5. Measures for adaptation to climate change

This chapter draws on the conclusions of the previous chapters, considering what might be feasible solutions. How can wildlife management and land use planning adapt to changing conditions, with an aim of achieving sustainability? Possible tools could be revised laws, regulations, policies and management plans, long-term monitoring and reporting schemes for indicator species (plants and animals), adaptive management, transboundary cooperation, the involvement of local people, the enforcement of international agreements, etc. The adoption of such tools and approaches is particularly important where severe negative implications of climate change for human well-being and livelihoods are to be expected. But they must be used within the context of a realistic strategy about what can be achieved and when.

Prevention is, of course, better than cure in the case of climate change; urgent steps to reduce climate change are generally recognized as essential but continue to prove difficult to achieve. Climate change is already occurring, and as global average temperatures continue to rise, it will be important to develop strategies to conserve the species and habitats that are unable to adapt to change.

The response to wildlife challenges due to climate change fall into four main categories:

1. Maintaining current ecosystems wherever possible.
2. Adapting management to address climate change.
3. Restoring damaged or changing ecosystems.
4. Adopting landscape/seascape approaches.

5.1 MAINTAINING CURRENT ECOSYSTEMS

There is increasing evidence that large, healthy and intact ecosystems are best able to withstand climate change (e.g. Noss, 2001 for forests). In addition, highly diverse ecosystems are likely to be most resilient in the face of rapid environmental changes (Thompson *et al.*, 2009). It is also recognized that the ecosystems that are most likely to retain their current form are those located in so-called "climate refugia", areas that are for various meteorological, geographic, geological and historical reasons predicted to be relatively unaffected by climate change.

Maintaining current ecosystems implies strengthening, extending and in some cases refining global protected area networks to focus on maintaining large blocks of intact habitat with a particular emphasis on climate refugia. Research suggests that protected areas are effective tools for maintaining ecosystems, as compared with other approaches, and can play a critical role in safeguarding wildlife in the face of climate change. Importantly, such areas also help sequester carbon by retaining natural vegetation and provide many of the ecosystem services that human communities need to withstand a rapidly changing climate, such as mitigation of natural disasters, provision of freshwater and maintenance of soils (Dudley *et al.*, 2010).

Many authors have recommended increasing the number and size of reserves as a means of providing greater habitat diversity and a higher likelihood of species persistence in a changing climate (Lawler *et al.*, 2009; Noss, 2001). It is important to integrate climate change models with the design and location of protected areas to ensure that they will be able to safeguard species over the long term (Lawler *et al.*, 2009). More and larger reserves would facilitate other proposed adaptation strategies such as the protection of climate refugia, the increase in connectivity and the reduction of non-climatic stressors on forests. Additionally, reserves and protected areas provide many important benefits, including recreational and economic values (Stolton and Dudley, 2010). Proven forest and biodiversity protection strategies such as reserves are particularly important in ecosystems where a high sensitivity to climate change, combined with extensive land conversion, represents a particularly acute threat.

5.2 ADAPTING MANAGEMENT TO ADDRESS CLIMATE CHANGE

In many cases, interventions will be needed to maintain wildlife under rapidly changing situations. The following section outlines a number of possible management strategies for addressing climate change.

Moving protected areas: If a reserve is created to protect a certain habitat and that habitat moves in response to changing conditions, it may be necessary to extend the protected area boundaries in one direction and to de-gazette areas that no longer contain the target habitat (for example, to move a coastal protected area inshore as sea level rises or to move a mountain protected area further uphill). Communities living in the path of a moving protected area will likely resist such a move unless they are compensated and given new land (possibly in the de-gazetted area). It is recognized that the practical challenges of such a strategy are daunting in most places. Ecologists are also considering options for allowing the temporary set-aside of land areas for a period of a few years or decades to allow natural migration to more suitable habitat.

Translocation: If a geographical barrier prevents their natural movement in response to climate change, it may be necessary to relocate animals and plants. This supposes that there is a suitable area that is not already populated by similar species. Experience in translocation has not always been successful: several translocations (e.g. for biological control) have resulted in the spread of alien invasive species, and there are now stricter guidelines governing movement of species (e.g. IUCN/SSC Reintroduction Specialist Group, 1998).

