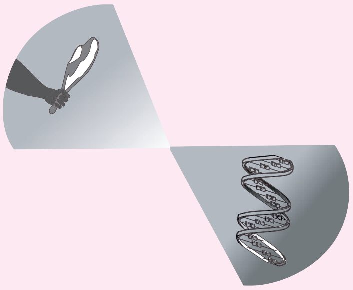
CHANGING THE LIVING WORLD 8

SHRINKING BIODIVERSITY

The European Bison, the last remnant of the European megafauna, was nearly extinct in the 1920s with only few individuals remaining in Poland and Belarus, but was saved. For most other threatened species only few individuals will not be able to maintain a viable population. We are today living in a time of massive extinction and reduction of biodiversity. The major causes are overhunting and overfishing, space intrusion and biotope destruction, and large scale spreading of species to new areas. All of this changes the living world. (Photo: Alexey Bunevitch, Belovezhskaya Pushcha National Park, research division.)

“There is a grandeur in this view of life, with its several powers, having been originally breathed by the creator into a few forms or into one: and that, whilst this planet has gone cycling on according to the fixed laws of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.”

Charles Darwin,
the final words in “On the origin of species”, 1859.



One of the most fundamental and serious environmental impacts is when a species of animal or plant disappears from a locality or, worse, is made extinct on the planet. Some of the first alarms from environmentalists in modern times dealt exactly with this threat. For example, Rachel Carson’s now legendary book *Silent Spring* from 1962, describes how the birds living at a lake disappeared due to the fact, as it turned out, that the insects they fed on were killed by DDT – and so the spring became a very silent one. The first widely noticed alarms of environmental impact on the Baltic Sea in the 1950s and later were also connected with disappearing species, as grey seals and white-tailed eagles drastically diminished in numbers. Some of the earliest measures of environmental protection concerned threatened animals, e.g. the hunting of the Bengali tiger was outlawed already in the 1700s.

This concern with species survival is well motivated. Biodiversity at the species level is in a way the ultimate indicator of environmental impact. The final loss, the extinction, of a species constitutes an irreversible loss of genetic potential, a loss of a natural resource and a final violation of bioethics.

Man’s onslaught against other species has a terrible history, which we need to understand to comprehend the contemporary situation. From earliest times man has either overused the resources provided by other species and thereby destroyed them forever, or simply changed their living environment so much that they could not continue to exist. All different kinds of environmental impacts influences the possibilities for other life forms to survive, multiply and flourish: spatial intrusion, reduced access to water, and of course chemical pollution, all limit the habitat of life forms.

Environmental impacts may be accidental, but in fact manipulation of the biology of the planet is to a very large extent intentional and part of the development of human societies from the very beginning. Since plants and animals are what feed us, this is natural, but nature has been exploited in an unscrupulous way. From extinction of the megafauna hundreds or thousands of years ago, to the large scale animal production of today, the consequences have been immense. Today some 90% of terrestrial higher animal biomass represents animals that are produced and owned by man. Wild animals like moose, foxes and the like, have been left with very little space. Deliberate and accidental introductions of animals and plants have lead to unintentional spreading of invasive species. In some environments this has been very destructive, leading to a completely changed flora and fauna.

Biodiversity studies tell us that the evolutionary period of a species – the time from its appearance on Earth until its extinction – is today about an order of magnitude shorter than normal. This means that we exist in one of the largest periods of extinction in the history of the planet, comparable for example to the situation 65 million years ago when the dinosaurs became extinct. The earlier six identified periods of mass extinction had cosmic causes. This time it is us – humans – that direct the ominous screen play.

A series of measures have been undertaken to protect biodiversity. These include nature conservation and establishment of protected areas. Inventories of species in a “Red List” of different levels of survival status helps identify species that need protection. In the end, however, it seems that the most necessary change is the one that must take place in our minds. Respect for other species and a willingness to share the environment with them is a prerequisite for creating a world where other life forms are given a chance of continued existence.

Authors of this chapter

Lars Rydén, main author; Pavol Elias, invasive species; Mats Höggren, biodiversity; Lena Kautsky, the Baltic Sea; Sören Svensson, the population variation in birds; Pawel Migula, nature protection.

Changing the living world
Shrinking biodiversity

From hunting to animal production

Invasive species

Control of pests and weeds

Biodiversity

Strategies for protection of biodiversity

From hunting to animal production

Man in an ecological perspective

From the perspective of ecology, humans are omnivores that live on plants and animals. This self-evident necessity may be benevolent and in harmony with the environment, but also very damaging when man's co-existence with the rest of the biosphere turns into ruthless exploitation. In this chapter we will explore the environmental aspects of how man interacts with animals and plants, how the "harvesting" of animals and plants was a prerequisite for the development of civilization, but also how the darker side of this development constitutes one of the major environmental impacts and disasters ever.

Homo sapiens sapiens, the ancestors of modern humans, populated the world, spreading from a place of origin in Africa some 50,000-100,000 years ago. The original ecological strategy of man was that of a hunter-gatherer. This strategy has been used by some human populations up to today, e.g. in areas of Australia and New Guinea, and for good reasons. However, hunting game and gathering plants is comparatively inefficient. Practically all members of a tribe have to take part in feeding the group. Even chiefs had to collect some of their own food. When conditions allowed, man therefore developed other strategies. These include various specialist strategies, e.g. nomads living almost exclusively on a single resource such as reindeer, but most importantly the domestication and the large scale cultivation of plants and animals.

Man also took plants and animals into his service for a long series of other purposes than food. This included micro-organisms for brewing, animals for work, hunting, herding, and clothing; and plants for building materials, decoration, and medicinal purposes. When considering all these uses, it is obvious that each individual species of animal, plant, fungus, bacteria, etc., represents an enormous potential for man and deserves to be protected for that reason alone.

The living world is also a world of beauty and joy. Aesthetic values may be looked upon as a resource for man and should then be included on the list above. Another dimension of man and his fellow living beings is that they might also be considered to have rights to be respected, at least as species. This question is discussed further in Chapter 21.

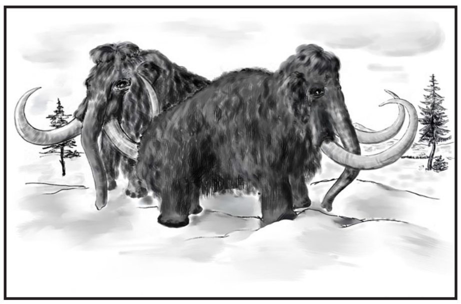
Figure 8.1. Medieval seal hunting in the Baltic Sea as illustrated in the map of the Baltic Sea region by Olaus Magnus, 1539. (Courtesy of Uppsala University Library, see further Figure 5.2.)

The extinction of the megafauna

When humans feed themselves, as with all animals species, normally a balance evolves between the eaten and the eater, between the hunter and the prey. If such a balance is established, both survive in a mutual adaptation to each other's strategies, as classical studies in ecology demonstrate (see Chapter 3). Too often, however, man was too "clever", and tipped the balance to the detriment of both, and hunted the prey so intensively that it became extinct. Man used his social and technical abilities to hunt in teams, build traps or otherwise outwit individuals and even whole herds of animals.

An early strategy to better feed the group was to hunt very large animals, the megafauna. Several of these large game went extinct as man spread across continents – much quicker than evolution allowed the animals to evolve counter strategies. The megafauna in Northern Europe contained for example the mammoth and the giant deer which went extinct some 10,000 years ago coinciding with the arrival of man. All evidence points to the fact that man in fact extinguished these species. Although we all know that much of African megafauna still exists, some larger species became extinct when man appeared

Figure 8.2. The extinct megafauna. The most remarkable megafauna in the Baltic Sea region was the mammoth, a member of the elephant family. The remains of many thousands of individual animals have been found in Siberia, and 25 in Sweden. During the iceage, mammoth lived far south in Europe, but became extinct due to hunting by man about 10,000 years ago. There were several species, the largest more than 4 m tall with up to 5 m long, curved tusks. (Drawing: Malgorzata Scheiki-Binkowska.)



Jagiello, the Polish and Lithuanian king in the 15th century, was the first who restricted hunting of large game animals such as the European bison and the brown bear, as he recognised a sharp decline in number due to over hunting. Only royalty was allowed to hunt these animals.

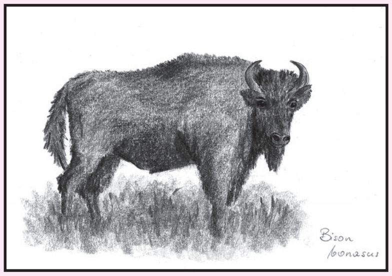


Figure 8.3. The European bison, vicent, *Bison bonasus.* (Drawing: Malgorzata Scheiki-Binkowska.)

A short history of the European bison

The European bison (*Bison bonasus*) inhabits mixed fresh forests, close to water reservoirs. It is the heaviest terrestrial European mammal. Bulls can reach a weight of more than 1,000 kg. Over the years hunting, poaching and diseases drastically reduced the population. At the time of the First World War the bison remained only in Białowieska Puszcza and in the Caucasus mountains, where a smaller subspecies (the mountain bison, *Bison bonasus caucasicus*) existed. From more than 700 animals in 1919 the species went extinct in the wild in 1925, when the last Caucasian bison died. Only 66 animals, six of them in Poland, then remained in zoological gardens and in private hands.

In 1932 the International Society for Bison Protection started to publish a studbook, (showing the breeding situation) of the species and initiated breeding of the animals. At the time of the Second World War 40 individuals existed. In 1947 out of the total number of 95 bisons, 44 were in Poland. In 1952, bisons were released in nature in Białowieska Puszcza. Some of them were bred with the Caucasian subspecies that had been separated and kept in the Bieszczady Mountains in southern Poland.

Recently, the total number of the European bison reached more than 3,100 individuals. In Poland there are less than 700 in nature and in breeding centres.

on the scene. Otherwise the African megafauna was in a different position since it evolved together with modern man and thus had a better chance to adapt. It is estimated that world-wide about 60% of the megafauna is extinct due to over-hunting by man.

Some of these large animals were easy prey since they lacked natural enemies, and thus an instinct to escape and protect themselves. Most dramatic examples are the large birds on some ocean islands, which man colonised. For example, on New Zealand it was possible for the newcomer to walk right up to the flightless moa birds and kill them. The bird was hunted into extinction in the 1600s.

Man hunted and killed animals for its own sake, not only for food. This provided fame and prestige to the hunter. The larger the prey, the better. Important individuals, kings, tsars, etc., organised hunting parties and shot incredible numbers of large animals. For example the European bison was nearly made extinct due to such hunts. On pictures of the last hunting parties in the Bialowieska Puszcza Forest on the border of present Belarus and Poland, dozens of bison and deer, and hundred of smaller games including, e.g. boar, are exposed in front of the hunting company with the tsar in the front.

Likewise when European colonisers arrived in North America, the enormous herds of bison which roamed the prairies were during a period shot only for their ears and tails as trophies, or to rob the native population of a key food resource. When just a few hundred bisons remained the hunting was outlawed. The species now survives in nature reserves. The European bison survived in the great forests, the Białowieska Puszcza between Belarus and Poland, but at the end of the First World War only seven individuals were still there. The species was saved by enthusiastic naturalists, starting with the last few individuals in European zoos. Today the bison, now established mostly in parks in Poland, Belarus, Ukraine, and Slovakia, is the last trace of the historic European megafauna.

Ruthless hunting, however, hit not only the megafauna. The North American passenger pigeon, that has been estimated to number up to 5 billion, became extinct in the early 1900s. The guillemot in the Baltic Sea was hunted and eggs collected extremely easily since they bred exclusively on cliffs on Stora Karlsö Island west of Gotland. There were only some 20 individuals left when this practice was outlawed a hundred years ago. The roe deer, now very common in the Swedish landscape, was almost extinct at the turn of the 19th century. There are many more examples.

Domestication of plants and animals

Hunting, as mentioned, even if ever so efficient, was not sufficient to support large groups of people (Chapter 7). There are many reasons for this (Diamond, 1997).

> "Wild plant and animal species are normally useless as food since they are indigestible (bark), poisonous (many mushrooms), low in nutritional value (jellyfish), tedious to prepare (very small nuts), difficult to gather (most insects), or dangerous to hunt (rhinoceros). Most biomass on land is in the form of wood and leaves, most of which we can not digest. By selecting and growing those few species of plants and animals that we can eat, so that they constitute 90% rather than 0.1% of the biomass on an acre of land, we obtain far more edible calories per area" .

The capacity of an area to feed a population, its carrying capacity, is about 50 times larger for a society of herders and farmers than for collectors-gatherers. Domesticated animals provide services to a society by furnishing meat, milk, fertilizers (manure), and work. Some animals, like cattle, do all of this. Other services from animals that revolutionized human life were the provision of clothing (especially wool from sheep), fibre, and not least transport, with goods on wagons or on horseback.

Domestication of plants and animals evolved piecemeal over quite a long period, in only few areas in the world, but apparently on several independent occasions, as genetic analyses show. The very limited access to suitable wild plants and animals for domestication was a key difficulty. Diminishing, or even extinction, of resources for hunting and gathering pushed the process, as did the development of technologies for sowing, growing, harvesting, etc., and selection of crops and animals. As the human population increased, the sedentary and agricultural lifestyle became almost the only one that could support a society.

The key factor, wild species that could be domesticated, were uniquely available in what is commonly called the "fertile crescent," an area corresponding to today's middle east, or Southwest Asia. This is the place of origin for among others emmer wheat, einkorn wheat, barley, pea, lentil, chick pea, and flax. Also in a modern overview of possible source plant material for domestication this area is unique in that it provides a very large percentage of what in the long term is possible to use. The situation for animals is similar. The wild ancestors of the five most important domesticated animals – sheep, goat, cow, pig, and horse – all lived in Southwest Asia. This is again unique in the world. These environmental factors are the main reason why Europe became "the cradle of civilisation" – rather than Australia or America – and finally later Europeans "discovered" and colonized the rest of the world (Diamond, 1997).

Thus, some 10,000 years ago (8000 BC), at the time of the last deglaciation, societies with cultivated plant and animals had established themselves in the Middle East. Their lifestyle spread rather quickly in a western and eastern direction, probably since climate was similar. Only much slower did it establish itself further north. They took several thousand years to come all the way to the Baltic Sea region. Then, all the domesticated species were imported with the noteworthy exception of reindeer, which is the Baltic Sea basin contribution to the domestication of larger mammals. We can easily imagine how a development from reindeer *hunter* to reindeer *owner* took place. It was probably quite gradual. A first step was to follow and "harvest" (slaughter) the wild herd without threatening its viability. The next step was to protect it from other competing hunters such as the wolf, and thirdly to direct its migration to the best areas for grazing and reproduction.

Agriculture and animal production had dramatic environmental consequences. Obviously, if a piece of land is turned from "wild" with only some 0.1% of the biomass useful to man, to become cultivated where 90% becomes harvestable crops or animals, this constitutes a large scale change of biology and environment in favour of some species rather than others. The environmental impact of this increases as the areas taken into use for domesticated plants and animals increases. Today, a very large proportion of

Figure 8.4. Domesticated animals. Among the 14 main domesticated animal species in the world, the Baltic Sea region has contributed one, the reindeer. The wild reindeer, here photographed in the northern Swedish mountains, is today rare. It was domesticated about 10,000 years ago to provide meat, fur, horn, and bone, as well as to pull small sledges and to be kept as a pet. (Photo: Lars Rydén.)

