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HALTING BIODIVERSITY LOSS: FUNDAMENTALS AND TRENDS OF CONSERVATION SCIENCE AND ACTION

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Contents

Summary

The change and loss of biodiversity are understood as one of the most critical and challenging facets of the currently observed unprecedented anthropogenic change of global ecosystems. In the context of the traditional view shaped by a culture-nature dualism, it is apparent that the most underlying cause of the conservation problems is a phenomenon of the evolution of life on Earth: the origin and expansion of the primate species *Homo sapiens*. It was one of the first and few species to dynamically change the dimensions of its ecological niche. *Homo sapiens* managed to control and change virtually all types of ecosystems of the world, at an accelerating rate and with increasing effectiveness. The direct consequence was that humans started to be harmful to species not exploited as resources. Among the evolutionary insights is that human action and planning is calibrated to a restricted and easily understandable meso-cosmos evolved as an answer to man's living conditions in the Pleistocene, while the technology allows and achieves development of inestimable large-scale impacts. Humans are evolutionarily programmed to maximize resource use and individual or horde gains, not to live in an ecologically sustainable way. Thus, conservation can be seen as an attempt at ecological civilizing—heading for a conscious cultural evolution. This chapter describes the origins of conservation, and its changes of motivation and focus. Finally, the recent development of concepts and terms, such as biodiversity, helps overcoming the old man-nature antagonism. However, as it is becoming ever clearer that the idealized harmony of nature and nature without human impacts do not exist, it is no longer possible to orientate conservation to negative characteristics such as the elimination of human activities. Rather, conservation has to be defined as a cultural concept orientated to the nature and needs of biodiversity, including humans. It is guessed that about 99% of all species that ever lived are extinct today. Several mass extinctions can be distinguished during the evolutionary past. The recent, sixth extinction is caused by spreading humankind. Although it is impossible to provide numbers of species losses, while the total number of existing taxa is unknown, the rate of habitat conversion and loss alone, is unprecedented and an enormous and very rapid loss of biodiversity can be observed. Ecosystem conversion must not necessarily lead to species loss. Instead, some species benefit from human impacts on their habitat. Thus, human impacts on biodiversity must be analyzed carefully. However, the ongoing ecosystem conversion is a major concern of everyone who is aware of the immeasurable goods and services provided by intact ecosystems. Important examples of stresses to biodiversity and their sources are discussed. Among the most relevant future conservation problems, the accelerated and anthropogenic global climate change is identified. Halting biodiversity loss is among the formally accepted goals of international policy. Current trends in conservation planning and action are explained. The question of identifying conservation targets and visions is discussed, stressing the importance of considering biological and ecological processes. In conservation science the question of *what* to conserve has been very important. However, increasingly, conservationists feel the need to get a better idea of *how* to conserve. It is claimed that conservation should become more strategic and effective. An important recent trend is the development of an increasingly holistic perspective in conservation planning, taking into account larger dimensions of space and time. In the framework of different macro-ecological approaches, such as ecosystem management, bioregional or ecoregional management, the conservation

objectives are more integral and more ambitious than they used to be in classical conservation visions that focused merely on representation of current patterns of biodiversity at rather small sites. It is of special importance to conserve and enhance biodiversity's adaptability to the impacts of global change processes. Among the important management trends is involving people much more actively in conservation planning and action. A facet of this trend is the increasing role of indigenous peoples and local communities in the management of protected areas, with sharing of decision-making power. The biggest challenge for conservationists is to forge synergy between conservation, maintenance of life support systems and sustainable development.

Conservation of biodiversity as systematic science and action is a very young discipline. Nevertheless, the abundance and diversity of treatments, text books, journal articles and internet resources on this topic is overwhelming and virtually unmanageable. Even in the context of other EOLSS material, biodiversity conservation problems and solutions have already been considered (e.g. Gherardi *et al.* 2004). Increasingly, change and loss of biodiversity are understood as one of the most critical and challenging facets of the currently observed unprecedented anthropogenic change of global ecosystems. Consequently, many actors and scientists from different continents, cultures and disciplines try to describe, analyse, understand, and abate the problems. The present contribution is a rather brief and summarizing review focussing on frequently neglected aspects of the evolution of biodiversity loss and the culture of the conservation movement. The understanding of conservation problems and solutions as an evolutionary and cultural issue is significant for the further development of conservation concepts and action. Additionally, some of the latest trends and challenges of biodiversity conservation are described.

1. Culture vs. nature? Biodiversity loss and conservation as facets of human culture and evolution

1.1 Humans as drivers of biodiversity loss—evolutionary roots of conservation problems

Sometimes, in the context of the traditional view shaped by a culture-nature dualism, it is overlooked that the ultimate underlying cause of the conservation problem is a phenomenon of the evolution of life on Earth: the origin and expansion of the primate species *Homo sapiens*. Many conservationists follow a simplified approach that nature is good, and humans are not part of and are generally bad for nature. Consequently, any biodiversity conservation vision should aim to eliminate the presence and impacts of humans in 'natural' ecosystems. Recognising that this is absolutely impossible, it is challenging to reflect that *Homo sapiens* evolved normally, as all the other species did, under specific historical and environmental conditions.

Today it is practically clear that the human species is an African primate that evolved as an omnivore of open, more or less semiarid vegetation formations. Although it is so basic for understanding our own species and managing the world's conservation problems, many people do not acknowledge that it was in this environment where we acquired our 'human' characters by the means of natural selection. The anatomically modern humans appeared about 100 000 years ago, having evolved as a member of the hominid family. This family, about 5-7 million years ago, diverged from the lineage leading to the chimpanzees. The predecessors of the genus *Homo* are believed to be species of the genus *Australopithecus*; there is a probable direct line from *Australopithecus anamensis* and *A. afaraensis* to *Homo habilis*, *H. erectus* and finally, about 400 000 years BP to *H. sapiens*. *H. erectus* and *H. sapiens*, originally occupied a similar ecological niche. Their evolution was favoured by environmental changes such as a drying climate, the opening of the vegetation in Eastern Africa and the evolution of megaherbivore-rich savannas.

Organized as a social organism, the modern *Homo* species managed to exploit new (meat) food resources shifting to the niche of a hunter of megaherbivores. While more and more breaking into the guild of the carnivores, natural selection forced humans to compensate for lack of weapons and strength by improved communication in the hunting group, the use of technology, and, especially, the controlled application of fire. The use of fire by prehistoric humans, first for purposes such as staying warm, fending off predators, and cooking meat, developed into a history of efficient anthropogenic ecosystem conversion (Williams 2002). This might have happened much earlier than was believed for a long time, in the epoch of *Homo erectus,* about 750,000 years ago.

Probably for more than 90% of the species' life time, *Homo sapiens* lived as a hunter and gatherer. Thus, the human characters evolved and became stabilized in this ecological niche, e.g. physical endurance and related characters such as loss of fur and sweating, taste and diet preferences, the senses and their limitations. This was the time when humans developed the ability to think and plan, in the context of a meso-cosmos of limited dimensions. Natural selection favoured any ability that permitted optimization of the resource use of the group or horde. There was no need to develop capabilities to feel or foresee long-term or long-distance consequences of their actions. The efficiency of the human resource-use system probably in very early times led to local extinction of food resources. Today it is supposed that *Homo sapiens* contributed to the pleistocenic extinction of many mega-herbivores on all continents, possibly due to overhunting and habitat changes by burning for hunting purposes (Williams 2002).

The problem of local food scarcity was avoided by the excellent migration capacities, possibly related to the acquired technological skills (especially fire management). These skills were well developed even in the times of *Homo erectus* which spread from Africa to Europe and Asia. The mechanism of emigration in order to avoid food scarcity has been an important theme of human history until modern times, finally coming to an end in most continents because most productive ecosystems of the world are populated and utilised. We can, however, still observe population shifts, e.g. from the degraded semiarid tropical Andes towards the humid foothills of the Amazon.

In the early history, when migrating to other ecosystems, even beyond the tropical latitudes, *Homo sapiens*, as one of the first and few species, started to dynamically change the dimensions of its ecological niche. That was something innovative in the course of biological evolution. Other species before *Homo sapiens* had become changers of the structure of the ecosystems they were inhabiting, such as elephants destroying trees and keeping open savannah ecosystems, or competitive trees shading out other species. But those ecosystem converters and changers used to stay, for a rather long time, within a certain geographical and ecological range. *Homo sapiens* managed to control and change virtually all of the Earth's ecosystems, at an accelerating rate and with increasing effectiveness.

A new stage was reached when agriculture was invented. This meant that humans no longer concentrated on the use of wild resources naturally distributed on Earth, and this led to more or less important changes in the ecosystems through reducing the abundance of populations of selected species. With agriculture, humans started to design new ecosystems according to their own needs, leading to a complete change of the ecological niche of the species (Eldredge 2001). Obviously, humans are not the only ecosystem engineers who change the environment in order to establish adequate habitat conditions; another example is the beaver. However, in the history of evolution the dimensions of intentional ecosystem change implemented by a species, and the subsequent significant and very rapid switch-over of the ecological niche, is unique.

The direct consequence was that humans started to be harmful to species traditionally not exploited as resources. Those species belong to two groups: the organisms that cannot coexist with agroecosystems and others that can but which are combated by the farmers (so-called pests—species that destroy cultivated plants or harm domesticated animals). The most important conservation fact related to the invention of agriculture was that humans and their 'domesticated ecosystems' started to compete for space with 'natural' or 'wild' ecosystems. Today, the need for agricultural land for a permanently growing human population is the main and ever-increasing reason why man is changing the face of Earth. The expansion of the agricultural frontier is the principal driver of loss of biodiversity and its functions, especially in the most biodiversity-rich regions of the world.

Increasingly, it is claimed that conservation biology should develop a more evolutionary perspective considering that ecological and evolutionary processes are closely related, and that evolutionary responses to anthropogenic environmental change can be very fast and pronounced. A consequent evolutionary conservation approach will take into account the analysis of human evolution. This is important in order to understand, among others, the potential to combat the conservation problems and halt the biodiversity loss. It is important that anyone who tries to promote environmental education should understand the human being as a species with characters conferring adaptation to a pleistocenic environment, and that *Homo sapiens*—without significant evolutionary changes—left his original ecological niche.

The principal cultural problem that conservation is facing is that human action and planning is calibrated to a restricted and easily understandable meso-cosmos while the technology permits inestimable large-scale impacts. It is a trivial statement that humans were not made for a world with globalized environmental problems. "Evolution provided human beings with a nervous system with perceptual constraints that make it hard to deal with slowly developing environmental problems" (Ehrlich & Ehrlich 2004), because it was not required for survival in the pleistocenic African savanna.

Another instructive example that illustrates the evolutionary anachronisms modern humans are facing, is related to human food habits. The pleistocenic humans evolved a permanent appetite to maximize food intake in order to be prepared for the next period of food shortage. Food scarcity was an ever existing selection factor while illness due to obesity was not. As food-shortage has been eliminated in most industrialized countries, over-weight has become one of the most important health problems. Humans are evolutionarily programmed to maximize resource use and individual or horde gains. People do not feel the need to restrict food intake, and they do not feel the need to manage natural resources in a sustainable way. They are programmed to eat and use as much as they can. This makes both nutrition and environmental education so difficult.

Fortunately, humans developed an intellectual flexibility to learn how to control or to rationally change certain attitudes and habits, if personal advantages are expected as outcomes. On the one hand, we can never rely on humans to have a natural feeling for sustainability, but, on the other hand, there is a potential for a process of ecological civilizing or maybe even a conscious cultural evolution (Ehrlich & Ehrlich 2004).

Perhaps the only logical strategy is that we make individuals and societies understand that they can earn a (a rather short-term) net gain. On a rational level, the cultural evolution has started development of the concept of biodiversity conservation. However, since the individual humans tend to prioritize their short-term well- (and better-) being, it is much easier to get a broad support for measures that enhance immediate economic growth than for activities that safeguard resources required by future generations.

1.2 From nature protection to biodiversity conservation—origins of conservation, changes of motivation and terminology

Agriculture evolved, independently, during a slow process in different regions of the world. Barley and wheat species were among the principal 'founder crops' of southwest Asian agriculture that started with the use of grains at least 12 000 years before systematic cultivation, some 10 000 years ago. South America was the last continent (with ecosystems bioproductively adequate for agriculture) to be colonized by humans and changed for agricultural purposes. In the Amazon, for example, a comparatively short history of 6000 years of maize cultivation has been reported.

It was with the rise of agriculture that many human cultures started to differentiate nature and culture. The alienation of man from nature, in the sense of biodiversity existing outside of agroecosystems, was personal and cultural. In the framework of the development of agrocentric cultures and religions, gods and sanctuaries tendentially (in the most distinct cultures, in the Near East as well as in China) were shifted from Earth to heaven, elements of biodiversity were desecrated, and the pious humans were legitimated to tame wilderness according to their needs. For example, Christians were called upon to subdue the Earth (e.g., Kates *et al.* 1990) in order to improve their chance for a life in heaven. Maybe it can be claimed that the more populated a region and the longer the agricultural history, the more heaven-orientated the religion. For example, the religions of the more recent Central-Andean cultures show a transition from pantheistic concepts with gods on Earth, such as the creator (*Con Tiki*) *Viracocha* and the mother Earth, *Pachamama*, to shifting the gods to heaven, especially the sun god *Inti*.

Farmers, wherever in the world, increasingly felt that they lived by their own efforts, not depending so directly on the presence or absence of wild living resources. Indeed, in most agricultural cultures, the ecological services of biodiversity were and are taken for granted because they just exist. It is only recently that it has become understood how human well-being depends on biodiversity services (Alcamo *et al.* 2003), and this may lead to a new, more functional and utilitarian conservation motivation, vision and movement (compare Costanza *et al.* 1997, Daily *et al.* 1997, Pagiola *et al.* 2002).

It is interesting to note that the origin of modern biodiversity conservation is related to the conceptual dualism of nature and culture. And in this context, it is not surprising, that systematic and conscious conservation evolved in the epoch of industrialization and urbanization in Europe and North America, when the contrast between the artificial and the natural human habitats became clearer.

Industrialization, after ‘agriculturalization’, was the next step of the cultural evolution towards a completely globalized anthropogenic impact on biodiversity—and a pronounced further alienation of man from nature. The industrial production of goods through processing natural resources using fossil energy sources rang in an era of new conservation problems, mainly caused by changing the quality of habitats of other species through producing and emitting more or less toxic substances. Additionally, humans started to change the composition of the Earth’s atmosphere, emitting gases that, among other effects, increase the natural greenhouse effect. Human actions became completely global, environmentally effective at any site of the Earth, even in wilderness areas without the presence and immediate impact of human activities.

People always noticed when their land-use caused undesired impacts. For example, Plato wrote about his concern that the ecosystems of Attica were so drastically converted: "like the skeleton of a body wasted by disease" (Page 1935, cited by Wright & Mattson 1996). Different cultures in very early times, e.g. in India or the Andes, established laws in order to protect certain natural resources like soil or the wild species they used. In Europe, the first ‘protected’ areas were created for hunting by the ruling classes.

The very first scientific work that challenged the notion of an inexhaustible Earth was "Man and Nature" by the American George Perkins Marsh, first published in 1864 (Kates *et al.* 1990). Marsh showed how humankind is changing nature and that this may imply dangers when not done properly; his work was cited by many conservationists and influenced views of the relationship of nature and society. It is especially noteworthy how Marsh—deriving his conclusions from empirical impressions—focused on functional aspects of ecosystems, such as forests, advocating better management. Although the functional approach to conservation, thanks to Marsh, in the USA was more important than, for example, in Europe, it took a long time to really make it important.

In USA, from the nineteenth century on, there was a debate on whether conservation had to be approached in a utilitarian or a preservationist way. The renowned game-management specialist and former Forest Service forester, Aldo Leopold, had been trained at the Yale Forest School in the utilitarian principles of Gifford Pinchot-style conservation, but in an article in the November 1921 Journal of Forestry, he startled his colleagues by questioning the traditional notion that ‘the policy of development…should continue to govern in absolutely every instance’. Wasn't it possible, he asked, that ‘the principle of highest use’ demanded that ‘representative portions of some forests be preserved as wilderness’? Leopold’s essay "The Land Ethic" has been considered the philosophical heart of twentieth century environmentalism. Its thesis main is stated as follows: "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts.... The land ethic simply enlarges the boundaries of community to include soils, waters, plants, and animals, or collectively: the land.... In short, a land ethic changes the role of *Homo sapiens* from that of the land-community to plain member and citizen of it".