Artificial feeding: In the short term, it may be necessary to provide key populations with supplementary feed and water to keep them alive until a more sustainable solution is found, for example, in the event of a drought causing a mass die-off of species with limited distribution (see Box 2). This type of intervention has has been carried out in the Al-Talila Wildlife Reserve (Al Badia Steppe, Syrian Arab Republic) for the Arabian oryx (*Oryx leucoryx*) and the Arabian sand gazelle (*Gazella subgutturosa marica*; FAO, 2005b) and for hippopotamus populations, which were saved by providing feed during droughts in both Kenya (Born Free Foundation, 2009) and Zimbabwe (Paolillo, 2011).

Habitat modification: If certain food plants that are critical for the survival of particular species are dying as a result of climate change, it may be possible to enrich the habitat by planting alternative food plants better able to thrive at higher temperatures. Droughts have also necessitated the artificial filling of key wetlands in some countries, as in the case of Keoladeo National Park in Rajasthan, India, although this can be controversial if it is seen to be taking water away from agriculture.

Habitat creation: In a worst-case scenario, for instance where rainforests are replaced by arid conditions, it may be necessary to attempt to move entire ecological communities of plant, animal and fungi species to areas that are newly watered by changing rainfall patterns. Some projections indicate that the Sahel in Africa and parts of Antarctica might experience increased rainfall and, while there will be tremendous pressure from land-hungry human migrants seeking new plots to cultivate, some areas might be designated in these regions for the re-building of ecosystems.

EDGAR KAESLIN

Arabian oryx (Oryx leucoryx) *being fed and watered in the Al-Talila Wildlife Reserve, the Syrian Arab Republic.*

5.3 RESTORING DAMAGED OR CHANGING ECOSYSTEMS

The wholesale movement of habitats extends considerably beyond what is usually understood as management. Similarly, in a growing number of places, ecosystem degradation has already gone so far that management responses necessarily approach full-scale restoration. The new UNEP Rapid Assessment Report *Dead Planet, Living Planet* (Nellemann and Corcoran, 2010) gives many examples of ecosystem restoration, such as the West African Mangrove Initiative and the Mekong Delta Mangrove Forest Restoration. Both of these initiatives sought to reverse the loss of mangrove forests, which protect the hinterland from extreme weather events, such as storm-surges and hurricanes. Given the key role that restoration is likely to play in wildlife management in the future, this issue is addressed in greater detail below.

5.3.1 Mangrove restoration

Swamps have a reputation for being dangerous, smelly and of little value until drained and converted to agriculture or other land uses. Concerns over biodiversity loss and fear of runaway dangerous climate change have, however, led to a reappraisal of their worth. In terms of ecosystem services, wetlands and mangroves have a huge value. They act as breeding grounds for many commercially valuable fish and shellfish and help to protect low-lying areas from storm-surges and tsunamis. Freshwater wetlands act as water-filtration systems and, in the case of peat bogs, store huge quantities of carbon that has been sequestered over millennia. In many places, improved land use planning and restoration of these important ecosystems have led to a dramatic resolution of problems associated with their destruction or degradation.

CHEM7

Endangered proboscis monkeys (Nasalis larvatus) *foraging in mangroves of coastal Borneo.*

In the 2004 tsunami in the Indian Ocean, areas with healthy mangroves were less damaged by the tsunami, but the need of timber for reconstruction meant that mangrove forests were under greater threat after the tsunami than ever before. The restoration and protection of mangroves has multiple benefits and provides ecosystem services, such as carbon sequestration, improved fish stocks, local climate regulation (cooling through transpiration, shade and wind protection), local erosion control (slope stabilization) and coastal protection (Mangroves for the Future Secretariat, 2010). Unlike some other habitat types, mangroves are also relatively easy to restore, providing short-term benefits for both local and more distant communities.