Domesticated animal	Wild ancestor
The major five	
sheep	Asiatic muoflon sheep
goat	West Asian wild goat
cow	Eurasian aurox, now extinct
pig	Eurasian wild boar
horse	Southern Russian wild horse
The minor nine	
Arabian (one-humped) camel	wild dromedary, now extinct
Bactrian (two-humped) camel	wild camel, now extinct
llama and alpaca	Ande's guanaco
donkey	African wild ass
reindeer	Northern Eurasian wild reindeer
water buffalo	Southeast Asian wild water buffalo
yak	Himalayan and Tibetian wild yak
Bali cattle	Southeast Asian banteng (relative to aurox)
mithan, gayal	Indian and Burmese gaur (relative to aurox)

Table 8.1. Main domesticated animals in the world. (Slightly modified from Diamond, 1997.)

land is used for either crop or animal production, and it is estimated that about 90% of all higher animal biomass on land is domestic.

The process of domestication has continued since its beginning. The American continents contributed at a later stage with, e.g. potato and corn while rice was domesticated a long time ago in Asia. More recent is e.g. domestication of fruit trees, bushes, and other plants that require several years cultivation before they can be harvested. Some resources are still used without or with only minor efforts of domestication, e.g. many trees and forests, some wild berries and bushes, and most importantly marine resources. Aquaculture, however, often requires a great effort and is today a major field of domestication of animals for food production.

Genetics – animal breeding and genetic engineering

At an early stage, selection was used to improve the genetic properties of domesticated plants and animals. This trial and error process was slow, but still important for improving production. The relative success of "pre-scientific" breeding can be seen by the many varieties of dogs, horses, pigeons, etc., that existed in early societies and up to the 1800s. With the establishment of Mendelian genetics from 1900 a real breakthrough occurred in plant and animal breeding. The efficiency of agriculture and animal production increased several-fold in the few decades that followed. A series of factors, among them better genetic properties, contributed and the importance of each factor is difficult to establish, since they were so interlocked. The new varieties gave higher yields but also required the new techniques that were introduced simultaneously: fertilizers to promote growth, biocides to control pests, and so on. In this way, new varieties became part of a larger environmental impact of agriculture in general.

Figure 8.5. Gene technology. Plants were domesticated for use as food about 13,000 years ago. The cultivated *barley* in the picture has little resemblance to the wild forms. Today, gene transfer is used to improve the existing varieties of the plant e.g. to make it more resistenat to disease or improve productivity. Genes are still recoverd from wild plants, found in e.g. north Africa. (Photo: Inga-May Lehman Nådin.)

Since the 1980s new genetic techniques have made it possible to "design" the genomes (species) of plants and animals. It became possible to improve and better control what one did traditionally, but also, and more dramatically, to introduce entirely new genes from other completely unrelated genomes or even synthetic genes. The new varieties, commonly called GMOs, *Genetically Modified Organisms*, might thus have properties not thought possible up to recently. From a very careful beginning when each introduction of a GMO in field trials was carefully considered from ethical and risk perspectives, there are now many GMOs in full scale use. One example is an oil seed plant with genes (from a bacterium) that allow them to resist and grow with a specific biocide (Roundup). This is sold together with the plant variety to control weeds. But genes are not only there to make the production of the crop weed resistant. Other introduced genes may improve the nutritional value of the plant, or make it contain specific substances.

Today, animals can also be given new genes by introduction of a small piece of DNA into the germ cell, the fertilized egg. Animals that develop from such eggs are called trans-genic. Today trans-genic mice are routine in the laboratories of biomedical research, while the production of trans-genic larger animals is still a challenge for researchers. But we do have e.g. sheep that have human genes for specific proteins such as coagulation factors, which then may be extracted from the milk. This is called *genetic farming*, and is foreseen to be important in the future. The intention is to produce so called biological pharmaceuticals, that is human proteins that are used as pharmaceuticals. Plants may also be used for similar purposes.

The use of GMO plants is controversial. One discussion concerns the risk that a gene artificially introduced into a GMO is transferred from the original plant to a wild species, especially if this is related to the cultivated one. This will most likely be possible and probably has already happened. The question is what is the next step. Most likely the wild species will lose the gene if it does not give the host a specific advantage. Protection against a biocide might be such an advantage, and then resistance properties might spread among the weeds against which it was directed. This would constitute a kind of "biological pollution" where genes are compared to chemicals, as pollutants. The question is further discussed below.

A most relevant objection to the use of GMOs seems rather to be on a political level. GMOs are sold as seed from big companies, and the individual farmer is not able to grow his own seeds for the next year. At the same time the new varieties might be so efficient that the farmer can not afford to use old varieties. Farmers are thus completely controlled by the companies. Further, the varieties are protected by patent rights and thus the companies protect themselves in this development, which is upheld by market forces. The smaller farmers will lose in this process which in the end leads to further industrialization of agriculture.

Biotechnology

Biotechnology in general refers to the use of living cells or organisms or parts thereof in technical contexts. In a wider understanding of the concept one might include all domestication of plants and animals. However, classical biotechnology normally includes e.g. use of yeast for fermentation of alcoholic beverages, bacteria for souring wine, milk or meat, and special enzymes in the production of cheese. All tools – cells, enzymes, etc. – for biotechnology are taken from the environment which again underlines the importance of a protected biodiversity to preserve the potential for finding new interesting genes. An example of a perhaps unexpected such source are the micro-organisms from hot springs in volcanic areas, where several enzymes which revolutionized genetic engineering were found. Many medicinally very important pharmaceuticals have been extracted from more or less exotic sources.

Biotechnology usually refers to three different activities: cultivation of micro-organisms or cells in general including mammalian cells; genetic design of such cells, e.g. by the introduction of new genes; and use of biological macromolecules, especially enzymes, in technical systems. An example is the use of enzyme reactors in chemical procedures, mostly through immobilization of the cells or enzymes to a carrier to allow rational management of the system. Very often all three activities are used in a co-ordinated way to set up biotechnical production.

Another way to see biotechnology is to refer to controlled biological systems, small ecosystems, which provide special services. A well known example is the biological step in wastewater treatment. However, much more special functions may be developed in special ecosystems, "biological machines." Examples include the extraction of heavy metals – bioextraction of copper is economically almost as important as mining – precipitation of phosphorus, production of biomass, etc. A rather undeveloped possibility is to let cell cultures, mostly plant cell cultures, produce specific products instead of harvesting these in nature. A glycocorticoid, used as a heart medicine, was extracted from the first such system in large scale production. Other proposed systems may also produce bulk amounts of e.g. ginseng and cacao butter. It is difficult to see that such systems would be a threat to the environment. Rather, it would allow some natural resources, now pushed too far, to be less exploited. The environmental impact would be smaller if cacao could be produced in a small, cell cultivation in the kitchen corner rather than importing it from a plantation in west Africa, where it is extracted from a small nut on a big tree.

Biological machines seem to be the last logical step in a development that started 10,000 years ago in domestication of the living world. The ultimate "biological machine" may be a device that, using photosynthetic components, would produce a fuel from air, water, and sunshine, to replace fossil fuels and thus turn the combustion process into a renewable scheme. Such systems are being researched today.

Biotechnology

Biotechnology refers to the use of living cells or organisms or parts thereof in technical contexts. Biotechnology usually refers to three different activities: cultivation of micro-organisms, or cells in general including mammalian cells; genetic design of such cells, e.g. by the introduction of new genes; and the use of biological macro-molecules, especially enzymes, in technical systems.

Figure 8.6. Controlled ecosystems. Controlled ecosystems are able to provide important biological services to man. Here, a series of dams recieve wastewater from Södertälje, a town just south of Stockholm. The wastewater is cleaned through nitrification, denitrification, and in the end growth of hydrophytic plants which are harvested. The water becomes increasingly clean before it continues to the Baltic Sea. The area is used as a park for leasure activities. (Photo from video: Bengt Littorin.)

Figure 8.7. Invasive species. All over the Baltic Sea region the colourful leguminosic (pea family) plant *Lupinus polyphyllos*, introduced from North America, has become increasingly common along roads, as here in northern Poland, and along river sides. Since it is capable of nitrogen fixation it often competes successfully on nutrient poor soils. In Belarus *Lupinus* has been introduced to improve soil and covers large areas. (Photo: Lars Rydén.)

Invasive species

Introduction of species by man

Over his entire existence man has moved species around the world. The early domesticated plants and animals are the first examples. They were followed by a long series of species taken into the service of man to be decorative, nutritious, or useful in other ways. Many thousands of such plants and animals are part of our everyday life.

Over a period scientists systematically collected plants and animals from all over the world and brought them to gardens, for the purpose of studying them. Monks were among the first to establish gardens with many unusual plants in the monasteries. Linnaeus grew bananas and kept a couple of monkeys in his garden in Uppsala. Both became a big attraction for the Royal family in mid-18th century Sweden.

But more often alien species of plants and animals were introduced to fulfil practical and economic purposes. In the last decades however, the introduction of new species has primarily been driven by leisure activities and hobbies. Fish, birds, and mammals have been introduced for sport, plants and birds for aesthetics, and insects for biological control of pests.

Most of the new species were kept as cultivated or captured. In some cases they were released into nature, e.g. to be hunted. Some of these have become very successful, e.g. pheasant in the forests of Northern Europe. In other cases they unintentionally escaped into nature.

Species which become very successful in the new environment are called "invasive species." Invasive species are the second greatest threat to biodiversity globally, after habitat destruction, and the number one cause of species extinction in most island states. Invasive species can be defined as species spreading into areas where they are not native. The aliens, known variously as "exotics," "invaders," "non-natives," or "non-indigenous species," can be aggressive, threatening or harmful to the natural ecosystem.

There are many examples of disastrous invasions by such species that resulted in losses of native species, changes in community structure and function, and even alterations of the physical structure of the system (Drake et al., 1989).

Invasive species

Invasive species can be defined as species spreading into areas where they are not native. The aliens, known variously as "exotics", "invaders", "non-natives", or "non-indigenous species", are aggressive to, or threaten, or harmful to indigenous species.

Figure 8.8. Introduced species. In 1930 the Canada goose, *Branta canadensis*, was introduced in the Baltic Sea outside Kalmar and Hudiksvall by Swedish biologists, an introduction that was repeated several times. It is today well established in the region and 13,000 birds were shot yearly in Sweden in the 1990s. (Photo: Tero Niemi.)

Invasive species may be considered to be environmental weeds or a kind of environmental ("biological") pollution.

Not all alien species cause damage. Simberloff (1981) has suggested that in fact only a few do – and fortunately so, because there are few areas that remain free of non-native species. However, the evidence for severe damage in particular instances is compelling, and there are many cases of communities devastated by alien plants and animals. Some of the most clear examples are native fish of North American desert lakes which became extinct as a result of introductions of predatory exotic fish (Minckley and Deacon, 1991).

How introduced species become invasive

The process of invasion can be divided somewhat arbitrarily into four successive stages: arrival or introduction, establishment, range expansion, and integration (Figure 8.9).

Introduction. The beginning of invasions includes introduction or the arrival of a species in a new locality and its success or failure in establishing itself. Species are introduced for a number of ways, either accidentally (e.g. when species imported for a limited purpose escape), or deliberately. In modern times there are three major processes of introduction:

- European colonization – settlers arriving to the new colonies released hundreds of different species originating in Europe;
- Horticulture and agriculture – large numbers of plant species have been introduced and grown as ornamentals, as agricultural species, or as pasture grasses;
- Accidental transport – species are often transported unintentionally. Common examples include weed seeds that are accidentally harvested with commercial seeds and sown in new localities, rats and insects that stow away aboard ships and airplanes, and disease and parasitic organisms transported along with their host species. Ships frequently carry alien species in their ballast – soil ballast dumped in port areas brings in weed seeds and soil arthropods, and water ballast introduces algae, invertebrates, and small fish.

In addition, intentional introductions were inevitably accompanied by numerous accidental ones.

Establishment of a viable population. Once an invading species arrives in a new environment, it must overcome a sequence of barriers for successful establishment. In most cases, invasion is started by a few individuals, which survived against odds, since a small initial population will likely be eliminated due to the effects of genetic drift, and demographic and environmental random events. At least a small amount of genetic polymorphism is necessary for the survival of a population in a new environment. The likelihood of establishment is thus not very high (Shigesada and Kawasaki, 1997).

Range expansion – spatial spread of invaders. The middle stage of invasions starts once a species has established itself in a new place. After an invading species becomes well established in a new locality, its range sooner or later starts to expand into the surrounding environment.

The relationship between range distance and time illustrates when the expansion begins and how fast it proceeds. We may qualitatively classify the range distance-versus-time curves into the three types (Figure 8.10). All three types have in common "initial establishment phase" during which little or no expansion takes place, followed by an "expansion phase," and a final "saturation phase," if there is a geographical limit to the available space (Shigesada and Kawasaki, 1997).

During the early stages, the rates of population growth and range expansion of an alien species may vary markedly. Some invasive species (e.g. Africanized bees, muskrats, and zebra mussels) have rapid rates of local population growth and range

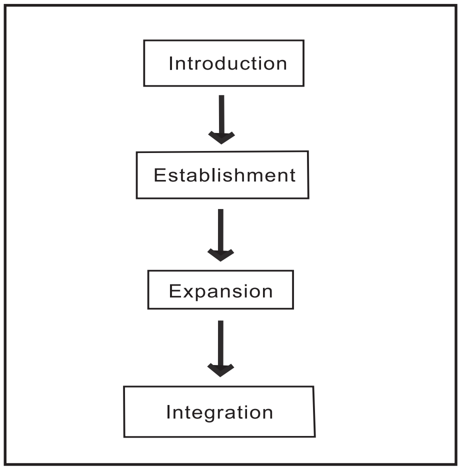
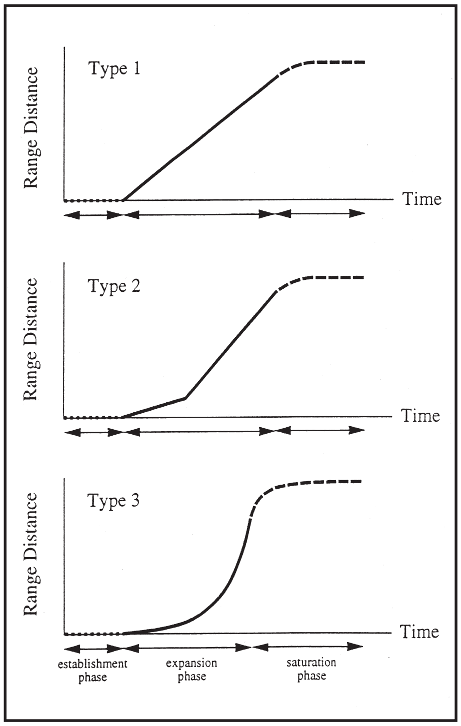


Figure 8.9. The process of invasion. The process is delineated as going from *introduction* and *establishment* which leads to *expansion* and *integration* into the environment. From there on the species may colonise new areas.

Figure 8.10. The process of expansion. The process, going from establishment to saturation, exists as three types. They may be linear (type 1), pass through first a slow and then a more rapid phase (type 2), or very fast after a long established phase (type 3). (From Shigesada and Kawasaki, 1997.)



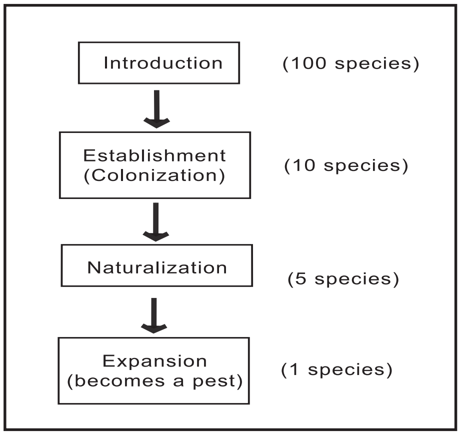


Figure 8.11. How many alien species become invasive? The tens rule says that 1/10 of introduced species will establish themselves and colonise the new area. Of these 1/10 will expand and become invasive or pests. If we add that only 1/10 of those imported will be introduced successfully, we have the ten-ten-ten rule.