Leopold was a co-founder of the Wilderness Society, created in the 1930s, that has its roots in a wilderness movement starting with John Muir and allies who wished to save places of extraordinary natural beauty—the grand spectacles of nature and places. These "preservationists appealed to patriotism, deism (respect for God's creation), spiritual inspiration, and aesthetics in their advocacy for wild places" (Noss & Soulé 1998). In this context it becomes understandable that the first prominent conservation actions of the nineteenth century had a more distinct motivation than conserving functionality as claimed by Marsh, and it was not a purely preservationist action neither: Both in USA and elsewhere, the year 1872, when the Yellowstone National Park was created, is often seen as the starting point of nature protection. This protected area was set apart mainly for its scenic beauty and in order to serve as a place where people can enjoy nature. Until rather recently this has been a common motivation for the creation of national parks, worldwide.

Early conservationists of the nineteenth century were guided by rather romantic feelings and not by utilitarian or scientific arguments. In 1832, in the USA, the young artist George Catlin proposed a "nations park" in Montana, "containing man and beast, in all the freshness of their nature’s beauty" (Catlin 1841, cited by Wright & Mattson 1996).

Similarly, in Germany, it was an artist who, in 1888, invented the term ‘nature protection’ ("*Naturschutz*"): the pianist and composer Ernst Rudorff observed that the application of land-use technology changed the traditional cultural landscape of his homeland, and this made him start a ‘homeland protection’ movement in order to conserve the traditional characters of the landscape, establishing sanctuaries and natural monuments. Consequently, the official and more scientific nature conservation activities in Germany for some time focussed on natural monuments (Conwentz 1904). At the same time enthusiasts and specialists of birds started to be concerned about species protection. In 1895, in Paris, the first conference on bird protection was held.

Generally, modern people considered man as contrary to nature, changing and harming it. Thus, it was logical that the idea of protected areas was developed to set apart sites ‘where nature could be just nature’, whatever this means, but definitely without human influence. Following this "preservationist" approach, nature was to be protected from bad human influence and conserved in a status without suffering from human impacts. Thus, it is not surprising that the most important advances of biodiversity conservation, until now, refer to the establishment of protected areas. Without doubt, protected areas have proven to be an effective, essential and most valuable element of conservation strategies, maintaining mature non-degraded ecosystems, but it is now acknowledged that they are not sufficient to guarantee effective long-term and large-scale conservation (see below).

Principally, in the context of the development of Biosphere Reserves (UNESCO program Man and Biosphere), from 1971 onwards, people were regarded as part of ecosystems. Today, the bioregional, ecoregional or ecosystem management approaches (see below), more or less related to the biosphere reserve concept, have taken over the conservation management schemes, replacing the pure preservationist approach.

In the nineteenth century, the term ‘preservation’ (in USA) was much more dominant than conservation. Into the twentieth century in Europe, *protection* (German: *Schutz*; *Naturschutz*; French: *protection*; e.g. Massart 1912, Heim 1952) was and is used much more frequently than *conservation*. With the international Convention on Biological Diversity (CBD), ‘conservation’ worldwide became the most important term (e.g. German: *Erhaltung*, Spanish: *conservación*, French: *conservation*). At the same time, the CBD catalyzed a new boom of the utilitarian approach to biodiversity and its conservation.

The differences between *conservation*, *preservation* and *protection* are of a subtle semantic nature, but they definitely matter. The term *nature* (see: nature conservation, nature protection) itself is anything but clearly defined, and of course, the interpretation, perception and valuation of what is nature influences the outcomes of conservation efforts. As nature is still understood as the sphere that is not impacted by humans, nature conservation becomes restricted to some functions and isolated sites that no longer correspond to the science and practical needs of conservation. In the real world, the conservationists increasingly have to deal with resources used by humans and with anthropogenically transformed ecosystems. The terminological diversity and imprecision around conservation, as a result of its conceptual evolution, reflect the variety of approaches, the lack of common definitions, and the lack of clearness with regard to the goals and targets of conservation.

In this context, the invention of the term and concept of biodiversity, in the 1980s, has been highly important (original definition by Norse & McManus 1980, and redefinition by Norse *et al.* 1986). Today, biodiversity is a buzz word that achieved a deep "market penetration" and that is much more frequently used and cited than other scientific concepts or sciences such as molecular biology, climate change, or oceanography (Norse & Carlton 2003). Biodiversity became a key topic of social and political concern when, in September 1986, Washington, D.C., the term was introduced by the National Research Council staff at the first National Forum on BioDiversity (published 1988). It is not surprising that at the same time conservation was ‘reinvented’ by Michael Soulé (Soulé 1985; compare the book "Conservation Biology", Soulé 1986; the foundation of the Society for Conservation Biology and the journal with the same name: "It was decided to found a new journal, *Conservation Biology*. That a successful European journal, *Biological Conservation*, devoted to the same topic, had been in existence since 1968 apparently went unnoticed" (Sarkar 2004)). Hence, between 1985 and 1987, conservation biology emerged in USA as an organized academic discipline and its focus became biodiversity.

Biodiversity is much better defined than the diffuse ‘nature’ and it describes the object of modern conservation. As humankind, clearly, is part of biodiversity, the concept of biodiversity conservation helps in overcoming the old man-nature antagonism. This antagonism was developed especially in the industrialized countries with Christian culture that additionally, among others, led to the conceptual separation of natural sciences and humanities which, for a long time, has been (and maybe still is) an important obstacle to problem solving in conservation.

When the expansion and action of *Homo sapiens* is understood as a biological phenomenon in the course of the evolution of biodiversity, it can be more difficult to derive normative conservation visions that define what is to be conserved and why. A mechanistic definition of nature as an object not affected by humans leads to a static conservation approach that tries to focus on a pristine nature that does not exist (any longer); and as it is becoming ever clearer that the idealized harmony of nature and nature without human impacts do not exist, it is no longer possible to orientate conservation to negative characteristics such as the elimination of human activities (Gnaiger 1991). Conservation has to be defined as a cultural concept orientated to the nature and needs of biodiversity including humans, and to the ecological laws.

2. Dimensions, causes and consequences of biodiversity loss

2.1. Biodiversity loss and extinction in the evolutionary past

Understanding the phenomenon of biodiversity loss on Earth is going to be a long-distance dash through several hundreds of million years at the speed of light, building a bridge between happenings in the past and the events in front of our eyes today that make conservation necessary.

Several decades of research and latest methodologies, complemented by results from geological studies, allow paleontologists to make assumptions about the history of living organisms of this planet. Comparison of fossils (from the Latin word *fossilis* meaning excavated) from older and younger layers of sediment rock clearly reveals shifts in between floral and faunal compositions, the disappearance of species and the development of new ones.

The story of life on Earth is filled with losses of species and new developments. The phenomenon of extinction is as old as the first living organisms, and has always and constantly taken place on the stage of our planet. Scientifically, two different kinds of extinction can be distinguished due to the different nature of records and other characteristics: the mass and the background extinction. A mass extinction event is characterized by the extinction of large numbers of different plants and animals within a rather short time (in relation to Earth history) but on a large scale in space. Moreover, mass extinctions have influenced the evolution of plant and animal species. According to Bowring *et al.* (1999), mass extinctions are "comparable to natural selection, because they may trigger the demise of dominant species and massive reorganization of ecosystems". To determine a mass extinction event from the sediment layers, so-called boundaries need to exist: one sediment layer containing fossils of a large range of taxa, and in the next younger one, a large proportion of these taxa can no longer be found. Contrary to mass extinction, background extinction is the disappearance of a single or small numbers of species in different parts of the world and at different times. The background extinction rate can also be explained by the pressure of natural selection although on a smaller scale; it always forces species to withstand changing environmental conditions or to adapt to them.

There is much debate about whether background extinction progressively turns into mass extinctions with a rising number of vanishing taxa on a rising spatial scale; alternatively, both types of extinction can be seen as clearly distinguishable events. Nevertheless, most of the scientific literature on the subject clearly distinguishes between the two types. As the term suggests, background extinctions are part of the daily evolution business; in comparison, they have received less scientific attention. Therefore in the following paragraphs the focus will be on those extinction events that stand out as playing a significant role in shaping today’s faunal and floral compositions. Many mass extinction events have occurred during the story of living organisms, all differing in time and spatial scale, in duration, consequences for remaining biota and of course in magnitude. The so-called *Big Five* represent the most conspicuous ones. Five massive extinction events have happened since the development of life around 3.8 billion years ago, each of them eliminating more than 50% of relatively abundant marine invertebrate genera (Jablonski 2001). Paleontologists often prefer to talk about a generic loss instead of a species loss, as identification of organisms up to the species level only referring to fossils is a daunting task, and because the fossil discoveries are far from constituting a quantitative record of the extinct species. The fossil data is biased, among other reasons, because the remains of organisms of certain habitats and of certain life forms tend to be much better conserved than others. In this context, there is a need to recognize that better data is available on marine organisms than on terrestrial ones; and, of course, dinosaurs make better fossils than earthworms.

As such, numbers of species loss are generally the results of statistical calculations and extrapolations (see Table 1). The total amount of existing species during the ages of the Phanerozoic can only be roughly guessed, and research on fossil records steadily reveals "new" organisms. This is hardly astonishing given that humanity needs to rely on guesswork for the number of species with which it shares the biosphere of the Earth.

Table 1. Extinction intensities at the genus and species level for the five massive extinction events of the Phanerozoic. Genus extinction percentage are based on direct fossil analysis whereas for the percentage of species loss a statistical technique, *reverse rarefaction*, has been used (numbers are taken from Jablonski 1991).

Extinction	Genus loss (%) observed	Species loss (%) estimated
End Ordovician	60	85
Late Devonian	57	83
Late Permian	82	95
End Triassic	53	80
End Cretaceous	47	76

Debates about what on Earth can be powerful enough to cause the mass extinctions seem to be never-ending. As soon as one possible trigger is identified, focus turns on its plausibility and debates run on.

The oldest mass extinction is called the end-Ordovician event. Approximately 440 million years ago, and in two bursts divided by a break of about 1 million years, as much as an estimated 85% of marine invertebrate species vanished from Earth (terrestrial habitats had not yet been colonized by multicellular organisms). Detailed studies have been carried out into the brachiopods of today's South China as one of the major groups of marine benthic invertebrates in the Paleozoic time. It was found that of the 54 brachiopod genera in total in the mid-Ashgill period, 39 (72.2%) did not survive the first pulse into the Hirnantian, and of 33 families, 22 (66.7%) did not persist. For the second pulse, they state a loss of 20 out of 29 brachiopod genera (69%), whereas on the familial level, only one out of 29 families was eliminated—a rather low rate of familial loss. For the final stage of the Ashgill/lower part of the Hirnantian, it is assumed that mass extinction and glacio-eustatic sea-level changes are associated with shifts in marine stable isotope compositions. Due to these detectable shifts, onset and demise of the end-Ordovician glaciation can be identified. The glaciation is assumed to have been triggered by continental drift of large landmasses to the South Polar Region followed by a global temperature drop. Results from an ocean general circulation model under a range of atmospheric CO_2 levels support this assumption: the results indicate that the cooling trend was a consequence of progressive cooling of the global ocean in response to falling levels of atmospheric CO_2, sea level change, and palaeogeographic change. So along with the climatic change, the decreasing sea levels further contributed to the magnitude of the extinction event. This chain of happenings led to intense destruction or transformation of habitats, much too fast for many organisms to follow up with the necessary adaptations, and ending in one of the biggest biotic crises ever.

The second mass extinction event took place during the mid-Late Devonian period around 376 million years ago. Actually, this was a series of extinction events (Erwin 1998): a first decline of several groups of organisms in the mid-Devonian, then a closely spaced, stepwise extinction at the so-called Frasnian-Famennian boundary, eliminating 50-55% of genera and 70-80% of marine invertebrate species and a smaller biotic crisis at the close of the Devonian. The root causes are much debated and less clearly understood than in other cases. However, it has been proposed a close correlation of a series of comet showers with sea-level rises, then to a global cooling that ended in southern hemisphere glaciation followed by a sea-level drop, and finally to the late-Frasnian extinction. Furthermore, ocean anoxia is very likely to have played an additional role in this mass extinction event. In Germany, those anoxic events have left their traces as two-decimeter thick bituminous limestones, called the Lower and Upper Kellwasser horizons. Although the lower one does not coincide with traces from anoxian events elsewhere in Europe and thus seems not to have been developed universally, the upper one correlates very well with European-wide anoxic conditions. In addition to the explanations mentioned, leading theories also include oceanic volcanism as a possible reason for the late-Devonian mass extinction (Erwin 1998).

The third and the biggest of the 'big five' massive extinction events occurred about 251 million years ago in the late-Permian period. At least twice as many species—approximately 95% of marine and 70% of land-dwelling species—as in the next biggest mass extinction event, were wiped out. This may be the reason why a lot more information can be found about the end-Permian extinction than about the end-Ordovician or late Devonian. Plainly, the sea level rose, and the biotic crisis was accompanied by two discrete anoxic events and high carbon dioxide (CO_2) levels. Whether a cometary impact or CO_2 and sulphur releases due to large volcanic activities played an additional role remained unproved for a long time. Recent publications have, however, finally unraveled parts of the mystery: It was possible to confirm the presence of trapped helium and argon with isotope ratios similar to the planetary component of carbonaceous chondrites within fullerenes found in the sediment layers of the Permian-Triassic boundary. The authors conclude that an impact event (cometary or asteroidal) may have accompanied the Permian-Triassic extinction. Lately, so-called *Siberian traps*, vast volumes of volcanic lava, could be dated more precisely and their peak in eruptions could be observed, matching exactly the Permian-Triassic boundary some 251 Million years ago. Some authors hypothesize a dark matter scenario for having initiated a flood basalt volcanic episode: WIMPs (weakly interacting massive particles) as a class of dark matter candidates could possibly, when occasionally passing through the Earth, produce immense quantities of heat—up to five times the order of present day terrestrial heat production. It has been assumed that these quantities of heat could have possibly triggered large flood basalt volcanic activities, leading to the creation of the Siberian traps. Furthermore, the volcanic eruptions may lead to explosive release of huge amounts of dissolved methane gas bringing up anoxic waters from the deep ocean and thus promoting the anoxic events. Finally, Visscher *et al.* (2004) shed even more light on the end-Permian extinction event: obviously, ecosystems experienced a dieback of woody vegetation allowing surviving herbaceous lycopsids to take on a pioneering role in repopulating deforested terrain. Astonishingly, microspores of those plants showed a high degree of mutation that negatively affected the spore development process but nevertheless, this organismic group was dominant in that period. Visscher *et al.* (2004) explain this phenomenon by going back to the Siberian Traps: as a consequence of the volcanic emissions the ozone layer was partly destroyed leading to higher UV-B radiation that could have resulted in a very high mutation rate. In conclusion, the root causes of the mass extinction event of the end-Permian can be seen as a trigger for a complex chain of cause and effect relationships.

The end-Triassic extinction event, that took place about 210 million years ago, is less clearly understood than the other four mass extinctions. There is no consensus about an exact definition of the Triassic-Jurassic boundary (TJB). The onset and duration of the end-Triassic extinction were determined by two distinct and different organic carbon isotope anomalies that could be found at the Norian/Rhaetian (Late Triassic) and the Rhaetian/Hettangian (Triassic/Jurassic) boundaries. Strata approaching the older boundary show evidence for increasing ocean anoxia, whereas at the younger one a series of negative anomalies has been identified. Those two events, separated by the Rhaetian age, would comprise the end-Triassic mass extinction. Various mechanisms associated with ocean anoxia have been proposed as responsible for the biotic crisis including both gradualistic mechanisms throughout the Late Triassic, as well as catastrophic processes.

Last but not least, the list of the 'big five' is completed by the end-Cretaceous event (*KT event*). Although being the smallest in comparison to the above-mentioned ones, the KT event is the most well-known as it terminated the presence of dinosaurs on earth, approximately 65 million years ago. The proximate cause only came to light when researchers in the late 1970s carried out measurements of the amount of cosmic dust in the KT boundary. They aimed to refine the duration of a "gap" in the record. Instead they found huge amounts of cosmic debris that could only be explained by the impact of an extraterrestrial body, namely a meteorite, of approximately 10km diameter. This hypothesis was finally confirmed when the corresponding crater of about 200 km diameter on the Yucatán peninsula in eastern Mexico was identified. Certainly, this discovery was followed by intense research on possible consequences of the impact, and latest theories include a subsequent sea level drop followed by short-term cooling or heating, and/or acid rain. However, there are still many unanswered questions regarding the dinosaur extinction, such as the question of why other taxa were not as impacted by the extraterrestrial body, and how some dinosaur relatives have managed to survive until the present (crocodiles and birds).

