & Newton, 200?; Caldecott & Miles, 2005).

GREAT APE DISTRIBUTION OF THE WORLD



Source : Caldecott, J., Miles, L., eds (2005) World Atlas of Great Apes and their Conservation. Prepared at the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA.

Orangutans

There are *57,000* Orangutans remaining in Borneo, and only *7,300* in Sumatra. They have declined by *75%* and *93%*, respectively, since 1900, mostly as a result of habitat loss. In Borneo *55,000* km^2 of breeding habitat was lost between 1993 and 2002 through logging and forest fires, and the draining of peat swamp for rice cultivation destroys many more thousands of km^2 of prime Orangutan habitat. Subsistence agriculture was also reported to have affected *27%* of the land area of Kalimantan (Indonesian Borneo), *87%* of which was considered prime Orangutan habitat. Forests are increasingly being transformed into oil palm plantations, whilst fire has been responsible for massive forest loss. The fires of 1997/98 destroyed *95%* of lowland forest in Kutai National Park, and large numbers of Orangutans were killed by people fleeing the flames, or by smoke. As a result of the fires, *1/3* of Borneo's Orangutans may have been lost in one year alone. The situation for the critically endangered Sumatran Orangutan is even more dire. There has been a *61%* decline in forest area in Sumatra between 1985 and 1997. Even in the Leuser ecosystem, which is the best protected Sumatran Orangutan site and the heart of their present range, at least *1000 individuals per year* were being lost in the later 1990s. Very little forest below 1000m is expected to survive in either Sumatra or Kalimantan beyond 2010.

African Great Apes

Major threats are hunting, disease, and the massive upsurge in forest loss since the 1990s. most forests in the Congo Basin are under logging and mining concessions controlled by companies in the EU. By 2000 more than half of Gabon's forests had been allocated as logging concessions, whilst at the same time in Cameroon *76%* of forests were either logged or allocated to concessions. Analyses suggest that more than *70%* of African great ape habitat has already been affected by such development, and future scenarios suggest a continued loss of undisturbed habitat of *2% per year*. By 2030, it is predicted that less than *10%* of African great ape habitat will be free of disturbance. Mountain gorillas number only *a few hundred*, but the sub-species is stable in a handful of well-protected areas in the Albertine Rift area of central Africa. The surrounding Eastern Lowland Gorilla is much more numerous but of much greater immediate concern due to hunting and armed conflicts. This conflict has also begun to again threaten the Mountain Gorilla, with several individuals in the groups visited by tourists having been killed during 2007. Chimps are more numerous and more adaptable than Gorillas, and less sensitive, in the short term, to habitat disturbance due to their large home ranges. However they remain in decline. In Gabon the combined population of chimpanzees and gorillas declined by more than *50%* from 1983-2000 due to logging, hunting and the spread of Ebola virus. The latter resulted in *a 99% decline* in chimpanzees in Minkébé forest. In southern Sudan, chimpanzees were thriving in the 1960s but are now thought locally extinct. In some areas chimpanzee populations are stable, but overall trends are negative; current continental estimates range from *170,000-300,000*, down from a possible *1 million* in 1960. Chimpanzees will find it increasingly hard to survive as forests fragment in the face of expanding farming and settlement, and they come into contact with human diseases. Bonobos probably number fewer than *100,000* distributed patchily over a large area of the Congo basin. They are hunted for food in many areas particularly in times of conflict and food shortage. In more accessible areas numbers have declined by 25-75% during the late 1990s.

Major threats to species include habitat destruction, overexploitation, invasive alien species, disease, pollution and climate change. The IUCN RLIs for birds and amphibians show that habitat loss is a very important cause of decline in both groups, but that invasive species on islands are a greater threat to birds, while disease is more serious for amphibians. Early indications suggest that overexploitation in fisheries will prove to be the greatest cause of decline among marine fish species. It is anticipated that future assessments of a broader group of species are likely to demonstrate the growing impact of climate change. Most threatened terrestrial species occur in the tropical latitudes – particularly on islands and mountains. This uneven distribution of threatened species means that tropical developing countries have a comparatively large number of species at risk of extinction

4.7.2 Impacts of invasive alien species

Invasive alien species (IAS) have led and continue to lead to a wide range of ecological and socio-economic impacts including changes in species composition and dynamics, habitat characteristics, provisioning of ecosystem services (e.g. provision of food, water retention and regulation of erosion and forest fires). Invasive alien species also have negative impacts on health and cause damage to infrastructure (see for an overview Van der Weijden et al., 2007).