BOX 19

Mangrove restoration helps people and wildlife in Gazi Bay

The natural mangroves of Gazi Bay on the southern coast of Kenya have been exploited for many years. In the 1970s, the wood was used as industrial fuel and for building poles. Between 1991 and 1994, the area became the site of experimental reforestation activities. These included local communities, who participated in planting saplings. The local fishing community was interested in participating because the resources they relied upon were decreasing at an alarming pace and their conditions were worsening. Local goat-keepers agreed not to let their animals enter the new plantations to graze and to tie the animals up until the trees had become established. (Bosire *et al.*, 2004)

Bosire *et al.*'s 2004 study reported on the richness of species found in the reforested stands, comparing the number of crab and fish species present in the regenerated areas with those in open areas without mangroves and relatively undisturbed areas. A higher density of crabs was found in the reforested sites as compared to the natural sites, although no difference was recorded in the crab species diversity between the sites. When comparing the number of species between regenerated sites and bare areas, however, it appeared that new species of crabs had been recruited into the reforested areas, which did not occur in the bare sites.

Sediment infauna was found at highest densities in reforested sites, with new taxa found in these sites. Mangrove reforestation had led to the recovery of ecosystem functioning, in terms of habitat provisioning for the sediment infauna and crab species. Subsequently, the area was managed for tourism, with women from the local communities participating in the Mangrove Boardwalk Project. The project enables visitors to enjoy a 300 m walk through the mangrove forest and offers fishing products for sale. (Bosire *et al.*, 2004; Wahinya, 2010)

5.3.2 Inland waters restoration

Drainage, pollution, damming waterways for irrigation and hydroelectric power, straightening water channels, canalizing and the introduction of invasive fish species have all created massive changes in freshwaters throughout the world. Many of these changes have had direct impacts on wildlife; others are being

NIGEL DUDLEY

Removal of the common water hyacinth (Eichhornia crassipes)*, an Amazon native, in Keoladeo National Park, Rajasthan, India.*

questioned because of their potential impacts on humans. For example, damming natural floodplains causes greater flood impacts downstream. Pollution can cause catastrophic losses to local fishing communities.

Restoration can range from pollution control to removal of invasive species, re-establishment of traditional flow or flooding patterns and the wholesale recreation of wetland areas. While it is difficult, if not impossible, to restore a freshwater community to its exact original composition and functioning, small changes can make major differences in its ability to support wildlife.

Under conditions of climate change, some local authorities are proposing to abandon certain areas of low-lying land to seasonal flooding or tidal incursion, thus providing space for rising water, which could also have major benefits for wildlife. In addition, the restoration of natural floodplains and freshwater ecosystems can reduce flood control costs while restoring habitats for water birds and freshwater species. It can also reduce water purification costs for domestic use by serving as a natural filter (Bergkamp *et al.*, 2003).

BOX 20

Wetland restoration brings power to the people

Rwanda, with its abundant rainfall and undulating terrain, generates much of its electricity from hydroelectric power stations. Ninety percent of its electricity comes from two stations: the Ntaruka and the Mukungwa. Ntaruka is fed by water from Lake Bulera flowing into Lake Ruhondo, both of which are fed from the Rugezi wetlands. These wetlands are Rwanda's only Ramsar Site, meaning they are listed as of international importance by the Ramsar Convention (The Convention on Wetlands of International Importance), and host what is probably the world's largest population

Continues

Box 20 continued

of Grauer's scrub-warbler (*Bradypterus graueri*). This watershed encompasses one of the most densely populated areas in rural Africa, with more than 500 people per km^2 eking out a living off the land. (Hove, Parry and Lujara, 2011)

In 2003–2004, the country experienced a serious power shortage when reduced water levels meant that the Ntaruka power station could operate only one of its three turbines at a time. As the hydroplant's output declined, the Rwandan Government had to make up the shortfall by using generators that burned fuel imported by road from the East African coast – at a cost of up to US$65 000 per day – making Rwanda's electricity among the most expensive in the world at that time. In addition, the lowered water table also adversely affected local fishing communities, soil loss from erosion damaged farms on steep hillsides and water turbidity increased. (Hove, Parry and Lujara, 2011)