It is not just the causes of mass extinction events that are point of interest to scientists; also of interest are the patterns in which species vanished, and of course the question: which species died, which survived and why or how have some been able to survive? Is the extinction of a species caused by 'bad' genes, or is it rather bad luck that eliminates an entire taxonomic unit (for further discussion on this topic see, for example, Leakey and Lewin 1996, Raup 1991). Questions like this arose from the observation that extinction does not seem to happen randomly but in many cases according to different modes of selectivity. As an example, for the Rhynchonellidae, a family belonging to the larger taxon of brachiopods, a comparatively high survival rate can be observed after the Frasnian-Famennian extinction, whereas Atrypida and Pentamerida suffered dramatic losses. It is not only a taxon-specific selectivity that can be recognized, but also other forms of selectivity (see also Raup 1994): passive taxa (defined as sedentary benthos or non-swimming plankton) can be shown to have been harder hit by extinction events than active ones (all taxa capable of independent and regular locomotion) in the end-Permian extinction. Feeding strategy has been shown to be closely correlated with survivorship, for example among sea urchins at the end of the Cretaceous period. And it should not be forgotten that in addition to all the species that have vanished from Earth, others survived all the biotic crises and have hardly changed to the present day, at least with regard to morphological characters. These creatures are known as "living fossils" and it is assumed that they have been either extremely tolerant of every historical crisis, or they are just extremely lucky.

Another interesting phenomenon with respect to mass extinction events is currently attracting attention: the so-called *Lazarus-effect* that is characterized by the disappearance of taxa from the fossil record in an interval after a mass extinction event, only to reappear again later. Such taxa are consequently called *Lazarus-taxa*. (Wignall and Benton 1999). It can be hypothesized that the abundance of Lazarus-taxa in the aftermath of extinction events is a reflection of the extreme rarity of organisms at this time. Of course, not all the species that at first survived the mass extinction event do reappear. Changing environmental conditions like CO_2- and O_2-levels and rising or falling temperatures, or catastrophes like bolide impacts or volcanic eruptions, are by no means the only factors putting life-threatening pressures on organisms. Several other mechanisms may be triggered by the same factors that cause mass extinction but lead to a slower mode of species disappearance.

As in most scientific disciplines, the advancement of extinction science led to insights and confusion at the same time. Not only the magnitude but even the existence of the discussed mass extinctions is questioned by Kerr (2001a, 2001b), after research by paleontologists from Harvard University (Bambach *et al.* 2002). Intense studies of the Cretaceous-Turonian (CT) boundary, marking one of the half dozen lesser extinction events, and younger sediment layers revealed the reappearance of 15 of the 29 genera 20 million years after their apparent extinction. The CT extinction of echinoderms consequently shrinks from a catastrophic 71% to 17%, a loss that might simply reflect natural background extinction. But Bambach *et al.* go even further by stating that from the big five, for the extinction event on the Frasnian-Famennian boundary 364 million years ago (the late Devonian), estimated numbers of extinct species probably have to be corrected as well, as the number of echinoderm taxa following the boundary proved to be five times greater than previously found. The next one of the big five that may have been much smaller in magnitude and therefore drop from the top five list, is the end-Triassic one. Bambach *et al.* draw an interesting conclusion from his studies: the late Devonian and end Triassic intervals may have lost more of their generic diversity through "a failure to produce new genera" than through extinction (Kerr 2001b).

The subject and the term extinction has often been treated as purely negative. This may be caused by the situation that the following section will deal with. Let us try to cast a constructive glance at the described biodiversity loss events: despite the large extinction events, the fossil records reveal an obvious increase of the total number of species over time since the development of life (although this may be partly due to greater availability of younger fossils) (Solé and Newman 2002). So maybe the disappearance of a huge amount of species can also be seen from another perspective than the one of biodiversity loss—at least looking back at Earth history. Following Jablonski (2001), mass extinctions can be seen to have played many evolutionary roles, involving differential survivorship or selectivity of taxa and traits, the disruption or preservation of evolutionary trends and ecosystem organization. Of course a certain time of recovery is needed after a huge biotic crisis. This phase can turn out to be of different length. For the end-Permian extinction, Payne *et al.* (2004) found that unusual behavior of the carbon cycle after the event caused a *delayed* biotic recovery. This leads to the assumption that there is a direct correlation between Earth system function and biological rediversification. As delivered by fossil records, for an era of mostly 5-10 Myr after a mass extinction event, floras and faunas are impoverished and often dominated by only one or two species (Raup 1994). After such a period, however, it is clear that an event of the magnitude of a mass extinction opens up space and possibilities for evolution of new species. The loss of species reduces the competition for resources and may allow certain organisms that would not have been able to successfully establish before—due to their poor competivity—to develop and hone an ecological niche and withstand the forces of natural selection. A suddenly missing predator gives advantage to potential prey populations, allowing them to evolve without always having to face the danger of being hunted. The natural capacity of habitats to be suddenly colonized by living organisms is not extensively used anymore. Thus, the potential for speciation events is much higher than before. It is supposed that this potential may have been responsible for rapid radiations of species, such as the rise of the mammalian species after the extinction of the dinosaurs (Jablonski 2004).

2.2. The sixth extinction and the Anthropocene

It is guessed that about 99% of all species that ever lived are extinct today (Jablonski 2004). This implies that extinction as such should be accepted as something natural, belonging to Earth history, just like the evolution of species. But there is still the difference between background and mass extinction. And the big five presumably won't remain at five indefinitely—another mass extinction is inevitable. At least that is what more and more scientists hypothesize (Thomas *et al.* 2004b) or even state in public and with increasing emphasis (Chapin III *et al.* 2000). Of course, this is subject to a lot of debate, as to date there is no scientific proof of a sixth mass extinction event (van Loon 2003). The current extinction rate is said to exceed the natural background rate by 1000 to 10 000 times (UNEP 2002). Some authors have stated that an estimated three species per hour are irreversibly lost (Eldredge 2001). Although it is easy to argue that it is impossible to provide numbers of species losses while the total number of existing taxa is unknown, the rate of habitat conversion and loss alone is unprecedented, and we are therefore justified in stating that an enormous and very rapid loss of biodiversity is currently underway.

In contrast to the past five extinction events, the sixth one is not several million years behind our time but instead humanity finds itself in the very center of it. Neither glaciation nor a bolide impact can be identified as a root cause for the current massive loss of living organisms, but for the first time in life's history the problem is a biotic agent: the human species. The continuously rising pressures on ecosystems originate in the escalating need for natural resources as a consequence of the global economic system. In addition, the increasing conversion of habitats on a large scale represents the biggest direct threat to the world's biodiversity. So when did the sixth extinction event set in? Eldredge (2001) distinguishes between two distinct phases, the first one starting with the dispersal of modern humans to different parts of the world some 100,000 years ago, and the second one following the transition to agriculture about 10,000 years ago (see above). Those regions that already supported earlier hominid species display a much lesser loss of organisms within the first phase of the sixth extinction. This may be due to the degree of adaptation to hominid presence that could already have taken place over a long period as a co evolutionary process, whereas the later discovered habitats had to face the arrival of humanity without any "preparation".

With early humans arriving in North America approximately 13 400 years B.P., a threatening competitor joined an "untouched" community of living organisms. Fossil records proving the extinction of mammoths and mastodons within the following 1000 to 1200 years are spread throughout the continent. The outcome of a multi-species-overkill simulation by Alroy (2001) supports the hypothesis, that human-overexploited hunting was directly related to the disappearance of 30 out of 41 large mammalian herbivores. Australia was reached by the human species much earlier than other parts of the world, namely about 56 ± 4 thousand years B.P. Burial ages for megafauna from 28 Australian sites report extinction around 46,400 years ago. In fact, all Australian land mammals, reptiles, and birds with a body weight of more than 100 kilograms, and six out of the seven genera between 45 and 100 kilograms disappeared during the late Quaternary. A period of overlap of humanity and megafauna until the onset of extinction can be observed, representing one of two different models to explain the vanishing of species after human arrival. The first alternative assumes an immediately starting biodiversity crisis and is therefore called the "blitzkrieg"-model or the global overkill hypothesis. It certainly has to be mentioned that with an increasing period of overlap there is also increasing probability of contribution of other impact factors to the extinction event. Nevertheless, Barnosky *et al.* (2004b) drew the conclusion from their studies that climate change as an impacting factor preferentially effects mammals of lower trophic level and size categories, whereas for higher categories human impacts are implicated. This again supports the hypothesis of early anthropogenic ecosystem disruption followed by extinction.

Certainly, there is more than one opinion about this. From 76 North American sites where artefacts of the Clovis-age archaeological material can be found, only 14 showed strong evidence of early human hunting of those large mammals (as reviewed by Grayson and Meltzer 2002). The authors also state that no evidence for widespread human-caused alteration of the landscape could be found—"no massive burning, no rats, no pigs, no chicken". In the same way, other authors discuss their doubts on the early humans having been exclusively responsible for megafaunal extinction in Australia. However, specialists do generally agree at least on the possible contribution of human hunting to the loss of large mammals. Islands generally show a closer correlation between human arrival and species loss than mainland. In the Caribbean, fossils hold evidence for the loss of several large species after humans touched ground some 8000 years ago. After having escaped anthropogenic influence until 2000 years, Madagascar was finally reached by the human species and their arrival was shortly followed by the loss of elephant birds (*Aepyornis*), a certain hippo species and some of the larger lemurs (Eldredge 2001). New Zealand seems to be the prime example in the circle of island species loss after human settlement: it was only about 900 years ago that humans reached this mammal free island, quickly wiping out 11 species of ratite moas (Aves; Dinornothiformes) within just a few hundred years (Grayson and Meltzer 2002) (the number of species has to be reviewed as later studies revealed new taxonomic insights). Up to now focus has been on large mammals that are extinct today, with the sole exception of the moa. But the ratite moa was a massive graviportal browser weighing up to 250 kilograms. As a consequence, the relation of body size and weight with extinction risk has been assumed and intensively studied. Cardillo (2003) links a smaller body size to higher reproductive output and smaller home ranges. Indeed a larger litter size seems to be correlated with lower vulnerability of the species but there are still other environmental factors that can contribute to the vulnerability of a species.

Today, although a high percentage of the still existing large mammals is included in the IUCN's red list of threatened species (Baillie *et al.* 2004), the number of smaller animals facing extinction—even the smallest ones—is also high. This is supposedly one of the differences between those early times discussed above and the so-called Anthropocene—the era of the most rapid and most intensive biodiversity loss the onset of which is determined to a much younger time. Crutzen (2002) used the following definition and explanation for the beginning of the Anthropocene: "It seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch, supplementing the Holocene… The Anthropocene could be said to have started in the latter part of the eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane. This date also happens to coincide with James Watt's design of the steam engine in 1784". Even if the Anthropocene had started as a new era by the end of the last but one century, a significant delay can be observed for the impact of local symptoms of this era on different regions of the Earth. Starting from Middle Europe, where humans had already transformed forest ecosystems several centuries earlier, to increased pressure on natural habitats and their biodiversity as a consequence of the discovery and use of fossil energy, influences of modern anthropogenic economic strategies rapidly spread to other continents. Nevertheless, especially in South America, there still remain large areas that show hardly any indication of the local manifestation of the Anthropocene.

From whatever angle one approaches the subject, reviewing the latest literature about extinction rates and numbers causes serious headaches. For Singapore (total area ~ 540km²) and especially forest specialized taxa, substantial rates of documented and inferred extinctions were found: the greatest proportion of extinct taxa was found to be in butterflies, fish, birds and mammals and is supposed to be lie between 34 and 87%. Estimations like this one can be done by applying different approaches: analysis of past observed extinction rates and appropriate inference or appliance of the principles of island biogeography to terrestrial "islands" remaining in a "sea" of converted land. For tree species of the Atlantic forest of Southeast Brazil, another approach was created: the specific characteristics of plant species, their avian dispersers and the distribution of the forest remnants on the landscape were evaluated. Results revealed an approximate loss of 33.9% in this region on a regional scale. Extinction rates within tropical forests in total have been subject to a paper published by Pimm and Raven (2000). They calculated extinction rates in accordance with two different scenarios: if the habitat area of the 17 biodiversity hotspots found in the tropics (identified by Myers *et al.* 2000) remains intact, tropical forests will nevertheless lose about 18% of their species. But if the hotspots are cleared as well, the extinction rate will certainly be much higher. Regarding the population levels and assuming that population extinction is a linear function of habitat loss, about 1800 populations per hour, or 16 million annually, are supposed to vanish as a consequence of tropical deforestation (Hughes *et al.* 1997). With respect to these numbers plus the fact that the "evolutionary powerhouses" of tropical forests and wetlands are currently threatened and as such probably causing a significant delay of biotic recovery by several million years, Myers (1997) concludes: "Within a generation we may commit the biosphere to a grand-scale depletion that will disrupt evolution for at least 200,000 generations, or 20 times as long as humans have been a species".

The disappearance of species from temperate forests is no less alarming: Poland's popular Bialowieza forest is reported to have lost 45% of 133 herbaceous plant species in a period of only 23 years (1969-1992). The marine realm is not exempted from human activities and their consequences. Studies have shown that an increase of mean seasonal sea temperature of about 1 °C can lead to serious coral bleaching—breakdown of coral-algal symbiosis. The importance of coral reefs is rather to be found in the immense number of species inhabiting them than in the diversity of the corals themselves. One estimate of the total number of reef building corals is 835 species, providing habitat for another 1-9 million marine species. It was reported a species loss of 30 to 60% on reefs degraded by human activities (sewage, sedimentation, and/or industrial pollution). In 1998, the combination of high sea surface temperature with the El Niño event caused global coral bleaching of immense magnitude. Between October 1998 and January 1999, 18 to 91% of colonies of the gorgonian coral *Briareum asbestinum* on seven 52 x 2m transects died (mean = 68%), having been attacked by diseases once weakened due to the bleaching .

The IUCN red list (Baillie *et al.* 2004) ranks a total of 762 plant and animal species as "Extinct" (in the year 2000 the red list contained 18,000 species assessments, representing about 1% of the currently described species, so the real number of extinct species might be much higher). Examples can be given from every group of organisms, birds, fishes, reptiles, mammals, insects, etc. BirdLife International in its report State of the World's Birds (BirdLife International 2004) report a loss of more than 150 bird species since the year 1500. For the last two millennia they estimate a loss of approximately 2000 bird species just on Polynesian islands. Even more endangered than mammals and birds seem to be the amphibians, of which about 32.5% are estimated to be globally threatened (birds: 12%, mammals: 23%. Literature booms with latest news about population crashes of numerous species of which only a very little selection from different taxa can be mentioned: For scalloped hammerhead, white and thresher sharks, a population decline of more than 50% in the past 8 to 15 years is estimated. In France, the number of breeding males of the little bustard (*Tetrax tetrax*) has declined by 92% since 1980. Populations of the large non-migrating herbivores of the Masai Mara in Kenya have suffered a 58% reduction within the years 1977 and 1999. It is not only for the large or easily seen organisms but also for less popular groups like molluscs and amphibians, that a strong species and population decline can be observed. The next step following a population crash is to be declared "near extinction" or "in danger of extinction" like the Spanish Imperial Eagle (*Aquila adalberti*) and the Iberian lynx (*Lynx pardinus*).

This is only a very short extract of what can be found about extinction rates and numbers. Nevertheless, awareness should be given concerning the fact that, as already mentioned in the previous sections, there is no clear idea of the real number of species sharing the planet with us. Of course in cases where a certain set of species has been monitored for several years and within this period some of the species could not be recorded any longer, like in the example of the Bialowieza forest, this does not count. But such an amount of data in the form of timelines only exists for a very small percentage of species. As monitoring of a single species is such a time-intensive and laborious process, the species monitored are often large and easily detectable, or of high economic importance, and thus covering only a small fraction of organisms. However they are presented, extrapolated numbers are vague and cannot become more trustworthy as long as the estimated total number of species on Earth is thought to lie somewhere between 10 and 50 million.

