

# Chapter 2

## Biodiversity at Risk

Juliette Young and Allan Watt

### 1 Why Are We Writing About This Topic?

Biological diversity, or biodiversity, is broadly defined as the variety of life on Earth and the natural patterns it forms. Almost two million species have now been identified and the actual number of species in the world is estimated to be between 10 and 30 million (IUCN 2006). This enormous biodiversity is an essential provider of ecosystem goods and services. However, despite the important role biodiversity plays in our lives, all species that together comprise biodiversity face risk.

It is important, however, to differentiate between different types of risk to biodiversity. The science of ecology arose from the study of the way that animals and plants respond to *natural risks* in their environment and although ecologists have often quantified the enormous mortality caused by many factors, they have also identified the traits that organisms have evolved to cope with the risks that they are exposed to. Although all species face natural risks and are adapted to them, biodiversity is increasingly facing *new risks*, mainly caused by human activities, that species cannot respond to quickly enough and therefore threaten their survival.

Perhaps the first example of the widespread realization that biodiversity faced risks that it has not evolved the ability to respond to was the organochlorine insecticide DDT. This and related insecticides were developed in the 1930s and used to control agricultural pests and insect-borne diseases such as malaria. However, they were also found to be responsible for the decline of predatory birds because they are slow to break down in the environment and accumulate in predators as they consume contaminated prey. In 1962, Rachel Carson published *Silent Spring*, highlighting the risk of pesticides. Although DDT and related pesticides are particularly toxic to fish and other aquatic species, most attention was focussed on their impact on birds of prey such as the bald eagle *Haliaeetus leucocephalus* (Bowerman et al. 1998) and the sparrowhawk *Accipiter nisus* (Newton and Wyllie 1992).

---

J. Young (✉)

NERC Centre for Ecology and Hydrology, Bush Estate,  
Penicuik EH26 0QB, United Kingdom  
e-mail: jyo@ceh.ac.uk

These pesticides and their breakdown products are a major risk because they affect eggshell thickness and hatching success. This led to restrictions in their use and a greater awareness of the risk of novel chemicals in the environment.

Pesticides and other chemicals still pose major risks to biodiversity; organochlorine insecticides are still responsible for mortality in birds such as the white-faced ibis *Plegadis chihi* in the USA (King et al. 2003). However, recent global assessments list many other risks.

The five most important risks to biodiversity at the global scale were identified by the Millennium Ecosystem Assessment (2005) as:

- Habitat change, including habitat loss and fragmentation
- Climate change
- Invasive species
- Overexploitation and persecution
- Pollution, for example, nitrogen deposition and acid rain

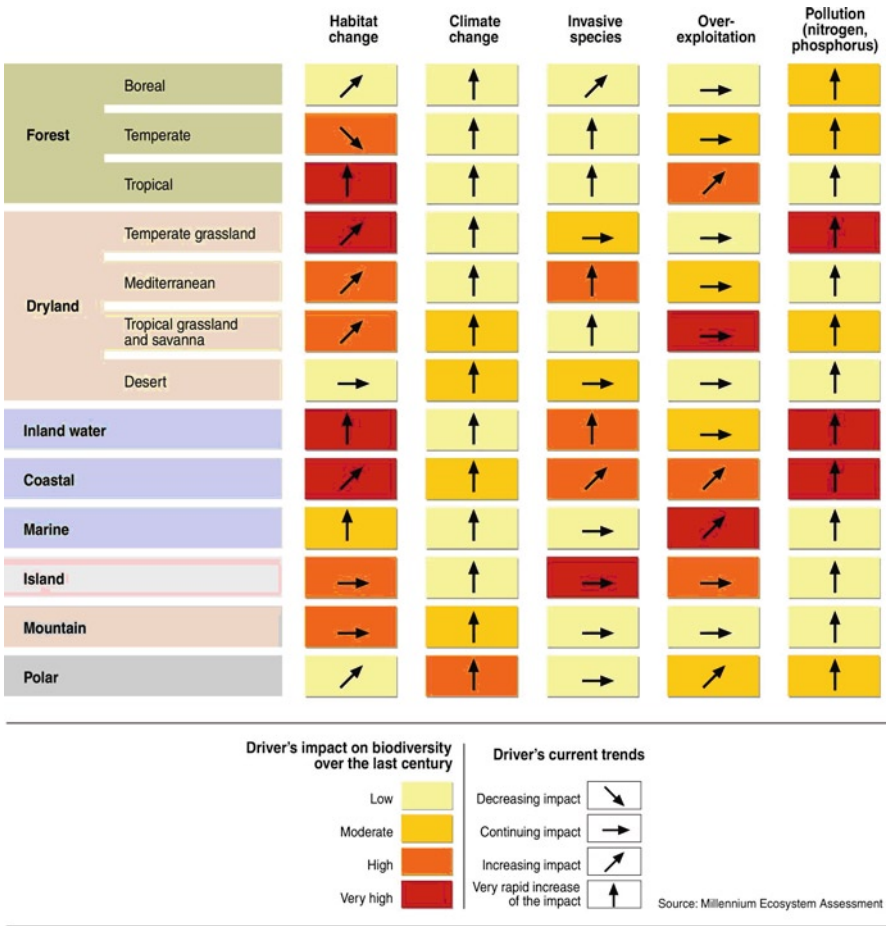
The Millennium Ecosystem Assessment also estimated the degree of importance of different risks, or “direct drivers” of change as they named them, in different ecosystems, and their trends (Fig. 2.1). We will discuss several of these risks to biodiversity in this chapter.

These risks affect the survival of many species: about 800 are known to have become extinct since 1600 (Baillie et al. 2004). IUCN, the World Conservation Union, provides regular estimates of the number of globally threatened species. Its 2006 Red List puts the number of known threatened species at 16,119 (IUCN 2006). IUCN’s estimates are based on well-known groups of species such as birds; the total number of threatened species is likely to be much larger. Organizations such as IUCN, World Wide Fund for Nature (WWF), Conservation International and the United Nations Environment Programme (UNEP) have been warning of the increasing rate of extinctions for many years and researchers have added to these concerns with many scientists referring to a “biodiversity crisis” (e.g., Koh et al. 2004).

The current rate of species extinction is estimated to be 1,000–10,000 times higher than the estimated “natural rate” of one species out of every million each year (Singh 2002).

This rapid loss of species and habitats is happening throughout the world. Perhaps the most worrying is the current rate of extinction in tropical areas of the world, where most species occur. However, species extinction is also happening in other parts of the world such as Europe, where an estimated 30% of all European plant species are endangered, while 40% of mammal species are now considered to be under threat, especially predatory species such as the brown bear *Ursus arctos*, the lynx *Lynx lynx* and the otter *Lutra lutra* (Stanners and Bourdeau 1995).

With the United Nations predicting a world population of nine billion people in 50 years time, the future pressures on and risks to biodiversity and its services are likely to be significantly more considerable than they are at present and, as such, require increased efforts to better understand and manage such risks. Another reason for discussing risk to biodiversity in the context of the direct risk caused by human activities is that other chapters in this book focus on the opposite – environmental



**Fig. 2.1** Main direct drivers of change in biodiversity and ecosystems identified by the Millennium Ecosystem Assessment (2005). The impact of each driver on biodiversity in each ecosystem type over the last 50–100 years is indicated by the color of the cells, high impact, for example, indicating significant change to biodiversity in the relevant biome due to the particular driver. Trend is indicated by *arrows*: increasing trends in impact are represented by *diagonal and vertical arrows* and continuation of the current levels of impact are shown by *horizontal arrows*

risks to humans. These contrasting perspectives lead us naturally to a recurring theme in considering risk to biodiversity, that of conflict between the conservation of biodiversity and human activities such as hunting, fishing, and a range of agricultural practices. The latter include the use of genetically modified crops, the topic of Chap. 4. That chapter considers the risk of such crops to human health. The possibility that genetically modified organisms also pose a risk to biodiversity has also been considered (Hails 2005). The aim of this chapter is therefore to provide an overview of biodiversity risks before presenting a range of existing options to assess and manage biodiversity risks.

## 2 Why Is Biodiversity Important for the World and for Everyday Life?

There are no simple answers to the question of why biodiversity is important for the world and everyday life and why we should take steps to conserve biodiversity. On the one hand, one can argue that all species have the inherent right to exist and therefore should be conserved at all cost. On the other hand, one species more or less, what does it matter in the grand scheme of things? To make some sense of the issue, we can unpick the different values of biodiversity, namely direct and indirect use values, and the way in which these values impact on everyday life.

Direct use values of biodiversity include all the goods or products used by humans. Perhaps the most important is the provision of food. All our food comes from other organisms. It is estimated that over 7,000 species of plants and several hundreds of species of animals have been used, at one time or another, for food consumption (Millennium Ecosystem Assessment 2005). Although nowadays only about 20 species of plant account for 90% of all vegetable food consumption, it is essential to bear in mind that biodiversity constitutes a valuable and essential resource with over 35,000 edible plants available for exploitation (Leakey and Lewin 1995). Therefore, the potential direct use value of biodiversity in terms of food provision is huge.

Another direct use value is the provision of medicine. Compounds extracted from certain species are used to treat diseases affecting humans. The most famous is probably aspirin, derived from a constituent of meadowsweet *Filipendula ulmaria*. Other compounds include digitalin from foxgloves such as *Digitalis purpurea*, prescribed for patients diagnosed with heart failure; quinine, from the cinchona tree *Cinchona officinalis* is used to combat malaria; and paclitaxel, a compound found in the bark of the Pacific yew tree *Taxus brevifolia* is effective in treating patients with lung, ovarian, and breast cancer.

In addition to these benefits, biodiversity also provides fuel (e.g., through timber and coal), shelter (timber and other forest products used as building materials and for shelter) and fibers (wool and cotton, for example).

As well as these more tangible benefits, biodiversity has a wealth of indirect use values, providing humans and other species with essential ecosystem services such as nutrient cycling, pollination, and regulation of the atmosphere and climate.

All species are supported by the interactions among other species and ecosystems, each providing an ecological value to one another. Producers (plants) get energy from the sun captured through photosynthesis, a process whereby glucose, carbon dioxide, and water are all synthesized by plants creating oxygen as a waste product. Nearly all life depends on this essential process. These same producers gain inorganic nutrients such as carbon, nitrogen, or phosphorus from the atmosphere, water, or soils to produce living biomass. Producers form the food base for primary consumer species (herbivores) who, in turn, provide the food base for secondary consumer species (carnivores). Producers and consumers all produce dead tissue and waste products. Decomposers transform these waste products into living biomass, which, in turn, forms the food base for consumers. Finally,

decomposers and consumers produce inorganic nutrients by mineralization, completing the cycling of nutrients between organic and inorganic forms. This process illustrates that if species are lost, the ecosystem might become less resilient and less productive.

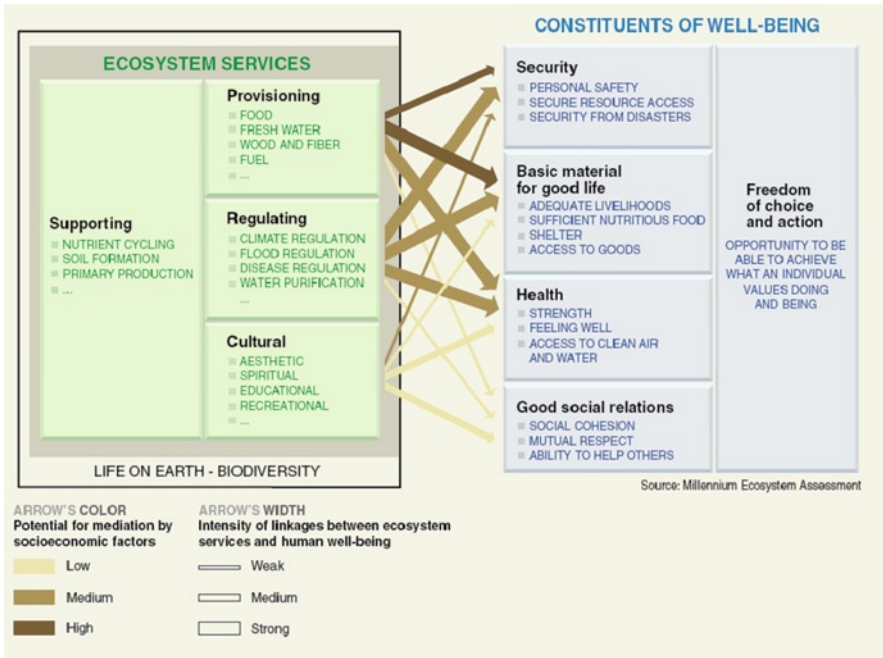
Biodiversity also provides a number of regulating processes such as climate and flood control, as well as pest, pollution, and disease control. Biodiversity also plays an essential role in pollination, with thousands of species of bees, birds, bats, wasps, and flies responsible for the pollination of flowering plants. The most important pollinators are bees, which are responsible for the pollination of some 73% of the world's crops (Roubik 1995). Of the approximately 240,000 species of flowering plants with known pollinators, nearly 220,000 are pollinated by animals. Pollination has important repercussions for humans in terms of food production, as an estimated two-thirds of the world's 3,000 species of agricultural crops require animals for pollination. The annual value of pollination in the worldwide is estimated to be worth \$65–70 billion (Pimentel et al. 1997).