Characteristics of invaders and invaded communities

Successful invaders are/have

- High reproductive rate, pioneer species, with short generation time
- Long-lived
- High dispersal rates
- Single-parent reproduction (a pregnant female can colonize)
- Vegetative or clonal reproduction
- High genetic variability
- Phenotypically plastic, i.e. adaptable
- Broad native range
- Habitat generalist
- Broad diet (polyphagous)
- Human commensural (able to live in habitats populated by people)

Invadable communities are

- Climatically matched with original habitat of invader
- Early successional, belong to early phases of ecosystem succession
- Low diversity of native species
- Absence of predators on invading species
- Absence of native species morphologically or ecologically similar to invader
- Absence of predators or grazers in evolutionary history (“naive” prey)
- Absence of fire in evolutionary history
- Little connected food web
- Anthropogenically disturbed, that is spread by means of man

Communities likely to exhibit large invasion effects are

- Simple communities
- Anthropogenically disturbed communities

expansion. Many other species, however, (e.g. the collared dove) appear to have long lag times between initial introduction and subsequent population explosions. Kowarik (1990) presented data from the survey of 184 introductions in the area of Berlin and Brandenburg for the time that passed between the introduction and the spontaneous spreading of non-native trees and shrubs. The average time lag was 147 years, the extremes ranging from 8 to 388 years. Despite these apparent differences in the colonizing history of invasive species, the relevant biological factors operating during the early stages of invasions are poorly understood.

Integration or “Equilibrium” stage. The final stage of an invasion can be described as the integration, a process in which the invading species establish interactions with other species native in a recipient community, with new hosts and parasites. The invader is naturalized in the recipient biota and region.

How frequently do invasive species establish themselves? How could we know? We are not even aware of how many accidental introductions failed – the successes are obvious. But there have been enough deliberate introductions to provide some records of failures. Across various animal taxa, success rates of more than 50% are rare, 10-40% are common, and, in some groups, any success is unusual (Meffe et al., 1994).

How frequently do introduced species become pests? A useful rule of thumb is that 10% of introduced invaders, living outside captivity in any sense, become established, and 10% of those established become pests. Success is thus fairly rare. The rule is statistical, and known as the ten-ten rule (Holdgate, 1986). Adding that for plants, 10% of those imported escape to become introduced, the rule can be extended to a ten-ten-ten rule: one out of a thousand introductions results in a pest (Williamson, 1993).

Characteristics of invaders and invaded systems

The actual invasion process varies depending on multiple factors such as:

- the characteristics or behaviour of the *invading species*;
- environmental conditions of the *invaded sites* and
- interactions with *indigenous species*.

The basic question “What attributes make some species more invasive ?” does not yet have a satisfactory answer. Invaders are species coming from elsewhere. Some general characteristics of invasive species and “invadable” communities, include absence of their natural predators in the new habitat to control their population growth. Alien species also may be better suited to take advantage of disturbed conditions than are native species. Human activity may create unusual environmental conditions, such as nutrient pulses, increased incidence of fire, or enhanced light availability, to which exotic species sometimes can adapt more readily than native species (Primack, 1993). The characteristics of invaders and invaded systems are summarised in the margin.

Although most countries today practise a quarantine system as a line of defence against biological invasions, more and more people are travelling and intermixing on an international scale and this creates increasing opportunities for invasions by organisms or diseases. There is also the danger that new life forms which were created artificially through bioengineering may escape from the laboratory and spread. Meanwhile, artificially disturbed areas, such as forests and rivers destroyed by human activities or cultivated land and pastures, are rapidly increasing, and this has increased the number of cases in which organisms which had hitherto been unsuccessful are now succeeding in invading and inhabiting new areas.

Introduction of new species in marine environments

Ships have been recognized as a major vector for the introduction of non-indigenous and harmful organisms. Several reports have reviewed the state of knowledge and

Figure 8.12. ***Heracleum***. This huge, up to 3 m tall, umbellate plant, with several species, originating from Southwest Asia, is today in the midst of an expansion phase and is becoming a pest on the European continent and south Scandinavia. The largest species *H. mantegazzianum*, whose leaves have a toxic liquid damaging unprotected skin, may form entire small "forests" on nutrient rich soil. They are often found along roads as here on the east-coast of southern Sweden. (Photo: Lars Rydén.)

the risks associated with transplantation to fisheries and aquaculture, including from ballast water. It has been found that modern aquaculture development in the coastal zone is at high risk of disease transfer from ballast water when the aquaculture facilities and areas of fishing are located near shipping routes.

Ships have used water as ballast regularly since the 1880s. Holds are flooded for balance and stability, and then discharged at or near ports to make room for a new cargo. But since the advent of very large tankers, container ships and bulk cargo carriers in the 1960s the volume of water discharged has increased greatly, ships are faster and the ballast tanks are cleaner. More species can be and are transported. Any species of plankton, or of benthos that has a planktonic larva, may be caught up and carried long distances in the ballast water. While most individuals imported this way will not survive in the new environment, and thus not produce a major invasion force, pressure can increase from propagules.

Risk from transfers of harmful species by aquaculture are now considerably reduced because deliberate introductions of useful species should follow the 1994 ICES Code of Practice, dealing with useful quarantine methods. This leaves shipping as the main vector for future introductions (Rosenthal et al., 1998).

What about the Baltic Sea from this point of view? The Baltic Sea is a very young, brackish, water body. Its water is too diluted for marine species, and too saline for freshwater species. Practically all the animal and plant species have invaded during the last 10,000 years, and the immigration still continues. More than 80 aquatic exotic species have been found in the Baltic Sea, ranging from phytoplankton to fish (see Box 8.2).

Hot spot areas for possible new introductions to the Baltic Sea are areas that probably have comparable abiotic conditions, e.g. the Black Sea, Great Lakes, and estuaries such as Chesapeake Bay. The Baltic Sea can be a donor area for introductions into other parts of the world. *Mysis relicta*, the freshwater opossum shrimp, originated in freshwater lakes in Scandinavia, Germany, and the British Isles, as well as in some brackish waters such as in the northern Baltic Sea region. It was introduced to more than a hundred lakes in northern and western North America and produced marked changes in many populations, notably decreases in most cladocerans and copepods.

The fact that the Baltic Sea has suffered frequent species invasions clearly demonstrates the vulnerability of its ecosystems. The lack of harmful impact events in the Baltic Sea up to now may also be due to a lack of appropriate

Ballast water as a vehicle for invading species

Ballast water is the water that a ship intentionally takes aboard for stability, trim, and other purposes. Ballast water is carried both in empty cargo holds and in actual ballast tanks.

A list of 45 successful invaders representing eight phyla, all probably brought in in ballast water between 1971 and 1990, covers all parts of the world (Carlton and Geller, 1993). A particularly remarkable example is the Ctenophoran (comb jelly) *Mnemiopsis leidyi*, which travelled from the western Atlantic to the Black Sea, causing havoc there.

Species introductions by international ship traffic are very high. More than 400 species ranging from microalgae to 15 cm long fish were collected from ballast tanks and ship hulls (Gollasch, 1996). Because of the diverse shapes and sizes of ballast tanks, up to 5% of the original ballast water volume remains in a tank after "complete" emptying, containing up to 25% of the entire biotic ballast water load.

Ballast water is thus an international "biotic conveyer belt," transporting, according to some estimates, more than 3,000 species per day around the world (NRC, 1995). This is, of course, a game of ecological roulette – a game no wise person plays, because it is most often lost than won. With this world of water in motion, it is thus not surprising that we have seen scores of ballast-mediated invasions around the world – and the number of invasions may be in the hundreds (Carlton, 1996).

information. There are already examples of habitat or/and trophic flow modifications by invasive species: *Dreissena polymorpha* in the Curonian Lagoon, *Marenzellaria viridis* in the Vistula Lagoon and Darst Zingst Boddens, and *Neogobius melanostomus* in inshore waters of the Gdansk Bay.

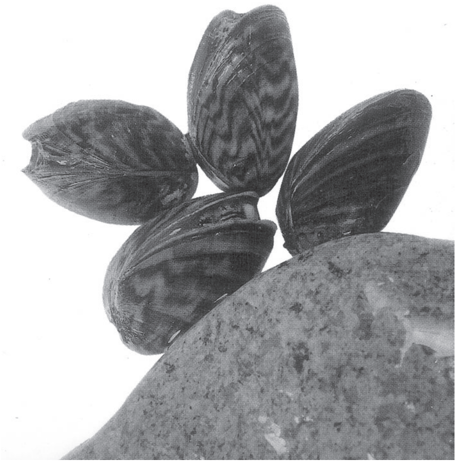


Figure 8.13. The Baltic Sea invader the zebra mussel, *Dreissena polymorpha*, is spreading over large areas in some parts of the Baltic Sea, for instance the Curonian Lagoon, and causes problems as biofouling organism. It is overgrowing water constructions and clog cooling systems. (Photo: Dan Minchin, Northern Ireland Zebra Mussle Control Group.)

Ecological and economic impacts of species introductions

Recent invasions and population explosion of non-indigenous species in various parts of the world are causing ecological and economic damage.

Ecological consequences. Most invaders have minor consequences (tens rule), but in individual cases the negative effects are serious. These lie along a scale going from depressed populations to individual extinctions and further up to ecosystem restructuring. A major mechanism of ecological effects is eating or consuming other species (vertical food-chain processes). For example, the lobate ctenophore *Mnemiopsis leidyi,* a species from the western Atlantic, particularly estuaries, which invaded the Black Sea, the Aegean and the Mediterranean, is considered to be a most successful invader. The predator, which can eat animals up to 1 cm long, including young fish, must have a large ecological effect. The invasion is a "dramatic example of the catastrophic effect of ballast water introductions" and "one of the most outstanding global invasion stories in the last 50 years." The effect on Black Sea fisheries is also "one of the hottest issues that has broken out in the last few years in marine biology" (Williamson, 1996). Other examples include pathogens causing tree diseases and animal diseases, competitors, grazers and mechanisms such as amensalism and swamping (when one species overgrows others).

The community consequences of introduction and extinction of particular species depend critically on which species are removed and the patterns of trophic interactions. Removing a plant species from the base of a simple food chain destroys the entire community. Alien species can have severe effects on lake communities and isolated stream systems. Such freshwater communities are somewhat similar to oceanic islands in that they are isolated habitats surrounded by vast stretches of inhospitable and uninhabitable terrain. There has been a long history of introducing commercial and sport fish species into lakes where they do not naturally occur. Often these exotic fish are larger and more aggressive than the native fish fauna, and they eventually drive the local fish to extinction.

Over 120 fish species have been introduced into marine and estuarine systems and inland seas, while some of the introductions have been deliberate attempts to increase fisheries, the majority of introductions were the unintentional result of canal building and the transport of ballast water in ships (Baltz, 1991). Following many of these introductions, the native fish species disappeared or were greatly reduced in numbers as a result of competition with and predation by the exotic species.

Aggressive aquatic exotics are not confined to fish, they include plants and invertebrate animals as well. The effects of exotic species are generally greatest on islands and in continental areas that have experienced human disturbance (Coblentz, 1990). The isolation of island habitats encourages the development of a unique assemblage of endemic species but it also leaves these species particularly vulnerable to invading species (Gagné, 1988).

Disease-causing microorganisms are another important category of harmful non-indigenous species. Microorganisms can cause epidemics among the native plants and animals when they are introduced to a new locality.

Genetic and evolutionary effects are related to the genetic changes caused by invading populations by hybridization, longer-term changes and speciation. A special class of exotics are those introduced species that have close relatives in the native biota. When exotics hybridize with the native species and varieties,

Case

Box 8.1

Neogobius – an invasive fish in the Baltic Sea

From where does it come?

Neogobius melanostomus has been known earlier only from the Black, Caspian, Azov, and Marmara seas. In 1990 it was also discovered in the Gulf of Gdansk (Skóra, 1993; Skóra and Stolarski, 1993). This fish is not a good swimmer (Berg, 1948). It is unlikely that it reached the new basin by itself, but rather came with ballast water. The most probable route is from the Caspian Sea to Volga river, Ribin reservoir, Onega and Ladoga lakes, and Gulf of Finland, as it has recently also been seen in the Moscow River (Sokolov et al., 1989).

Its spread in the Baltic Sea has been as quick as the earlier expansion in the North American St. Clair River and then Great Lakes (Jude et al., 1992). The first specimen caught in Gulf of Gdansk were not more than 4 years old. This means that they established themselves in this region in the mid-1980s. Today the species is abundant along the whole Polish coast, including Vistula lagoon, and also in German waters around Rügen Island and Estonian Pärnu Bay. The invasion occurs also in European rivers. Round goby can be found in the Belarusan part of the Dniepr and in the Danube close to Vienna harbour.

Negobius in its new habitat

Neogobius apparently has a good conditions in its new habitat and has spread quickly. Nowadays it is present in the mouth of the Wisla river. Its increasing biomass indicates that it has found good shelters (between stones, piles of mussels or various materials on the bottom, such as tyres, cans, vessels, etc.) and space for reproduction. It has thus successfully competed for space with other native species, reaching a density of up to several individuals per square meter. *Neogobius* spawns between April and August; the males protect the spawn. Their diet mostly consists of mussels, but they also eat crustaceans, eggs of other fish species, and even small fish (Skóra and Rzeznik, 2001). They are competitors in the food chains of the Gobiidae as well as other fish such as eelpouts, flat fish, eel, and perch.

Figure 8.14. A ***Neogobius melanostomus*** caught in the Gulf of Gdansk. It is a good fish to eat, but not always accepted. (Photo: André Maslennikov.)

Environmental effects

During recent years, due to the eutrophication of the Gulf of Gdansk, the blue mussel population has increased and is becoming important as a natural biofilter. The new invader may possibly strongly reduce this population. On the other hand, *Neogobius* has became an important part of the diet for other species, such as cod and cormorants. This, in turn, would reduce the pressure on their natural food, e.g. sprat and sandeel.

Neogobius is easily caught by anglers who are not happy as they catch fewer perch, roach, vimba, and eels. It is also caught in nets, and it is easy to get about 30 kg/net. The price for the new fish is, however, low. Customers are sceptical even though it is a good fish to eat.

Krzysztof E. Skóra

unique genotypes may be eliminated from local populations, and taxonomic boundaries become obscured (Cade, 1983).

Economic losses. A 1999 report by the US Congress estimates that more than 80 non-indigenous species caused documented losses of 183 billion USD in control costs and losses of marketable goods per year. The impact of alien species is most severe in the energy industry – several aliens block cooling water systems and water intakes of vessels. In shipping and boating aliens increase the use of fuel and the use of poisonous anti-fouling paints. Negative effects are registered also in fisheries – introduced fish caused unwanted shifts in trophic structure of pelagic ecosystems and effect commercial fish species.

Positive value of species invasions. Not all species introductions result in disaster. Introduced species can be important tools for land rehabilitation and restoration of biological diversity in damaged sites where natural succession is arrested. For example, Vitousek and Walker (1989) documented nitrogen enrichment in nitrogen-poor lava flows in Hawaii by the exotic tree *Myrica faya*. The greater availability of soil nitrogen where the alien occurs favours the entire ecosystem and results in higher productivity. One would expect that higher productivity would eventually result in a greater capacity to fix carbon, circulate nutrients, and support more species.

Review

Box 8.2

Introduction of new species to the Baltic Sea

Introductions in a species-poor environment

Practically all the marine flora and fauna found in the low diverse Baltic Sea have invaded the area during the last 10,000 years and the immigration is still continuing. This species-poor enclosed sea can be regarded as a "brackish water island" isolated from other major brackish areas by physical barriers of oceans and land. Through man's activities many of these barriers have been weakened by heavy traffic on the seas. Thus the intentional or unintentional importation of species via ballast water, fouling communities on boat bottoms, and transplantation of commercial species of shellfish and fish, and associated organisms have increased drastically over the last 50-100 years.