IAS, together with habitat destruction, have been a major cause of extinction of native species throughout the world in the past few hundred years. For example the introduction of the Nile perch (Lates nilotica) into lake Victoria in 1954 resulted in the extinction of over 200 endemic species of fish. In China’s Dianchi Lake, the number of native species fell from 25 to 8 over a 20 year period that coincided with the introduction of 30 alien species of fish McNeely et al (2001). The Indian mongoose, introduced to Fiji, West Inies, Mauritius and Hawaii to control rats has led to the extinction of several endemic species of birds, reptiles and amphibians (McNeely et. al., 2001).

Additionally, it has been suggested that 80% of endangered species worldwide could suffer losses due to competition with or predation by IAS (Pimentel *et. al*., 2005). For example, the grey squirrel (*Sciurus carolinensis*), the Asian lady beetle (*Harmonia axyridis*) and the Argentine ant (*Linepithema humile*) are known to out-compete and displace native species in several parts of the world. The European Mink (*Mustela lutreola*) - one of the only two endemic carnivores in Europe - is at risk of extinction from competition with the America mink (*M. vison*). In addition to threatening native species, the introduction of IAS between continents, regions and nations has often had significant impacts on the structure and functioning of the recipient ecosystems. For example, the invasion of alien shrubs and trees in the South-African native fynbos ecosystem and the consequent increase in vegetation biomass has resulted in a significant decrease of the overall water supply in the area.

IAS are also increasingly seen as a threat to ecosystem services and negatively affecting economic development and human well-being. For example, a number of human health problems, e.g. allergies and skin damage, are caused by IAS. The economic effects are related to the negative impacts of IAS on various human activities, such as hindering navigation by blocking waterways, and causing damage to forestry and crops (see Box 4.6).

Furthermore, increasing pressures on ecosystems, caused mainly by destruction of habitats, spread of IAS, over-exploitation and pollution, are weakening ecosystem resilience and ability to adapt to new conditions. The ability to adapt to climate change is weakening with biodiversity loss, and there is also a continuously declining capacity for providing ecosystem services. Box 4.6 presents the list of ecological problems IAS are known to cause.

Box 4.6: **List of negative ecological impacts of invasive alien species (***see also Annex III)*

- **Competing with other organisms** (e.g. plants like Japanese knotweed - *Fallopia japonica* or the Giant hogweed - *Hercleum mantegazzianum*) and change habitat structure
- **Predating** on native organisms (e.g. the fish Nile perch - *Lates niloticus* causing the extinction or near-extinction of several hundred native species in Africa)
- **Hybridising** with a related species or varieties, such as the North American grass *Spartina alterniflora* which hybridized with the European *Spartina maritima* and produced the very invasive hybrid *Spartina anglica*, which has radically changed coastal mudflat habitats in Great Britain, Denmark and Germany
- **Causing extinction** of native species, e.g. displacement of native species is known for the invasive multicoloured Asian ladybeetle (by intra-guild predation) and the Argentine ant (superior competitiveness)
- Being **toxic** (toxic algae blooms caused by alien phytoplankton such as *Chattonella verruculosa* and *Alexandrium* species)
- Being a reservoir for **parasites** or a **vector** for pathogens (rainbow trout which is a host for the salmon parasite *Gyrodactylus salaris* , signal crayfish which is a carrier and host of the crayfish plague)
- **Disrupting pollination** (e.g. *Impatiens glandulifera*. The alien plant competes for pollinators such as bumblebees with the native riverbank species, and so reduces seed set in these other plants)
- **Altering energy and nutrient flows**, as well as physical factors in habitats and ecosystems (freshwater plants like the Canadian waterweed (*Elodea canadensis*) and the Nuttall's waterweed (*Elodea nuttallii*)
- **Altering the local food web**, e.g. alien plants alter nutrient availability (e.g. nitrogen-fixing *Robinia pseudacacia*, *Lupinus polyphyllus*)
- **Altering the composition and functioning of habitats and ecosystems**. E.g. alien tree (Snichona pubescens) covering originally treeless highland of Santa Cruz island, Galapagos.

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