Biodiversity is important for climate regulation, with plant functional diversity and habitats influencing the sequestration of carbon, evapotranspiration, temperature, and fire regime (Millennium Ecosystem Assessment 2005). Forests affect rainfall patterns through transpiration losses and protect the watershed of vast areas. Deforestation can therefore affect the amount and distribution of rainfall locally. Deforestation also results in erosion and loss of soil, which in turn could lead to flooding. Deforestation through burning also impacts on climate, due to the decrease in the amount of carbon dioxide taken in by plants through photosynthesis and by releasing vast quantities of carbon dioxide into the atmosphere. Both these processes lead to a global increase of carbon dioxide in the atmosphere, one of the main greenhouse gases responsible for global warming.

All these ecosystem services have been the subject of a number of studies, one of which estimated the *direct* economic value of these services to be in the region of US\$33 trillion every year (Costanza et al. 1997).

Finally, biodiversity has important indirect use values including cultural and spiritual values, such as esthetic, educational, and recreational values. Biodiversity is often closely linked to cultural identity. Animals are often referred to in religious texts and worshipped as animal deities. In Greek mythology a myriad of half-human half-animal gods exist including Pan, depicted with the hindquarters, legs, and horns of a goat and Poseidon, depicted with a fish tail. In Hinduism, one animal deity is Ganesh, a man with a one-tusked elephant head. Outside of formal religion, many people feel connected to species. Edward O. Wilson (1984) referred to the connections that human beings subconsciously seek with the rest of life as biophilia. This hypothesis explains to a certain degree why people empathize with other species, care for animals, visit zoos, national parks, and aquaria, and often like to grow plants and flowers.

The Millennium Ecosystem Assessment (2005) report describes in greater detail the goods and services touched on in this section. They outline the status of provisioning services such as food, fresh water, wood and fuel; regulating services such as climate regulation, flood regulation, and water purification; supporting services such as primary production, soil formation, and nutrient cycling; and cultural services such as esthetic and recreational services (see Fig. 2.2).



**Fig. 2.2** Linkages between ecosystem services and human well-being. *Source:* The Millennium Ecosystem Assessment (2005)

In summary, although we may consider risk to biodiversity as a separate topic to risk to humans, biodiversity, as pointed out above, provides human society with food, fuel, shelter, and many other goods and services that are essential for our survival. Many species do not, of course, contribute directly to human survival. However, some of these species are esthetically or culturally valued. Others possess the genetic material for the crops and drugs of the future. We probably underestimate the value of biodiversity: plants and animals provide the food we eat; plants provide the oxygen necessary for life and sequester the carbon that we produce; microbes and invertebrates cycle the chemicals essential for crop growth; birds and insects pollinate our crops. There are many more examples where biodiversity plays a critical role in human survival, some of them complex. The conclusion is, however, simple: risk to biodiversity can pose a very serious risk to human society.

### 3 Science and Background

The risks facing biodiversity are complex, individual species tend to face multiple risks and the severity of direct risks are usually determined by one or more driving forces. These drivers are usually socio-economic in nature as are many of the direct risks affecting biodiversity. In order to develop ways of managing risk to biodiversity,

we need to consider both the direct risks and their socio-economic drivers. This requires an interdisciplinary approach, involving disciplines such as ecology, toxicology, economics and social science. The topic of risk to biodiversity can best first be illustrated by examples where individual species are at risk from relatively simple pressures. We will consider some examples of species where they are at risk from local human activities, and then consider examples at larger spatial scales where multiple risks affect species and ecosystems. We will also look at the issue of situations where risks are uncertain or ambiguous. In these examples, we will also highlight the issue of conflict in relation to the development of approaches to minimizing risk to biodiversity.

### 3.1 Simple Risks to Biodiversity

No risk to biodiversity can be considered as “simple.” As we saw in the preceding section, species are closely interconnected, therefore a risk to a particular species can have repercussions on a range of other species and the ecosystem processes they perform. For the purposes of the chapter, however, we understand simple risks here as conflicts between particular human activities and individual species.

Birds of prey, or raptors, such as the hen harrier *Circus cyaneus*, the peregrine *Falco peregrinus* or the sparrowhawk *Accipiter nisus* are protected in the UK under the Protection of Wild Birds Act of 1954. Despite this protection, these species are rare and endangered. A major reason for their endangered status is that they are at risk from the actions of farmers and other land managers who consider that these birds of prey in some way threaten their livelihoods. Thus many raptor species are shot, trapped or poisoned (Whitfield et al. 2003).

One notable example is the persecution of birds of prey that consume game birds as part of their diet. There are many such species: Valkama et al. (2005), for example, considered research on the feeding behavior of 52 such predatory species in Europe. In most cases, there is insufficient evidence to support the view that these birds cause significant damage to game birds. The view that birds of prey are a threat to game birds is, however, a common perception of game managers and in some cases research has supported this view.

In the UK, hen harriers and peregrine falcons *Falco peregrinus* has been shown to be able to reduce the size of red grouse *Lagopus lagopus scoticus* populations and the number of birds killed by driven shooting (Redpath et al. 2004). In driven grouse shooting, hunters stand in “blinds” or “butts” while the grouse are driven toward them by lines of human beaters. Grouse densities of over 60 grouse/km<sup>2</sup> are required for this type of hunting, which generates the greatest amount of income for these areas. Large numbers of raptors may lead to significant loss of income for managers of grouse moors and potentially lead to a change in land use to increased densities of sheep and deer or commercial afforestation. This change in land use means a loss of internationally important heather-dominated moorland habitat and the range of upland birds and other species that it contains.

Thus, this is not only an example of a rare species of bird being put at risk because it threatens the livelihoods of certain land managers. Conservation of these birds of prey may also lead to situations where the land managers abandon game bird shooting and change land use to one that has a detrimental impact on biodiversity. Large numbers of raptors therefore present a conservation dilemma (Redpath et al. 2004). This apparently simple example demonstrates the potential complexity of the nature of risk to biodiversity and how conflicts need to be addressed in order to manage this risk.

In direct contrast with birds of prey, the great cormorant *Phalacrocorax carbo* is neither rare nor endangered in Europe, but remains at risk from anglers and commercial fisheries. Indeed, over the last 30 years, great cormorant populations in Europe have expanded both in numbers and geographical range, as a result of increased protection particularly the EC Wild Birds Directive of 1979, the Bern Convention on the Conservation of European Wildlife, the Bonn Convention on the Conservation of migratory species and Wild Animals and the Ramsar Convention on wetlands of international Importance. This bird has also benefited from a non-limiting food supply.

This increase in population size and range, combined with a great ability to fish, has resulted in a number of conflicts between cormorants and commercial fisheries and recreational anglers, angered by the damage caused by cormorants to fishery yields. While some fisheries call for the reduction in size of cormorant populations, conservationists argue that reducing levels of protection could lead to increased risks of illegal killings and unsustainable population levels. An Action Plan for the Management of the Great Cormorant in the African-Eurasian Region has been formulated but has since been largely ignored by individual Member States.

In order to reinforce the Action Plan and reduce the risks to cormorant populations, the REDCAFE project aimed to compile and synthesize all available information on cormorant conflicts and ecology as well as the possible tools for effective conflict management (Carss 2003). This pan-European project provided a novel approach to the conflict as it involved natural and social scientists, as well as all relevant stakeholders to produce an integrated and equitable reporting on the issues. This enabled not only a more complete picture of the conflict issues, but also a better understanding of stakeholder values and opinions.

As the two above examples show, in addition to the many positive effects biodiversity has in terms of use and positive value to humans (as seen in Sect. 2 of this chapter), some biodiversity can be harmful, i.e., have a negative value (Conover 2001). This can take different forms, including damage to livelihoods (e.g., agricultural crops), damage to households, and direct threats to humans. Because of these negative values, certain species face serious threats of persecution.

Large carnivores, for example, have been and still are a controversial subject in many countries in view of their interactions with domesticated animals, game species, and humans (Boitani 2000; Breitenmoser et al. 2000; Vitterso et al. 1998; Vos 2000). In the Indian state of Madhya Pradesh, for example, 1,094 people were injured or killed by wildlife attacks in a 5-year period (Conover 2001). Of these, 121 attacks were from tigers. Because of this direct threat to humans, as well as the poaching

of tigers for skins and traditional medicine, and threats from habitat fragmentation, encroachment and developmental projects, the tiger population in India has shrunk to a little over 3,000 individuals. Although the tiger is now considered endangered and protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), tigers continue to be poached. Since 1994, 327 tigers are known to have been killed according to the Wildlife Protection Society of India's (WPSI) Wildlife Crime Database. This number, however, is likely to be highly under-representative of the actual extent of tiger poaching.

The reintroduction of predators, such as the white-tailed eagle *Haliaeetus albicilla* in Scotland, for example, have given rise to major conflicts between those in favor of reintroduction and those against it. Some repercussions have included the poisoning, snaring, and shooting of "problem" animals threatening the livelihoods of local farmers. Further studies have indicated that, despite widespread perceptions that white-tailed eagles were directly responsible for high lamb predation in the area, eagle predation was in fact limited at the broad scale, and in many cases targeted on nonviable lambs.

In addition to large carnivores, large herbivores also have important impacts on agriculture. In Africa, for example, a study over a 14-month period reported that elephants raiding crops outside the Amboseli National Park were responsible for causing \$200,000 worth of damage to crops and 12 human deaths and injuries (Conover 2001). In India, elephants are responsible for the deaths of 100–200 people a year (Veeramani et al. 1996). Because of these damages, local villagers often see elephants as a serious threat. In a study carried out near Cameroon's Maza National Park, 73% of local villagers thought that more elephants needed to be killed. These negative perceptions pose a very serious threat to the continued survival of elephants across Africa (Tchamba 1996).

In addition to these conflicts between humans and individual species, biodiversity also faces more complex risks that impact on a variety of different species and on different spatial and temporal scales.

### 3.2 *Complex Risks to Biodiversity*

Land use change, particularly habitat loss and fragmentation, is the driver expected to have the largest global impact on biodiversity by the year 2100 (Sala et al. 2000). Increasingly, grasslands and forests are being converted into cropland to feed growing food and biofuel demands. Deforestation, in particular, is a major threat. The total area of forest is currently about 4 billion hectares, but it is unevenly distributed with two-thirds of the total forest area found in the ten most forest-rich countries (FAO 2006).

Although its rate is reported to be slowing, deforestation, mainly conversion of forests to agricultural land, is about 13 million hectares per year. The net rate of forest loss is slowed by forest plantations and natural expansion of forests: a net loss of 7.3 million hectares per year is estimated during 2000–2005, compared with

a loss of 8.9 million hectares per year from 1990 to 2000. This loss of habitat results in the extinction of local plant species, as well as animal species that depend on plant species composition to survive. The greatest rate of deforestation is in Africa and South America (FAO 2006). Considering that it is estimated that at least 50% of the world's species are found in tropical forests, which cover only 6–7% of the earth's surface (Groombridge 1992), the loss of these forests presents a disproportionate risk to biodiversity.