Species introduction by man into marine and brackish water systems has been little studied prior to the 1950s. The first review of the Baltic Sea appeared in the mid-1980s by Leppäkoski (1984). Most introduced species are unable to maintain a self-sustaining population. The final success can only be established after long time. For example, the soft-shell clam (*Mya arenaria*), introduced to European waters from North America in the 16th or 17th century with ballast water, has been able to persist and thrive here for 300-400 years. Most species have invaded from the south and are restricted by low temperatures combined with low unfavourable salinity.

Due to the ecological and evolutionary history, the Baltic Sea may receive and has received most of the introduced species from the shallow coastal shores of Kattegat and Skagerack (Leppäkoski, 1984). More than 30 species, mainly unintentionally introduced animals, have been reported from the central and northern Baltic Sea coastal areas, both water and terrestrial ecosystems.

A slight increase in the salinity during the last decades has also been observed, resulting in a spontaneous invasion of several eurohaline (salt loveing) fauna species, a process known as "oceanization".

Changing ecosystems or even new ecosystems

In the Baltic Sea alien species are numerous and locally very common especially in strongly modified habitats. Ecosystem disturbance, e.g. anoxic conditions, pollution or eutrophication, as in the Baltic Sea, are often followed by major changes in species composition, including the invasion of alien species. Man made environments, e.g. harbours, aquacultures, and cooling water discharges, often house new species. These both tend to alter the physical structure of the environment and also change interspecific interactions and energy flow patterns.

Several introductions into the Baltic Sea have resulted in large structural and functional changes. For example, when an entirely new growth form is introduced into a community, such as sessile filter-feeders (e.g. barnacles or the bivalve *Dreissena polymorpha*) they will change the flow of particles and nutrients in the area. The introduced *Dreissena* is now the basis for a food chain.

Table 8.2. Invasive organisms in the Baltic Sea by taxonomic groups

Taxonomic group	Number of alien organisms Absolute	Relative (%)
1. Phytoplankton	8	9.6
2. Macrophytes	6	7.2
3. Invetebrates	46	55.4
4. Fishes	20	24.1
5. Mammals	2	2.4
6. Birds	1	1.2
Total	83	100.0

Source: complied by P. Elias from Baltic Research Network on Ecology of Marine Invasions and Introduction, NEMO (Olenin and Daunys, 1998).

Table 8.3. Introduced species. The exact manner of dispersal is in most cases unknown. See further http://www.ku.lt/nemo/species.htm.

Category	Species
Ballast species	*Chara, Elodea, Eriocheir, Potamopyrgus*
Attached to the bottoms of ships	*Polydora, Dreissena, Corophium, Balanus, Cordylophora*
Introduced fish species occasionally found in the Baltic Sea	Salmonidae Rainbow trout (*Oncorhynchus mykiss*) Lake trout (*Salvelinus namaycush*) Peled whitefish (*Coregonus peled*) Cyprinidae Carp (*Cyprinus carpio*) Ictaluridae Brown bullhead (*Ictalurus nebulosus*)

Species belonging to all trophic levels have been introduced although the most successful species are members of the detritus food chain (e.g. *Dreissena* and *Potamopyrgus*). Young *Dreissena* are of importance as food for certain fish and water fowl and in Gdansk bay crab feeds as adult on *Dreissena* and as young on *Cordylophora*. The *Rithrpanopeus* crab is in its turn a valuable food item for fish. In this way a whole food chain is constructed by introduced species.

The Gulf of Riga is highly productive with high quantities of small bottom animals and drastic changes have taken place in the benthic communities. In 1991 the dominant species *Pontoporeia affinis* decreased and in 1993 the bristle worm (*Marenzellaria viridis*) started to spread rapidly throughout the whole Gulf.

Only few invaders are damaging and several of them are even useful

Most introduced species do not have any influence on man's economic interests and their impact on the ecosystem may be difficult to observe. However some introduced species are also appreciated e.g. the Canada goose (*Branta canadensis*) which is hunted both in Finland and Sweden.

Only a few are harmful. In the terrestrial environment the muskrat (*Ondatra zibethica*) may cause damage by their burrowing activities and the mink *(Mustela vison)* is a strong predator on water fowl, especially in the archepelago. Three species cause problem as biofouling organisms, the hydrozoan (*Cordylophora caspia*), the barnacle (*Balanus improvisus*) and the zebra mussel (*Dreissena polymorpha*). *Balanus improvisus* has been very successful in the Baltic Sea since the late 1800s. The spionid polychaete from North America is now found in the southern Baltic Sea.

Some of the introduced species are nuisance organisms: e.g. *Eriocheir* and *Cordylophora* may damage fishing gear, *Dreissena* may overgrow underwater constructions and clog cooling systems, the muskrat may damage constructions. A new invader, originally from Japan, with a high capacity to compete with some of the native fucoid species, is *Sargassum muticum*, which is now commonly found growing in shallow areas at low salinity along the Kattegat coast. Especially in many small harbours several-meter high plants are found growing that out-compete native species.

An easy way to reduce the risk of unintentional introductions of brackish water species into the Baltic Sea would be to exchange the ballast water when at sea if the ship is coming from a brackish water area.

Lena Kautsky

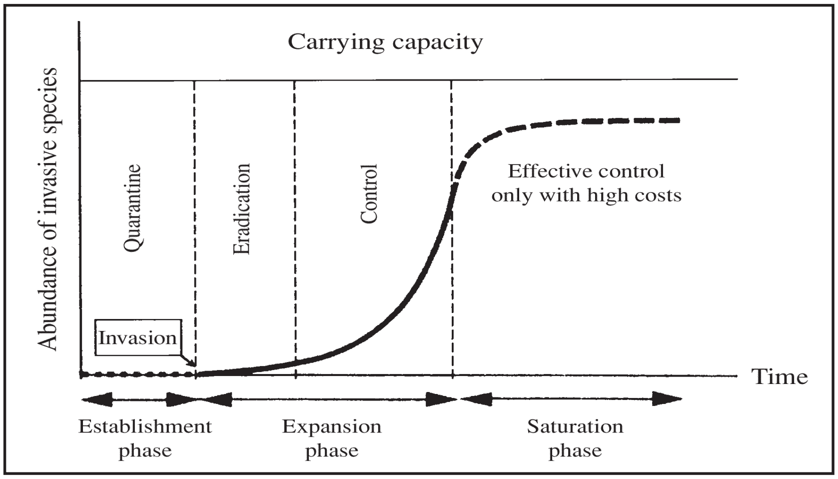


Figure 8.15. Control of invasive species. The most efficient measures may be taken at an early stage of invasion, using quarantine or eradication. Later on control measures are much more expensive and less efficient.

Control of introduction of alien species

The course of action for management of alien species could range from no action, simply monitoring populations of potentially invasive species and watching for negative effects, to a program of complete eradication. A manager would ask questions such as, "Will my attempts to control the invasive species cause other kinds of damage? Does the eradication program pose an unacceptable risk to the natural community and habitat?" In the real world of limited budgets and competing demands, a manager will also have to ask, "Will eradication be so costly that other priority programs would suffer?" (Meffe et al., 1994).

Quarantine is, at best, only moderately effective. Removing, or reducing to an acceptable density, an unwelcomed invader will normally require control. Chemical control is costly, and has to be kept up, quite apart from any undesirable side effects it may have. Biological control, when it works, is permanent and usually cost-free after release, though the earlier stages are expensive. In practice in most cases, a combination of methods, including habitat management, will be necessary (Groves, 1989).

Prevention of accidental introductions should include identifying biotas and ecosystems which are at particular risk, e.g. sites of high endemism such as oceanic islands, and promoting education, awareness and quarantine efforts on these sites and controlling transport opportunities for invasion.

International treaties and instruments to control introductions are very important. The forecasting and preventing of introductions involves: 1) a proactive approach related to predictions of future invasions/invaders and potential consequences; 2) conservation approaches which include re-establishment of native species which formerly were abundant but became either rare or absent (e.g. sturgeon and harbour seal).

It is better to prevent new introductions, rather than combat existing ones, and some tools have this purpose. The ICES "Code of Practice on the Introductions and Transfers of Marine Organisms" is one internationally agreed convention. There is also the IMO Voluntary Guidelines for Preventing Unintentional Introductions by Ballast Water and/or Sediment Discharges. In general, however, current legislation totally lacks ecological considerations. Article 8 of the Convention on Biological Diversity (CBD) calls on the parties to the convention to "...prevent the introduction of, control, or eradicate those species which threaten ecosystems, habitats or species". In 2001 the Global Invasive Species Strategy, GISS, has been developed to support the implementaion of Article 8 of CBD on a global as well as a national level.

NEMO – non-indigenous estuarine and marine organisms

NEMO is the Baltic Research Network on Invasions and Introductions. The objectives of the Research Network are:

- stimulation of scientific training, mobility and co-ordination of research effort on non-indigenous species in the Baltic Sea area;
- development of an up-to-date and standardized inventory of alien species;
- documentation of effects and impacts (ecological, economic, and social) posed by unwanted introductions of alien species;
- elabortion of schemes for fast dissemination of information on new invasions and introductions within and outside the Baltic Sea region.

For more details see the Website http://www.ku.lt/nemo/mainnemo.htm

A *pest* is an animal which competes with people for food, space or any other material needs. Species become pests only if its population on a given area grows uncontrolled. A *weed* is usually a plant species growing in the wrong place, competing for resources such as light, water, or minerals.

Control of pests and weeds

Pests in agricultural society

Just as man is promoting certain species useful to him through domestication, other species are controlled and limited by him because they are damaging. These nuisance animals and plants are called pests and weeds.

The species now considered to be pests and weeds existed in the ecosystems long before man was there. Thus the attacked species have evolved an arsenal of mechanisms to defend themselves. These include development of physical barriers, such as thick skin, and "chemical warfare". Mostly plants, but also some animals, excrete substances that are toxic to the invading weed or pest. Normally this is enough to control the population, and extreme numbers of a weed or pest do not often occur. However, there are exceptions. An overwhelming number of grasshoppers (locusts) are mentioned already in the Bible to have invaded ancient Egypt, and devastate crops and certainly large areas of other green fields as well.

The natural fine tuned balance between vegetation and herbivore, prey and predator, host and pest are often upset in the domesticated situation of agriculture, especially when very large areas are covered with a single cultivated species. The reasons are: 1) that the sheer huge amount of a cultivated crop species will be able to support enormous amount of a pest, 2) that the individuals of the cultivated species are very close to each other and thus facilitate spreading of the pest, and finally, 3) that the natural enemies of the pest often are removed. It might also be that natural resistance has been weakened or removed entirely in breeding.

The growth of a pest in a cultivated area can be costly and considerable efforts have been made to control pests. A large share of harvests every year is destroyed by pests. Better pest control is particularly very important in developing countries.

What are pests and weeds?

Pests and weeds are found along the whole evolutionary ladder of organisms. Micro-organisms include mostly beneficial species but there are "pests" among viruses, bacteria, and yeasts that may be extremely damaging. All plant species that are a nuisance in agriculture, horticulture, etc. are included in the weed category. Some of them are more difficult to deal with for the simple reason that modern agriculture creates ideal situations for them. Sometimes a plant appreciated in one situation might be regarded as a weed in other places, e.g. *Centaurea* species, and even roses (*Rosa rugosa*).

Insects are the classical pests in agriculture and cause the majority of problems. Several kinds of insect create problems. Many butterfly species are pests in pine forests, others in gardens. Species of beetles are classical pests in e.g. turnip fields, or for oil plants. Also higher mammals may behave as pests. Rabbits, deer, and moose may all become problems in the agricultural landscape, in forests, or in gardens if they become too numerous.

Pests most often damage a crop by eating it. A plant may also be infected and die of a disease (viroses, bacilliaroses, various fungi, etc.). There are, however, other possibilities as well. They may e.g. destroy the structure which lead to the death of the host.

Figure 8.16. Brown-tailed moth *(Euproctis chrysorrhoea)*, an example of a pest species in orchards. (Photo: Pawel Migula.)

Use of biocides

Chemicals that are toxic to pests and weeds are called biocides. These are spread to control pests and weeds. The shear amounts of such chemicals used in modern agriculture is a scary environmental problem. The first insecticide employed in large scale was DDT, introduced in the 1940s. DDT was used to kill mosquitoes, not least in malaria-struck areas. Since malaria, spread by mosquitoes, is one of the most devastating diseases in the world, DDT was considered a major discovery and its inventor was even awarded a Nobel prize. It was not until later that it was discovered that DDT was accumulating in ecosystems and caused havoc not only for the mosquitoes. Birds were also in the end hit and killed by DDT which remained in the environment. Later we have discovered that many chemicals which persist in nature in the way that these biocides did are harmful to the environment (see further Chapter 13).

The challenge of controlling pests and weeds

Biological or natural control of pests and weeds are often very specific and in addition applied exactly where needed and in reasonable amounts by the attacked plant or other organism. When man is attempting to control pests and weeds several of these rules are broken. The means that have been developed to combat pests and weeds are chemical, biological, and mechanical.

Biocides are often not specific, and are spread in huge amounts and over a large area where not only the pest is growing. Consequences do not limit themselves to the intended one – that the crop is protected – but there are often very many others. Thus a large variety of insects might be wiped out, including beneficial ones. Good or even necessary species in the ecosystem might be disappearing such as those who in fact control some pests for example by eating them, or pollinating insects. The killed species might also serve as food for others. The classical story in "Silent spring" deals exactly with this. As the mosquitoes were killed by DDT, the food for birds disappeared and there was a silent spring, no bird songs were heard.

An alternative is biological control. These methods include a series of possibilities. One is to use natural insect pheromones, substances attracting a defined species of e.g. butterfly, to be trapped and killed selectively. Other control methods include spreading bacteria over an area, especially the *Bacillus thuringensis* which is specifically directed against bugs. The use of predators is also an alternative. A parasite or predatory species are reproduced on a mass scale in the laboratory and then released to the endangered area, as a species protecting the crop. For example, lady bugs eat certain lice and can thus be either spread or just favoured in an area. A significant effort has been made recently towards improvement of the use of biological control. Biological control has the potential to be both cheaper and of course much more healthy for the environment than conventional use of biocides.

Monocultures in general are more vulnerable to pests and should be limited. Crop rotation will diminish the accumulation of disease organisms in soil or otherwise. Mixed cultures will also decrease the probability that large scale attacks by pests will occur.

In addition to chemical and biological control of pests and weeds there are the more simple mechanical methods. Mechanical removal of weeds, commonly called weeding, normally harms only the weed itself.

Integrated Pest Management

Since the mid 1960s Integrated Pest Mangement, IPM, has been advocated by numerous organizations as the preferred pest control strategy. IPM is the careful integration of a number of available pest control techniques which discourage the delevopment of pest populations, and keep pesticides and other interventions to levels that are economically justified and safe for human health and the environment. IPM emphasizises the growth of a healthy crop with the least possible disruption of agro-ecosystems, thereby encouraging natural pest cotrol mechanisms (http://www.fao.org).

Pheromones

Pheromones – chemical substances released into the environment by one sex of a species to attract the other sex, or to cause other changes of behaviour; also called ectohormones. Insects, especially butterflies, are sensitive to pheromones at very low concentrations.

Many pheromones have been characterized chemically and can be produced synthetically. They are today used as a very convenient and cheap tool to attract butterflies to pheromone traps, where the attracted individual is killed. They may also disturb normal sexual behaviour of a species, or at least act as a potent tool to give advance notice that a pest species is dangerously increasing in number.

Pheromones are not harmful to the environment and are, in comparison with pesticides, used in minute quantities.