If a species cannot be found any longer within its recent distribution range, this can be due to different reasons. Maybe as a consequence of changing environmental conditions, the distribution range has shifted, the species is less abundant and harder to find or maybe it is just that nobody was trying to find it again. Insecurity like this even exists for the Tasmanian tiger, whose survival has not been confirmed for the last 70 years. There have been several cases of species which were thought extinct being rediscovered many years later. By just reviewing the web page of Birdlife International several headlines can be found like "*'Extinct' flycatcher rediscovered in Indonesia*", "*Lost manakin is rediscovered in Brazil*", and "*White-eared Night Heron rediscovered in Vietnam*". For this reason, all the information given has to be treated with care, and conservationists are keen on getting closer to the real numbers of existing species living today to be able to make more realistic assumptions about probability, patterns and rates of extinction.

One general fact is proven: the state of biodiversity is getting worse from year to year. Conservation institutions have started to monitor a Living Planet Index (LPI): this is an "indicator of the state of the world's biodiversity: it measures trends in populations of vertebrate species living in terrestrial, freshwater, and marine ecosystems around the world. The LPI currently incorporates data on approximately 3000 population trends for more than 1100 species. It is the average of three separate indices measuring changes in abundance of 555 terrestrial species, 323 freshwater species, and 267 marine species around the world. While the LPI fell by some 40% between 1970 and 2000, the terrestrial index fell by about 30%, the freshwater index by about 50%, and the marine index by around 30% over the same period" (WWF *et al* 2004). The LPI is decreasing especially in those areas that are under severe human pressure. The remaining wilderness, where biodiversity is more healthy, can be illustrated using the of areas distance from human settlements, roads, or other infrastructure as a proxy indicator. "The greater the density of population centers or road networks, the lower the wilderness value".

Fortunately, at least for some species obviously suffering from human impact of any type, the population trend has been converted from sharply declining to significantly rising again. It is, for example, quite hard to imagine today that the beaver was once thought to be threatened with extinction due to over-exploitive hunting for its fur. A significant rise in the number of individuals has also been observed for the Black Rhinoceros, even allowing CITES to take up a controlled and limited hunt on the species again as could be found on the worldwide web the day after the decision at the last CITES Congress in Bangkok, Thailand, in October 2004. For instance, the The Endangered Species Act (USA) program delisted or downlisted the Brown Pelican, the American Alligator and the Grey Whale among others due to population recovery.

Ecosystem conversion must not necessarily lead to species loss. Instead, some species even benefit from human impact on their habitat. Whereas some species that have previously been competitors to others are driven away from the area affected, others are less sensitive to human influences and profit from the reduced competition. It is not just widespread generalists that show a reaction like this to human-induced alterations; even some species of specific concern have benefited. After the tremendous 1998 wildfires in Florida that burnt 500 000 acres, for several species of special concern, like, for example, Rugel's False Pawpaw, *Deeringothamnus rugelii* (Annonaceae), a rise in population size could be observed. The lessons learnt by such studies are converted into fire management plans, using prescribed fires as a management tool. In Australia, a continent with numerous wildfires each year, a high proportion of species is somehow adapted to fire. Consequently, planned controlled fires can in some cases be used to combat invasive species that are less fire-adapted, while supporting the native ones. In the same way it can be used to support natural regeneration processes. A similar effect can be observed for prescribed grazing, that is therefore also used as a management tool, e.g. in a project to conserve Bog Turtle habitat in New Jersey.

It is not just controlled activities like those described above that can result in benefits for some species. The same applies to habitat conversions that have no conservation objective as a driver. There are, for example, some epiphytic plant species of the *Bromeliaceae* that are successfully colonizing the power mains of Andean villages. Many different endemic and rare plant species grow perfectly well on rocks on the edges of agricultural land, railways and highways. In the same way, an astonishing amount of animal species benefits from human impacts. They not only build their niches in small villages but also in large towns. Popular examples are the numerous species of bats living in old and unused buildings and in towers of cathedrals. There is a long list of species that are more or less taken for granted in people's surroundings, like doves, rats and mice and in tropical countries maybe geckos and, although less appreciated, cockroaches. All those species preferably sharing human impacted environment are called ruderal species. Considering this perspective, the widely accepted view of having natural habitat and human created non-habitat, loses some of its very base. The concept of creating room for species within human settlements has been introduced by Michael L. Rosenzweig (2003) and named "reconciliation ecology", or "win-win ecology", as both sides may peacefully coexist.

Even species with restricted distributional ranges ('endemics'), often confined to azonal habitats like rock-outcrops or open vegetation formations with higher levels of abiotic stress, are less competitive and can benefit when the extent of 'climax' vegetation is reduced. For example, in South America, highly endemic terrestrial plant species of the dry inter-Andean valleys or the Chaco Dry Forest, such as cacti and bromeliads, have colonized deforested and edaphically degraded areas and are better off than before the human impacts accompanying deforestation, burning, extensive cultivation and cattle grazing. Thus, threat assessments of endemic species must be carried out very carefully. Several authors focused on endemic species in tropical countries, suggesting that most of them are threatened by extinction. However, this statement may be based on false assumptions regarding the sensitivity of endemic species to land-use changes. A small range-size of a continental species does not automatically imply an elevated risk of anthropogenic extinction. As has been said, many endemic plants, especially when adapted to more arid conditions, do not require intact mature forest habitats to survive. Often rare and endemic species are found in habitats where human impact never will rise to critical levels. On Cuba, for example, about 30% of the endemic plants are found within serpentine mountains, where agriculture is impossible. Land-use in endemism-rich regions with high habitat diversity, does not normally convert areas into homogeneous agro-deserts. Rather, a mosaic of cultivated fields, secondary forests, forest remnants and natural non-forest habitats, is created where endemics and other species may maintain viable populations.

It is scientifically supported that the tolerance of species for human alterations of habitat does, at least partly, depend on climatic conditions. Species of arid forest ecosystems of inner-Andean valleys in Bolivia have shown a high degree of resistance to moderate anthropogenic perturbations. It has been shown by that these ecosystems, when moderately altered, are as diverse as nearly intact ones, and still represent centers of endemism. In disturbed dry forests it can be observed that in the more or less degraded matrix nearly all the floristic elements of the mature communities are maintained, even under very severe intervention and degradation. In not very diverse dry forests it can be the same trees species that, under conditions of greater pressure and stress, instead of forming forests, form thickets or scrubland. Conversely, humid forest ecosystems show much more drastic responses to human perturbations. Once the canopy disappears, much more drastic changes are recorded in the species inventory than in dry forests. Normally, the degradation and succession communities consist of species adapted to stress and adapted to drier conditions with more solar radiation; these species seldom occur in mature communities. Pioneer trees and bushes abound, as do lianas. Secondary forests are structurally and floristically distinct. There are also other factors that generate enormous differences between the conservation problems in dry and humid ecosystems. For example, the drier ecosystems contain less diversity but a greater population density of the majority of the plant species. This can also be seen very clearly when comparing forest inventories. While in the Chiquitano Dry Forest, in southern Bolivia, the 10 most common tree species account for 1.8 to 14.6% of all the individual trees, in the Pando Amazon Forests, in northern Bolivia, the 10 most abundant species only make up 0.5 to 3.2%. In humid ecosystems the diversity tends to be high, and in many cases, this is related to smaller and more dispersed populations. Therefore, habitat degradation and reduction can more easily lead to conservation problems for certain species. For this reason, the conservation of species in humid forests requires much larger areas of relatively intact ecosystems.

The phenomenon of rising diversity at a moderate level of disturbance is called the intermediate disturbance hypothesis. It seems to be valid with regard to anthropogenic disturbances and ‘natural’ ones. While several studies support this concept others do not, so it belongs to the long list of heavily debated topics. In conservation activities no difference between background and mass extinction is made. If one realizes in time that a species might suffer extinction in the near future, conservation efforts are focused on the avoidance of its disappearance. At this time it is not questioned whether the species would survive without the root causes of the sixth extinction or would have gone extinct by just losing the fight against natural selection. Recently, in this regard, the first debates are getting started about the legitimacy of saving a species that in a ‘natural’ way just would not survive. The first voices have been heard stating that measures to save threatened species from extinction in fact counteract natural evolution (van Loon 2003), or at least that *Homo sapiens* is intervening in the evolutionary process and this contributes to shaping the biota of the next few million years (Ehrlich 2001; Myers 1997). Applying a strictly evolutionary perspective on extinction and ecological changes, it is difficult to deduce that the action of a species like *Homo sapiens* is not natural. The current mass extinction (that one day might include its major agent) could be the start of a completely new outbreak of evolution leading to innovative forms of life. Thus, it can be considered to be rather difficult to base conservation on ethical reasons, such as intrinsic values and rights to live. It is impossible to derive normative conclusions from the past rise and extinction of life. But it might be more honest and more effective to conserve biodiversity for anthropocentric reasons.

2.3. Stresses, sources and underlying causes of biodiversity loss

It is time to have a look at the causes of the current mass extinction. Today, species tend to go extinct because of anthropogenic threats. Threats are the combination of stresses and their sources. Populations shrink and vanish when they suffer high levels of stress. *Stress* can be defined as the types of degradation and impairment afflicting biological systems such as populations, species or ecosystems at a certain site (The Nature Conservancy 2003). The sources of stress are defined as the agents generating the stresses or extraneous factors, either human (policies, land uses) or biological (e.g. non-native species). The division of the term *threat* into two others has not been done to enhance complexity or confuse but instead to clarify-situations so that problems can be addressed more adequately. A threat could, for example, be a plantation that interrupts an intact forest. But the plantation might be accompanied by several stresses such as increase of toxic substances in the soil going back to a certain source that might be the application of pesticides in the plantation. Seeing the plantation just as a threat, the only solution would be to get rid of the plantation. But total avoidance in many cases does not represent a realistic solution. On then contrary, detailed analysis of stresses and sources allows a much broader range of possible actions to reduce and minimize the stresses. In the given example a more biocompatible alternative to the pesticide could be applied. The concept of identifying stresses and sources instead of mainly threats has been successfully established by The Nature Conservancy and is integrated in the well established 5-S approach, a method to support strategic site conservation planning and the measurement of conservation success.

The underlying causes of biodiversity loss prompt the following question: Where do the sources of the stresses come from? And as the term *stress* mostly refers to anthropogenic impacts (even non-native species mostly reach new areas after having been transported by human beings) the question above could be asked in more direct words as well: Why does the most intelligent being on Earth threaten its life maintaining base? Here it is getting obvious: Defining *Homo sapiens sapiens* as the biggest threat to biodiversity without differentiating stresses and sources would leave a single solution: getting rid of the *Homo sapiens sapiens*. This is why it is generally preferred to analyze the underlying motivations of humanity that keep causing sources of stress to biodiversity.

Conversion of natural habitat is a general expression for different types of activities that are changing the conditions of untouched habitat. Stresses can therefore be very different too and in the following section several will be mentioned. The underlying causes may certainly be and often are locally expressed but in general they reflect a serious global problem: More and more space and resources are needed to cope with alimentary and spatial requirements of the world's growing human population. By 2050, the Earth may be forced to hold approximately 9 billion human beings (Cohen 2003), all of them asking for a place to live, food, energy and the highest possible quality of life. The ongoing ecosystem conversion is a major concern of everyone who is aware of the immeasurable goods and services provided by intact ecosystems. But as long as alternatives are missing and the world's population is growing, the-situation can hardly change for the better. A plethora of specialists is working to find a solution to this misery—there are approaches to maximize crop yields, save energy, reduce over-consumption of resources, optimize resource distribution, etc. Nevertheless a high degree of insecurity exists about how future life on Earth will be for the living organisms of this planet, human as well as non-human beings. McKee *et al.* (2003) developed a model for the relationship between human population density and the number of threatened mammal and bird species by nation. Their findings confirm that abating human population growth is a necessary step to conservation of biodiversity on a global scale. For successful achievement of this aim work has to be done on a variety of societal levels: religious, ethical, political, historical, and many more.

In some cases habitat conversion means complete destruction. Here the stress for the species affected does directly coincide with the source and could therefore be replaced by the term 'threat': it is the destruction itself. Nevertheless, the surroundings of the destroyed natural habitats are stressed too, due to the same source but without coincidence with each other (e.g. edge effects, fragmentation, etc.).

The prime example for habitat destruction as such is doubtlessly deforestation. The news talks about the daily number of soccer field areas of forest that disappear from satellite images (Marijnissen *et al.* 2004): globally 32 soccer field areas of forest each minute. Metaphors like this are needed to make this magnitude tangible because the pure km² size is just a long line of numbers not connected with any idea of area size in our minds. Depending on the type of deforestation (e.g. slash-and-burn agriculture) the consequences for the surrounding area and its fauna and flora may vary. Stresses for different species can arise in countless forms: reduced soil water storage capacity, interrupted migratory pathways, reduced population size of pollinator species, suddenly exposed nesting sites, etc. The underlying causes are obvious and have been mentioned already: rising demands for space and natural resources. The occupation and alteration of undisturbed areas is required not only for the expansion of agricultural activities to feed the growing human population, but also for growing cities of the urbanizing world, for the extraction of renewable and non-renewable resources, such as timber, oil or metals. Other sources of relevant stresses to biodiversity are withdrawal of water, and pollution of water, soil and air.

Exploitation of natural resources can be interpreted as a reduced form of destruction. The difference is to be found in the degree of selectivity: Exploitation mostly refers to the selective extraction of commercially used species from their natural habitat. For the species affected the stress may again coincide with the threat (if not only 'parts' of organisms are extracted) but unlike complete disturbance in this case the impact of the stress on the surroundings is also generally lower and more selective. Wildlife trade in total, meaning the trade in cultivated species as well as those taken from their habitat, represents an important branch of economic business. Between 1996 and 2002, the 15 EU member states imported, for example, six million live birds, 1.5 million live reptiles, around 10 million reptile skins, 21 million orchids and 572 tons of sturgeon caviar. Unfortunately, not all of these species are sustainably conserved. Instead, the recognition of the potential threat which the exploitation may result in for many of those species, has led to CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and in USA the ESA initiative (Endangered Species Act), aiming to establish some form of control system for wildlife trade. There are many countries not signed up to or properly implementing CITES, however, and the extent of illegal trade and over-exploitation of plant and animal species is still of major concern to conservationists.

Some illegal trading is rooted in the need of people for medicinal help and alimentation, and therefore reflects a major societal and political problem: the lack of capacity to keep up with human necessities and even to distribute available resources adequately. But there are other reasons for over-exploitation such as trophy hunting and the demand of people for collecting and keeping certain species as pets—maybe for their rarity, luxury, fashion status or alleged properties. For these exceptional fancies, some stakeholders are willing to pay huge sums of money and this keeps the business going and makes it increasingly difficult to stop or control. The attraction of high rewards and low risks increases the involvement of organized networks, gangs and ultimately serious and organized crime groups—the latter at the high end of wildlife smuggling. Donovan Webster (1997) wrote in the New York Times about the year 1996: "Between $10 billion and $20 billion in plants and animals were traded illegally around the world last year, with the United States leading the list of buyers, at about $3 billion". For a single example of the last hyacinth macaws inhabiting the tropical savannas and forests e.g. in Bolivia, one can receive US$40 000 on the black market (in this country people live on a monthly salary of about 54 US$, and in rural areas even less). In Kyrgizstan up to US$11 000 can be charged for one live specimen of the snow leopard. These are just two examples from a long list. The remaining commercially exploited species face a serious stress: reduced number of reproductive partners, which means reduced probability of successful reproduction. The underlying cause in this case is the wish of people to own something rare and precious or to kill a wild animal that is usually stronger than the human. The underlying cause could thus be simply named the feeling of power.

Wildlife trade may also have a negative side effect that does not so much affect the traded species but rather human health and economy. It was stated that there is a strong likelihood that the SARS corona virus originated from wild animals that were traded in China for food. The disease resulted in a global economic loss of about US$ 50 billion in 2003.