Even though habitat loss is an obvious threat, the related threat of habitat fragmentation can also have a serious impact to biodiversity. Habitat fragmentation is common throughout the world, although difficult to document. Remote sensing has, however, made it easier to estimate loss and fragmentation of habitats, particularly forest habitats. In Chile, for example, there was an estimated reduction in natural temperate forest area of 67% between 1975 and 2000, and an increase in forest fragmentation, specifically a decrease in forest patch size, a decrease in area of interior forest and a decrease in connectivity among patches (Echeverria et al. 2006).

Some degree of fragmentation is not a serious risk: most species are adapted to patchily distributed habitats or resources. Many species of butterflies, for example, survive in habitat patches within fragmented landscapes. The study of butterflies in these situations, in particular, has given rise to the metapopulation concept (Hanski 1999). In a metapopulation, each local population has a separate probability of extinction and (re)colonization and occupied patches are connected by occasional migration.

Knowledge of the dispersal ability and other characteristics of the ecology of a species together with information on the fragmentation of a habitat can be used to quantify the risk of extinction to particular species in particular landscapes. Schtickzelle et al. (2005), for example, concluded that a patch system occupied by a metapopulation of marsh fritillary butterfly *Euphydryas aurinia* in Belgium could not survive under the present management of the area. Case studies have also shown that fragmentation history is important in determining risk in a changing landscape (Gu et al. 2002) and that the so-called matrix or habitat encountered between patches influences the degree of risk from fragmentation. Grassland butterflies are among those most at risk in this way. Ricketts (2001), for example, in an aptly titled paper “The matrix matters: effective isolation in fragmented landscapes” quantified the resistance to movement of willow thicket and conifer forest to a meadow-inhabiting butterfly community.

In addition to habitat loss and fragmentation, the way that habitats are managed can create threats to biodiversity. Some idea of the multiple threats facing individual species can be seen from the plans that have been put in place to conserve individual species. The UK has developed Biodiversity Action Plans for many species, including the bittern *Botaurus stellaris*, a rare bird species confined to wetlands dominated by the common reed *Phragmites australis*. It became extinct in Britain as a breeding species by 1900 but after recolonization and recovery it started to decline again in the 1950s so that only about 16 pairs were present by the 1990s (Gibbons et al. 1993). Clearly the loss and fragmentation of its habitat are key risks to this species. These were caused by drainage, water abstraction and natural

succession to “scrub” habitat due to a decline in reed harvesting. Other threats, however, include water pollution due to agrochemical run-off, pesticide and heavy metal pollution, and salt water intrusion into coastal reedbeds. The main message from this and many other examples is that biodiversity faces multiple risks.

Various risks therefore combine to threaten biodiversity. One example, referred to as “a deadly anthropogenic cocktail” (Travis 2003), is the combination of habitat loss together with climate change, in particular. Indeed, where we would expect that a species is likely to take advantage of climate change by extending its distribution, habitat loss or fragmentation might prevent such an expansion. An analysis of 35 species of butterflies in the UK, all of which were predicted to have expanded their range in response to recent climate change, showed that all but five species had not done so because of a lack of suitable habitat (Hill et al. 2002). Climate change, however complex, is also very uncertain risk to biodiversity, i.e., the short- and long-term effects of climate change are complex and as such not yet fully understood.

### 3.3 *Uncertain Risks to Biodiversity*

Climate change is now seen as a major threat to biodiversity, second only to land use change (Thomas et al. 2004; Millennium Ecosystem Assessment 2005). This is partly because of the increasing evidence that the global climate is changing and the growing awareness that climate change has an enormous potential for affecting biodiversity.

Although the Earth’s climate has always fluctuated, the current rate of climate change is greater than any experienced during the last 1,000 years, and there is strong evidence that most of this increase is due to anthropogenic climate forcing as a result of increased release of CO<sub>2</sub> (carbon dioxide) and other greenhouse gases into the atmosphere (IPCC 2001; Brooker and Young 2006; Brooker et al. 2007).

The concentration of CO<sub>2</sub> is predicted to rise by 2100 to between 540 and 970 ppm, compared to about 368 ppm in 2000 and about 270 ppm in the pre-industrial era. Climate models predict a rise in temperature of 1.5–5.8°C between 1990 and 2100, which is two to ten times greater than the rise in temperature observed in the last century. Annual precipitation is expected to rise on average by 5–20% over the same period, although the models suggest major regional and seasonal variations. The global mean sea level is expected to rise by 0.09–0.88 m between 1990 and 2100. An increase in the frequency, intensity and duration of extreme events such as more hot days and heavy precipitation events is predicted but the number of cold days is expected to decrease.

The changing climate is already reported to be having an effect on many species. In temperate countries, the bud burst and flowering of plant species is happening earlier, butterfly species are appearing earlier, amphibian and bird species are breeding earlier and migrating bird species are arriving earlier (Walther et al. 2002; Parmesan and Yohe 2003; Root et al. 2003).

There is evidence that birds (Thomas and Lennon 1999) and butterflies (Warren et al. 2001) are extending their ranges polewards. There is evidence of shifts in the range of plants too, although not as rapid (Walther et al. 2005). Although some movement in the distribution of insects and other species is already being detected, it is likely that more significant changes in distribution will occur in the future. Models have been constructed to predict the impact of climate change of the distribution of insects, plants, birds, and other species (Berry et al. 2002). These models demonstrate how some species are likely to contract in range within a country, whereas others are likely to expand their range. Models predicting the impact of climate change on species distribution are based on analysis of species bioclimatic envelopes – the relationship between their observed distributions and climate.

There is some evidence that species can adapt to a changing climate without changing their distribution. Research on four butterfly species within the same family, for example, showed that those living in dry and open habitats had a maximum fecundity and survival rate at a higher temperature than the shade-dwelling species studied (Karlsson and Wiklund 2005). Moreover, populations of the same species have been shown to be adapted to the different habitats they occupy. Populations of the woodland butterfly *Pararge aegeria* living in shady woodland landscape have a higher fecundity at lower temperatures than those originating from open agricultural landscapes and the opposite is true at higher temperatures (Karlsson and Van Dyck 2005).

The response of individual species to climate change should not be considered in isolation: its impact will depend upon interactions between other species of the same and different trophic levels (Bale et al. 2002). Changing temperatures can also have an indirect influence on species that interact with other species that have a different capacity to change their distribution in response to climate change. Although the responses of particular species to changes in climate are poorly known, it is probable that different species will respond in different ways and to different degrees; this will lead to changes in the balance between competing species, plants and herbivores, and insects and their predators (Lawton 1995).

Thomas et al. (2004) used species–area models, an approach discussed in more detail later in the chapter, in relation to predicting the effect of habitat loss on biodiversity, to predict the impact of both climate change and habitat loss on global extinction rates of butterflies and other species. They argued that extinctions arising from reductions in area should apply not only to habitat loss per se but also to climatic unsuitability of that habitat. On this basis, they predicted that for midrange climate scenarios, 15–37% of the taxa they studied would become committed to extinction by 2050. Three different modeling methods were used for three different climate scenarios and they did the analyses twice, once assuming no capacity to disperse and one assuming the species could disperse. This produced a wide range of predicted extinctions. They also predicted that habitat loss alone would result in extinction rates by 2050 of 1–29% in the areas they studied. Despite criticisms of their analysis, including concern about the use of species–area models (Buckley and Roughgarden 2004), Thomas et al. (2004) concluded that climate change represents the greatest threat to biodiversity in most if not all regions of the world.

### 3.4 Ambiguous Risks to Biodiversity

Many risks are indiscriminate, perhaps affecting only a few species but often affecting many. Certain types of birds, for example, are particularly at risk from nonindigenous invasive species. Often referred to as invasive alien species, these are species that have been deliberately or accidentally introduced outside their native habitats, and have the ability to establish themselves, successfully compete with native species and spread in their new environments. Despite our increasing knowledge of the threat of invasive species, they continue to be a major risk to biodiversity (Hulme 2003). The most infamous invasive species are rats, which have posed a serious risk to island birds and other species poorly adapted to face this risk. Ship rats *Rattus rattus*, Norway rats *R. norvegicus* and Pacific rats *R. exulans* have caused declines or extinctions of land-based birds, burrowing seabirds, flightless invertebrates, and ground-dwelling reptiles (Townsend et al. 2006). Globally, ship rats alone are thought to have been responsible for the extinction of about 60 indigenous island species.

Island species have also been at risk from introduced species such as cats (Rodriguez et al. 2006) and hedgehogs (Jones et al. 2005a). Indeed, such are the risks to island species that there is a widespread misconception that extinctions have been restricted to islands (Pimm 2002). Biodiversity is threatened in all parts of the world and invasive species pose a risk to many groups of plants and animals. Invasive species include mammals, reptiles, insects, and plants. More than 2,000 species of nonindigenous plants, for example, are established in the continental USA (Vitousek et al. 1997). Invasive plants include weeds of riparian habitats such as Himalayan balsam *Impatiens glandulifera* and giant hogweed *Heracleum mantegazzianum* (Wadsworth et al. 2000). Invasive insects include the yellow crazy ant *Anoplolepis gracilipes* whose super-colonies have occupied over 30% of the 10,000 ha of rain forest on Christmas Island since the 1990s, and killing of indigenous red crabs have brought about “invasional meltdown” (Abbott 2006). One of the most notorious invasive reptiles is the brown tree snakes *Boiga irregularis*, which caused the extinction or serious decline of most of the 25 resident bird species on the island of Guam (Wiles et al. 2003) and is now a major risk to the biodiversity of Hawaii (Burdick 2005).

Invasive species also pose serious risks to human economies. One example is the zebra mussel *Dreissena polymorpha*, native to the Caspian Sea region of Asia. This invasive species has spread rapidly to all of the Great Lakes since the late 1980s, causing billions of dollars worth in damage by covering the underside of boats and docks and by blocking off pipelines, thereby directly impacting water intake pipes used by cities for their water supply, or hydroelectric companies for power generation. Lafferty and Kuris (1996) estimate the economic impact of the European green crab *Carcinus maenas* to be in the region of \$44 million/year due to its impacts on commercial shellfish beds and on large numbers of native oysters and crabs.

Invasive species are, however, very ambiguous, in that the characterization of attributes of successful or unsuccessful invasions are often very general and qualitative. In addition, the actual effects of invasions are often difficult to predict. For example,

the common cordgrass *Spartina*, accidentally introduced to the Southern England coast from the East coast of America, have the beneficial effect of stabilizing soft coastal mud of tidal mud-flats through their extensive system of roots and rhizomes. As such, *Spartina anglica* has since been planted to stabilize salt marshes thereby protecting foreshores from erosion (Macdonald et al. 1989). Another example of successful introduction is that of the cactus moth *Cactoblastis cactorum* introduced as a biological control agent against the alien prickly pear cacti *Opuntia* in Australia in the 1920s. Since then, however, scientists have expressed concerns regarding the effects of these moths in Florida, where they now threaten the survival of indigenous *Opuntia* species (Zimmermann et al. 2001).

Other introductions also have very mixed results. One such example is the introductions of fish species into European waters. While the introduction of pikeperch *Stizostedion lucioperca* into many Western European lakes has resulted in major commercial fisheries, its release has also led to a collapse in the cyprinid fisheries. In a similar way, while in economic terms the introduction of rainbow trout *Oncorhynchus mykiss* supports major sport fisheries throughout Europe, rainbow trout has caused considerable loss of native species (Cowx 1997).

## 4 What Do We Do with What We Know?

### 4.1 Risk Assessment

#### 4.1.1 Species Assessment

Considering the enormous scale of the problem, we know very little about the impact of the major risks to biodiversity. Even our knowledge of which species are at risk is remarkably poor. The most comprehensive assessments of which species are endangered are done by IUCN. The IUCN Red List, which has been in use for over more than 40 years, classifies species in different categories including critically endangered, endangered, and vulnerable (IUCN 2001; Baillie et al. 2004; Rodriguez et al. 2006). Quantitative criteria are used to classify species in these categories. Species classified as critically endangered, endangered, or vulnerable are frequently described together as “threatened.”