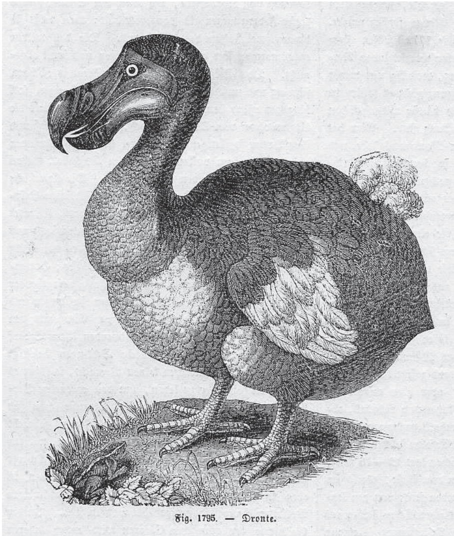


Figure 8.17. The Dodo or the Dronte. The extinction of the dodo (the dronte) is a symbol of human eco-vandalism. The dodo lived on Mauritius island in the Indian Ocean when Portuguese sailors arrived there three centuries ago. The flightless, defenceless birds were not able to escape when hunted and all of them were very quickly killed. The tragedy of the dodo illustrates the potential effects people can have on the environment. (Drawing by Eduard Friedrich Pöppig (1841). A German menagerie being a folio collection of 1100 illustrations of mammals and birds.)

Biodiversity

The dramatic loss of biological diversity in our time

Above we have reviewed and examined a number of different large scale processes that very deeply have influenced the living world, the composition of biological communities, the number of species, and reduced the space available for an almost endless number of ecosystems on our planet as a whole, and in the Baltic Sea region. In short we may summarise these processes under five headings:

- extinction of species by man during his entire history, not the least through hunting
- the change in landscape as a result of development of forestry, agriculture, and all kinds of infrastructure (Chapter 7)
- the domestication of plants and animals, useful to man, and the large scale cultivation of these plants and animals
- the control and combat of micro-organisms, plants and animals, including infectious micro-organisms, considered to be pest and weeds
- the large scale and global transport of species into new areas, where many become invasive and cause large scale damage to ecosystems

One might also add the use of traditional breeding and genetics and the introduction of new genetic tools to change, design and control organisms at the genetic level. Although it is not a process comparable to the others it does lead to large scale loss of genetic potential in the species being bred, since the domesticated races and brands are genetically much more homogenous than the natural population.

All of these processes have contributed to major change in the species composition of our Earth. Most of this is negative as life forms have become extinct or are close to extinction, and also because of the loss of economic value, biological value, of genetic potential and beauty. It is by many also considered a violation of ethical principles, namely if we accept that living nature should be respected in its own right and with its own integrity (Chapter 21).

The pace in which genetic potential and species diversity have been lost over the last few human generations is very high. It is in fact of the same order of magnitude as the loss of diversity during the large periods of species extinction in the history of the planet. Five such periods have been identified. The last and perhaps best known took place 65 million years ago. This was when the dinosaurs became extinct. The cause of this extinction was an astronomical event. A large meteorite hit Earth and led to global scale dust clouds, covering the Earth from the sun and causing a period of cooler climate. One assumes that the ectothermic dinosaurs, not being able to uphold their body temperature, succumbed during this event, while the mammals became the new group to diverge rapidly. Traces from the event, the meteorite impact, can today be seen in the Yucatan peninsula in south-eastern Mexico.

It is believed that similar astronomic events have been the cause of all previous major events of species extinction. Today, however, the extinction is cased by humans, thus, if you wish, the global ecosystem itself (since man is a biological species). The unusual situation is that the cause – humans – also has the power of changing the situation and, hopefully, reduce the loss of biological diversity.

What was lost can not be regained. But in the last few years the awareness of the threats to biological diversity has grown. Scientists have reacted by starting

Genetic variability in an individual is measured as percent variation in the nucleic acid sequence of homologous genes. In a population it is measured as number of variable (polymorphic) genes, so called alleles, and expressed as heterozygosity.

to study the diversity phenomenon in more detail. The concern for untouched environments, wildlife, and species diversity is growing. The reason why species appear in an area, thrive and disappear is studied and the measures to protect habitats and species are examined.

Threats and protection of diversity – the concept of biodiversity

When it finally became possible for western scientists to systematically visit the landscapes in the former communist countries after the change in political systems in 1989-91, they made up a complex and confusing picture for all those interested in nature conservation, species survival and the environment. In some parts, ecological degradation due to practices in forestry and agriculture and industrial pollution had been very destructive. In others the land, not least due to the ban to visit large areas considered important to the national defence, proved to have been large reserves of untouched nature and invaluable biological resources. In some other areas, slower economic development had been favourable for nature conservation. Better known was perhaps the western European landscapes, with its often severely exploited nature, industrial agriculture and urban and industrial infrastructure. Here protection of nature had limited successes, in spite of considerable political pressure.

The picture demonstrated, if nothing else, the complexity of nature conservation in the region, and the need to recognise and consider numerous interacting issues. Beyond the natural sciences these included underlying historical, philosophical, cultural and ethical aspects, as well as socio-economic mechanisms and political processes.

At about the same time a new discipline, or rather a new environmental concept, was created. The term biological diversity, or biodiversity (Wilson and Peter, 1988; and Huston, 1994), started to appear in research publications and the mass media. Although aiming at and encompassing much of the various factors that influence the quality of life on Earth, at least from an anthropocentric perspective, biodiversity has a scientifically adopted definition.

Basically, biodiversity breaks down into the hierarchical organisation of the organismal world in the biosphere, covering genetic variation between individuals, between populations and between taxonomic units, e.g. species, as well as higher and lower categories. Hence, biodiversity encompasses the entire global gene pool and all its evolutionary entities. It comprises all kinds of modified varieties derived from the wild, such as crops and other cultural plants, domestic breeds and genetically modified organisms (GMOs). Phenotypically unchanged organisms that are ”traditionally” harvested or utilised by man on a routine basis, from colon bacilli in a petri dish to blueberries and on to working elephants, are, despite exhibiting an original design, usually assigned to the cultivated biodiversity.

Further, biodiversity refers to life's spatial and temporal conditions from species communities to ecosystems, taking into account the dynamic interactions and functional properties of their components. Analogous to the organism level, in this context landscape is a spatial biodiversity level regardless of the effects of human activities. The limits between natural and cultural are not always easily discernible, or even meaningful to try to identify, a reflection which we will expand upon ahead. To summarise, the concept of biodiversity encompasses all levels of life in the biosphere, from genes to landscapes, and its ecological and evolutionary processes.

Today, the essence of applied, and political, biodiversity has expanded to incorporate more or less everything that aims at conserving and sustaining our natural heritage. Such wide-embracing objects render a rather vague notion among laymen in general, associating biodiversity with something beneficial and important. Biodiversity issues, however, can only be relevantly addressed

Figure 8.18. Spring in Białowieza forest. Botanists have identified 900 species of vascular plants in the Białowieza forest. The biodiversity is unusually high since both eastern and western species are found in the forest. (Photo: Pawel Migula.)

Figure 8.19. Arctic puffin, *Fratercula arctica*, found mostly on the Norwegian coast and further west, is a protected species. The puffin is a small bird, about 30 cm long, with a very remarkable and strong beak in red, blue, and yellow. (Photo: Ewa Boklak.)

within specified contexts (Heywood, 1995). Some of these contexts will provide major challenges for the global economy as we now have entered into the new millennium. Conflicting interests and opposing views of the environmental state of the art, such as our introductory example, will continue to demand carefully balanced multidisciplinary interpretations.

Richness of species

Biological diversity, in its technical sense, is still poorly investigated, even at the comparatively visual *species level*. The community of biological systematists has managed to discover and give binomial names to close to two million species, but the magnitude of anonymous creatures that remain out there is a matter of dispute. Estimates ranging from ten to even a hundred million have been suggested. We do know that diversity at the species level is not evenly distributed on Earth, or among phyla (Rosenzweig, 1995). Accordingly, for instance, there is a general correlation between species richness and latitude, and between species richness and age of an ecosystem.

At any rate, we are almost certain that the insects are the winning team in this contest. Tropical canopies alone have been assigned a hypothetical ten million species of beetles. But we have also begun to realise that the natural history and evolutionary pathways of many microbial life forms do not readily render them to fit into prevailing species concepts. Modern molecular techniques now provide important tools for reconstructing the past and for establishing systematic relationships (Hillis et al., 1996; and Karp et al., 1998), tools that will allow new insights into the secrets of the fossil world of micro-organisms. Thus, preliminary screening of DNA extracted from just a handful of soil has revealed an astonishing number of distinct genetic lineages, indicating a multitude of previously unknown evolutionary entities. Species and landscapes are, in comparison, fairly obvious biodiversity levels.

When attempting to expose *within-species* biodiversity, the largely "invisible" gene level, things get more complicated. It is a non-contradicted fact that genetic variability, or differences between individuals in nucleic acid sequences of homologous genes, is a fundamental component of all biological diversity. A population's genetic diversity is measured as the rate of variable genes (polymorphic loci), or in terms of heterozygosity. The latter refers to the frequency of individuals carrying two different variants (alleles) of a given gene, each inherited from each parent in the case of a diploid sexual species (which include all higher forms of life). It is generally adopted that the genotype distribution, as expressed by heterozygosity, is correlated to fitness. Although hard to prove empirically, wild populations that lose gene variants beyond a certain degree are expected to become less viable. One more obvious effect of the loss of gene variants is that for each generation, the likelihood increases that two individuals with similar alleles will mate. If this particular allele codes for a lethal recessive trait the offspring will die. More often though, effects of inbreeding are subject to more subtle quantitative genetics, where a combination of genes control a certain fitness trait, for instance growth rate or fertility. Such types of negative consequences due to mating between genetically similar individuals are usually referred to as inbreeding depression.

The prevalent notion is that high heterozygosity provides a buffering capacity in a changing environment, where new selective forces may alter a currently viable genotype (Hartl and Clark, 1989; and Avise and Hamrick, 1996). In short, genetic variation is the very raw material for evolution and domestic breeding programmes to work with. At the opposite extreme from inbreeding, genetic introgression by invasive or introduced populations also constitutes a significant risk to locally adapted natural populations. Such outbreeding depression, through

Case

Box 8.3

Environmental impacts that affect Baltic Sea bird fauna

Eutrophication and discharge of offal

The considerable release of nutrients from traffic and domestic and industrial sources has caused excessive growth of aquatic plants, zooplankton, and invertebrates. This has boosted the food basis for many species of birds. If we also include the waste provided at refuse dumps, and by fisheries, still more species have benefited.

Greebes, mute swans, coots, and some dabbling ducks have increased in numbers both because of the improved food conditions and better shelter. The expansion of reed stands has been particularly important.

Some of the diving ducks, especially the Eider, have been favoured by an increase of bottom-living invertebrates. The Eider is a specialist on the Blue Mussel which shows a strong growth in biomass.

The gulls have benefited most from eutrophication in the wide sense mentioned above. It is well known that waste from the fishing industry and refuse dumps has been important food for gulls. There has been an increase of gulls and other marine birds world-wide because of this. Recently, however, there has been a decline of several populations in the Baltic Sea region, particularly lesser black-backed, common, and black-headed gulls. This may indicate that domestic waste has been particularly important, because waste treatment has improved most during this period. Concerning eutrophication, which is normally considered to be negative to animal life, its effect on most bird populations in the Baltic Sea is the opposite.

Figure 8.20. Cormorant, *Phalacrocorax carbo*, is a species that after many years of being rare now is increasing rapidly along the Baltic Sea coasts. (Photo: Ewa Boklak.)

Toxic substances

We know little about the effect of toxic chemicals on the population development of most marine bird species. Toxic chemicals have so far been proved to be a major factor for the decline of only one species, the white-tailed eagle. Its position at the top level in the food chain made it particularly vulnerable. There is today little doubt that it was toxic chemicals that accumulated to such high concentrations in their bodies that reproduction failed. But the situation is much improved, and the white-tailed eagle is now recovering fast.

Oil spills

Oil spills comes from major tanker disasters, and hundreds of smaller releases from all kinds of ships. The latter seems to be the main threat because they are so frequent (500-1,000 per year). The oil destroys the plumage of the birds letting the cold water penetrate to their bodies so that they can no longer stay afloat and must seek land; in addition the birds ingest toxic constituents of the oil when they try to clean their feathers.

The problem of oil spills is mainly concentrated to the winter period and limited areas. There are several reasons for this. The spills most often occur in the open sea along the shipping routes. It is only during the winter that any appreciable number of birds live in the open sea. Another reason is that the oil both evaporates and is degraded faster when the water temperature is high. The species that is affected more than any other is the long-tailed duck which winter in numbers reaching about four million. The Baltic Sea is the major wintering area for the whole West-Palearctic population of this bird.

Physical exploitation and disturbance

Different kinds of human exploitation all around the Baltic Sea have encroached upon bird habitats. For certain kinds of exploitation it is quite easy to see that they mainly are negative for the birds: the expansion of cities, villages and summer houses, harbours, industrial areas, marinas and other recreational establishments, and land fills. They simply physically remove a former habitat for the marine birds.

Disturbances from leisure boats, sport fishing, swimming, etc., influences birds by preventing them from using breeding and moulting areas. To safe-guard good breeding areas, bird sanctuaries have been established, which are closed to visitors during the sensitive breeding season.

Invasion of non-native predators

During recent decades two non-native mammalian predators have invaded the Baltic Sea area. The North American mink escaped from fur farms early in this century and has colonised the whole coastal area except for islands or groups of islands situated far out in the sea. It has affected the water bird populations extensively. Some water bird species have adapted by moving to the outer islands but others have suffered considerable population decreases, even leading to local extinction and decreased species diversity. The racoon dog, originally an East Asian species imported into European Russia to be bred in fur farms, is now common in Finland and Estonia. Like the mink it is a skilful swimmer and is supposed to cause negative effects on the water bird fauna.

Hunting

The rural economies depended on long-term management of waterfowl, which involved for example provision of nesting sites, regulation of culling, and control of predators. In general the harvest seems to have been carried out in a wise way but there are also examples of over-exploitation.

One of the major recent events in the Baltic Sea area is the establishment of a large and increasing population of the barnacle goose. It was believed that this species was purely Arctic, but after its successful invasion of the Baltic Sea, previously used only as a stop-over site during migration, this is now questioned. It is possible that the barnacle goose is quite a natural bird for the region. But its habit of breeding in large and easily accessible colonies made it so vulnerable for hunting (flightless during moult) and egg culling that it was exterminated soon after humans settled in the area and exterminated repeatedly after every attempt to start a new breeding colony. Also the greylag goose population suffered a lot from intensive catching during the moulting period, but has recovered dramatically during recent decades.

For another species, the cormorant, it is known that persecution was the cause of its near extermination from the Baltic Sea region. A remarkable recovery is now taking place. The potential is not yet exhausted, and it is likely that the cormorant will become a breeder in most of the Baltic Sea, including the Gulf of Bothnia.

The old tradition of hunting of sea ducks during spring has long been a controversial matter. The argument against harvesting the population just before breeding is that birds that have survived the winter constitute the recruitment base. Hunting is better restricted to autumn, when the population size is maximal, and when it is likely that hunting does not act as an additional source of mortality but only compensates for a part of normal winter mortality which would otherwise be higher because of food competition. Hunting as a whole, including spring hunting on land, is probably presently not regulating any duck population in the Baltic Sea region. But if the shooting season is expanded further into the winter and if spring hunting is permitted more widely, hunting may be able to press population sizes down.

Sören Svensson

Case
Box 8.4

Red Lists

How to categorize threatened species

The following categories of threatened species were defined by IUCN (http://www.iucn.org/) in 1994 and are now used all over the world: (http://www.redlist.org/info/categories_criteria.html). There are five categoreis which belong to the red list:

- Extinct (EX)
- Extinct in the wild (EW)
- Critically endangered (CE)
- Endangered (EN)
- Vulnerable (VU)

Some organisations put the first two categories in a black, rather than red, book.