The power crisis led the Government of the Republic of Rwanda to implement the National Environmental Policy: all draining and agricultural activities in the Rugezi wetlands were banned and drainage ditches were filled in, but at the same time the subsistence farmers were helped with watershed protection training and support. This assistance included erosion-control initiatives, such as planting a belt of bamboo and grasses around the wetlands, planting trees on the surrounding hillsides and distributing fuel-efficient stoves to reduce demand for firewood and charcoal. (Hove, Parry and Lujara, 2011)

Today, the flow from Lake Bulera has been restored and the power station is operating at full capacity. The loss of biodiversity has been halted and people have benefited from the restoration of the system in many ways, such as through improved fishing in the lake, cleaner water supply, increased tourism providing job opportunities and training in other livelihoods. The World Wetland Network presented Rwanda with a Green Globe Award for the restoration of the Rugezi-Bulera-Ruhondo wetland system in 2010 (Kagire, 2010), in recognition of the importance of the ecosystem as a corridor for migratory birds and vast improvements of the wetland ecosystem following the removal of the drainage channels.

Although these successful measures were not triggered directly by climate change, they will make the country more resilient to changes in temperature and precipitation, and serve as a model for the benefits of land use planning (Hove, Parry and Lujara, 2011).

BOX 21

Restoring wetland connectivity in Somerset

The county of Somerset in southwest England, the United Kingdom of Great Britain and Northern Ireland, contains extensive low-lying areas that are naturally flooded every winter. Somerset literally means "summer settlement" because in prehistoric times farmers moved to higher ground with their livestock during the winter to avoid the rising water. Over the centuries, most wetlands were drained and peat cutting destroyed most heathland and fragmented other natural habitats. But in spite of these

Continues

Box 21 continued

changes, Somerset still retains a quarter of the country's coastal and floodplain grazing marsh, over 75 000 hectares, much of which is important bird habitat. (ADAS, 1995)

A number of natural habitats have been included in a series of state- and NGO-protected areas and further safeguarded through conservation controls on 25 Sites of Special Scientific Interest (a legal designation) and through the European Union's Environmentally Sensitive Area designation. Peatlands previously harvested for fuel have been bought by government or NGOs and restored by digging a series of interconnected lakes and encouraging native vegetation. As a result, populations of wading birds and raptors are increasing and the once-threatened European otter (*Lutra lutra*) has returned. Conservation is linking remaining native habitats through restoration and bringing back natural flooding patterns, which also connect sites on a temporary basis, allowing the dispersal of aquatic creatures. (English Nature, 1997; Dudley and Rao, 2008)

These efforts are being given further impetus by the likely impacts of climate change. In the next few decades, the frequency and scale of flood events are likely to increase and rising sea levels will only accelerate this process (Heathwaite, 1993). National and local governments recognize that it will be too costly to protect the whole county and are aiming instead to focus on centres of population, allowing seasonal flooding to return to some low-lying and marginal farmlands. Changes over the next century could bring back habitat types that have been declining or absent for thousands of years. A combination of pragmatic attempts to address likely climate change with focused restoration could create habitat links throughout the county, and, because of the presence of migratory water birds, have important regional impacts as well.

BOX 22

Peatland restoration brings multiple benefits

Peat only covers 3 percent of the world's land surface, but it is the planet's largest single carbon store. It has been estimated that 550 billion tonnes of carbon are stored in peat around the world. But the breakdown of peat habitats is releasing this carbon and most predictions on runaway climate change are based on the potential for boreal peatlands to break down further, creating a vicious cycle between carbon release and climate change (Parish *et al*., 2007; Sabine *et al*., 2004). The restoration of peat has therefore become an urgent priority. Such restoration actions can also have a positive impact on wildlife populations in peat areas, which over the past few decades have frequently been converted to other uses, including plantations. Conservation is likely to benefit particularly native flora and wildlife associated with wetland areas.