The original IUCN Red List classification system operated for nearly 30 years and classified threatened species as extinct, “endangered,” “vulnerable” or “rare” (“indeterminate” and “insufficiently known”) (Mace and Stuart 1994). It was clearly valuable in producing databases of threatened species, providing a basis for setting conservation priorities and monitoring the success of conservation efforts (Miller et al. 1995). However, this system was frequently criticized for being subjective; classification of species by different authorities varied and did not always correspond with actual risks of extinction (Groombridge 1992). Thus the new IUCN classification system, described above, was adopted in 1994 (IUCN 1994).

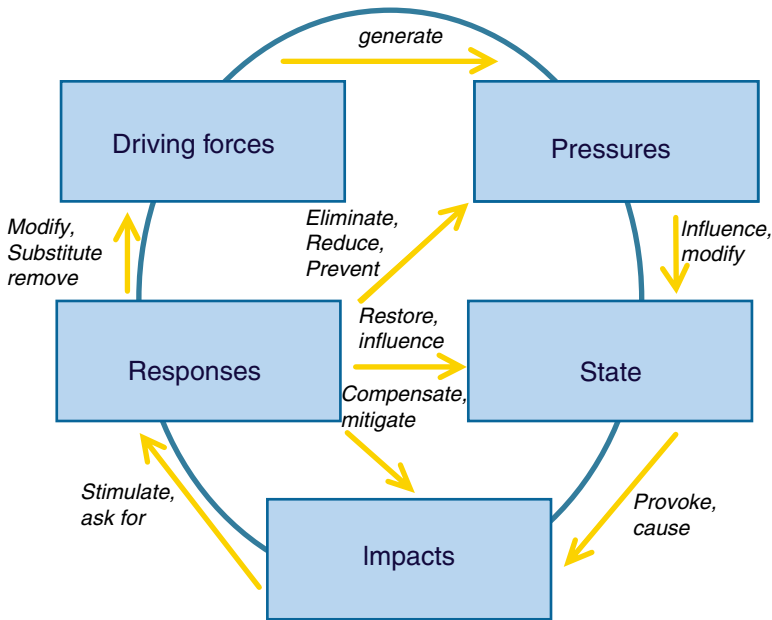
The 2004 IUCN Red List named 15,589 species threatened with extinction (Baillie et al. 2004). Amongst some groups of organisms, however, the identification of threatened species is made extremely difficult by our lack of knowledge of the ecology, distribution, and abundance of most species. For example, the 2004 IUCN Red List names 559 insect species but this represents only 0.06% of all described insect species. The equivalent figures for plants and vertebrates were 3 and 9%, respectively. However, the detailed procedures adopted by IUCN include an assessment of amount of data available and species are only evaluated if sufficient data exist. Only 771 insect species were, therefore, evaluated for the 2004 report. Thus 73% of all insects evaluated were classified in the threatened categories. Equivalent figures for plants and vertebrates were 70 and 23%, respectively. Although this suggests that insects are threatened to roughly the same amount as better-known taxa, such is the degree of uncertainty about the status of insects that the true percentage of threatened species should be taken as lying somewhere between 0.06 and 73% (Baillie et al. 2004).

The best overall assessments of the sources of risk to biodiversity come from international initiatives such as the Millennium Ecosystem Assessment (2005). This report concluded that humans have changed had a greater impact on ecosystems in the last 50 years than during any other comparable period. This has been due to the rapidly growing demands for ecosystem services, particularly food, fresh water, timber and fuel, and has resulted in “substantial and largely irreversible loss in the diversity of life on Earth.” The Millennium Ecosystem Assessment (MA) acknowledges that the changes made to ecosystems have contributed to substantial improvements in the well-being of humans but they have led to the degradation of many ecosystem services and led to a worsening of poverty for some groups of people. The degradation of many ecosystem services and an increased risk of nonlinear changes, are likely to lead to a decline in the benefits that future generations accrue from ecosystems unless these risks are addressed. The MA identified several examples of nonlinear changes. These include fisheries collapse, the impact of species introductions and extinctions, and regional climate change. The best-known example of fisheries collapse, for example, is the Newfoundland Atlantic cod, which collapsed in 1992 after hundreds of years of exploitation and led to the closure of the Newfoundland fisheries.

#### 4.1.2 General Risk Assessment Models

From a biodiversity perspective, there are several models that address risk. The most widely used models are the “pressure-state-response” and “driver-pressure-state-impact-response” (or DPSIR) models (Fig. 2.3) originally developed by the OECD and used for a range of purposes including biodiversity.

To illustrate how the model works, we can use an example such as industrial production. In this model, industrial production acts as a driving force of environmental change. This driver generates pressures on the environment such as discharges of waste in the air or water. In turn, these pressures will impact the state of



**Fig. 2.3** The driver-pressure-state-impact-response (DPSIR) model. Adapted from the OECD

the environment, for example, reducing the water quality of rivers or seas. This change in the state of the environment can cause the water to be unsuitable for drinking, with consequences to the ecosystem, the economy, and the population. The last step in the model is the response to these impacts. In this particular case, a response might be watershed protection, which would then affect all the other steps of the model.

The most interesting aspect of the DPSIR model is that it separates pressures from the drivers that determine the severity of the pressure. Thus, for example, climate change is a direct pressure on biodiversity but the drivers of climate change include various demographic, economic, and socio-political factors. The Millennium Ecosystem Assessment (2005) recognized the same separation but referred to drivers and pressures as indirect and direct drivers of change, respectively.

In addition to the more general models of risks to the environment, there are various approaches to evaluating specific risks to particular species, habitats, or pressures. Below we review a few of these models, specifically addressing risks to biodiversity from habitat loss and fragmentation and invasive species.

### 4.1.3 Species–Area Models

The risk to biodiversity of habitat loss and fragmentation, for example, is frequently assessed through species–area models. These models are based on the common observation that the number of species inhabiting an area increases as the size of the area increases. This observation was fundamental to the development of “island

biogeography” (MacArthur and Wilson 1967) and has been applied to many “island” situations. Indeed, many studies have now shown that the number of species on islands increase as their size increases, whether the study focuses on oceanic islands, soil habitat fragments, or urban roundabouts.

Species–area relationships have been explained through two main hypotheses: the equilibrium theory and the habitat diversity theory. The “equilibrium theory” (MacArthur and Wilson 1967) is that the number of species on an island is a result of the balance between extinction and colonization by new species. Extinction and colonization rates are affected by the number of species on the island, island size, and the distance of the island from other islands and the mainland. Although species are constantly colonizing the island and becoming extinct, an equilibrium is eventually reached which is directly related to island size and inversely related to the distance from other island or mainland sources of species.

The destruction, fragmentation, or modification of habitats poses an obvious risk to biodiversity. Probably the most serious example of this is deforestation, particularly the destruction of tropical forests. As discussed above, what applies to “real” islands often applies to habitat islands. Thus species are likely to become more and more vulnerable to extinction as their habitats become smaller. Species–area relationships may therefore be used to predict the consequences of habitat loss, particularly deforestation, on global species richness (Reid 1992).

The relationship between the number of species ( $S$ ) in an area and its size ( $A$ ) can be represented by the equation of a straight line:

$$\log S = \log c + z \log A$$

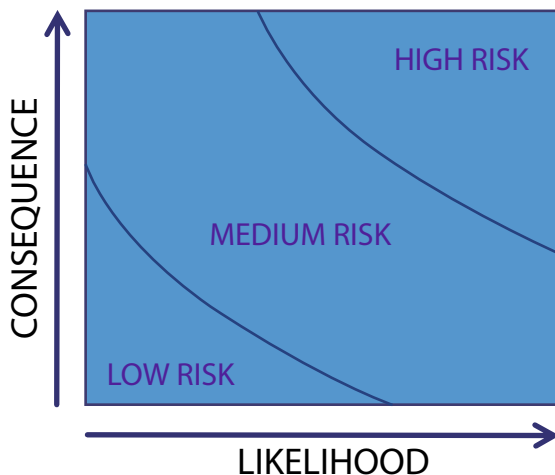
where  $c$  and  $z$  are constants.

Studies on islands, mainland areas and habitat islands have shown that the slope ( $z$ ) generally lies in the range 0.10–0.50 (Lomolino 2000). Reid and Miller (1989) based their predictions of species extinctions on a slope of between 0.15 and 0.40. These slopes predict that a 90% reduction in habitat size will result in the loss of 30–60% of the species present. Reid and Miller assumed a deforestation rate of 0.5–1% loss of forest area per year, one to two times the estimate for 1980–1985 (FAO 1988). The predicted rate of extinction based on these predictions was a loss of 2–5% of species per decade. Most extinction predictions based on habitat loss range from 2–6% to 8–11% species per decade (Mawdsley and Stork 1995). In Singapore, habitat loss exceeded 95% from 1819 to 2002 (Brook et al. 2003). Documented extinctions and inferred extinction rates for butterflies, freshwater fish, birds, and mammals ranged from 34 to 87%. A species–area model predicted that the current rate of habitat loss in South-East Asia would lead to a loss of 13–42% species, of which about a half would be global extinctions.

#### 4.1.4 Invasive Species Models

In view of the potential negative impacts of invasive species on local biodiversity as well as more far-reaching socio-economic aspects, it is essential to develop tools to assess the risks of invasives. One such tool has been developed by the ALARM

**Fig. 2.4** Invasives risk assessment tool. Adapted from the ALARM project (<http://www.alarmproject.net/alarm/>)



project, which assesses risk of invasives according to the potential consequences of invasive species (economic, social, and environmental impacts as well as management costs) and the likelihood of species becoming invasive (strength of pathways, establishment, population growth, dispersal) based on species distribution data (Fig. 2.4).

#### 4.1.5 Population Viability Analysis

A common approach to evaluating acceptable risk to biodiversity is population viability analysis. Population viability analysis is an ecological assessment: acceptable risk can also be considered from social, legal, and economic perspectives. From social and legal perspectives, acceptable risk relates to individual and societal values toward the conservation of particular species and habitats. For most species such values are irrelevant: most species are either so common or their status is so poorly understood that they are not perceived to be at significant risk. They are not afforded explicit legal protection and few people express concern about risks to their existence despite the fact that most major risks to biodiversity are likely to affect those species that we know very little about. There is, however, increasing public awareness of some relatively common species such as farmland birds. Indeed, the trend in abundance of farmland birds has become the single most important indicator of biodiversity in Europe. It is, of course, a relatively easy measure of biodiversity and it is assumed to be a good indicator of trends in species that are less easy to monitor. Nevertheless, its success as an indicator probably demonstrates the strength of the esthetic and cultural values that many people hold for species that are not endangered.

From an ecological perspective acceptable risk relates to long-term population viability. If the species is abundant and has a high rate of reproduction, then its susceptibility to risk is inevitably less important than if the species is rare. From a social point of view, however, the esthetic and cultural value attached to a particular species has an influence on what may be considered to be acceptable risk. Thus risks to common garden birds may be considered to be less acceptable than risks to rare snakes even though the latter is more susceptible to extinction. The latter example, of course, introduces the direct risk that some species pose to humans, an issue that we will return to later.

Whatever model is used to address risk to biodiversity, it is important to realize that there are factors that have a direct influence on biodiversity and factors that have an indirect influence by determining the magnitude of the direct influences. All of these indirect influences (or drivers) are associated with human action as are many of the direct influences. Thus, for example, the predatory birds that are a major example in *Silent Spring* continue to be at direct risk from pesticides residues in their food. However, the pesticides are applied to provide an economic return from agriculture, which is itself driven by human population size and the demands of that population for a specific amount and quality of food. The application of pesticides is not always economically effective, excessive food production is common in developed countries and food quality is often set by appearance rather than nutritional quality. Nevertheless, the main driving force behind pesticide application is human demand for food. Indeed, the apparently irrational behavior just referred to, which leads to more pesticide application than would appear to be necessary, is driven by factors such as economic risk averse attitudes in farmers, national policies that encourage excessive food production and public attitudes to food appearance. Thus the direct risk of pesticides to predatory birds is driven by a complex set of driving forces, each linked to demands and attitudes of human society.