The other categories are lower risk (LR), which means that the species is not threatened, data deficient (DD) and not evaluated (NE)

How to determine if a species is endangered

For the CE category, a taxon is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the following criteria (A to E):

A. Population reduction in the form of either: 1) an observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer, or 2) a reduction of at least 80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer.

B. Extent of occurrence estimated to be less than 100 km^2, or area of occupancy estimated to be less than 10 km^2, and estimates indicating either: 1) severely fragmented or known to exist at only a single location, 2) continuing decline, observed, inferred or projected, or 3) extreme fluctuations in extent of occurrence, area of occupancy, number of locations or subpopulations or number of mature individuals.

C. Population estimated to number less than 250 mature individuals and either: 1) an estimated continuing decline of at least 25% within three years or one generation, whichever is longer, or 2) a continuing decline, observed, projected, or inferred, in numbers of mature individuals and population structure.

D. Population estimated to number less than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer.

Swedish Red Lists

In Sweden the categories used in the present year 2000 Red List of the Swedish Species, are based on the IUCN Red List criteria. They are

RE Regionally Extinct: A species is Regionally Extinct when there is no reasonable doubt that the last individual potentially capable of reproduction within the country (region) has died or disappeared from the country (region).

CE Critically Endangered: A species is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the criteria A to E for that category (see above).

EN Endangered: A species is Endangered when it is not Critically Endangered but yet facing a very high risk of extinction in the wild in the near future, as defined by any of the criteria A to E for that category.

VU Vulnerable: A species is Vulnerable when it is not Critically Endangered or Endangered but yet facing a high risk of extinction in the wild in the medium-term future, as defined by any of the criteria A to D for that category.

Figure 8.21. The orchid *Cypripedium calceolus*, lady slippers is red listed in many countries. The orchid was once collected for its remarkable yellow ("the shoe" or "slipper") and red-brown flower. It is now protected. (Photo: Nikolai Mihalchuk.)

NT Near Threatened: A species is Near Threatened when it does not satisfy the criteria of any of the categories Critically Endangered, Endangered or Vulnerable, but is close to qualifying for Vulnerable.

DD Data Deficient: A threatened species is assigned to Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.

4,120 red listed species

The number of red listed species (all six categories above) in Sweden were in 2001, no less than 4,120. This amounts to 21% of the species assessed. The percentage red listed species is highest among some algae (62%) and lowest (6%) among some insect groups. It is 35% for birds and 37% for mammals. The number of red listed species in various phyla are given in Table 8.4.

Table 8.4. Numbers of red listed species (taxa) in Sweden. (Data from The new Red List of Sweden. (Gärdenfors, U., ed. 2001 and http://www.artdata.slu.se/redlist.htm).

Category	Threatened	Red listed (all categories)
Vascular plants	326	505
Stoneworts	47	62
Bryophytes	104	238
Macrofungi	254	609
Lichens	147	254
Mammals	15	23
Birds	47	88
Reptilia & Amphibia	9	12
Fish	13	33
Hymenoptera	65	185
Butterflies, Lepidoiptera	172	438
Flies, mosquitos, Diptera	73	172
Beetles, Coleoptera	543	1,123
Other insects	66	119
Myriapoda	2	8
Spiders, Arachnida	19	71
Crustacea	12	50
Mollusca	58	143
Echinodermata	12	26
Hirundinea & Tricladida	0	2
Total	1,953	4,120

Table 8.5. Number of threatened species among various animal groups in Poland (PL) and Finland (Fi) (after Glowacinski, 1992 and The Finnish Environment, 1997).

Classes	Total no of species		Extinct (Ex)		Endangered (E)		Vulnerable (V)		Rare (R)	
	Pl	Fi	Pl	Fi	Pl	Fi	Pl	Fi	Pl	Fi
Mammals	102	62	9	3	4	5	2	2	23	6
Birds	377	235	5	1	10	7	14	9	20	16
Reptiles	9	5	0	1	2	1	0	0	0	0
Amphibians	18	5	0	0	0	0	0	1	1	0
Fish	118	66	1	1	1	6	2	0	6	2
Insects	?	9,458	0	59	8	55	13	87	5	386

the break-up of co-adapted gene complexes, has repeatedly been claimed to cause local extinction.

Gene level diversity

By using DNA sequencing we are nowadays capable of screening complete genomes. Unfortunately though, even if the world's DNA laboratories restricted their combined efforts to the more variable gene regions of species and worked around the clock for the next 100 years, they would barely be able to scratch the surface of the entire global gene pool. This illustrates the practical necessity to concentrate on certain informative gene "markers" and to chose appropriate molecular techniques for the specific problem at hand.

Despite its undisputed significance, the gene level is often overlooked as an operational biodiversity unit. Visualizing genetic variation requires certain technical measures and may be regarded as costly and complicated. For this reason, to judge from various action plans and national agendas, it still seems more convenient to deal with biodiversity issues at the higher levels. In the meantime, each year, countless unique genes and viable gene combinations are lost forever, not to mention the great many species that go extinct without even having been discovered.

Our manipulation of biological resources dates back to the dawn of mankind and first attempts of humans to control external energy sources, such as food, fibres and fuel (Diamond, 1997). This process can be regarded either as a species' disjunction from its ecosystem or as a step-wise ecological niche expansion. The results are of course striking with all cultured domesticated species forming sometimes thousands of variants, which today constitute a large genetic resource often threatened by short-sighted economic interests. They differ quite often only in a single gene. This gene might, however, turn out to be an invaluable resource in breeding programs and thus a diversity worth protecting.

Red Lists and monitoring of biodiversity

A *Red Data Book* is a registration and diagnostic description of life at risk. The IUCN Red Lists (see Box 8.4) are recognized as the most comprehensive, apolitical global approach for evaluating the conservation status of plant and animal species. The IUCN Red Data Book has been successively published since 1962. The introduction in 1994 of a scientifically rigorous approach to determine risks of extinction which is applicable to all species and infra-specific taxa, has become a world standard. In order to produce Red Lists of all threatened species worldwide, a network of scientists and partner organizations working in almost every country in the world has been mobilized. The IUCN Red List Programme provides fundamental information on the status of biodiversity as it changes over time. The goals of the IUCN Red List Programme are to provide a global index of the state of degeneration of biodiversity, and to identify and document those species most in need of conservation attention.

The countries of the Baltic Sea region have already published or are preparing *National Red Data Books* (EPA, 1998). For example, the Polish Plant Red Data

The Swedish Biodiversity and Species Information Centra

The Swedish Biodiversity Centre (http://www.cbm.slu.se) is the national centre for research on biodiversity. At the centre the Swedish University of Agricultural Sciences and Uppsala University co-ordinate a network of departments, organisations and authorities all over the country.

The Centre's main function is research as well as research coordination with the purpose to preserve, sustainably use and restore biodiversity in Sweden. Education and information concerning biodiversity are other important issues. The Centre also participates in international projects related to biodiversity.

The *Species Information Centre* (www.artdata.slu.se/redlist.htm) works with biodiversity, serving as the focal point for information on threatened species and biodiversity in Sweden. Its main tasks are to collect, evaluate, and store the most important information about threatened and rare plant and animal species. A basic part of this work is to assess the types and degrees of threat, and to prepare the national Red List and Red Data Books. Much of the work is focused on information through publications, conferences, etc.

The *Threatened Species Unit*, has the task to document the status of vulnerable species of plants and animals in Sweden and to identify critical factors of threats.

The *Swedish Taxonomy Initiative* (http://www.artdata.slu.se/svenska_artprojektet.htm) aims at describing the more than 50,000 Swedish multicellular species The project started in 2001. The estimated 30,000 species which can be identified with conventional methods will be described in some detail, including maps and published in a book series. The residual 20,000 species that needs advanced techniques to be identified will be listed in catalogues for the specialists. It is estimated that the project will continue to about the year 2020.

Biodiversity in Belarus

the Belovezhskaya Pushtcha

Belarusan part of Belovezhskaya Pushtcha is a rich resort for biodiversity. The forest itself is especially interesting. Here we find six hundred year old oak trees surrounded by three hundred year old pine trees, and you may see the otherwise almost disappeared spruce *Abies alba*. All in all there are 26 zones of arboreal species and 38 areas of bushes. 52% of the trees are above 100 years old. There are areas with 250-350 year old and some areas with 300-600 year old trees.

Coniferous forest (*Pinopsida*) grows on 68,8% of forest-covered territory. Oak (*Quercus robur*), and birch (*Betula pendula, Betula pubescens*), *Carpinus, Alnus, Fraxinus excelsior* dominate. Rare species of leaved trees include *for example Quercus petraea, Ulmus laevis*, *Ulmus scarab, Astrantia major major, Melitis melissophyllum, Cimicifuga europaea, Isopyrum thalictroides, Allium ursinum*, and *Arnica montana.*

The number of vascular plant species are about 960. The large number is due to the fact that the forest borders two vegetation zones, east and west. Forty-seven plants are registered as very rare and disappearing.

The rich and variable vegetation of Belovezhskaya Pushtcha is a wonderful environment for wild animals. The fauna of Belovezhskaya Pushtcha include 59 species of mammals, and many birds, fishes, amphibia, and reptiles. The beauty and pride of Belovezhskaya Pushtcha is certainly the bison. This is the largest animal on the European continent. Bison is the real master of the woods. There are more than 300 of them. During last years many individuals were moved to other places of the country.

75 species of birds registered in the Red Book of Belarus are found in Belovezhskaya Pushtcha, among them *Circaetus gallicus, Haliaeetus albicilla, Botaurus stellaris, Ixobrychus minutus,* and *Acrocephalus paludicola*. The third most abundant population of *A. paludicola* in Europe is found in the marsh Vertlyavoye, situated on the edge of Belovezhskaya Pushtcha.

The nearby Buslovka park in the Brest region houses about 20 kinds of animals and plants redlisted in Belarus. The flora of 'Buslovka', which is rich and different, includes about 500 kinds of vascular plants. A considerable work was done to conserve the orchid Lady slippers, *Cypripedium calceolus*, and create a group of reservations for it in the southern part of Brest Polessye (woodlands). Here 15,000 specimen of this orchid were found (Figure 8.21).

Nikolai V. Mikhalchuk

Figure 8.22. White anemon, *Anemone nemorosa*, flowering in early May to greet the spring is a protected plant in Poland but not in Sweden, where it is very common. The flowers of its blue relative, *Pulsatilla vulgaris,* may be picked in Sweden, but roots should be left to allow new flowers the next year. (Photo: Pawel Migula.)

Book covers pteridophytes and flowering plants recorded in the 19th and 20th century within present boundaries of the country and describes 206 species. The list covers nearly 10% of Polish vascular flora. According to the IUCN categorisation, 34 species have lost their sites (RE), 36 taxa are endangered (EN), 72 are vulnerable (VU), 56 rare, and 6 are insufficiently known (DD) (Zarzycki and Kazimierczakowa, 1993). The Polish Animal Red Data Book (Glowacinski, 1992) also corresponds with the general arrangement of the IUCN Red Data Book and is based on a systematic order of animals. Some data selected for two Baltic countries, Poland and Finland, are compared in Table 8.5.

In Sweden, the Threatened Species Unit, which is linked to the Swedish Environmental Protection Agency and the Swedish University of Agricultural Sciences, is responsible for implementing the IUCN Red List Programme. The mandate of the Threatened Species Unit includes developing national monitoring programmes and compiling red lists for Sweden (see margin on page 245).

The *IUCN Red List* represents a radical new departure, so far as it focuses on using the data in the Red List for multi-species analyses in order to understand what is happening to biodiversity more generally. To achieve its goals, the following objectives are pursued (The 2000 IUCN Red List of Threatened Species Website):

- To assess, in the long term, the status of a selected set of species;
- To establish a baseline from which to monitor the status of species;
- To provide a global context for the establishment of conservation priorities at the local level; and
- To monitor, on a continuing basis, the status of a representative selection of species (as biodiversity indicators) that cover all the major ecosystems of the world.

Population change – why species vary in numbers

The study of red listed species demonstrates that the ecological systems and populations in an area is undergoing constant dynamic changes. Especially when it comes to birds this is obvious and there are many examples. In some cases it is clear why a species changes, such as with the near extinction of the white-tailed eagle and the peregrine falcon, where biocides was a main reason. Eutrophication, oil spills, acidification and other large scale changes of the environment, however, seem to be the reason for population decline more often than specific chemicals. But there are many factors. For example, if the major food for a species disappears, if proper places for nesting are diminishing, or simply the nesting is very disturbed by human activities, the species will be threatened.

Sometimes it is very difficult to understand exactly why a species increases or decreases in numbers. For example, it is not known why the cormorant in the Baltic Sea increased dramatically in numbers during the 1990s (see also Box 8.3).

Strategies for protection of biodiversity

Coexistence of man and the rest of the living world

Some of the long-term processes we have discussed in this chapter, although much changed, are still going on today. Man is still limiting competing carnivores. We are still threatening the megafauna. We are still changing the biotopes, living space, of an increasing number of species. The estimate of scientists is that some 16,000 species become extinct each year over the entire planet mostly through biotope destruction and impact of invasive species.

The largest animals ever living on Earth are the great whales in the oceans. Whale hunting, once very intense, may be seen as the contemporary hunting of the megafauna. Through the action of many concerned individuals and interest groups, protests against whaling has become a symbol for the fight to conserve a threatened species. Much has already been achieved to protect the whales. An international commission with participation of the major whaling nations, Norway among them, sets whale hunting quotas with the goal of not allowing more hunting than the population can tolerate. Although these decisions are based on purportedly scientific observations, there is not a consensus as to which whale populations may be hunted without threatening their survival.

The fight with competing carnivores continues. The grey seals in the Baltic Sea is one such species once hunted by fishermen. Seals were hunted for their meat, fat, and fur, but also because they competed with man. They ate fish in fishing gear or destroyed nets. Hunting caused a continuous decrease in seal populations from the early 20th Century. From the 1950s chemical pollution added to the process. In the 1970s the seals became a protected species. But today, after the recuperation of the seal population in the 1990s, the debate about seal hunting has started again. Fisherman claim that seals cause too much damage to fishing gear, and want to hunt them. At the same time there is a political consensus that we want to have a healthy seal population in the Baltic Sea. How these two goals are going to be combined is now debated. To achieve this, man has somehow to adapt to the competing carnivores, not exclusively the other way around. Fishing gear might be designed so that seals do not attack them. A certain destruction of equipment may have to be accepted and can be compensated for by the state.

Similar policies have to be developed when it comes to wolves. The wolf population is now increasing in Sweden, after the species was extinct in Sweden for a period of several decades. In other countries in the Baltic Sea region the wolf has always been present and often numerous, with hundreds of individuals. The bear and the lynx are in similar situations.

Nature conservation

One way to protect biodiversity is to protect living species and areas by law. This is nature conservation and protection. The idea of nature conservation had its beginning in medieval times. Kings reserved the privilege to hunt large game animals, especially the red deer, and in some areas the European bison or the brown bear, to themselves and the nobility and thus the game was otherwise protected. The reduction in number due to over-hunting was stopped.

When in the end of the 19th century these privileges ceased with the old societies, the farming population took the opportunity to hunt, and many animals

Figure 8.23. Saving a lost species. The sturgeon, once common, may be lost from the Baltic Sea. The last known individual, a 4 meter long specimen, was caught in Estonia in 1996. At Hel Marine Station Bartlomiej Arciszewski has successfully learned how to keep an Asian sturgeon hybride in cultivation. The hope is that it should be possible to do the same with the original species to reintroduce it in the Baltic drainage area. (Photo: Lars Rydén.)