Another significant problem is the so-called introduced alien species (IAS) turning into invasives. With the increase of long distance travel, the transport of species from one place on Earth to another increased enormously. In some cases the introduction and release of non-native species was part of a biological experiment that went wrong after a while (e.g. introduction of *Spartina alterniflora* to check erosion. In other cases alien species are introduced or at least released more or less by accident to some non-native habitat, even by tourists. It then depends on the degree of coincidence between the site conditions and the species' preferred conditions, and the competitiveness of the native species. These factors will determine whether a non-native species will remain without significant effects for the native flora and fauna or will become an invasive species. Although only a comparatively small fraction of introduced alien species become invasive, studies in USA and India have shown that the economic costs of IAS in these countries amount to approximately US$130 billion per year. In the UK alone, 3000 introduced alien plant species (mainly introduced by gardeners) had been identified by 1999, many of them causing environmental damage while showing high resistance to virtually all herbicides. The stress for native species may lie in reduced availability of resources when the invasive species uses the same resources and thus trigger competition. This may easily happen, as space to live is one of the most important basic resources. Studies about the invasive potential of IAS and the ability to buffer or adapt to them by native ones are aiming to increase knowledge and understanding about IAS, leading to development of appropriate management strategies. At the same time specialists are debating the actual danger of invasive species as they often co-occur with severe habitat alteration which could then be the reason for the loss of native species. As the topic is still gaining rising awareness and consequently the number of studies on IAS is still rising, more and more IAS that are potential stressors for native species are identified. Much more research will be needed to enable appropriate proactive management of IAS. The Global Invasive Species Programme (GISP, see www.gisp.org), an initiative of several key partner organizations, was established in 1997 to specifically address global threats caused by IAS and the development of possible solution mechanisms.

The last line of examples of possible sources of stressors to species is the phenomenon that is just starting to be recognized as a global concern at every societal level: Global Climate Change (GCC). The last voices of doubt are becoming quieter, and the amount of scientifically significant evidence is rising. Species ranges are shifting, flowering and migration seasons start earlier than before, and the sea-level is rising. As there is no simple stop-button for GCC, development of the best way to handle, manage, prepare for and deal with it is in full swing. Glaciers and polar ice-caps are melting, and different areas of the world are expected to become warmer, drier, colder or wetter, depending their geographical location. The concentration of carbon dioxide and several other gases in the atmosphere is changing. Global average temperatures have increased by 0.6 °C within the last 100 years and are expected to keep on rising for another 1.4 to 5.8 °C over the next 100 years (IPCC 2001). Projections for further development as a result of studies conducted in the Arctic paint a seriously concerning future: coastal communities and facilities face increasing exposure to storms; elevated ultraviolet radiation will affect people, plants and animals; forest fires; insect infestations and a long list of other disturbances. These are all projected to increase in intensity and frequency (ACIA 2004). Severely degraded areas are likely to become even more susceptible under predicted climate change scenarios.

For species a rise of mean temperature may turn out to become a stress when it suffers a lack of capacity to move to another place accompanied by a lack of capacity to adapt. The first shifts of habitat ranges have been observed: several European grassland species in the Alps have been observed 'creeping up the slopes' at a rate of about 4 metres per decade, responding to a 0.7 °C temperature increase. This is possible as long as it goes further up, a fact that is determined by the mountaintop. Furthermore, with higher altitude the area of space to live decreases. Simulations of a model for long-term trends in plant species distributions in Amazonia revealed that the distributions of 43% of plant species could change so drastically that they will be non-viable by 2095. Obviously, the effects of GCC will be much more complex and subtle than the simple shifting of ranges, especially when the change of interactions are taken into account. Structures and functions of communities and ecosystems are expected to change due to the changing viability of certain species and life forms. For example, there are signs that in the humid Amazonian forests there is an increase in the dominance of lianas. This could be a consequence of an elevated water stress and a symptom of the degradation of these forests, as lianas tend to increase the mortality rate of trees. Obviously, impacts with a rather sophisticated origin can occur, e.g. through climatic fluctuations affecting the availability of prey, periods of reproduction, etc. The synergism of the temperature increase and other stress factors like the conversion and fragmentation of natural ecosystems, can lead to the rupture of many interrelations between species, and a recombination of biological communities (Root *et al.* 2003).

It is very likely that the impact of GCC will be powered by local and regional climate changes caused by the alteration of land-use. In Costa Rica, it has been observed that the montane forests suffer climatic changes generated by the deforestation in the lowlands. In this case, the air warms up more over the deforested areas and rises to higher altitudes. As such, it no longer carries the humidity needed at the first condensation level, leading to a drastic change in humidity in the corresponding montane forests. This may be an important stress causing the observed disappearance of cloud forest species such as amphibians.

Until now, models of climate prediction have not managed to consider all the systemic feedback effects between vegetation, change in land use, and local, regional, and global climatic changes. However, there are models showing that in the Amazonian forests fatal effects can be produced once the forest is reduced to below a critical mass. This is even more crucial, because the rainfall in large areas such as the Amazon only surpasses by a few millimeters the critical value that allows the maintenance of humid forests. Here, a fall of 100-200 mm could cause the collapse of the humid forest (up to 40% of the Amazonian forests, especially in view of the increase in drought during the drier months along with an increased sensitivity to fires). This increased sensitivity to fires occurs especially in the drier years that are caused by climatic phenomena like the El Niño – Southern Oscillation "ENSO", (which could also occur more frequently due to anthropogenic climatic changes. The most serious forest damage caused by fires has been recorded in years influenced by ENSO. Also, forests that have suffered fires beforehand burn more easily. It is also known that there are positive feedback effects between fragmentation, reduction in rainfall, and fires.

Numerous methods to assess the vulnerability and responses of species and ecosystems to predicted climate change scenarios are currently in development and being tested in case studies (e.g., Thomas *et al.* 2004a). In actual fact the effects of climate change on shifts in species distributions are no longer theoretical but have been deduced exclusively from paleoecological data. The GCC has already left its "fingerprint" on the ecological systems of the planet: distribution range increases of 200 km to 1000 km (in 40 years) towards the poles have been documented. There is an average displacement of 6.1 km/decade towards the poles (or meters/decade towards higher elevations in mountains) (Parmesan and Yohe 2003).

The first negative economic consequences of GCC have already been identified for humans, e.g. the reduced productivity of ecosystems or ever-increasing damage of property by extreme weather events. Maybe economic deficits and risks such as this will finally be able to wake up the last disbelievers on the immense effects of Global Climate Change for human welfare.

2.4. Biodiversity loss as a self-enhancing process, the Earth's biological capacity and humankind's ecological footprint

The loss of a single species may happen unrecognized and without many further consequences. Ecosystems have never been stagnating but are in a constant dynamic and there have always been species vanishing and others arising. These dynamics may be connected to natural selection processes as well as to naturally changing habitat conditions. As long as those changes do occur within a certain frame in magnitude and at a pace that can be followed up, a healthy ecosystem will be resilient enough to buffer them. The problem is that we hardly know anything about the thresholds that should not be passed to ensure maintenance of ecosystems and their functionality.

It is pretty well known that the extinction of a species or the change of a certain habitat condition, in some cases, is the first stone of a domino game, triggering a whole wave of extinctions and in the worst case ending up in the complete collapse of the whole ecosystem. This in turn, would mean a loss of ecosystem functions previously provided, like purification of air and soil, protection against erosion, buffer against weather extremes, source of natural resources and even space for recreation and relaxation.

A very demonstrative example is the eutrophication of lakes: rising nutrient concentration as a changing component is more or less tolerated up to a certain degree. Then the lake shifts abruptly from clear to turbid, a phenomenon that is followed by the disappearance of the majority of submerged macrophytic vegetation resulting in the loss of those animal species depending on higher plants. Clearly, this issue is concerned with interactions and dependencies. And nature holds countless examples of both of them. Interactions may be intra- or interspecific, while dependencies include those concerning other organisms or biotic components as well as those on abiotic components such as climatic or geomorphological conditions. Intraspecific interactions include, *inter alia*, the exchange of genetic material, upraising, feeding and mating behavior. Interspecific interactions may refer to symbiotic or mutualistic relationships amongst many others. Many types of interactions can already be regarded as dependencies between organisms and they usually comprise the pieces of a whole web of interdependencies. One popular example to be given at this point is represented by the complex food web structures that can be found everywhere in natural ecosystems. Taking out one piece of such a complex system may still leave sufficient alternatives for the remaining species to replace the missing part. But again it is unknown whether some parts are more essential than others or which minimum fraction of the whole system needs to be maintained to avoid a complete crash. This is the crucial point of discussion in current debates about the relation between ecosystematic complexity and stability. Studies are being carried out to gain knowledge about the influence of separate aspects of ecosystem change on demography and extinction risk of species and ecosystem functioning. Results from those studies are then used to develop methods to model and extrapolate the probability of cascades of extinctions due to the loss of important components or massive conditional changes (see, for example, Allesina and Bodini 2004).

A selection of study results will be presented by looking at the effects and consequences of forest fragmentation—the split up of initially connected habitat into smaller pieces. Such an event causes not only subdivision of species populations but in some cases also genetic effects. There may also be severance of migration corridors separation of pollinators from host plants, and many other possible consequences. A study on the impact of forest fragmentation on understorey plant species in Amazonia revealed that the life-form composition and structure of the regenerative plant pool in fragments were shifting toward a species-poor seedling community. It was concluded that 'losses of understorey species diversity, but especially of tree seedlings, threaten the maintenance of rainforest biodiversity and compromise future forest regeneration'. Several insect-pollinated plant species in fragmented habitat suffer lower pollinator visitation rates and thus reduced seed sets and, if self-compatible, partly even reduced genetic variability as a consequence of increased inbreeding; this can clearly negatively affect the species' fitness. For exactly the same reason, it has been proven that corridors connecting habitat patches may be a key element increasing the chance of persistence of plant species by promoting seed dispersal between habitats. In general, not only the patch size of remaining forest may be of importance to species but also the possibly occurring side-effects of fragmentation such as reduced density of understorey vegetation. Furthermore, the subdivision of intact forest into smaller patches is certainly accompanied by increased edge exposure and thus as well to (micro)climatic impacts. Whereas most of the studies on consequences of fragmentation focus on plant and animal species, some recent results also reveal significant alterations of nutrient cycles and thus changes of abiotic components.

The importance of maintaining mutualistic interactions to preserve natural communities can also be demonstrated using the example of invasive species. It was proved that the invasion of South African shrublands by the Argentine ant (*Linepithema humile*), causing a disruption of important seed-dispersal mutualisms, induced a shift of the composition of the plant community and significant reduction in the densities of large-seeded plants. At this point, the differentiation of generalists and specialists is crucial. A model set up to assess the co-extinction of affiliate species and their hosts was used on a wide range of coevolved interspecific systems, such as parasites and their hosts and butterflies and their host plants. An estimated 6300 affiliate species were shown to be possibly co-endangered with their currently endangered-listed hosts. Projections from a stochastic model on the change of global avifauna indicate the extinction of 6 to 14% of all bird species by 2100 accompanied by another 7 to 25% of bird species being functionally extinct (Sekercioglu *et al* 2004). The authors conclude that 'important ecosystem processes, particularly decomposition, pollination, and seed dispersal, will likely decline'. Thus we enter the next level of consequences from biodiversity loss—the loss of ecosystem services. Human impact and alteration of ecosystems may lead to reduced resilience against changes that could have been absorbed before (Folke *et al* 2004). Numerous examples have already shown that the complete loss of ecosystem services can easily end up disastrous. Floods could have been prevented by intact ecosystems and the damaging power of storms buffered. The estimated sum for the material damage of catastrophes that could have been avoided is used as a political instrument for negotiations about conservation issues. By quantifying the material value of ecosystem services conservationists are trying to clarify the importance of intact ecosystems and thus raise public awareness for the topic. But it is exactly this quantification that holds huge difficulties. While after a catastrophe, the material value of the damage can be calculated comparatively easy, doing this in advance to illustrate what damage could be avoided remains an exceptional challenge. Attempts to do so include qualitative studies, e.g. questioning how much humanity would be willing to pay for resources that can usually be provided by intact ecosystems, such as drinking water. Due to the holistic, hardly manageable intricacy of natural systems, however, large scale predictions remain vague.

Without any doubt, there will be a final carrying capacity of the Earth to guarantee all living people a healthy and enjoyable life under ever rising stresses and pressures. There is increasing concern about the endurance of several natural resources and services, while in many regions people are living on a far lower standard and currently derive little benefit from those resources. This means the resources available may not even sustainably feed the demand of those people having access to them. It is necessary not only to enhance the livelihood in the developing countries but also to prepare for approximately 3 billion more people that will be interested in acceptable living conditions. How can this be achieved with the continuing loss of resources and services as consequences of declining biodiversity and collapsing ecosystems? The countries consuming the highest amount of natural resources are obviously the industrial ones, whereas many of the developing countries are economically dependent on them. So for example in the race for new sources of oil, who should care about conservation of biodiversity and thus also global climate: the countries in urgent need of the oil or the ones dependent on selling some?

Using the Ecological Footprint concept, some researchers have tried to demonstrate and quantify the carrying capacity of the planet, and the overshoot of the current use (e.g. Wackernagel and Rees 1996). Adopting the Ecological Footprint methodology, WWF *et al.* (2004) and WWF *et al.* (2002) showed that humankind, in the late 1980s, with the prevailing demand for renewable resources and space, exceeded the carrying capacity of the Earth. "In 2001, humanity's Ecological Footprint was 2.5 times larger than in 1961, and exceeded the Earth's biological capacity by about 20%. This overshoot depletes the Earth's natural capital, and is therefore possible only for a limited period of time" (WWF *et al.* 2004). The global Ecological Footprint grew by 70% from 1970 to 2000 (with the growth in the world's human population of 65%). This increase can be compared to the decline of the Living Planet Index mentioned above.

The United Nations has recently defined the so-called Millennium Development Goals to be achieved by 2015 (http://www.un.org/millenniumgoals/): these comprise a wide array of development challenges, from "Eradicate extreme poverty and hunger" to "Ensure environmental sustainability". The Convention on Biological Diversity, in decision VI/26 of the Conference of the Parties adopted a Strategic Plan. In its mission statement, the Parties committed themselves to a more effective and coherent implementation of the three objectives of the Convention, 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. This target was subsequently endorsed by the World Summit on Sustainable Development in Johannesburg (http://www.biodiv.org/2010-target/default.asp). Enormous tasks are lying ahead.

3. Halting biodiversity loss - conservation planning and implementation

3.1. Targets and visions of biodiversity conservation: conserving structure, patterns or function? Current manifestations or evolution?

The history of biodiversity conservation, as sketched above, clearly indicates the long way to go to reach understanding that biodiversity should be the general object of 'nature' conservation. In the past, the different epoch's conservation objectives changed according to cultural and scientific trends. Conservation had distinct peculiarities, such as romantic preservation of homeland and beautiful scenery, protection of the most charismatic animal species or the maintenance of especially biodiverse ecosystems. But what does this mean for the definition of conservation objectives? What are the conservation targets?

Conservation targets and priorities, unfortunately, must be defined, yet it is a fact of life that an Earth that carries a certain quantity of humans who require goods and services to be provided by anthropogenic ecosystems, such as agricultural or urban land, must suffer the conversion of natural ecosystems, and, hence, the loss of native biodiversity. Additionally awareness is required towards the fact that conservationists count with only limited resources which of course are expected to be applied in the most efficient, effective and strategic way. Thus, it is the tragic task of conservationists to select what they want to conserve—and selecting means sacrificing what is of lower priority. Conservationists who do not acknowledge this basic law of conservation are doomed to severely suffer from disillusion or to become a victim of misanthropy and might develop an anti-human cosmo-vision.

From an ethical or religious point of view it might be correct to claim that all the different manifestations of biodiversity have an intrinsic value and that humans shall not judge if another species can continue its evolution on Earth or not. But from a humanistic perspective that accepts the right of human beings and cultures to exist (or maybe only being pragmatic) it is impossible to target the conservation of 100% of biodiversity. Biodiversity loss, in the sense of reduction of extent of ecosystems, loss of genetic diversity of populations and even loss of species, cannot be halted unless the number of human beings and the consumption needs of individuals stop growing. As mentioned above, there is no alternative to defining conservation as a cultural concept orientated to nature and the needs of biodiversity, including humans. Realistically, the concrete goal of biodiversity conservation cannot be the final salvation of the world and its biodiversity. At the moment, it is an urgent task to save as much biodiversity as possible until humanity can (hopefully) implement a wiser use of the globe's resources than today. The hope is that the savable will be sufficient to satisfy the fundamental needs of future generations. "On a planet that is increasingly overcrowded with humans the survival of biodiversity will ultimately hinge on utilitarian, particularly economic, imperatives" (Myers 1996).