## 4.2 Risk Management

### 4.2.1 Biodiversity Policy

Public concern for biodiversity has risen in the last 50 years and has led to national and international policies, legislation, and actions to conserve biodiversity, notably the Convention on Biological Diversity (CBD). For an overview of major landmarks in international biodiversity policy, see Table 2.1.

In Europe, the first Environmental Action Programme was launched in 1973, the Birds Directive in 1979 and the Habitats Directive in 1992. However, the CBD led to a rapid increase in the development of policy on biodiversity in Europe and elsewhere (see Table 2.2 for a full overview of the major landmarks in EU biodiversity policy since 1979).

**Table 2.1** Major international biodiversity policy landmarks

| Date | Instrument                                                                                                   | Aims                                                                                     | Status                                                |
|------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------|
| 1971 | The Convention on Wetlands of International Importance especially as Waterfowl Habitat ("Ramsar Convention") | Wetland conservation and wise use                                                        | Came into force 1975, 152 Parties (as of 1 July 2006) |
| 1973 | Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)                      | Control of international trade in specimens of wild animals and plants                   | Came into force 1975, 169 Parties (as of 1 July 2006) |
| 1979 | The Convention on the Conservation of Migratory Species of Wild Animals ("Bonn Convention")                  | Conservation of terrestrial, marine and avian migratory species throughout their range   | Came into force 1983, 97 Parties (as of 1 May 2006)   |
| 1979 | Convention on the Conservation of European Wildlife and Natural Habitats ("Bern Convention")                 | Conservation of wild flora and fauna and their natural habitats                          | Came into force 1982, 45 Parties (as of 1 March 2005) |
| 1992 | Convention on Biological Diversity (CBD)                                                                     | Biodiversity conservation; sustainable use of biodiversity and equitable benefit sharing | Came into force 1993, 188 Parties (as of 1 July 2006) |

At the national scale, biodiversity strategies have been published in many countries including Sweden (1994), UK (1994), Slovenia (2001), and Slovakia (1997) and are in preparation elsewhere. The European Community published a biodiversity strategy in 1998, based on a policy of incorporating biodiversity concerns in sectoral policies and adopted four Biodiversity Action Plans in 2001 – on the Conservation of Natural Resources, Agriculture and Fisheries and on Economic and Development Co-operation.

However, realizing that current policies and action taken to conserve biodiversity were inadequate, the European Union at its 2001 summit meeting in Göteborg, Sweden, set the ambitious target to "protect and restore habitats and natural systems and halt the loss of biodiversity by 2010." A similar target was set by the CBD in 2002 "to achieve by 2010 a significant reduction of the current rate of biodiversity loss" and endorsed by the World Summit on Sustainable Development (WSSD) in 2002. In response, the European Commission published a detailed policy communication on biodiversity in 2006. In many cases, especially where habitats or species are particularly vulnerable to risk, protected areas and species protection are adopted as viable risk management methods.

**Table 2.2** Major landmarks in EU biodiversity policy

| Date | Instrument                                                                                                                                    | Remarks                                                                                                                                                                                                                                                             |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1979 | Directive on the Conservation of Wild Birds (79/409/EEC)                                                                                      | The Directive requires Member States to identify and manage areas of conservation for birds                                                                                                                                                                         |
| 1992 | Directive on the conservation of natural and seminatural habitats and of wild flora and fauna (92/43/EEC)                                     | The Directive requires Member States to identify and manage areas of conservation for selected species and habitats                                                                                                                                                 |
| 1992 | Agri-environment Regulation 2078/92                                                                                                           | Requires Member States to apply agri-environment measures where appropriate                                                                                                                                                                                         |
| 1998 | “Cardiff” process of environmental integration                                                                                                | Strategy setting out guidelines to integrate the environmental dimension into other policies. Nine sectoral strategies are presented (agriculture, transport, energy, industry, internal market, development, fisheries, economics and finance and foreign affairs) |
| 1998 | Sustainable Development Strategy                                                                                                              | The strategy sets objectives, targets, and concrete actions for seven key priority challenges for the coming period until 2010, including the better management of natural resources                                                                                |
| 1998 | European Community Biodiversity Strategy                                                                                                      | The strategy defines the framework for defining Community policies and instruments to comply with the CBD                                                                                                                                                           |
| 2001 | Biodiversity Action Plans in the areas of Conservation of Natural Resources, Agriculture, Fisheries, and Development and Economic Cooperation | Four Action Plans define concrete actions and measures to meet the objectives defined in the European Community Biodiversity Strategy, and specify measurable targets                                                                                               |
| 2006 | EC Communication on “Halting the loss of biodiversity by 2010 and beyond”                                                                     | The Communication sets out 10 policy objectives in 4 policy areas: Biodiversity in the EU; The EU and global biodiversity; Biodiversity and climate change; and The knowledge base                                                                                  |

### 4.2.2 Protected Areas

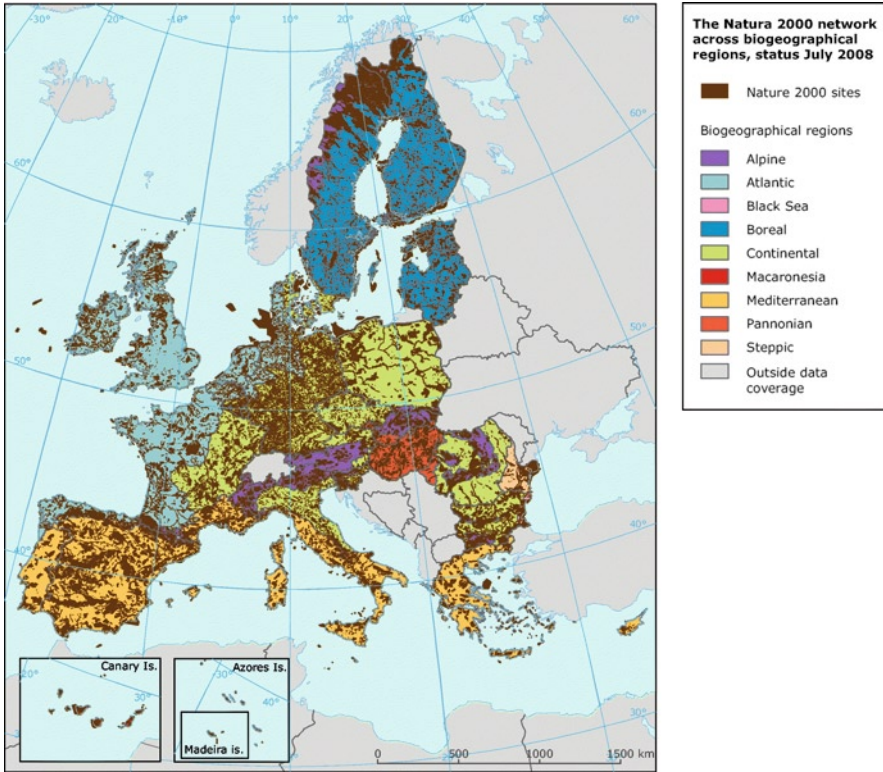
Potentially feasible management options exist for some risks to biodiversity, other risks are much more difficult to manage. Protected areas have been established mainly to minimize the risk of habitat loss to biodiversity. There are more than 104,000 protected areas in the world, covering over 12% of the land area, but only about 0.5 and 1.4% of the ocean and the marine coastal zone, respectively (Chape et al. 2005). The modern era of protected areas started when the Yellowstone National Park was established in 1872. A protected area has been defined by the IUCN and the World Commission on Protected Areas (WPCA) as “an area of land and/or sea especially dedicated to the protection and maintenance of biological

diversity, and of natural and associated cultural resources, and managed through legal or other effective means.” This definition covers many different types of protected areas; in response to these differences the IUCN proposed six categories including those afforded the strictest protection (Category I). The Yellowstone National Park, established in 1872, for example, is an IUCN Category II protected area, a national park. Protected area programs include the UNESCO World Heritage Sites, UNESCO Man and the Biosphere (MAB) sites, ASEAN Heritage Parks and Reserves, sites established under the Ramsar Convention on Wetlands, and the European Natura 2000 network. Despite the number of protected areas some ecosystems remain poorly protected, particularly those experiencing the greatest risk (Hoekstra et al. 2005); only about 5% of the tropical humid forests, for example, are protected to some degree (UNEP-WCMC 2003).

Without the threat of climate change and the decline in the degree to which species can move readily across the landscape between protected areas, protected areas may be considered to be an adequate management option. However, protected areas are unlikely to be able to protect biodiversity from all the risks it faces. And, as discussed below, the establishment of protected areas is often done in such a way as to alienate the local population and increase the risk to biodiversity.

Despite the many advantages of protected areas many rare species exist outside them and their continued survival requires the presence of sustainable populations in nonprotected areas. In Europe, the Birds and Habitats Directives aim to address this issue by creating Natura 2000, a pan-European network of Special Areas of Conservation and Special Protection Areas to ensure the favorable conservation status of habitats and species in their natural range. The network of Natura 2000 sites is illustrated in Fig. 2.5.

Natura 2000 is, however, not a network of strictly protected areas but rather a network of areas in which active steps are being taken to reconcile biodiversity conservation in Europe with the need to “take account of economic, social and cultural requirements and regional and local characteristics” (Article 2(3) of the Habitats Directive). This is particularly important in the context of Natura 2000, where the sites selected are in the main owned and, more importantly, managed by private landowners. However, despite this drive to include local actors in the development of Natura 2000, this initiative has seen a number of conflicts, leading to serious delays in its implementation. Participants of the Bath conference on Natura 2000 and People 1998 identified the “resistance of local people concerned that their economical and social interests might be threatened by the designation of a site” as one of the main reasons for the delay in implementing the Natura 2000 network. One extreme example is the “Groupe de 9” in France, who questioned the legitimacy of the implementation in France and ultimately caused the national suspension of the directive in 1996 (Alphandery and Fortier 2001). Other examples of conflicts caused by the Directive include Finland (Sairinen et al. 1999) and Germany (Wagner 2000). Preliminary lessons learned from these delays and conflicts are that increased communication and transparency at every stage of implementation with local actors is essential for the acceptance and future involvement of local communities in biodiversity conservation.



**Fig. 2.5** Natura 2000 coverage across biogeographical regions. *Source:* European Environment Agency

### 4.2.3 Species Protection

After protected areas, the most common option for managing risk to biodiversity is species protection. Many species are afforded legal protection, either directly or indirectly through legal restrictions on trade. The latter includes CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Birds of prey are protected by national and international legislation. But, as with many species and habitats, legislation is only partially effective: either the risks are too complex to be suitably addressed by legislation or it is too difficult to adequately enforce the legislation. Legislation will also usually fail to address the driving forces that created the risk that the species faces. Thus, laws protecting birds of prey usually do not address the economic damage that they do or are perceived to do to livestock or gamebirds.

Consequently, a further management option is to use methods that minimize the economic damage done by birds of prey and other threatened species. Research on the hen harrier has showed that supplementary feeding may be useful in reducing

the number of grouse chicks taken by these birds of prey (Redpath et al. 2001). It is unlikely that methods such as supplementary feeding could be developed for many threatened species. In some cases, threats to rare species can be managed by compensating farmers or other land managers for the actual or potential income lost by the activities of those species. According to a cost–benefit analysis on overwintering brent geese *Branta bernicla* grazing on farmers' crops in Britain, compensation was found to be the optimal financial solution for farmers (Vickery et al. 1994). This has been put in place in some countries, such as Estonia, where farmers can be compensated for losses incurred due to migrating birds feeding on cereal fields.

Compensations paid for attacks by carnivores on livestock vary greatly according to country, ranging from no compensation at all, to direct compensation for damages incurred, to subsidies paid for implementing measures to reduce risks of attacks. Another possibility is to pay farmers according to the risks within the area they live. This could hypothetically mean that provided that a farmer is rigorous about protecting his livestock against large carnivore attacks he could actually gain financially from this system.