Figure 8.24. Amphibians are among the most threatened animal group since their habitat, wetlands, are shrinking. The common toad, *Bufo bufo*, is a protected species in many countries in the Baltic Sea region. (Photo: Pawel Migula.)

Case Box 8.5 Marine mammals in Poland – from extinction to protection

Among four species of marine mammals inhabiting the Baltic Sea two are acknowledged in Poland as members of the native fauna, grey seal (*Halichoerus grypus*) and harbour porpoise (*Phocoena phocoena*). Polish waters are visited by two other Baltic seal species, ringed seal (*Phoca hispida*) and common seal (*Phoca vitulina*), and occasionally by other cetaceans, the most frequent being the white-beaked dolphin (*Lagenorhynchus albirostris*), which has been observed several times during the past 20 years.

Seals

At the turn of the 19th century a colony of grey seals, about 1,000 individuals, inhabited the Gulf of Gdansk on the eastern part of the Polish coast. Fishermen perceived them as pests, since they were destroying nets and competed for fish. Since 1945 grey seals have become extremely rare and are at present considered to be an exterminated species in Poland. Legal protection of pinnipeds was introduced in 1984.

Although seals have been under legal protection for many years in Poland the number of these animals is too low to sustain a growing population. Thus, passive species protection seems to be insufficient and it has been decided to undertake more offensive action to re-establish the grey seal population in the southern Baltic Sea. One of the measures is releasing pups of seals bred in captivity in seal sanctuaries established in suitable areas (now in Hel Marine Station). It is as important to protect their natural environment as it is to consistently follow the protection rules.

Harbour porpoise

There are some historical references to harbour porpoise catches in the Baltic Sea off the Polish coast. The earliest come from the 14th century from the statutes of the town Hel, where it is stated that the porpoise boats has to pay a tax of 2 mark each year. At the beginning of the 20th century the population of harbour porpoise on the Polish coasts was big enough that there was a bounty on them. In the 1920s and 1930s, porpoises were perceived as pests that destroyed fishing gear and the fish resources. Catch statistics provided for the Gulf of Gdansk in the 1930s, when every catch of harbour porpoise was paid a bounty, indicate that the population of the animals was numerous. Thanks to official payment statistics for the years 1922-35, we know 717 porpoises were killed. After 1935 no data regarding Polish fish catches in general were published, and hence no information on the porpoise catch is available.

Figure 8.25. Porpoise in the Baltic Sea. (Courtesy of Hel Marine Station.)

In the 1940s, a significant decrease in numbers was observed. Not more than a few specimens each decade were noticed. The occurrence of harbour porpoise became so sporadic that each record of observation or catch was published in the press as a curious detail. A regular observer scheme implemented in 1990 resulted in 55 observations up to 1997 of specimens found stranded or accidentally caught in nets in Polish coastal waters. In 1988, harbour porpoises were protected under the environmental laws of Poland.

Fishing gear appears to be the most serious threat to porpoises in the Polish coastal zone. Among the reports on porpoise occurrence since 1990 over 70% concerned caught animals. On one occasion only during these recent years fishermen managed to release a porpoise found alive entangled in a net. Salmon nets, usually with a mesh size of 80-95 mm, are the major cause of entanglements. Traditionally the net was attached to boats, but today they are often anchored to the bottom at one side. That kind of semi-drifting salmon net is typical in the Puck Bay area and seems to be the greatest danger for porpoises.

Iwona Kuklik

In 1946 the International Whaling Commission (IWC) was established to protect all species of whales from excessive hunting. In 1986 the IWC established a moratorium on killing whales for commercial purposes. However, since 1986 it has been estimated that more than 21,000 whales have been killed for commercial and scientific purposes. About 1,000 whales (mostly the minke whale, *Balaenoptera acutorostrata*) were killed in 2001, and the number of whales killed each year continues to increase.

were close to extinction. Concerned individuals, in particular naturalists and newly formed hunter's associations, were however able to stop this development just before it was too late.

Regulation of hunting, protection of rare animals, and the protection of entire areas were legally introduced. These measures for the protection of wildlife have continued to develop to the present. Policies of wildlife conservation vary between countries. Most legislative regulations cover at least four main areas:

- protection of species
- protection and conservation of sites
- integration of protection of nature with national and regional planning and management
- international initiatives and regulations of nature conservation

Figure 8.26. The peregrine falcon, *Falco peregrinus*, is a threatened species, earlier because of biocides, now more often by egg collectors who disturb the breeding and steal eggs. Naturalists support the species by protecting the nests or feeding chickens non-toxic food. (Photo: Peter Lindberg.)

A number of international conventions have been developed to protect global wildlife. Not all of them have yet been signed by the Baltic Sea region countries. Major conventions include:

- The Convention on Wetlands of International Importance – Ramsar, Iran (1971), designated more than 360 wetlands in Europe to be of international importance. The Convention also established the Ramsar Fund for developing countries to be used for protection and promotion of the sustainable use of wetlands. This convention is of particular importance for protecting bird wildlife.
- World Heritage Convention – Paris (1972) concerning world cultural and natural heritage.
- The Convention on International Trade of Endangered Species of Fauna and Flora (CITES) – Washington (1973), ratified by over 110 countries.
- Convention on Migratory Species – Bonn (1979).
- The Convention on the Conservation of European Wildlife and Natural Habitats – Bern (1979), came into force in 1982.
- Convention on Biological Diversity – Rio (1992), now ratified by over 170 countries, came into force in 1993. The Convention aims to preserve and sustain biodiversity, and promote equitable sharing of benefits arising from the use of biological resources.

Which strategy for nature conservation should we choose?

Within the European Union the nature conservation legal framework is developed with the directives of *Natura 2000* (page 215). This strategy is much influenced by the situation in the large continental European states, where population density is high and private property is protected. The strategy adopted is mainly that of establishing protected areas, Nature Reserves or National Parks. In many cases the state is owns the property. In other cases there are

Case Box 8.6 — Protection of wildlife in Denmark

Protected plants

Among vascular plants, 240 species (20%) are categorized as endangered, vulnerable or rare. Far worse is the situation of lichens, where more than 50% are listed in these categories. The Danish Red List 90 (“Plants and animals in need of special protection in Denmark”) published in 1991 by the National Forest and Nature Agency, gives also a selected list of species in relation to the needs of special protection of their habitats. Most of the species are from woodlands, grass commons or bogs, indicating once again how important the protection of natural habitats is to maintain a high level of biodiversity.

Protected birds

Among 185 counted breeding species, more than 50% are noted in the Red Book with 11 classified as endangered , 7 vulnerable, 16 declining and 36 as rare. A number of reservations were established for breeding and migratory species. Quite common in Denmark is the Mute swan, while breeding pairs of storks are rare. In 1988, 20 pairs were seen in Jutland. In 2001 not a single successful breeding of stork was observed in Denmark. Two geese species, the light bellied brent and pink footed, are very abundant as they gather over winter from the entire northern part of the region, but as they extensively use farmlands as feeding grounds they cause serious damage to crops. Many bird species are threatened by the agricultural use of chemicals. Skylarks are good examples of the problem, because indirect effect of pesticides and a reduction of food availability (insects killed by chemicals) reduced their populations strongly from the mid-1970s. For the same reasons the number of lapwings and swallows has been reduced by half.

Monitoring birds, protecting key sites

Denmark is an important wintering base for waterfowl. In inland waters more than 5 million waterfowl from 30 species spend their winter season. The Department of Wildlife Ecology of the National Environmental Research Institute (NERI) in Risö monitors changes in numbers of mammals and birds. Direct aeroplane counting and ringing showed growing population of eiders which were nearly 800,000 during January 1991. The increased number of birds is due to better survival of the young.

Pawel Migula

private properties in the parks but with strict rules limiting e.g. hunting and forestry. National parks allow for public access, outdoor life and "ecotourism." If the National parks are the only areas in the country where this is possible we will – more or less – have a society where wildlife and man is separated and nature becomes "a museum."

In the Nordic countries the situation is different. The "right for everyone" (*allemansrätten*) is a very old notion that secured the right for anyone to enter into forests, grazing areas, etc., and to walk and pick mushrooms and berries if no damages was done, regardless of who owned the land. This has been possible since the population pressure is much smaller, properties larger and resources such as berries were traditionally important in the household. This strategy leads to a society where, at least in principle, man and nature live together. But this is a situation where man and nature also collide in conflict: wolves kill the sheep of farmers, moose eat young trees, roe deer enter into gardens and eat tulips, and so on.

In the former socialist countries, the situation is today in a state of change. State land is quickly becoming privatised from a situation where private land barely existed at all. Even if nature reserves are developing rapidly we do not know yet in which way most of these areas are going to be protected.

The United States has a more narrow range of public interests, a strong tradition of private property and at the same time a strong civil society. Since some years the possibility to protect a piece of land by buying a right – not necessarily the complete ownership – for the use of the area is increasingly used. All kinds of interest organisations and foundations may in this way secure the right for their members to simply walk and enjoy being in a forest, to hunt there, to protect a group of trees, etc. Private capital is in this way securing the rights that are secured through public law or public ownership in Europe. We may in fact, by comparison, calculate the immense economic values of these rights in our countries.

An important aspect is that many areas need to be managed properly to stay in a state where they continue to be a resource for biodiversity and nature protection. This is the case for many areas of traditional agriculture, such as meadows, beaches, forests, etc. For the public interest, it seems to be a better strategy in this situation to pay the farmer or owner for managing the area and allow public access, rather than to buy it to create a reserve or let the owner earn money on the land by e.g. developing a forest. This is recognised as a reasonable way to use the large subsidies that now are paid within the European Union's common agricultural policy, CAP, and is already to no small extent done. The farmer becomes both a landscape manager and a producer of food and is paid for both.

The strategies discussed will lead to rather different societies. From the biodiversity point of view it seems impossible to protect enough nature by publicly owning it. Some kind of coexistence seems to be the most reasonable goal for nature conservation policy.

Figure 8.27. Co-existence with wildlife. An increasing number of wild species adapt to a more or less urban environment. In Sweden roe deers are today quite often seen in gardens where they either are admired for their graceful look or hated since they eat the flowers. Roes in a garden north of Kalmar. (Photo: Margareta Grauers Rydén.)

A new ethics for man and the living world

We need to find a way to coexist with the living world, with the animals and plants around us. Such a formula for coexistence may be on its way. There are three factors which pave the way for such a change.

1. A new ethics with more regard for the conservation of natural values. A new ethics, based on respect for nature and the insight that the living world has a value of its own is developing. This biocentric or ecocentric ethics has developed, in particular, with IUCN's 1980 publication *World Conservation Strategy* and the 1990 *Caring for the Earth*, both key documents in the debate on sustainable development (see further Chapter

21). This new ethics tell us that man does not have the moral right to destroy the "natural world" to the extent that entire biotopes disappear forever and that species become extinct. Greater efforts have to be taken to promote conservation of biodiversity.

The respect for animals inherent in this ethics has in a way spilled over to the area of animal production. A new attitude to domesticated animals, also those kept for meat production, is that they should be given a chance to have natural behaviour. Thus, in ecological farming according to the rules now implemented in e.g. Sweden, cows may no longer be locked into a small space indoor all year around, but rather should be allowed to roam around in fields. This is now introduced in normal meat and milk farms. Hens should be allowed to move around and not be kept in small cages. More unusual is that pigs are allowed outdoors and even breed outdoors by building their own nests. Not surprisingly this has improved the health of the animals and the quality of meat.

A new animal ethics is slowly established also in other areas of animal-man interaction: animals as pets, animals for sports, and animals for research.

2. Economic interests are favouring more respect for biodiversity and nature conservation. Even if hunting is still important, an increasingly larger number of people are much more interested in watching and enjoying wildlife and are prepared to pay for it. Whale watching is replacing whale hunting, for instance on the Norwegian coast. Even the same individuals and boats that were once used to hunt whales might now be used to take tourists to see these enormously impressive animals and their play. Such "ecotourism" has been economically important for a long time to the East African countries with their large savannah, where visitors from the whole world want to see with their own eyes the impressive herds of zebras, antelopes and elephants, the megafauna still available in Africa, together with carnivores such as lions and leopards. The same scenery is not available in the Baltic Sea basin, but there is an increasing number of eco-tourists visiting the mountains in the north, the coasts of the three Baltic States and the large forests between Poland and Belarus. This shows that preserved biodiversity is an economic resource.

3. Biodiversity is in itself an important resource and needs to be managed properly to be preserved. Hunting and other similar forms of use of nature

Figure 8.28. Can we live with the wolf? The wolf, *Lupus lupus*, causes more debate than any other species in discussions on man and wildlife. The wolf has through centuries been hated for attacking and killing domestic animals. This led to the extinction of the wolf in several countries e.g. Sweden and Norway, while it was always represented by fairly large numbers in the east. There are for instance an estimed 600 wolves in Estonia (1998) and some 120 in Finland (2001). Today the wolf is rapidly increasing in Sweden with about 90 individuals (winter 2001), and the debate is back. Official policy (Swedish EPA) is that the country should have some 100 individuals. In spite of a considerable numer of sheep being killed, hunting of individual animals have so far (2002) not been licensed in Sweden, although it has in Norway.

The populations of the three other large terrestrial carnivores in Sweden are an estimated 900 brown bears, 1,500 lynx, and 160 wolverine. Of these the wolverine is in danger due to its small number. Some people add humans to the list of large carnivores and, of course, it is undeniable that humans hunts and kills by far more animals than any other species. (Source: http://www.snf.se/verksamhet/djur-natur/rovdjur.htm; Photo: Staffan Widstrand/www.de5stora.com) was once and is an important activity. For wildlife to continue to be important it needs to be managed properly. Hunting thus requires management of wildlife. There are a few outstanding examples. The number of moose shot in Sweden yearly is around 100,000 and accounts for an important part of the Swedish meat consumption. A hundred years ago the moose was rare in Sweden, but through good management and carefully regulated hunting the population has increased to a level where a further increase would constitute a serious problem for forests and increase the number of road accidents. Similar management of wildlife with efforts to optimize hunt versus drawbacks of an excessive population exists for a number of animals: roe deer, waterfowl, fish species, etc. Thus, management may include not only quantitative regulation of hunting but also careful protection during breeding season, feeding during harsh times, especially winter, and full protection of special areas.

Thus, a harmonious coexistence of civilization and nature, man and beast, may be the ultimate goal regardless if this is done for the moral duty of respecting nature, short-term economic gain, or for the long-term interest in resource conservation. This gives hope for a better future for biodiversity.

Review questions

1. Give a brief history of the extinction of species during the history of mankind. Comment on the megafauna as an example.
2. What are the reasons and consequences of changing an area from wild to domesticated? What are the consequences for biodiversity?
3. Why do we call some alien species "invasive" or even "biological pollutants?"
4. Identify phases of settlement of an alien species in a new site. What prevents some alien species from exploiting new areas? What are the chances that a new species in an area becomes invasive?
5. Find examples of invasive plant and animal species in your region. Explain why they are a threat for the native species and the function of the invaded ecosystems.
6. Define pests and weeds, and explain why such categories of living organisms have been identified, and their role in natural and man-made ecosystems.
7. Compare chemical and biological control of organisms, and list their advantages and disadvantages.
8. What methods would you apply for control of unwanted populations of insects or plant species in your own, small, private garden?
9. Name the methods used to monitor biodiversity in the terrestrial, freshwater, and marine environment. What should be done to acquaint society Red List books?
10. Describe the recent situation for conservation of an endangered animal species in the Baltic Sea region. Give successful and unsuccessful examples. Also, give your opinion of the national policy in your country for conservation of endangered species.
11. Describe various categories of site protection for conservation purposes. Describe and comment on how the national park is understood as a conservation strategy in various countries in the Baltic Sea region?
12. Give detailed information about the national park nearest to where you live, and a national park in another country in the Baltic Sea region.
13. Discuss the aspects of animal rights versus human rights.