Sometimes, conservationists tend to think that conservation visions and targets are just given by nature, and that all people feel the same about their decisions. This is a common misunderstanding because the cultural quality of conservation—that implies that every decision must be subjectively influenced by individual or societal preferences and needs—is neglected. The natural laws are not normative with regard to conservation and priority setting. Thus, priority setting must be based on the best science available, which, however, can never lead to entire objectivity. Finally, what can be conserved is only what *people* want to conserve. Why conserve what? This is a central question to be answered if conservation action is to be implemented in a strategic way. If the targets and objectives of conservation efforts are not well defined, the subsequent implementation of action may not be measurable or effective, and it can be very difficult to communicate to humans who are, as mentioned before, not *natural* conservationists.

Traditionally, conservation priorities were defined according to the presence or absence of certain taxa. Shifting to the biodiversity approach meant that spatial biodiversity patterns like species-richness and endemism came into the spotlight. The hierarchical levels of biodiversity above the species, such as communities or ecosystems, received some attention as well.

The focus of conservation planning had been clearly set upon aspects of ecological and biogeographical patterns rather than processes, as pointed out by Rouget *et al.* (2003). However, it is the ecological and evolutionary processes that finally represent the mechanisms of biodiversity maintenance. It is important that the simple representation of biodiversity features and samples, e.g. in protected areas or zoos, requires less space and less effort than the long-term conservation of viable biological systems. Thus, it is a rather recent insight that interactions and processes must be taken into account in conservation planning (e.g., Rouget *et al.* 2003).

Several authors claim a change of paradigms from feature-centered protection to a functional approach of conservation. Bowman (1998) even provokes conservationists with his article "Death of biodiversity—the urgent need for global ecology" stressing the need of the conservation of the endangered geochemical cycles of the biosphere: "I believe that focusing on global biogeochemical cycles such as carbon, nitrogen, oxygen and water, will necessarily result in the conservation of landscapes and therefore entire ecosystems and their component diversity".

The selection of conservation targets is a crucial step in the design of conservation strategies that used to be somewhat intuitive at first, but has then been developed systematically under certain conservation approaches (e.g. 5-S-approach proposed by The Nature Conservancy). Conservation targets are selected biodiversity elements that represent biodiversity as a whole so that ecosystem functionality remains when only the targets are conserved through specific actions. A conservation vision is an anticipated ideal or desirable state of the conservation targets (and the landscape in which they are embedded), and that should be achieved by the implementation of the current and future conservation action.

An important question is whether ecological processes can be taken into account as conservation targets. Traditionally, tangible elements of biodiversity, especially species, groups of species, or guilds were selected. There are different approaches to identify the most appropriate species targets that should serve as key, umbrella or focal species (compare Groves 2003). A fear has been expressed that by targeting ecological processes a substantial biodiversity loss could be tolerated, as explained by Margules & Pressey (2000): The "major concern is that it is possible to maintain ecosystems in which measurable ecological processes appear to function properly, yet the biological component of these systems could be substantially impoverished due to losses of native species and introduction of exotic ones". Theoretically, it might be possible that processes can be maintained or re-established without the need of conserving all the original biodiversity elements, especially in rather simple and anthropogenic ecosystems. For example, in a dry forest, the functions and services provided by a native legume tree could be replaced by an introduced species (e.g. an *Acacia* producing fodder and improving soil quality within agro-ecosystems). In very diverse ecosystems with generally low abundance of the different species, many functions tend to be product of multi-species (inter)actions. However, in many ecosystems, the key holders of ecological functions could be replaced without greatly affecting the outcome (e.g. interception of precipitation by cloud forests, soil erosion control). Thus, an important issue is to define what is preferable: conservation of some or many non-functional biodiversity components of an ecosystem or a functional system where some key functions are provided by originally non-native species, but where hopefully many species can persist and continue evolution. The more complex a natural system, the more difficult is the imitation of the different functions by designing the ecosystem with introduced species. Even if a certain species can be replaced by a functionally similar one the further consequences for the entire system remain unsure as the identification of all (inter)actions of one species with its environment is an enormous challenge. Especially, when evolutionary processes of native organisms are included as a conservation target, their conservation means the maintenance of those species that are expected to continue evolution, and, thus, the idea of replacement is inadequate.

The higher the hierarchical level of a biodiversity element the more it includes processes and functional aspects. Ecosystems include the interactions of its species and the abiotic factors, and recently, meta-ecosystems have been defined as another complex level of biodiversity, being based on processes: "Meta-ecosystems can be defined at different scales, again depending on the kind of organisms, ecosystems and processes considered… For some processes, however, such as spatial flows driven by highly mobile animals or global biogeochemical cycles involving large-scale air or sea currents, the meta-ecosystem concept could legitimately be applied at the regional or global scale, well beyond the conceptual arena of landscape ecology, as it is usually defined" (Loreau *et al.* 2003). Actually, it might be elegant to define meta-ecosystems as tangible conservation targets, and include thereby biological and ecological processes as integral part of them.

A polemic example question could be: What is more important? The functional cloud forest or the diverse cloud forest orchids? Orchids represent the most species-rich plant family. However, they seem to provide only a few goods and services for other species. They are especially diverse and abundant in tropical montane rain forests, including many charismatic and endemic species. Clearly, the presence of this kind of species leads to a prioritization according to traditional conservation approaches. However, without many doubts, the montane rain forests with all the other plants and vertebrates and even practically all the invertebrates could persist as a functional system if you take out the hundreds of species of orchids. On the other hand, the orchids cannot exist without functional montane rain forests with many critical requirements regarding microclimate, the presence of phorophytes on which they can grow, fungi that facilitate their germination, and a variety of insects and maybe birds that serve as pollinators. It is definitely very important to wonder which kind of ecosystem is more valuable—the species and endemic-rich or the functional. Of course, ideally, the whole forest system including the orchids should be conserved, and the question of whether the orchids can be taken out should not arise. However, in the case of two cloud forest ecosystems, one less intact and less functional but with a much higher orchid diversity than the other, the priority setting could be much more difficult.

The orchid-cloud-forest-question comprises more polemic facets: What is to be prioritized? The functional system that is currently not threatened or the highly threatened biodiversity that already might have lost its viability? This question leads to the hot- versus cold-spot debate. Hotspots are promoted by the conservation NGO Conservation International and are very important in the global conservation priority debate (Myers *et al.* 2000). They represent regions with a rather high diversity and endemism of certain indicator taxa, and which are threatened by human action. Rather recently, Kareiva & Marvier (2003) criticized the approach by pointing out that it is not a sufficient conservation vision to conserve a tiny portion of the globe's biodiversity, especially in those regions where it is densely concentrated. They argue that conservationists should not focus on the conservation of hotspots at the expense of addressing other important concerns, including the need to maintain "services" that natural areas provide. "Because many conservation threats are now global in their origin and scope (for example, climate change and invasive species), place-based priorities risk disenfranchising too many people from the challenge at hand. Indeed, on reflection, we worry that the initially appealing notion of getting the most species or greatest biological value per unit area is, in fact, a thoroughly misleading strategy. How much of a victory would it actually be if people did manage to conserve only the 1.4% of the Earth's land surface that contains almost half the world's vascular plants? The reality is that people must make conservation progress everywhere. Doing that requires not a ranking of theoretically deserving places but a prioritization that takes into account the effectiveness of past conservation efforts. Although biodiversity hotspots are indeed an academically appealing idea, blind adherence to this mantra runs the risk of leaving the world with a sizable collection of species in a few areas but with an environment that is otherwise largely degraded. Rather than trying to identify dense concentrations of species on a map, we and other conservationists should be more flexible and should be prepared to reward effective actions on the ground as they happen. If we do so, we will surely discover plenty of coldspots deserving of our attention".

As it is a criterion of the hotspot areas that its biodiversity is highly threatened by human activities, additionally, it is doubtful that the hotspots' biodiversity is the most functional and viable. Thus, the question arises whether in the hotspots there will be conserved many "living deads" instead of species that can continue evolution. It becomes increasingly clear that conservation should turn its focus to maintaining or enhancing the adaptability of biological systems to (natural and human-induced) changes of the environment. This means conserving evolution instead of taxa.

If aiming to conserve evolution, it is easy to arrive at some seemingly absurd reflections: Evolution means speciation and extinction. Extinction of certain organisms may enable the rise of new life forms; or, vice versa, new types of organisms, due to their more effective resource use mechanisms or more efficient reproduction, can drive out older taxa. But does the conservation of evolution mean that extinction should actually be conserved too? Indeed, evolution has 'benefited' by mass extinction events, in the sense of a net gain of complexity and diversity after extinction. Van Loon (2003) formulated a corresponding provocative thesis: "It is an interesting thought that modern man, *Homo sapiens sapiens*, would most probably not have developed if there had not been a mass extinction at the Cretaceous/Tertiary boundary that created apparently optimum conditions for the further evolution of mammals. This should make man much more humble than he is, and make him more reluctant than he is with respect to his present-day efforts to influence the evolutionary process… Measures to save threatened species from extinction do, however nature-friendly they may seem, in fact counteract natural evolution… If extinction takes place at a natural rate, it is to be expected that new species also will appear at a natural rate. Then why save species that might have become extinct for natural causes? It is difficult to imagine that the introduction of 'extinct' plants (the seeds of which had been stored in seed banks) in an ecosystem that has gradually evolved in a natural way would be in the interest of the ecosystem involved. Most Earth scientists, who are used to including time factor in their considerations about natural developments, would not consider an introduction of species from 'another time' advisable." Van Loon distinguishes a natural extinction from a man-made. But if we consider the anthropogenic mass-extinction as natural, because *Homo sapiens* himself is a product of evolution, any currently observed extinction event can be important for the progress of the evolution of life, increasing the chance of occurrence of highly innovative life forms.

Obviously, this train of thought leads to questioning traditional conservation imperatives derived from ethical considerations, and may facilitate an anthropocentric conservation approach: When evolution does not 'tell' mankind what to conserve, humans should define the conservation targets mainly according to their needs with regard to the actual or potential use of biological and ecological resources (goods and services). And in this context it even makes sense to store seeds of almost extinct species in seed banks—not in order to influence evolution as complained by van Loon, but in order to save a potential resource for future generations.

In this context, as well, it is relevant to reflect whether conservationists should try to restore lost ecosystems or re-establish historical conditions of certain ecosystems. The same conclusion as above is valid: there is no evolutionary necessity or imperative recommending storage of past landscape in an open-air museum, but if human societies decide that they want to enjoy and learn from historical (and cultural) landscapes, then conservationists should conserve or restore them. But clearly, the accomplishment of this documentary conservation vision is a purely cultural endeavor based on a subjective decision. And, considering the limited conservation resources—it must be carefully weighed up whether a certain historical restoration measure has a high priority in comparison to the maintenance of a functional ecosystem. Sometimes the discussion of conservation visions should be more complex and self-critical than many conservationists think or prefer.

3.2. Strategic conservation planning and implementation

Once the conservation visions and targets are defined, the first step towards a conservation strategy is made. A conservation strategy is a broad course of action intended to achieve a specific objective (i.e. outcome) that abates a threat or enhances the viability of a conservation target (TNC 2003). Thus, subsequent steps are the definition of the objectives and potential actions that might accomplish them, taking into account the current contextual-situation that generates an undesirable state of the conservation targets. Modern conservation strategies, such as the 5-S-approach suggested by The Nature Conservancy, try to be cyclical, integrating a monitoring and evaluation system in order to detect if the implemented action generates the intended positive effect on the status of the conservation targets. If this effect is not observed the strategy must be adapted. Adaptive management is a key characteristic of modern conservation approaches, such as the ecosystem approach (see below).

If conservation strategies are designed for larger regions, the spatial component of the planning is of special importance. Spatial conservation priority setting, in the beginning, especially meant the identification of areas that should become formally protected. First, scientists developed methods to guarantee an adequate representation of all species within protected areas. From the late 1980s this kind of analysis was called gap analysis (e.g. Jennings 2000). Another complementary approach seeks to represent surrogates for the majority of taxa, especially when the knowledge of the totality of the species is poor. The most effective selection of a minimum set of adequate sites that should become protected developed to a sub-discipline of conservation biology applying a variety of algorithms for the reserve selection (e.g. Margules *et al.* 1988, Brooks *et al.* 2001). Normally, gap analyses are carried out with better-known groups, such as birds, mammals or terrestrial vertebrates (e.g. Brooks *et al.* 2001). As the distribution of taxa, in many regions, is only deficiently known, gap analyses are developed referring to higher hierarchical levels of biodiversity, such as ecosystem types (mostly indicated by vegetation types). A more complex approach simultaneously considers different levels of biodiversity and even takes additional information into account, e.g. on the threat status of the studied biodiversity elements. Coarse and fine filter are differentiated, meaning analyses of coarse elements like vegetation or landscape types, and fine elements especially related to species, species richness, endemism, critical habitats or minimum habitat requirements of viable populations. The combination of fine and coarse filter analyses is widely accepted and is the basis of the US *National Gap Analysis Program*. This program, from 1987 onwards, has been an important motor in the development of the science of gap analyses. It is an initiative that continually develops, adapting to improving information availability, and that tries to homogenize and standardize the applied methods.

However, sophisticated gap analyses, that are developed as high-quality academic exercises, have an inherent risk of forfeiting potential for practical application. The mathematical calculation of a minimum set of representation of species within protected areas will not have any value if it does not take into account additional criteria related to biological processes, shifts of distributional ranges, and especially patterns of human land use. By integration of information on the distribution of land properties, a gap analysis becomes more realistic (e.g. Wright & Scott 1996). In this context, it is important to acknowledge that a gap analysis is not a conservation plan, but can be a useful tool in such a plan (e.g., Pressey & Cowling 2001).

Gap analyses have been very important for the development of spatial conservation planning. Nevertheless they also created an exceptional focus on protected areas while ignoring alternatives or without studying whether identified conservation targets will really be better off due to their occurrence within a protected area (or if they require different conservation treatments). Another negative outcome is the concentration on current distribution patterns of biodiversity neglecting the dynamics of biodiversity in space and time, besides aspects of viability and functionality. In fact, there can be a gap because of the lack of representation of a certain conservation target within well-conserved land, but the gap may also exist because of the lack of connectivity between two populations or two patches of a certain ecosystem type. Actually, the gap analysis concept bears many possibilities to be developed as an integral conservation planning tool. Indeed, conservation planning has become a rather complex and complete science: "Pictures are beginning to take shape of approaches that combine statistics, GIS, selection algorithms, decision-support systems, population viability analyses, metapopulation models, expert workshops, ecosystem management, and experience in making conservation happen on the ground" (Pressey 2001).

An important recent trend is the development of an increasingly holistic perspective in conservation planning, taking into account larger dimensions of space and time. This is especially important in the face of the dynamic character of biodiversity. Paleoecological data prove that species act in a very individualistic manner and thus make up communities and ecosystems that are much more ephemeral than had previously been thought (Bush 1994). For continental regions, the species' ability to shift their distributional ranges in response to changing habitat conditions, e.g. due to climate changes, has always been a key condition for functionality. Recent knowledge on the probable anthropogenic climate change clearly reveals that conservation of biodiversity must guarantee the opportunity for species to move through the landscape. Thus, regional or macro-ecological conservation approaches are required in order to enhance the ability of biodiversity to adapt to accelerated climate changes (compare e.g. Noss 2001). Regional biodiversity management is therefore a key element of climate change-integrated conservation strategies, as suggested e.g. by Hannah *et al.* (2002).

In the framework of all macro-ecological approaches —as a matter of fact there are different schools, such as ecosystem management, bioregional or ecoregional management—the conservation objectives are more integral and more ambitious than they used to be in the context of classical conservation visions that focused merely on the representation of current patterns of biodiversity. Some approaches increasingly recognize the systemic characteristics of biodiversity and its threats, giving a proper weight to aspects of functionality and environmental change (e.g. Miller *et al.* 1995). Some start the regional conservation strategies from a global perspective (e.g. the ecoregional approach proposed by WWF, Olson & Dinerstein 1999), others focus on local protected areas that are considered in a regional context (e.g. Margules & Pressey 2000, Groves 2003,). Some conservation planning approaches are more sensitive to socioeconomic aspects, and others integrate biological and sociocultural criteria (e.g. Miller 1995, Miller *et al.* 1995).

The ecosystem approach is of special importance because it has been adopted as an official strategy of the Convention on Biological Diversity for the management of natural resources (UNEP 2000). The ecosystem management approach arose in the 1990s in the quest for reconciliation of human resource and biodiversity conservation (e.g. Grumbine 1994).

3.3. How to conserve: *ex situ* or *in situ*, protect or manage?

Once the conservation targets and visions are defined there are different options for achieving them. In general, there are two conservation strategies: 1. enhance the viability of the conservation targets, or 2. abate the threats which actually reduce the viability and functionality of the targets or which might do so in the near future.