Legal protection of species and their habitats requires knowledge of which species are most at risk, a process led internationally by IUCN and nationally by many government agencies, NGOs, and researchers. Monitoring plays a key role in identifying which species and habitats are most at risk and in estimating trends in the severity of particular risks. Biodiversity monitoring activities have increased in recent decades. The number of species monitored in detail is, however, limited to better-known groups of species. For example, the identification of endangered species has been successful for well-known groups of species such as birds (Lei et al. 2003) and butterflies (Wenzel et al. 2006), and the process itself has clearly also brought more effective nonregulatory action (De Juana 2004). Nevertheless, monitoring of some species has been important in exposing the emergence of new risks.

Monitoring can also be focussed on particular risks such as DDT and other persistent organochlorine pesticides. Although *Silent Spring* led to their restricted use in many countries, these chemicals are still widely used and are detected in monitoring of bird tissue (e.g., Kunisue et al. 2002). Monitoring is also done to assess exposure to chemicals such as polychlorinated biphenyls (PCBs) (Wienburg and Shore 2004). However, many groups of species are too poorly known for accurate assessments of risk to be possible.

Regulation will continue to play an important role in managing the risks that threaten biodiversity. The legal protection of species and their habitats, and legal restrictions on activities that put them at risk, are all necessary, although unlikely to be completely effective (e.g., Holdich and Pockl 2005).

Regulatory actions that focus on particular species are most suitable where the species is directly threatened by human action but, as discussed above, regulation is unlikely to be completely effective where human livelihoods are themselves threatened. Regulatory actions that focus on the risk rather than on species and habitats have the considerable advantage of potentially providing protection for many species. Many of the major risks to biodiversity, however, do not easily lend themselves to regulation, notably climate change. The risks posed by invasive species have, however, been frequently addressed by regulation (Stohlgren and Schnase 2006).

#### 4.2.4 Conflict Management

The successful management of risk to many threatened species and habitats requires an acknowledgment that human activities are a significant source of that risk and that, therefore, the conservation of these species and habitats is in conflict with these activities. Thus, for example, the conservation of birds of prey is often in conflict with activities such as livestock farming, hunting, fishing, pigeon racing, and wind farming.

In an attempt to explore ways of managing the conflict between the conservation of a legally protected raptor, hen harrier *Circus cyaneus*, and the commercial hunting of red grouse *Lagopus lagopus scoticus*, Redpath et al. (2004) quantified the views of stakeholders on raptors and management options using hierarchical decision trees and multicriteria decision analysis. The decision-modeling exercise not only reengaged stakeholders in a dialog, but also allowed stakeholders to better understand different, and potentially conflicting, perceptions of raptors.

As the examples discussed above demonstrate, the management of risks to biodiversity cannot therefore be adequately done without consideration of the impact of biodiversity on stakeholder livelihoods, the perceptions of these stakeholders and their actions. Stakeholder perceptions of the issue and of other stakeholders involved in the process are essential aspects to consider in all risk management options. The perceptions of groups of stakeholders can be very strong and can negatively affect communication among groups, sometimes so much so that certain groups will face disapproval before any direct contact has even taken place (Stoll-Kleemann and O'Riordan 2002).

The main drivers of conflict in Europe are related to changes in land use. Such changes include the intensification or abandonment of silvicultural and agricultural practices, recreation and hunting, and policy-related threats, particularly policies such as the Common Agricultural Policy and EU environmental Directives including the Wild Birds Directive and Habitats Directive (and the associated Natura 2000 network mentioned above). Conflicts in themselves vary tremendously according to the issues and stakeholders involved in the conflict. However, even though the choice and applicability of conflict management strategies will depend on the dimension of a conflict, a number of potential biodiversity conflict management strategies exist (Jones et al. 2005b; Young et al. 2005).

Biodiversity conflict management options can include political, economic, or legislative means to reduce biodiversity conflicts, ranging from the provision of incentives for biodiversity conservation such as agri-environmental schemes under the CAP, to EU level initiatives aiming to legislate for the conservation of biodiversity such as the Natura 2000 network. As with most conflict management strategies, political, economic, or legislative means can, however, lead to further exacerbation of conflicts, with stakeholders potentially resisting such top-down approaches unless they feel they have a level of control over the creation and implementation of laws or regulations. Other potential conflict management options are the buying or leasing of land for conservation purposes and the application of strict Environmental Impact Assessments (EIAs) to identify and avert negative effects of infrastructure projects and thus potentially defuse conflicts. The application of new

technologies, management practices, or land-use patterns, applying spatial planning methods (Nowicki et al. 2005) and other techniques can all contribute to conflict management processes.

Deliberative and inclusionary processes such as community-based management, communication and dialog, educational programs and co-management planning can assist conflict management through the inclusion of different stakeholders, sharing of common visions and positive social capital that is built by different parties working together on practical projects.

#### **4.2.5 Increased Research**

As argued above, the management of risk to biodiversity requires attention to the direct drivers of biodiversity loss such as chemical pollution and species persecution and their underlying causes, which are almost always human in origin. Risk management therefore often means conflict management. However, the sustainable management of conflict and the successful reversal of biodiversity loss requires that their underlying causes are understood. This needs a much better understanding of public attitudes to biodiversity and its loss.

However, although public involvement in biodiversity management is now heralded as essential for the success of conservation initiatives and the reduction in conflicts between conservation and other human activities, scientists and policy makers often argue that public knowledge of biodiversity and biodiversity conservation options is insufficient to allow for effective decision-making. A number of studies have refuted this, including a recent study in the Cairngorms area of Scotland that found that a cross-section of members of the general public expressed rich views and concepts of biodiversity, which in turn informed their attitudes on biodiversity conservation (Fischer and Young 2007). Although the participants of the study had, in many cases, a little knowledge of the term biodiversity, they developed very complex constructs of biodiversity informed by the normative and idealistic components of biodiversity concepts.

Despite increased interest in public attitudes and public participation in environmental decision-making, more research is required on interpreting biodiversity concepts in order to better understand public attitudes to biodiversity and better involve the public in conservation options. This increased involvement could be instrumental in bridging the gap between conflict and the sustainable use of biodiversity.

### **4.3 Risk Communication**

The communication of risks to biodiversity to the public is not a new phenomenon, and has gained ground in certain years, particularly with issues such as climate change increasingly making it to the front page of newspapers. However, these reports are often presented in the media in a rather dramatic way, leading to confusing and often seemingly conflicting messages.

**Table 2.3** Two models of communication

| "Marketing" model                                                              | "Education" model                                                                     |
|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Treats environmental information as a "brand"                                  | Treats environmental information as an aid to understanding                           |
| Focuses on presenting messages in an attractive format, rather than on content | Focuses on providing accurate content                                                 |
| Success is measured in terms of "brand awareness"                              | Success is measured in terms of understanding                                         |
| Eliminates contextual information in order to present a simple message         | Ensures that contextual information is provided in order to facilitate interpretation |

*Source:* Adapted from C. Richards, RISK Workshop, Banchory 30th October 2007

Perhaps because of these problems and other pitfalls of communication, research scientists rarely engage in the communication of their research to the wider public, leaving others to communicate the implications of their research for biodiversity on their behalf. Communication of environmental research to the public therefore often implicitly or explicitly adopts a "marketing model," aiming to convey simple messages "as a brand that can be sold," as advocated by the Institute for Public Policy Research (Ereaut and Segnit 2006). Approaches such as those more typically used in education, which aim to develop the capacities of audiences to evaluate competing messages and to understand the reasoning behind them, are employed much less often in the communication of research findings, but seem likely to be of more lasting value. This has led to the development of a number of models of communication, including, among other the marketing model and the education model (see Table 2.3).

These various models all aim to communicate risks. However the ways in which these are communicated vary greatly from alarmism to lists of particular actions needed to alleviate risks, and processes to develop capacities and understanding. The result in the case of a complex situation like the communication of climate change is a "very messy and noisy language landscape with advocates apparently arguing among themselves in the battle for consensus" (Ereaut and Segnit 2006).

In summary, current approaches to biodiversity risk communication still lack a clear understanding as to the steps required in developing a framework to create a successful communication strategy where risks to biodiversity are presented in such a way that the information (including uncertainties) is clearly communicated to all relevant groups of people. From the above, it would appear that three main steps to achieving this communication mechanism are necessary, including the identification of current barriers to communication; the recognition of risks of communication and finally; and the evaluation of the effectiveness of communication.

**4.3.1 Barriers to Communication**

The majority of issues relating to biodiversity and risks to biodiversity are remarkably complex not only in themselves, due to the relationships between components of these systems, but also due to the multitude of interlinkages among environmental

phenomena (van den Hove 2000). This complexity is often reflected in the language used by research scientists and is often difficult to translate into simpler terms.

In addition, a certain amount of uncertainty exists in all scientific research including extrinsic uncertainties (i.e., insufficient scientific knowledge) and intrinsic uncertainties inherent to the complexity and indeterminacy of environmental issues (van den Hove 2000). When communicating research results, scientists often feel compelled in the light of ethical considerations to highlight these uncertainties, even in cases where the uncertainty is comparatively low. However, once communicated, these voiced uncertainties can potentially lessen the impact of particular messages.

#### **4.3.2 Risks of Communication**

As the example above shows, a major risk associated with current communication of risks to biodiversity can lead to simplistic or hysterical messages to the public, which can in turn become saturated and jaded. In some cases, scientists also choose to present their finding in a more sensationalist manner. However, are they then presenting risk in an unethical way? Indeed, what are the rights and responsibilities of scientists in communicating risks? One major consideration is the examination of the reasons behind communication. Indeed, the current assessment of scientists in many universities and research institutes relies on the number and quality of publications in peer-reviewed journals. These are very rarely read in their current forms by the wider public. In this respect, not only are the incentives in place for scientists to communicate to the wider public lacking, but the abilities and skills to communicate effectively are also absent.

#### **4.3.3 Evaluating the Effectiveness of Communication**

As highlighted above, communication of risks to biodiversity is currently taking place, with, in some cases, very high budgets spent on communicating to certain sectors of the population. Despite these efforts, very little evaluation of the effectiveness of communication has or is taking place. Although some studies have recently highlighted the ability of the public to understand complex biodiversity issues including risks to biodiversity, little is known on the willingness of these different groups to understand these issues. In addition, little is known on the impact of different information sources on public perceptions and beliefs and indeed on how these different information sources vary from the source to the recipients of such information.

## **5 Future Perspectives**

Risk to biodiversity is largely associated with global change, the nature and degree of which has been impossible to predict over the last 50 years. Although we know an increasing amount about climate change, land use change, the spread of invasive

species, and other factors that pose risk to biodiversity, we cannot accurately predict their future impact. Increasingly, however, plausible alternative scenarios are being produced, coupling possible environmental trends with possible responses.

Sala et al. (2000) developed three alternative scenarios of change for the year 2100 based on scenarios of change in atmospheric carbon dioxide, climate, vegetation, and land use and known sensitivities of biodiversity to these parameters. These scenarios were based on the assumption of no interactions among causes of biodiversity change, antagonistic interactions and synergistic interactions. In all scenarios, grasslands, and Mediterranean ecosystems experience the greatest loss of biodiversity due to their sensitivity to all drivers of change. In the first scenario, based on the assumption of no interactions among causes of biodiversity change, changes among biomes are relatively small. In the second scenario, based on the assumption of antagonistic interactions, tropical and southern temperate forests, and arctic ecosystems experience the greatest changes due to land use change (for forests) and climate change (in the arctic). In the last scenario, based on the assumption of synergistic interactions, grasslands and Mediterranean ecosystems are most affected, with the range of expected changes in other biomes expected to be broader than in the first scenario. This kind of study is increasingly important to understand drivers of change and their potential impact on biodiversity. However, the authors warn that scenarios such as these need to be further refined through quantitative regional analysis and research on the interactions between drivers in order to be useful for policy makers.

The Millennium Ecosystem Assessment (2005) has also produced four contrasting scenarios (Box 2.1). Each of their scenarios has a different effect on biodiversity, as shown below in Fig. 2.6.