Literature and references

Avise, J.C. and J.L. Hamrick (eds.) (1996). *Conservation Genetics - Case Histories from Nature*. New York: Chapman & Hall.

Baltz, D.M. (1991). Introduced Fishes in Marine Systems and Inland Seas. *Biological Conservation,* No. 56, pp. 151-157.

Berg L.S. (1949) *Neogobius melanostomus (Pallas). - Bychok kruglak* in: Ryby presnych vod SSSR i sopriedielnych stran. Opredelitel po faunie SSSR, Moskva - Leningrad, 30(3), 1083-1086. (In Russian)

Bromley, P. (1997). *Nature Conservation in Europe. Policy and Practice*. E&FN Spon.

Cade, T.J. (1983). *Hybridization and Gene Exchange among Birds in Relation to Conservation*.

Carey, J.R. et al. (eds.) (1996). *Invasions Biology. Biol. Conserv*., Vol. 78, Special Issue. Elsevier Appl. Science.

Carlton, J.T. (1996). Man's Role in Changing the Face of the Ocean: Biological Invasions and Implications for Conservation of Near Shore Environments. *Conservation Biology,* No.3, pp. 265-273.

Carlton, J.T. and J.B. Geller (1993). Ecological Roulette: the Global Transport of Nonindigeneous Marine Organisms. *Science*, 261, pp. 78-82.

Coblentz, B.E (1990). Exotic Organisms: A Dilemma for Conservation Biology. *Conservation Biology*, No. 4, pp. 261-265.

Di Castri, F., A.J Hansen and M. Debussche (eds.) (1990). *Biological Invasions in Europe and the Mediterranean Basin*. Dordrecht: Kluwer Academic Publishers.

Diamond, J. (1997). *Guns, Germs and Steel*. Newbury Park: Vintage Press.

Drake J.A. et al. (eds.) (1989). *Biological Invasions: A Global Perspective*. New York: John Wiley.

Elias, P. (ed.) (1997). *Invasions and Invasive Organisms*. Bratislava-Nitra: SNC SCOPE et SEKOS, 219 p.

Gagné, W.C. (1988). Conservation Priorities in Hawaiain Natural Systems. *BioScience*, No. 38, pp. 264-271.

Glowacinski, Z. (1992). *Polish Animal Red Data Book*. Warszawa: PWRiL.

Gollasch, S. (1996). *Untersuchungen des Arteintrages durch den internationalen Schiffsverkehr unter besonderer Berucksichtigung nichtheimischer Arten*. (Examination of introduction of species through international ship transport with special consideration given to alien species.) (Dissertation University Hamburg, Germany) Verlag Dr. Kovac, Hamburg, 314 p. (in German)

Groves, R.H. (1989). Ecological Control of Invasive Terrestrial Plants. In: Drake et al. (eds.). *Biological Invasions: a Global Perspective*. SCOPE 37. Chichester: John Wiley et Sons, pp. 437-461.

Gärdenfors, U. (ed.) (2000). *Rödlistade arter i Sverige - The 2000 Swedish Red List of Swedish Species*. ArtDatabanken, Uppsala: SLU

Hallnaro E-L. (ed.). (1997). *The Environment in Finland. Current Status and Measures to Protect It*. Ministry of Environment, Helsinki, 51 p.

Hartl, D.L. and A.G. Clark (1989). *Principles of Population Genetics*. Sunderland: Sinauer.

Heywood, V.H. (ed.) (1995). *Global Biodiversity Assessment*. UNEP. Cambridge: Cambridge University Press.

Hillis, D.M., C. Moritz and B.K. Mable (eds.) (1996). *MolecularSystematics*. Sunderland: Sinauer.

Holdgate, M.W. (1986). Summary and Conclusions: Characteristics and Consequences of Biological Invasions. *Philos. Transact Royal Soc*. B 314, pp. 733-742.

Huston, M.A. (1994). *Biological Diversity - the Coexistence of Species on Changing Landscapes*. Cambridge: Cambridge University Press.

IUCN (together with UNEP and WWF) (1980). *World Conservation Strategy*. IUCN, Gland, Switzerland.

IUCN (together with UNEP and WWF) (1990). *Caring for the Earth*: *A Strategy for Sustainable Living*. IUCN, Gland, Switzerland.

Jude, D.J., Reider, R.H. and Smith, G.R. (1992). Establishment of Gobiidae in the Great Lakes basin. In: *Canadian Journal of Fisheries and Aquatic Sciences*. Vol. 49, No. 2. pp. 416-421.

Karp, A., P.G. Isaac and D.S. Ingram (eds.) (1998). *Molecular Tools for Screening Biodiversity*. London: Chapman & Hall.

Kowarik, I. (1990). Time Lags in Biological Invasions with Regards to the Success and Failure of Alien Species. In: P. Pysek et al. (eds.), *Plant Invasions*. The Hague: SPB Academic Pub, pp.15-38.

Leppäkoski, E. (1984). Introduced species in the Baltic Sea and it's coastal ecosystems. *Ophelia, suppl. 3*. pp. 123-135

May, R.M. (1992). How Many Species Inhabit the Earth. *Scientific American* 267 (October), pp. 42-49.

McKnight, B. B. (1993). *Biological Pollution: the Control and Impact of Invasive Exotic Species*. Indianapolis: Indiana Academy of Science.

Meffe, G.K., C.R. Carroll et al. (1994). *Principles of Conservation Biology*. Sunderland: Sinauer Assoc. Inc., 600 p.

Minckley, W.L. and J.E. Deacon (1991). *Battle against Extinction: Native Fish Management in the America West.* Tucson, University of Arizona Press.

Olenin, S. and D. Daunys (eds.) (1998). *Inventory of the Baltic Sea Non-indigeneous Estuarine and Marine Species*. Klaipeda, NEMO.

Primack, R.B. (1993). *Essentials of Conservation Biology*. Sunderland: Sinauer Assoc,. Inc., 564 p.

Rosenthal, H. et al. (1998). Testing Monitoring Systems for Risk Assessments of Harmful Introductions. In: K.G Barthel et al. (eds.). *Third European Marine Science and Technology Conference*, Lisbon, 23+27 May 1998, Project Synopses Vol. II, Strategic Marine Research, pp. 919-928.

Rosenzweig, M.L. (1995). *Species Diversity in Space and Time*. Cambridge: Cambridge University Press.

Sandlund, O.T, O.T. Schei and A. Viken (eds.) (1996). *Proceedings of Norway/UN Conference on Alien Species*. The Trondheim Conferences on Biodiversity, 1-5 July 1996. Trondheim: DN et NINA, Norservice, 233 p.

Shigesada, N. and K. Kawasaki (1997). *Biological Invasions: Theory and Practice*. Oxford: Oxford University Press, 205 p.

Simberloff, D. (1981). Community Effects of Introduced Species. In: M. Nitecki (ed.), *Biotic Crisis in Ecological and Evolutionary Time*. New York: Academic Press, pp. 53-81.

Skóra K.E. (1993) Ichtyofauna. In: Korzeniewski K. ed. *Zatoka Pucka (Puck Bay)*.Inst. Ocan. Univ. Gda., Gdansk: 455-467 (in Polish)

Skóra K.E. and Rzeznik, J. (2001) Observations on Diet Composition of Negobius melanostomus Pallas 1811 (Gobiidae Pisces) in the Gulf of Gdansk (Baltic Sea). In: *Great lakes Res.* 27 (3): pp. 290-299.

Skóra K.E. and Stolarski J. (1993) *New fish species in the Gulf of Gdansk*. Bulletin of the SFI Gdynia, 1(128): 83

Sokolov, L.I., Tsepkin, E.A., Sokolova, E.L., Golovatyuk, G.Yu. (1989) New inhabitants of the Moskva River. *Priroda*, 9: p. 80-81 (in Russian).

Stanners, D. and P. Bourdeau (1995). *Europe's Environment*. Copenhagen: European Environment Agency.

Union for the Conservation of Nature and Natural Resources (1975). *World Directory for National Parks and Other Protected Areas*. Morges, Switzerland: IUCN.

Vitousek, P.M. and L.R. Walker (1989). Biological Invasions by *Myrica faya* in Hawaii: Plant Demography, Nitrogen Fixation, Ecosystem Effects. *Ecological Monographs*, 59, pp. 247-265.

Williams, E.S., E.T. Thorne, M.J.G. Appel and D.W. Belitsky (1988). Canine Distemper in Black-footed Ferrets (*Mustela nigripes*) from Wyoming. J. Wildl. Dis., 24, pp. 385-398.

Williamson, M. (1993). Invaders, Weeds and the Risk from Genetically Modified Organisms. *Experientia*, 49, pp. 219-224.

Williamson, M. (1996). *Biological Invasions*. London: Chapman and Hall, 244 p.

Wilson, E.O. and F.M. Peter (1988). *Biodiversity*. Washington, D.C.: National Academy Press.

Zarzycki, K. and A. Kazimierczakowa (1993). *Polish Plant Red Data Book*. Warszawa: PWRiL.

Further reading

Bright, C. (1995). Biological Invasions: The Spread of the World's Most Aggressive Species. *WorldWatch* 8 (July/August), pp. 10-19.

IUCN Red Data Book, Morges/Lausanne since 1966 – registered endangered, extinct or vanishing species, their causes, prognoses, dynamics, distribution, etc.

Goodwin, H.A. and J.M. Goodwin (1973). *List of Mammals Which Become Extinct or are Possibly Extinct since 1960*. Morges, Switzerland: IUCN.

Internet resources

Baltic Sea Alien Species Database
http://www.ku.lt/nemo/mainnemo.htm

BASICS The Baltic Sea region statistical database on sustainable development, natural resources and environment
http://www.grida.no/prog/norbal/basics/index.htm

Bialowieza Primeval Forest - Basic Data
http://bison.zbs.bialowieza.pl/puszcza/puszcza.htm

Birdlife International
http://www.birdlife.net/

The cave of Chauvet-Pont-d'Arc
http://www.culture.gouv.fr/culture/arcnat/chauvet/en/

DIAS - Database on Introductions of Aquatic Species
http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm

European Bird Database.
www.biodiversity.org/members.html

European Bison, Visent
http://www.ultimateungulate.com/wisent.html

European Crane Working Group
http://grus-grus.com

European Topic Centre on Nature Protection and Biodiversity
http://nature.eionet.eu.int/activities/products/redbooks/index_html

Food and Agriculture Organization the United Nations (FAO)
(http://www.fao.org).

The Great Transition - The emergence of Agriculture and City Life
http://www.mc.maricopa.edu/anthro/lost_tribes/hg_ag/index.html

Integrated Pest Management
http://www.fao.org/IPM/Issues.htm

Invasive Species
http://www.invasivespecies.gov/index.shtml

IUCN Invasive Species Specialist Group
http://www.issg.org/

The IUCN Red List of Threatened Species 2000
http://www.redlist.org/

IUCN SSC bryophyte specialist group
http://www.artdata.slu.se/guest/SSCBryo/SSCBryo.html

Megafauna
http://kokogiak.com/megafauna/

Neogobius melanostomus
http://www.ku.lt/nemo/neogob.htm

Nordic Gene Bank
http://www.ngb.se/

Ohio State University, Department of Agriculture
http://www.hcs.ohio-state.edu/hcs/TMI/HCS210/HortOrigins/NEOrigins.html

The Pest CABWeb
http://pest.cabweb.org/

Stork-on-line
http://www.vattenriket.kristianstad.se/stork/frame.htm

Swedish Biodiversity Centre
http://www.cbm.slu.se

Swedish Environment Protection Agency
http://www.environ.se

Swedish Society for Nature Conservation
http://www.snf.se/verksamhet/djur-natur/rovdjur.htm;

The Swedish Ornithological Society
http://www.sofnet.org/

Swedish Species Information Centre
http://www.artdata.slu.se/

Threatened Species in Finland
http://www.vyh.fi/eng/environ/naturcon/threat/2000/2000.htm

UNEP World Conservation Monitoring Centre
http://www.unep-wcmc.org/

World Species List - Noxious, pest, weed, and disease species
http://species.enviroweb.org/onoxious.html

Glossary

aquaculture
cultivation of fish, or other seafood

ballast water
water that a ship intentionally takes aboard for stability, trim, etc.; ballast water is carried both in empty cargo holds and in ballast tanks

biocentric, ecocentric ethics
an ethics based on respect for nature and the insight that the living world has a value of its own

biocides
chemicals that are toxic to pests and weeds and used to control them

biodiversity
term introduced to describe variability of life on earth; biodiversity breaks down into the hierarchical organisation of the organismal world, covering genetic variation between individuals, populations and taxonomic units, species, as well as higher and lower categories

biological control
methods to limit insect pests by e.g. use of natural insect pheromones, natural toxins or natural enemies

biotechnology
the use of living cells or organisms or parts thereof in technical contexts; biotechnology usually refers to cultivation of micro-organisms, or cells in general including mammalian cells, and genetic design of such cells, e.g. by the introduction of new genes, and to the use of biological macromolecules, especially enzymes, in technical systems

cell culture
a cell cultivation from which one might extract a useful product, e.g. a pharmaceutical

conservation of nature
processes supporting protection and preservation of a species in a given area

Convention on Biological Diversity
UN convention signed by over 150 countries which gives a framework for national actions towards biological conservation activities and development of national policies, plans and programmes

domestication
taming animals for the purpose of providing meat, milk etc, and plants for cultivation

ecotourism
tourism where the goal of tourists is to enjoy nature, watch animals, etc.

endangered species
a species of plant or animal which is in danger of extinction

extinction
elimination of all individuals from a given taxon (i.e. species or higher rank)

genetic engineering
genetic techniques that allow genomes of plants and animals to be "designed" especially by the introduction of entirely new genes, either from other completely unrelated genomes (species) or synthetic ones

GMO, Genetically Modified Organism
variety of plants made by genetic engineering

heterozygosity
frequency of individuals carrying two different variants (alleles) of a given gene of a diploid sexual species (incuding all higher forms of life); genotype distribution, as expressed by heterozygosity, is correlated to fitness

hunter-gatherer
original survival strategy of people; provision of basic needs by hunting game and gathering plants, roots, and berries

International Whaling Commission (IWC)
established in 1946 to protect all species of whales from excess hunting; the IWC moratorium for not using whales for commercial purposes failed

invasive species
species spreading into areas where they are not native, also called aliens, exotics, invaders, non-natives, or non-indigenous species, often aggressive or harmful to the indigenous species

megafauna
very large animals, largely made extinct by people; in Europe included e.g. mammoth and giant deer, that both became extinct about 10,000 years ago

Natura 2000
the European Union nature conservation legal framework

periods of species extinction
five periods in the history of the planet, the last and perhaps best known took place 65 million years ago, when the dinosaurs became extinct

pest
an animal competing with man for food, space or anything else

pheromones
chemical substances released into the environment by one sex of a species to attract the other sex, or sometimes to cause other changes of behaviour; also called ectohormones; pheromones are used to attract a defined species of insect, to be trapped and killed selectively as a biological control of populations of pest species (specially for insects)

Red Data Book
a registration and diagnostic description of life at risk, endangered to become extinct in a national or global scale; the global Red Data Book is published by the World Conservation Union (IUCN) as a compilation of national reports

"right for everyone" (allemansrätten)
the Swedish right for anyone to enter into forests, meadows, etc., to walk, and pick mushrooms and berries as long as no damage is done, regardless of who owns the land

species introduction
process of conscious or occasional settlement of a new species without predicting ecological consequences

trans-genic
an animal which has new genes introduced as a small piece of DNA into the germ cells, the fertilized egg

weed
a plant species growing in the wrong place, competing for natural resources with other species planted for humans use

wildlife management
managing a wild animal population for its protection and stability, especially for hunting