Ex-situ conservation: If the viability is very limited and the threat level very high, very intensive measures might be required in order to achieve at least a short-term maintenance of the target. In the case of small populations or individuals it might be adequate to extract them from the habitat and try to enhance their viability off-site. Botanical and zoological gardens or seed banks practice this so-called ex-situ conservation. According to the Convention on Biological Diversity, ex-situ conservation "means the conservation of components of biological diversity outside their natural habitats" (http://www.biodiv.org/convention/articles.asp)—this definition indicates that this type of conservation can be used for species or populations.

In the best case, the viability is enhanced through a controlled and supported reproduction, carefully guaranteeing the highest level of genetic diversity. In the worst case, the institutions promoting ex-situ conservation just store the genetic information (e.g. as frozen seed) stopping the evolution of the conserved organisms, or even lose genetic information by maintaining only a few clones and by hybridrization. There are some success stories, especially of vertebrate populations that have recovered in captivity and, in some cases, have then been re-introduced into the native habitat, e.g. the Californian Condor or the Przewalski horse (Frankham *et al.* 2003). Critically small populations characterize many species that are conserved *ex situ*, and, of course, it is not clear if they are really safe in the long run. Ex-situ conservation efforts are difficult and expensive, and their success is not guaranteed at all. However, they might make the difference between existence or extinction of species. It is impossible to think of a ex-situ conservation of a large proportion of species, but in some cases it might be fully justified to make big efforts. The reasons can be of a cultural or scientific nature. For example, the majority of species that are or were genetically close to our species have gone extinct, so it should be important to maintain the last of our living relatives, such as chimpanzees and gorillas. The world would go round without apes, giraffes and elephants, as it can without mammoths or glyptodons. The ecosystems giraffes are part of would change and impoverish, when these vanish, but still there would be ecosystems that function somehow. So why conserve giraffes? A reason might be that for humans it makes a difference to see and admire those tallest terrestrial vertebrates.

Definitely, there are some taxa that have a very high priority for humankind and that must be conserved *ex situ* if necessary: these are the genetic resources needed for the actual or potential subsistence of the human population on Earth. The food genetic resources are of special importance. In 1983 the development of the Global System on Plant Genetic Resources (now the Commission on Genetic Resources for Food and Agriculture - CGRFA) was started. "The objectives of the Global System are: to ensure the safe conservation, and promote the availability and sustainable use, of plant genetic resources by providing a flexible framework for sharing the benefits and burdens". In 1989, the CGRFA called for the development of The International Network of Ex-situ Collections under the Auspices of FAO, in line with Article 7.1(a) of the International Undertaking on Plant Genetic Resources, because of lack of clarity regarding the legal-situation of the exsitu collections. Twelve centres of the Consultative Group on International Agricultural Research (CGIAR) signed agreements with FAO in 1994, placing most of their collections (some 500 000 accessions) in the International Network. They have agreed to hold the designated germplasm in trust for the benefit of the international community, and not to claim ownership, or seek intellectual property rights, over the designated germplasm and related information.

In-situ conservation: If the viability of the conservation targets still is tolerably good and if the threats are not critically severe, it is preferable to conserve biodiversity on the site or *in situ*. The ex-situ conservation is an option for biodiversity levels below ecosystems, such as species and populations, but if complex ecosystems are to be conserved, *in-situ* conservation is the only option. And if functional ecosystems are conserved *in situ* there is a good chance that many of its components may endure as well, hopefully continuing their natural evolution. Of course, there are cases that certain species suffer specific pressures although their habitat-ecosystem is functional, e.g. the case of a rain forest mammal that has conservation problems due to a severe hunting pressure. Additional conservation measures abating the specific threat are then required. In general, however, it is preferable to start biodiversity conservation at the highest possible levels (e.g. ecoregions, landscape ecosystems) that include finer levels such as small-scale ecosystems and species.

The Convention on Biological Diversity (CBD) defines in-situ conservation as "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties". The CBD is stressing the natural character of the habitat and surroundings of the biodiversity to be conserved *in situ*. However, of course, in-situ conservation (even of non-domesticated species) can be practiced in environments that have been strongly influenced by humans. There are two different types of in-situ conservation: protection of wilderness, and management of anthropogenic ecosystems, such as agroecosystems or urboecosystems.

Wilderness protection aims at minimizing the impacts of humans on more or less remote areas shaped by mature ecosystems and natural processes. The most important and (so far effective) strategy is the establishment of protected areas belonging to strict categories which restrain the use of natural resources and any change or conversion of the ecosystems within their borders. "The idea of setting aside areas of natural or semi-natural land stretches back thousands of years. Many early ‘protected areas’ were actually hunting reserves, for example in northern India more than 2000 years ago and in Indonesia almost 1500 years ago. Other places were protected because they were considered sacred: homes of the gods, resting places for the dead, or places for spiritual reflection. That protection might be for nature without hunting, or for aesthetic appeal, was only generally recognized in the latter half of the nineteenth century" (Mulongoy & Chape 2004).

The Convention on Biological Diversity defines protected areas as "geographically defined areas which are designated or regulated and managed to achieve specific conservation objectives", and regulates, under the Article dedicated to in-situ conservation: "Each Contracting Party shall, as far as possible and as appropriate: (a) Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity; (b) Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity; (c) Regulate or manage biological resources important for the conservation of biological diversity, whether within or outside protected areas, with a view to ensuring their conservation and sustainable use; (d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings; (e) Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas (...)". Clearly, the CBD considers protected areas as the most important mechanism for promoting in-situ conservation—it is generally accepted that in protected areas, where conservation is a priority over other land uses, extinction can be fought with less expense and more chance of success in the long term by maintaining viable populations in their native habitats (Balmford *et al* 2003, Rodrigues *et al* 2004).

As mentioned above, the "establishment of Yellowstone National Park in the United States in 1872 is usually seen as the start of the modern protected area movement, being the first time the term 'national park' had been used. In the following decades, many other countries started protecting sites, such as Banff in Canada, El Chico in Mexico, Tongariro in New Zealand and the Swiss National Park. In the decades that followed, what had started as a trickle rapidly became a flood as new protected areas were created in virtually every country in the world" (Mulongoy & Chape 2004). First, the protected areas were largely "wilderness areas" where there was no significant human impact, and where the place of humans was restricted to visitors (Secretariat of the Convention on Biological Diversity 2004). Today, there are distinguished several categories of protected areas, according to the strictness of use restrictions. Six protected area management categories, based on primary management objective, are defined by the IUCN.

The year 1962 can be considered as an important milestone of protected area development, when the First World Conference on National Parks in Seattle, United States, initiated a more formal worldwide movement. "In 1962 there were 10 000 protected areas around the world, which already seemed a huge figure" (Mulongoy & Chape 2004), yet by 2003 the number of protected areas has been rising enormously during a few recent decades and is now in excess of 100 000 sites (Secretariat of the Convention on Biological Diversity 2004). The total area has also increased continuously from less than 3 million km² in 1970, to more than 12 million km² by the late 1990s, and more than 18.8 million km² in 2003. This figure is equivalent to 12.65% of the Earth's land surface, or an area greater than the combined land area of China, South Asia and Southeast Asia (Secretariat of the Convention on Biological Diversity 2004, UNEP-WCMC, WCPA & IUCN 2003). The present analysis suggests that the 10% target established for the protection of biomes at the 3rd World Parks Congress in 1982 has been reached or exceeded for nine of the 14 biomes. (*The IUCN World Congress on Protected Areas or IUCN World Parks Congress as it has become known, is a 10 yearly event which provides the major global forum for setting the agenda for protected areas (PAs). The Congress is a major international event for IUCN. It offers a unique opportunity to take stock of protected areas; provide an honest appraisal of progress and setbacks; and chart the course for protected areas over the next decade and beyond*). The biomes that still fall well short of the target are Lake Systems (1.54%) and Temperate Grasslands (4.59%). While the representation of terrestrial ecosystems (and included inland aquatic systems) is rather satisfactory, marine protected areas are not well developed: comprising 70% of the Earth's surface, less than 1% of the marine environment is adequately conserved (see Levin & Kochin 2004: "Is conservation biology too dry?"). The high sea, out of national jurisdiction so far has been neglected (UNEP-WCMC, WCPA & IUCN 2003).

Carrying out a global gap analysis, with 11 633 species of terrestrial vertebrates, 1424 gap species were identified that are not at all represented within protected areas; it is not surprising that 75.8% are found in the tropics where anyway 45.8% of the global protected area network is located (Rodrigues *et al.* 2004). This analysis, published in the journal *Nature*, facilitates a global quantification of the effectiveness of the global protected area network in representing species diversity. However, it does not allow an assessment of the real conservation status of the studied species. On the one hand, species can be represented within a protected area without being conserved, especially when occurring in "paper parks" that have been established but which are not really managed. On the other hand, species can occur outside protected areas and do not suffer any conservation problems because of a well-conserved habitat without a formal protection status (especially in countries with a low population density) or because of their adaptation to anthropogenically altered habitats (see above). In recent times, especially the first problem has been tackled: several studies deal with the effectiveness of protected areas, analyzing the comprehensiveness, adequacy and efficacy of protected forest areas taking into account different geographical and socio-economic conditions and the specific management problems (Hockings *et al* 2000, Bruner *et al* 2001, WWF 2004).

Indeed, from all over the world, evidence is mounting that protected areas experience less deforestation, habitat conversion and fragmentation than areas outside. According to a recent study, the majority appear to effectively conserve species, habitats and landscapes of value, but less than 25% of the forest protected areas are adequately well-managed with a good infrastructure. A large proportion of forest protected areas (in countries that have submitted corresponding CBD reports in May 2003) had no management at all, and only 1% of forest protected areas are regarded as secure in the long term (Secretariat of the Convention on Biological Diversity 2004). In the framework of the largest ever global assessments of protected area effectiveness, WWF (2004) surveyed almost 200 forest protected areas in 34 countries. An important outcome is that, in general, *well addressed* issues by the protected areas are protected area design, legal establishment, boundary demarcation, resource inventory / assessment and setting objectives. In general, *less effective* are activities relating to people (both local communities and visitors), management planning, monitoring and evaluation, budget security and law enforcement.

Protected Area Management can be defined as the process of leading and directing protected areas, through the effective and efficient deployment and manipulation of resources, in order to achieve the objectives defined for the area, mostly related to the conservation of biodiversity. Obviously, there are a lot of important aspects of protected area design and management related to natural science, but many components of management deal with people. Once the biodiversity to be protected has been identified—including its distribution and values, and especially its conservation needs—then management should be about seeking to get people involved in conservation, helping people to reduce pressures on biodiversity (threat abatement!), solving conflicts, planning and controlling objectives, decisions and measures strategically, raising funds for being able to do all this, etc.

Shafer (1999) gives an overview of important issues related to protected area management. Like many recent authors, he stresses the need to sensitively work with people. Indeed, social scientists are becoming more fully engaged in conservation. "One of the great hopes for conservation in the future is this need to look at issues through others' eyes. Just as ecologists now need to be able to perform quantitative analyses, so recently trained conservationists cannot get by without learning social science" (Milner-Gulland 2004). Kothari (2004) states that local people have had long-standing traditions of conservation and restrained resource use, which the conventional model of protected areas tends to ignore. In many regions of the world, biocentric and fundamentalistic conservation approaches promoted by ‘ecologically correct’ conservationists have been rather counterproductive. Physical displacement, denial of access to resources that have been traditionally used, alienation from sites of cultural value, and even human rights violations have generated considerable hostility and reduced public support for protected areas. Therefore, the classical focus on protected areas as islands of conservation, with increasingly destructive land use around them, is considered dangerous. Actively involving people in the protected area management becomes a necessity. An important trend, among others, is increasing role of indigenous peoples and local communities in the management of government-managed protected areas, with sharing of decision-making power (Collaborative Management of Protected Areas).

The problem of lack of support for protected areas is not a phenomenon of tropical or developing countries where people, in the context of the natural resource use, tend to have more direct necessities and, thus, more direct conflicts with conservation. In many developing countries there have been more intensive efforts to achieve adequate participation of stakeholders than there have at many sites in industrialized countries. In many developed countries there are enormous barriers and opposition to protected areas and biodiversity conservation. There is an urgent need not only to permit participation in protected area planning but to achieve a real partnership between public institutions and the huge variety of private stakeholders. Traditionally, conservation was promoted by biologists. Thus, the conservationists know rather well *what* to conserve, but there can still be a lot of uncertainty about *how* to achieve it.

In September 2003, the 5th IUCN World Parks Congress was held in Durban, South Africa. One idea of the congress was to show how protected areas are relevant to the broader economic, social and environmental agenda for humankind in the twenty-first Century. Among the many outcomes of the congress there is a detailed list of recommendations and The Durban Action Plan. Many outcomes and covered topics refer to the management of protected areas. With the Durban Accord, the more than 3000 participants made clear the current vision of protected areas: "In this changing world, we need a fresh and innovative approach to protected areas and their role in broader conservation and development agendas. This approach demands the maintenance and enhancement of our core conservation goals, equitably integrating them with the interests of all affected people. In this way the synergy between conservation, the maintenance of life support systems and sustainable development is forged. We see protected areas as a vital means to achieve this synergy efficiently and cost-effectively. We see protected areas as providers of benefits beyond boundaries—beyond their boundaries on a map, beyond the boundaries of nation-states, across societies, genders and generations". There are concrete goals: for example, "by 2015, all protected areas are to have effective management in existence".

Management of protected areas often does not mean strict protection but management of their biodiversity. It is necessary to accept the fact that the majority of protected areas cannot focus the goals on wilderness protection. Within certain types of protected areas it is necessary to implement a management of the ecosystems, especially if already transformed to agroecosystems. This management should be as *sustainable* as possible guaranteeing the long-term persistence of all the components, processes and services of the ecosystems. The sustainable management of anthropogenic ecosystems, such as agroecosystems or urboecosystems, is required on all land outside protected areas, as well. It must be the complementary action to protected area management in order to accomplish the 2010 goal of the CBD to halt biodiversity loss. The idea of sustainable use of biodiversity is a very important component of modern conservation approaches although, until now, there are few indications that it has really been achieved anywhere. Sustainability is a good and necessary concept that often is abused. Criticism among conservationists is abundant: "The entire concept of sustainable use has been based on the ecological fallacy and on utopian thinking, not on science or on a thorough analysis of historical, social, economic, and political relationships" (Brandon 1997). However, those critical conservationists do not provide alternative concepts.

The Durban congress, as well, documented the need to get rid of the vision of protected areas as conservation islands in a sea of degradation. Target 5 of the Durban Action Plan is: "All protected areas are linked into wider ecological/environmental systems of resource management and protection on land and at sea by the time of the next World Parks Congress". A large scientific literature supports the need for big, interconnected reserves with corridors and a matrix between protected areas that facilitates connectivity (e.g. Bennett 1999, Briers 2002). In this context, it is important to understand that corridors are more than narrow protected strips in the landscape. The goal is that a large proportion of the matrix between more intensively protected sites can serve as a temporary habitat for as many species as possible. This is required in order to maintain large-scale and long-term ecological functionality, especially when the predicted climate changes are taken into account (e.g. Shafer 1999, Walter 2004). In this context, the technical key elements of *climate change-integrated conservation strategies* are: "(1) regional modelling of biodiversity response to climate change, (2) systematic selection of protected areas with climate change as an integral selection factor, (3) management of biodiversity across regional landscapes, including core protected areas and their surrounding matrix, with climate change as an explicit management parameter; (4) mechanisms to support regional coordination of management, both across international borders and across the interface between park and non-park conservation areas" (Hannah *et al* 2002).

Accelerated anthropogenic climate change might turn out to be the most important stressor of biodiversity and the biggest challenge for conservation. Enormous efforts to mitigate climate change are fully justified, not only for conservation reasons, but especially for the protection of humankind. A paradigm shift is required from ‘steady-state conservation’ and ‘museum-keeping protection’ to a ‘global change management approach’, enhancing biodiversity’s adaptability to the various global change processes that become more and more important. This will not be achieved in protected areas alone; this requires the active, conscious and careful management of the world's ecosystems under use. Therefore, the conservationists can even learn from climatologists: "After global warming was identified as a threat, some leading climatologists became highly effective lobbyists, pounding the corridors of power to stress the importance of their work. They won increased research funding and the establishment of the influential Intergovernmental Panel on Climate Change. So far, taxonomists and ecologists have failed to muster a comparable response to the galloping loss of our planet's biodiversity. It's time that they did" (Anonymous 2004).