### **Box 2.1** Millennium Ecosystem Assessment scenarios

*Global Orchestration* – This scenario depicts a globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education. Economic growth in this scenario is the highest of the four scenarios, while it is assumed to have the lowest population in 2050.

*Order from Strength* – This scenario represents a regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems. Economic growth rates are the lowest of the scenarios (particularly low in developing countries) and decrease with time, while population growth is the highest.

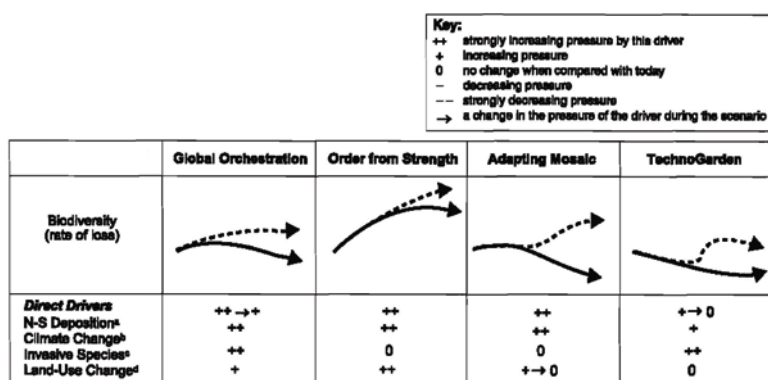
*Adapting Mosaic* – In this scenario, regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a

(continued)

**Box 2.1** (continued)

strongly proactive approach to the management of ecosystems. Economic growth rates are somewhat low initially but increase with time, and population in 2050 is nearly as high as in Order from Strength.

*TechnoGarden* – This scenario depicts a globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems. Economic growth is relatively high and accelerates, while population in 2050 is in the midrange of the scenarios.



**Fig. 2.6** Rate of loss of biodiversity in four contrasting scenarios. The *solid line* indicates the best case and the *dashed line* indicates the worst case envisioned for each scenario. *Source:* Millennium Ecosystem Assessment (2005)

## 6 Chapter Summary

Risk to biodiversity is inevitable but the natural resilience of species and habitats means that adaptation to these risks is continually occurring. For this reason and because of the poor knowledge of the many species that comprise biodiversity, the realization of the scale of its loss is relatively recent. Action to reduce these risks have, however, been going on for a long time, notably through protected areas, legislation to protect particularly threatened species and habitats, and measures to minimize the risk of particular threats. The management of risk to biodiversity has therefore been very responsive and has had many successes. But it has often lacked

a strategic element so that, it may be argued, some of the most threatened species and the most serious risks have not been adequately addressed.

This situation has changed due, in particular, to the Convention on Biological Diversity, the actions of NGOs including IUCN, the emergence of a new approach to protected areas, the Millennium Ecosystem Assessment and the development of a more strategic approach to research on biodiversity.

A more strategic approach to the management of risk to biodiversity is now possible. Although this would have had a much more effective if implemented 30 years ago, it was inevitable that the awareness of biodiversity loss and its causes would be a gradual process. Moreover, there is much more to be learnt about trends in biodiversity and the risks it faces.

Although better monitoring of biodiversity, better assessment of risk and a more strategic approach to conserving biodiversity are all essential elements to successful risk management, an equally pressing need is the effective and targeted communication of risk to the public, policy makers, and other stakeholders. As demonstrated in this chapter, risk to biodiversity and to humans is complex and constantly changing. As such, future perspectives developed by scientists from a range of disciplines including natural sciences and social sciences need to be continually developed, updated, and communicated effectively in a timely manner to policy makers and the public.

## Glossary

**Acid rain:** The deposition of sulfur compounds in rain and other forms of precipitation, after sulfur dioxide emitted into the atmosphere undergoes chemical transformation and is absorbed in clouds.

**Alien species:** In a given ecosystem, an alien species is any species that is not native to that ecosystem.

**Biodiversity:** The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

**CO<sub>2</sub> (carbon dioxide):** A gas produced during the combustion of carbon-based compounds such as fossil fuels and wood (and during respiration). CO<sub>2</sub> contributes to climate change as a greenhouse gas.

**Convention on Biological Diversity (CBD):** The first global agreement on the conservation and sustainable use of biological diversity, signed by world leaders at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil in 1992.

**Ecosystem:** A dynamic complex of plants, animals, and micro-organisms and their nonliving environment interacting as a functional unit.

**Ecosystem approach:** A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way.

**Ecosystem functioning:** The collective activities of plants, animals, and microbes and the effect these activities have on the physical and chemical conditions of their environment.

**Ecosystem goods:** Physical elements that are directly or indirectly consumed by humans.

**Ecosystem services:** Services provided by the movement of energy and nutrients through the air, water, and land and through the food chains.

**Endangered:** A species is endangered when it is facing the risk of becoming extinct.

**Endemic:** Unique to or confined to a particular area.

**Evapotranspiration:** The process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants.

**Extinct:** A species is extinct when there is no reasonable doubt that the last individual of that species has died.

**Fragmentation (of habitat):** The conversion of large areas of contiguous habitat such as native forest to other types of habitat leaving remnant patches of habitat (e.g., forest) that are isolated from each other. Habitats may also become fragmented by roads and other forms of transport. This may have a detrimental effect on species requiring a certain minimum area and species may also face greater risks when dispersing across fragmented, rather than un-fragmented, landscapes.

**Invasive species:** A species, usually an alien species, whose introduction does or is likely to cause economic or environmental harm or harm to human health.

**Monitoring:** The continuous investigation of a given population or subpopulation, and its environment, to detect changes in numbers, distribution, or behavior.

**Nitrogen deposition:** The input of nitrogen to terrestrial and aquatic habitats from the atmosphere (in precipitation, aerosols or in gaseous forms).

**Rate of extinction:** The background rate of extinction is the number of extinctions that would be occurring naturally in the absence of human influence. The current rate of extinction is the number of extinctions that are currently occurring in the presence of human influence.

**Sequestration of carbon:** The process of removing carbon dioxide from the atmosphere.

**Species:** Group of organisms that have a high degree of physical and genetic similarity, and that generally interbreed only among themselves.

**Sustainable use:** The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

## References

- Abbott KL (2006) Spatial dynamics of supercolonies of the invasive yellow crazy ant. *Anoplolepis gracilipes*, on Christmas Island, Indian Ocean. *Diversity and Distributions* 12(1):101–110
- Alphandery P, Fortier A (2001) Can a territorial policy be based on science alone? The system for creating the Natura 2000 network in France. *Sociologia Ruralis* 41:311–328
- Baillie EM, Hilton-Taylor C, Stuart SN (eds) (2004) *2004 IUCN Red List of threatened species. A Global Species Assessment*. IUCN, Gland, Switzerland and Cambridge, UK
- Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, Butterfield J, Buse A, Coulson JC, Farrar J, Good JEG, Harrington R, Hartley S, Jones TH, Lindroth RL, Press MC, Symnioudis I, Watt AD, Whittaker JB (2002) Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology* 8(1):1–16
- Berry PM, Dawson TP, Harrison PA, Pearson RG (2002) Modelling potential impacts of climate change on the bioclimatic envelope of species in Britain and Ireland. *Global Ecology and Biogeography* 11(6):453–462
- Boitani L (2000) *Action Plan for the conservation of wolves (Canis lupus) in Europe*. Council of Europe Publishing, Strasbourg
- Bowerman WW, Best DA, Grubb TG, Zimmerman GM, Giesy JP (1998) Trends of contaminants and effects in bald eagles of the Great Lakes basin. *Environmental Monitoring and Assessment* 53(1):197–212
- Breitenmoser U, Breitenmoser-Würsten C, Okarma H, Kaphegyi T, Kaphegyi-Wallman U, Müller UM (2000) *Action Plan for the Conservation in Europe of the Eurasian Lynx*. Council of Europe Publishing, Strasbourg
- Brook BW, Sodhi NS, Ng PKL (2003) Catastrophic extinctions follow deforestation in Singapore. *Nature* 424:420–423
- Brooker R, Young J (eds) (2006) *Climate change and biodiversity in Europe: a review of impacts, policy responses, gaps in knowledge and barriers to the exchange of information between scientists and policy makers*. Final Report for Department for Environment, Food and Rural Affairs, UK. <http://www.defra.gov.uk/wildlife-countryside/resprog/findings/climatechange-biodiversity/report.pdf>. Accessed 12 Feb 2007
- Brooker R, Young J, Watt A (2007) Climate change and biodiversity: impacts and policy development challenges – A European case study. *International Journal of Biodiversity Science and Management* 3(1):12–30
- Buckley LB, Roughgarden J (2004) Biodiversity conservation – Effects of changes in climate and land use. *Nature* 430(6995):1–119. doi:10.1038/nature02717
- Burdick A (2005) *Out of Eden: An Odyssey of Ecological Invasion*. Farrar, Straus and Giroux
- Carss DN (ed) (2003) Reducing the conflict between Cormorants and fisheries on a pan-European scale - REDCAFE Final Report. Natural Environment Research Council, Centre for Ecology and Hydrology, Banchory, Scotland, UK
- Chape S, Harrison J, Spalding M, Lysenko I (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Phil Trans R Soc Lond B* 360:443–455
- Conover MR (2001) Resolving human-wildlife conflicts: The science of wildlife damage management. Lewis Publishers, Boca Raton, Florida
- Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. *Nature* 387:253–260
- Cowx IG (1997) Introduction of fish species into European fresh waters: Economic successes or ecological disasters? *Bulleting Francais de la Peche et de la Pisciculture* 344–45:57–77
- De Juana E (2004) Changes in the conservation status of birds in Spain, years 1954 to 2004. *Ardeola* 51:19–50

- Echeverria C, Coomes D, Salas J, Rey-Benayas JM, Lara A, Newton A (2006) Rapid deforestation and fragmentation of Chilean Temperate Forests. *Biological Conservation* 130(4):481–494
- Ereaut G, Segnit N (2006) *Warm words: How are we telling the climate story and can we tell it better?* Institute for Public Policy Research, London
- Fischer A, Young J (2007) Understanding mental constructs of biodiversity: implications for biodiversity management and conservation. *Biological Conservation* 136:271–282
- FAO (1988) An interim report of the state of the forest resources in developing countries. Food and Agriculture Organization, Rome
- FAO (2006) Global forest resources assessment 2005: Progress towards sustainable forest management. Food and Agriculture Organisation of the United Nations, Rome
- Gibbons DW, Reid JB, Chapman RA (1993) The New Atlas of Breeding Birds in Britain and Ireland: 1988–1991. T & AD Poyser, London
- Groombridge B (1992) *Global biodiversity: status of the earth's living resources*. Chapman & Hall, London
- Gu WD, Heikkila R, Hanski I (2002) Estimating the consequences of habitat fragmentation on extinction risk in dynamic landscapes. *Landscape Ecology* 17(8):699–710
- Hails RS (2005) Assessing the impact of genetically modified crops on agricultural biodiversity. *Minerva Biotechnologica* 17(1):13–20
- Hanski I (1999) Habitat connectivity, habitat continuity, and metapopulations in dynamic landscapes. *Oikos* 87(2):209–219
- Hill JK, Thomas CD, Fox R, Telfer MG, Willis SG, Asher J, Huntley B (2002) Responses of butterflies to twentieth century climate warming: implications for future ranges. *Proceedings of the Royal Society B-Biological Sciences* 269(1505):2163–2171
- Holdich DM, Pockl M (2005) Roundtable session 2 – Does legislation work in protecting vulnerable species? *Bulletin Francais de la Peche et de la Pisciculture* 376–77:809–827
- Hoekstra JM, Boucher TM, Ricketts TH, Roberts C (2005) Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* 8:23–29
- Hulme PE (2003) Biological invasions: winning the science battles but losing the conservation war? *Oryx* 37:178–193
- IPCC (2001) *Climate change 2001: the Scientific Basis, contribution of the working group I to the third assessment report of the Intergovernmental Panel of Climate Change*. Cambridge University Press, Cambridge
- IUCN (1994) *IUCN Red List Categories. Prepared by the IUCN Species Survival Commission*. IUCN, Gland, Switzerland and Cambridge, UK
- IUCN (2001) *IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission*. IUCN, Gland, Switzerland and Cambridge, UK
- IUCN (2006) *2006 IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>. Accessed 4 May 2006
- Jones C, Moss K, Sanders M (2005a) Diet of hedgehogs (*Erinaceus europaeus*) in the upper Waitaki Basin, New Zealand: Implications for conservation. *New Zealand Journal of Ecology* 29(1):29–35
- Jones PS, Young J, Watt A (2005b) *Biodiversity Conflict Management: A report of the BIOFORUM project*. CEH Banchory, Scotland, UK
- Karlsson B, van Dyck H (2005) Does habitat fragmentation affect temperature-related life-history traits? A laboratory test with a woodland butterfly. *Proceedings of the Royal Society B-Biological Sciences* 272(1569):1257–1263
- Karlsson B, Wiklund C (2005) Butterfly life history and temperature adaptations; dry open habitats select for increased fecundity and longevity. *Journal of Animal Ecology* 74(1):99–104
- King KA, Zaun BJ, Schotborgh HM, Hurt C (2003) DDE-induced eggshell thinning in white-faced ibis: A continuing problem in the western United States. *Southwestern Naturalist* 48(3):356–364
- Kunisue T, Minh TB, Fukuda K, Watanabe M, Tanabe S, Titenko AM (2002) Seasonal variation of persistent organochlorine accumulation in birds from Lake Baikal, Russia, and the role of the South Asian region as a source of pollution for wintering migrants. *Environmental Science and Technology* 36(7):1396–1404