Glossary

Agriculturalization :	Is a process of social and economic change whereby a human society is transformed from a pre-agricultural to an agricultural state (from hunters and gatherers to food producers). This social and economic change is closely intertwined with technological innovation, particularly the tools required for preparing the soil for plant cultivation and the domestication of wild animals and plants.
Agrocentric cultures and religions :	Cultures and religions that reflect that the corresponding people's main concern and most important element of the daily life is agricultural subsistence.
Agroecosystems :	Ecosystems that with regard to biotic composition and structure have been shaped by human agricultural activities.
Anoxia :	Absence of oxygen.
Anthropocene :	The present, in many ways human-dominated, geological epoch, supplementing the Holocene. It could be said to have started in the latter part of the eighteenth century, when mankind started to have a globalized impact on the biosphere indicated by the moment when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane.
Anthropogenic :	Caused by the activities of human beings.
Ashgill :	The Ordovician period is subdivided into six time series, of which the youngest is the Ashgillian age, the time in between 448 and 438 million years ago.
Basalt :	A hard, dense, dark volcanic rock composed chiefly of plagioclase, pyroxene, and olivine, and often having a glassy appearance.
Biodiversity Hotspot :	Regions that harbour a great diversity of endemic species and, at the same time, have been significantly impacted and altered by human activities.
Bioregional conservation :	A holistic conservation management approach with elements drawn on the concepts and the experience of bioregionalism, Man and the Biosphere Program, international conservation and development projects, protected area management, and ecosystem management. A bioregion is described as a territorial unit of planning and management defined by geographical limits of human communities and ecological systems, which is large enough to maintain the integrity of the region's biological communities, habitats and ecosystems, yet small enough for local residents to consider it home. Bioregional management seeks to establish a political and institutional framework for cooperation among governments, communities and other stakeholders, with a planning process that incorporates cooperation, available information, goal setting, and evaluation and adaptation of management approaches. Bioregional conservation should be complementary to ecoregional conservation that tends to be more (natural) science-focussed. Both are compatible with the ecosystem approach.
Biosphere :	Irregularly shaped envelope of the Earth's air, water, and land encompassing the heights and depths at which living things exist. The biosphere is a closed and self-regulating system, sustained by grand-scale cycles of energy and of materials—in particular, carbon, oxygen, nitrogen, certain minerals, and water.
Bituminous :	Like or containing bitumen, e.g. any of various flammable mixtures of hydrocarbons and other substances, occurring naturally or obtained by distillation from coal or petroleum.
Bolide impact :	Impact of a meteoric fireball.
Brachiopod :	a marine animal with bivalve shell having a pair of arms bearing tentacles for capturing food; found worldwide.
Chondrite :	A stone of meteoric origin characterized by chondrules, e.g. small round granules of extra-terrestrial origin found embedded in some meteorites.
CITES :	Convention on International Trade in Endangered Species of Wild

Fauna and Flora, set up after a conference in Washington, D.C., in 1973, attended by 80 nations, after the danger of trade of wild species had been recognised.

Clovis-age : Of or relating to a prehistoric human culture widespread throughout North America from about 12 000 to 9000 B.C., distinguished by sharp fluted projectile points made of chalcedony or obsidian.

Conservation (of nature, of biodiversity) : Any action heading at the maintenance of a certain state of the target to be conserved (e.g. a landscape, an ecosystem, a species). The action is guided by a philosophy of managing the environment in a manner that does not despoil, exhaust or extinguish (especially the biotic) natural resources, applying the scientific knowledge of many biological and social disciplines, such as ecology, biogeography, evolution, socioeconomics, anthropology, etc.

Conservation targets : Biodiversity elements selected for specific conservation actions or treatments that represent biodiversity as a whole so that ecosystem functionality remains when only the targets are conserved through specific actions.

Conservation vision : An anticipated ideal or desirable state of the conservation targets (and the landscape in which they are embedded), and that should be achieved by the implementation of the current and future conservation action.

Convention on Biological Diversity (CBD) : At the 1992 Earth Summit in Rio de Janeiro, world leaders agreed on a comprehensive strategy for "sustainable development" - meeting our needs while ensuring that we leave a healthy and viable world for future generations. One of the key agreements adopted at Rio was the Convention on Biological Diversity. This pact among the vast majority of the world's governments sets out commitments for maintaining the world's ecological underpinnings as we go about the business of economic development. The Convention establishes three main goals : the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources.

Conversion (of habitats, of ecosystems) : The anthropogenic transition of an ecosystem (that can represent the habitat of a certain conservation target species) from a state not impacted by human beings (and/or their cattle) to an impacted one, normally meaning a loss of structural and biological complexity and of ecological functionality (degradation).

Coral bleaching : A whitening of corals indicative of colony stress, where symbiotic algal cells, or zooxanthellae, either leave or are ejected from the colonies.

Dark matter : Physical objects or particles that emit little or no detectable radiation of their own and are postulated to exist because of unexplained gravitational forces observed on other astronomical objects.

Deforestation : Specific form of degradation of forest ecosystems, often caused by human beings in order to create or extend used ecosystems, such as agroecosystems or urboecosystems.

Degradation (of habitats, of ecosystems) : The transition of an ecosystem (that can represent the habitat of a certain conservation target species) from a more complex, diverse and functional state to simpler one.

Demography : Science of human population that represents a fundamental approach to the understanding of human society.

Echinoderm : Any of numerous radially symmetrical marine invertebrates of the phylum Echinodermata, which includes the starfishes, sea urchins, and sea cucumbers, having an internal calcareous skeleton and often covered with spines.

Ecological footprint : The ecological impact of human activities as measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated. The Ecological footprint concept provides a measure for the ecological sustainability of the use of land and natural resources.

Ecoregion : A large area of land or water that contains a geographically distinct assemblage of natural communities that (a) share a large majority of their species and ecological dynamics; (b) share similar environmental conditions, and; (c) interact ecologically in ways that are critical for their long-term persistence. The use of the term *ecoregion* is an outgrowth of a surge of interest in ecosystems and their functioning. In particular, there is awareness of issues relating to spatial scale in the study and management of landscapes. It is widely recognized that interlinked ecosystems combine to form a whole that is "greater than the sum of its parts." There are many attempts to respond to ecosystems in an integrated way to achieve "multi-functional" landscapes and various interest groups from agricultural researchers to conservationists are using the *ecoregion* as a unit of analysis.

Ecoregional conservation : A large-scale conservation approach that tries to accomplish the most commonly accepted goals of conservation (1) representing all kinds of ecosystems, across their natural range of variation, in protected areas; (2) maintaining viable populations of all native species in natural patterns of abundance and distribution; (3) sustaining ecological and evolutionary processes within their natural ranges of variability; and (4) building a conservation network that is adaptable to environmental change. Ecoregional conservation should be complementary to bioregional conservation that tends to be more management-focussed. Both are compatible with the ecosystem approach.

Ecosystem approach : A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems (CBD concept).

Edge effect : Change in the conditions or species composition within an otherwise uniform habitat as one approaches a boundary with a different habitat. Edge effects at the boundary between natural lands and human-occupied lands arise due to human-related intrusions such as lighting, noise, invasive species, exotic predators (dogs, cats, and opossums), hunting, trapping, off-road activities, dumping, and other forms of recreation and disturbance. They are generally unfavorable to native species. Edge effects have to be taken into account when reserves are designed.

ENSO : **E**l **N**iño / **S**outher **O**scillation - During an El Niño, sea level pressure tends to be lower in the eastern Pacific and higher in the western Pacific. This see-saw in atmospheric pressure between the eastern and western tropical Pacific is called the *Southern Oscillation*, often abbreviated as simply the SO. Since El Niño and the Southern Oscillation are related, the two terms are often combined into a single phrase, the *El Niño-Southern Oscillation*, or *ENSO*.

Epiphytic plant species : Plant species, e.g. some tropical orchids or ferns, that grow on another plant upon which they depend for mechanical support but not for nutrients.

Ex-situ conservation : Means the conservation of components of biological diversity outside their natural habitats (CBD definition).

Focal species : Species that are chosen on ecological grounds as surrogates for more complex biodiversity elements in order to facilitate conservation planning; especially, indicators, species at-risk, umbrella species and keystone species are frequently used groups of focal species.

Fullerene : Any of various cagelike, hollow molecules composed of hexagonal and pentagonal groups of atoms, and especially those formed from carbon, that constitute the third form of carbon after diamond and graphite.

Genetic resources : Means genetic material of actual or potential value (CBD definition); with biological resources including genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity (CBD definition).

Genetic variability : Because of the myriad genes in the nucleus of every parent cell, the probability of two individuals inheriting identical characteristics is almost zero; thus, innumerable new variations do arise from recombination and mutation processes.

Glacio-eustatic sea-level change : fluctuations in global sea level as a result of changes in global ice volume.

Graviportal : Weight-bearing.

Hirnantian : Synonym for the Late-Ashgill and as such part of the Late Ordovician, defined from 444 to 446 million years ago.

Holocene : Of or belonging to the geologic time, rock series, or sedimentary deposits of the more recent of the two epochs of the Quaternary Period, beginning at the end of the last Ice Age about 11 000 years ago and characterized by the development of human civilizations.

Hominid family : Systematic primate family of modern man and extinct immediate ancestors of man.

Industrialization : Is a process of social and economic change whereby a human society is transformed from a pre-industrial to an industrial state. This social and economic change is closely intertwined with technological innovation, particularly the development of large-scale energy production and metallurgy.

In-situ conservation : Means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (CBD definition).

Key(stone) species : A strongly interacting species in ecosystems, that regulates local species diversity in lower trophic levels, energy/nutrient dynamics, and "intraguild competitors/predators" structure niche partitioning among closely related species, or a species that modulates the physical habitat of other species (as ecosystem engineers).

Limestone : A common sedimentary rock consisting mostly of calcium carbonate, $CaCO_3$.

Lycopsids : Also known as lycophytes and lycopods, a group of very ancient vascular plants that are only distantly related to other land plants. They have a long history stretching back possibly to the late Silurian period. Their living representatives include club mosses and quillworts, but in past ages they dominate the landscape with huge forests.

Mass extinction event : The loss of a large fraction of species due to heavy environmental changes or exceptional catastrophes (e.g. meteorite impact) within a comparably short period of time but on a large scale in space.

Mastodont : Extinct elephant-like mammal that flourished worldwide from Miocene through Pleistocene times; they differ from mammoths in the form of the molar teeth.

Mature (non-degraded) ecosystems : An ecosystem in the most complex, diverse and functional state that is possible at a certain moment under the given resource conditions (e.g. soil, climate); maturity does not imply a stable and steady state of the system and that the system, in the future, cannot develop into an even more complex and diverse state (thus, maturity is thought to replace the "climax" ecosystem/community, a much more static concept).

Megafauna : Large or relatively large animals, as of a particular region or period, considered as a group.

Megaherbivore : Large animals, mostly mammals, that are herbivorous (live from plants).

Molluscs : Belong to the large and diverse phylum Mollusca, which includes a variety of familiar creatures well-known for their decorative shells or as seafood. These range from tiny snails and clams to the octopus and squid (which are considered the most intelligent invertebrates).

Mutualism : A form of symbiosis where both species involved benefit from the partnership.

Natural selection : The constant pressure on organisms to successfully adapt to dynamic environmental conditions, that leads to the survival of only the "fittest" organisms or species.

Paleozoic : An era of the Phanerozoic, starting approximately 545 million years ago and lasting for about 315 million years, encapsulating the periods Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian.

Pantheistic : The view that everything, the whole environment, is of an all-

concepts	encompassing immanent god.
Phanerozoic :	Eon that started around 544 million years ago and runs until the present time. It is subdivided into several eras and even more periods in some of which the mass extinction events occurred.
Pleistocenic extinctions :	The phenomenon that many large animals, especially mammals, on practically all continents, vanished in the late Pleistocene, a geological epoch usually dated as 1.8-1.6 million to 10 000 years before present, and in which the human species rose and extended its range to all continents.
Protected area :	means a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives (CBD definition).
Protection (of nature, of biodiversity) :	A rather intensive and concrete form of conservation of a certain conservation target, often comprising formal action steps related to legislation and the establishment of areas especially reserved for the protection purpose (protected area). Often, the protection of a species or an ecosystems excludes the possibility of its use, manipulation or management.
Proxy indicator :	An indicator used to study a situation, phenomenon, condition or change for which no direct information—such as instrumental measurements—is available.
Radiation :	Diversification of a species or single ancestral type into several forms.
SARS coronavirus :	**S**evere **A**cute **R**espiratory **S**yndrome, a communicable viral disease that can progress to a potentially fatal pneumonia.
Slash and burn agriculture :	All the vegetation in a chosen patch is slashed and burned. Then the area is cultivated for one or a few years and then abandoned for another forested patch. The ash from the burned vegetation helps fertilize the soil but the method requires a large region, as the recovery of forest may take decades. One of the side effects is erosion.
Sources (of stress of conservation targets) :	The agents generating the stresses or extraneous factors, either human (policies, land uses) or biological (e.g. non-native species).
Speciation :	The evolutionary formation of new biological species, usually by the division of a single species into two or more genetically distinct ones.
Strata :	Plural of stratum, e.g. in geology a bed or layer of sedimentary rock having approximately the same composition throughout.
Stress (of conservation targets) :	The types of degradation and impairment afflicting the biological systems such as populations, species or ecosystems at a certain site.
Symbiosis :	The habitual living together of organisms of different species. The term is usually restricted to a dependent relationship that is beneficial to both participants (also called mutualism).
Threats (*to conservation targets)* :	Combination of stresses and their sources.
Trophic level :	A group of organisms that occupy the same position in a food chain.
Umbrella species :	Umbrella species are generally large species, with large home ranges whose minimum area requirements encompass those of the rest of the community (area- limited). If the umbrella species are adequately conserved it is supposed that the rest of the species can survive under "their umbrella".
Urboecosystems :	Ecosystems that with regard to biotic composition and structure have been shaped or created by the establishment of cities.
Viability :	Capability of normal growth and development of living things; especially relevant for populations with regard the ability to achieve a long-term persistence reproducing itself without a significant loss of genetic diversity.

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Note: The manuscript is based on almost three hundred references referring to original research or reviews. Due to the encyclopaedic character of the EOLSS contributions, it is not possible to include all of them in the bibliography. However, a complete reference list can be provided by the authors. In the following, we give a list of recommended publications - especially in English language - that facilitate further comprehension of relevant topics.

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Biographical Sketches

Pierre L. Ibisch (Prof. Dr. habil.) is currently a professor for Nature Conservation with the University of Applied Sciences Eberswalde, Germany. He trained as a biologist with experience in basic research related to botany, biodiversity and taxonomy at the at the Rheinische Friedrich-Wilhelms University in Bonn, Germany (Prof. W. Barthlott). As a conservation scientist he started to work in Bolivia, South America, where he lived for almost 9 years (between 1991 and 2003). As a consultant he was involved in a rural development project developing an agroforestry concept and promoting environmental education, as well as the cooperation and networking of environmental NGOs. After gathering work experience in Germany, among others, analysing the contribution of Botanical Gardens to biodiversity conservation, he became an expert of the German development cooperation supporting Bolivia’s largest conservation NGO (Fundación Amigos de la Naturaleza, FAN). As head of the Sciences Department of FAN, e.g. he developed methodologies for ecoregional conservation planning in Bolivia and was involved in biodiversity and conservation policy. He was adviser of the Bolivian government supporting the formulation of the Bolivian biodiversity strategy. He is the author of many scientific papers and books (in English, Spanish and German); among others, he is the principal editor and author of the first monograph on biodiversity and conservation in Bolivia.

Monika Bertzky studied biology (M.Sc.) from 1998 to 2003 at the Rheinische Friedrich-Wilhelms University in Bonn, Germany. Her main fields of activity are biodiversity, tropical ecology and conservation science, with working experiences in Tanzania, Bolivia, Cuba, and Thailand. By the beginning of 2004 she has been working as lecturer in international study courses at the University of Applied Sciences Eberswalde, Germany. Since July 2004 she has been working as a PhD candidate in an interdisciplinary project (GoBi – Assessing Biodiversity Governance and Management Approaches) at the Humboldt University of Berlin, Germany (www.biodiversitygovernance.de). Within the project she is now dealing with the integration of scientific and qualitative social research in the face of biodiversity management effectiveness.

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