- Koh LP, Dunn RR, Sodhi NS, Colwell RK, Proctor HC, Smith VS (2004) Species coextinctions and the biodiversity crisis. *Science* 305(5690):1632–1634
- Lafferty K, Kuris A (1996) Biological control of marine pests. *Ecology* 77:1989–2000
- Lawton JH (1995) The response of insects to environmental change. In: Harrington R, Stork NE (eds) *Insects in a Changing Environment*. Academic Press, London, pp 3–26
- Leakey R, Lewin R (1995) The sixth extinction: Biodiversity and its survival. Doubleday, New York
- Lei FM, Qu YH, Lu JL, Yin ZH (2003) Conservation of diversity and distribution patterns of endemic birds in China. *Biodiversity and Conservation* 12:239–54
- Lomolino MV (2000) Ecology's most general, yet protean pattern: the species-area relationship. *Journal of Biogeography* 27:17–26
- MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton
- Macdonald IAW, Loope LL, Usher MB, Hamann O (1989) Wildlife conservation and the invasion of nature reserved by introduced species: a global perspective. In: Drake et al (eds) *Biological invasions: a global perspective*. John Wiley & sons, Chichester, pp 215–255
- Mace GM, Stuart SN (1994) Draft IUCN Red List Categories, Version 2.2. *Species* 21–22:13–24
- Mawdsley NA, Stork NE (1995) Species extinctions in insects: ecological and biogeographical considerations. In: Harrington R, Stork NE (eds) *Insects in a Changing Environment*. Academic Press, London, pp 321–369
- Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being. General Synthesis*. Island Press, Washington, DC
- Miller K, Allegrretti MH, Johnson N, Jonsson B (1995) Measures for conservation and sustainable use of its components. In: Heywood VH (ed) *Global Biodiversity Assessment*. Cambridge University Press, Cambridge, pp 915–1061
- Newton I, Wyllie I (1992) Recovery of a sparrowhawk population in relation to declining pesticide contamination. *Journal of Applied Ecology* 29(2): 476–484
- Nowicki P, Young J, Watt ADW (2005) *The Ecosystem Approach applied to Spatial Planning*. A report of the BIOFORUM project: CEH Banchory, Scotland, UK
- Parmesan C, Yohe G (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37–42
- Pimentel D, Wilson C, McCullum C, Huang R, Dwen P, Flack J, Tran Q, Saltman T, Cliff B (1997) Economics and Environmental Benefits of Biodiversity. *BioScience* 47(11):747–757
- Pimm SL (2002) The dodo went extinct (and other ecological myths). *Annals of the Missouri Botanical Garden* 89(2):190–198
- Redpath SM, Thirgood SJ, Leckie FM (2001) Does supplementary feeding reduce predation of red grouse by hen harriers? *Journal of Applied Ecology* 38:1157–1168
- Redpath SM, Arroyo BE, Leckie FM, Bacon P, Bayfield N, Gutierrez RJ, Thirgood SJ (2004) Using decision modeling with stakeholders to reduce human-wildlife conflict: a raptor-grouse case study. *Conservation Biology* 18(2):350–359
- Reid WV (1992) How many species will there be? In: Whitmore TC, Sayer JA (eds) *Tropical Deforestation and Species Extinction*. Chapman and Hall, London, pp 55–73
- Reid WV, Miller KR (1989) *Keeping Options Alive: the Scientific Basis for Conserving Biodiversity*. World Resources Institute, Washington, DC
- Ricketts TH (2001) The matrix matters: Effective isolation in fragmented landscapes. *American Naturalist* 158(1):87–99
- Rodriguez C, Torres R, Drummond H (2006) Eradicating introduced mammals from a forested tropical island. *Biological Conservation* 130(1):98–105
- Root TL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA (2003) Fingerprints of global warming on wild animals and plants. *Nature* 421:57–60
- Roubik DW (1995) Pollination of cultivated plants in the tropic. Food and Agriculture Organization, Rome. *FAO Agricultural Services Bulletin* 118:1–196
- Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL,

- Sykes MT, Walker BH, Walker M, Wall DH (2000) Biodiversity - Global biodiversity scenarios for the year 2100. *Science* 287:1770–1774
- Sairinen R, Viinikainen T, Kanninen V, Lindholm A (1999) *Future visions of Finnish environmental policy*. Gaudeamus, Helsinki
- Schtickzelle N, Choult J, Goffart P, Fichetef V, Baguette M (2005) Metapopulation dynamics and conservation of the marsh fritillary butterfly: Population viability analysis and management options for a critically endangered species in Western Europe. *Biological Conservation* 126(4):569–581
- Singh LS (2002) The biodiversity crisis: A multifaceted review. *Current Science* 82: 638–647
- Stanners D, Bourdeau P (1995) Europe's Environment: The Dobris Assessment. European Environment Agency, Copenhagen
- Stohlgren TJ, Schnase JL (2006) Risk analysis for biological hazards: What we need to know about invasive species. *Risk Analysis* 26:163–173
- Stoll-Kleemann S, O'Riordan T (2002) From participation to partnership in biodiversity protection: Experience from Germany and South Africa. *Society & Natural Resources* 15:161–177
- Tchamba MN (1996) History and present status of the human/elephant conflict in the Waza-Logone region, Cameroon, West Africa. *Biological Conservation* 75:35–41
- Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BFN, de Siqueira MF, Grainger A, Hannah L, Hughes L, Huntley B, van Jaarsveld AS, Midgley GF, Miles L, Ortega-Huerta MA, Peterson AT, Phillips OL, Williams SE (2004) Extinction risk from climate change. *Nature* 427(6970):145–148
- Thomas CD, Lennon JL (1999) Birds extend their ranges northwards. *Nature* 399(6733):213
- Towns DR, Atkinson IAE, Daugherty CH (2006) Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* 8(4):863–891
- Travis MJM (2003) Climate change and habitat destruction: a deadly anthropogenic cocktail. *Proceedings of the Royal Society of London Series B- Biological Sciences* 270(1514):467–473
- United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC) (2003) World Database on Protected Areas (WDPA). Version 6. WCMC, Cambridge, U.K
- Valkama J, Korpimäki E, Arroyo B, Beja P, Bretagnolle V, Bro E, Kenward R, Manosa S, Redpath SM, Thirgood S, Vinuela J (2005) Birds of prey as limiting factors of gamebird populations in Europe: a review. *Biological Reviews* 80(2):171–203
- Van den Hove S (2000) Participatory approaches to environmental policy-making: the European Commission Climate Policy Process as a case study. *Ecological Economics* 33:457–472
- Veeramani A, Jayson EA, Easa PS (1996) Man-wildlife conflict: cattle lifting and human casualties in Kerala. *Indian Forum* 122:897–902
- Vickery JA, Watkinson AR, Sutherland WJ (1994) The Solution To The Brent Goose Problem – An Economic-Analysis. *Journal of Applied Ecology* 31:371–382
- Vitousek PM, D'Antonio CM, Loope LL, Rejmanek M, Westbrooks R (1997) Introduced species: A significant component of human-caused global change. *New Zealand Journal of Ecology* 21(1):1–16
- Vitterso J, Kaltenborn BP, Bjerke T (1998) Attachment to livestock and attitudes toward large carnivores among sheep farmers in Norway. *Anthrozoos* 11:210–217
- Vos J (2000) Food habits and livestock depredation of two Iberian wolf packs in the north of Portugal. *Journal of Zoology* 251:457–462
- Wadsworth RA, Collingham YC, Willis SG, Huntley B, Hulme PE (2000) Simulating the spread and management of alien riparian weeds: are they out of control? *Journal of Applied Ecology* Suppl 1 37:28–38
- Wagner S (2000) Privatwaldbewirtschaftung in Natura 2000 Gebieten. Beschränkungen und ihr finanzieller Ausgleich. *AllgemeineForstZeitschrift/Der Wald* 20:1069–1070
- Walther G-R, Post E, Convey P, Menzel A, Parmesan C, Beebee TJC, Fromentin J-M, Hoegh-Guldberg O, Bairlein F (2002) Ecological responses to recent climate change. *Nature* 416:389–395
- Walther G-R, Berger S, Sykes MT (2005) An ecological "footprint" of climate change. *Proceedings of the Royal Society of London Series B- Biological Sciences* 272:1427–1432

- Warren MS, Hill JK, Thomas JA, Asher J, Fox R, Huntley B, Roy DB, Telfer MG, Jeffcoate S, Harding P, Jeffcoate G, Willis SG, Greatorex-Davies JN, Moss D, Thomas CD (2001) Rapid response of British butterflies to opposing forces of climate and habitat change. *Nature* 414:65–69
- Wenzel M, Schmitt T, Weitzel M, Seitz A (2006) The severe decline of butterflies on western German calcareous grasslands during the last 30 years: A conservation problem. *Biological Conservation* 128(4):542–552
- Whitfield DP, McLeod DRA, Watson J, Fielding AH, Haworth PF (2003) The association of grouse moor in Scotland with the illegal use of poisons to control predators. *Biological Conservation* 114(2):157–163
- Wienburg CL, Shore RF (2004) Factors influencing liver PCB concentrations in sparrowhawks (*Accipiter nisus*), kestrels (*Falco tinnunculus*) and herons (*Ardea cinerea*) in Britain. *Environmental Pollution* 132(1):41–50
- Wiles GJ, Bart J, Beck RE, Aguon CF (2003) Impacts of the brown tree snake: Patterns of decline and species persistence in Guam's avifauna. *Conservation Biology* 17(5):1350–1360
- Wilson EO (1984) *Biophilia: The Human Bond with Other Species*. Harvard University Press, Cambridge, Massachusetts
- Young J, Watt A, Nowicki P, Alard D, Clitherow J, Henle K, Johnson R, Laczko E, McCracken D, Matouch S, Niemela J, Richards C (2005) Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. *Biodiversity and Conservation* 14:1641–1661
- Zimmermann HG, Moran VC, Hoffmann JH (2001) The renowned cactus moth, *Cactoblastis cactorum* (Lepidoptera: Pyralidae): Its natural history and threat to native *Opuntia* floras in Mexico and the United States of America. *Florida Entomologist* 84(4):543–551

<http://www.springer.com/978-1-4419-7867-7>

Safe or Not Safe

Deciding What Risks to Accept in Our Environment and Food

Pechan, P.; Renn, O.; Watt, A.; Pongratz, I.

2011, XII, 145 p., Hardcover

ISBN: 978-1-4419-7867-7