Projects are taking place in many countries. In Belarus, for instance, 40 000 ha of degraded peatlands have been restored to their natural state and a further 150 000 ha are awaiting restoration. Half of these areas are already located in officially protected areas so that their future should be assured; the rest will be protected once they have been restored. It is calculated that the work already completed has led to an

Continues

Box 22 continued

annual reduction of greenhouse gas emissions equivalent to 448 000 tonnes of CO_2 from peatland fires and mineralization. The rehabilitation of degraded peatlands also saves the Government some US$1.5 million annually in terms of the avoided costs of fire-fighting operations. The restoration projects are widely supported by local communities, who benefit from access to wetland hunting and fishing grounds and from collecting medicinal plants and wild berries. (Rakovich and Bambalov, in press)

5.3.3 Forest restoration

Deforestation has been a human activity for thousands of years. Estimates suggest that we have destroyed about half of the earth's forests and that, over the past century, the rate of destruction has been increasing. Recently, however, there are signs that the trend is beginning to be reversed. Forest restoration is part of this change, and projects to restore denuded hillsides have proliferated, though often on an ad hoc basis. A more systematic approach that addresses the causes of deforestation and landscape planning for future use is more likely to succeed (Hobbs and Norton, 1996). In some cases, the use of indigenous tree species results in the recreation of an ecosystem similar to one that was lost decades or even centuries before. In others, planting exotic trees for timber or wood-pulp may increase the area of land that is covered in trees, though some would question whether monoculture plantations can be called forests.

Forest restoration can be divided into three main types (Mansourian, Vallauri and Dudley, 2005), listed here in order of increasing cost:

1. *A natural process:* This occurs when existing pressures on the forests are removed, such as the abandonment of farmland in Europe, which has led to major forest re-establishment.
2. *Planned restoration:* This occurs when areas are artificially removed from pressures, such as fencing to protect against grazing animals, and regrowth occurs through natural processes.
3. *Active tree planting:* This occurs when public and private organizations, as well as individuals, transplant tree seedlings.

Wildlife conservation and forest restoration are often mutually supportive. Use of natural seed dispersal agents to enhance reforestation has proved successful in several cases. Up to 95 percent of tropical tree species have their seeds dispersed by animals – including birds, bats, primates, elephants, ungulates and even (in seasonally flooded Amazonian forests) fish. In African and Asian forests, elephants (*Loxodonta* spp. and *Elephas maximus*) disperse more seeds than any other species in terms of quantity, number of species and distance from the parent plant, leading them to be described as the "mega-gardeners of the forest" (Campos-Arceiz and Blake, in press). Some tree species, such as *Balanites wilsoniana,* produce such large seeds that only elephants are able to disperse them (Babweteera, Savill and Brown 2007). Primates also play a critical role in maintaining forest diversity. In Taï National Park, Côte d'Ivoire, monkeys were found to disperse 75 species of tree, of which 69 percent were dispersed almost exclusively by them (Koné *et al.*, 2008).


BODHI SURF SCHOOL

Toucans (Ramphastidae *spp.*) *are important seed dispersal agents in neotropical forests.*

Protecting seed dispersers is therefore an important element of reforestation, if restoring a biodiversity-rich forest is the aim. If a corridor between an existing natural forest and the reforested area can be maintained, animals will carry seeds in their gut after feeding on fruit in the natural forest and deposit them in the newly reforested area. The likelihood of this occurring can be increased by planting "framework species," which produce fruit that attracts frugivores from neighbouring forests. Even if no corridor survives, birds and bats will fly to the reforested area as soon as the new trees begin fruiting and some animals, such as primates and elephants, will even venture across agricultural landscapes to access new food sources.

BOX 23

Restoration of dry tropical forests aided by birds and mammals

The northern highlands of Thailand are characterized by seasonally dry tropical forests, which are likely to be exposed to additional stress from even drier conditions under climate change. Commercial logging represents the main immediate threat to their conservation, leading to increasing problems of forest degradation and fragmentation. The Government has banned logging in response to the threats and has established protected areas to stop destructive human activities in key zones. In a few cases, international collaboration has led to the development of management practices to combat forest clearing and degradation. These practices include forest restoration activities in Doi Suthep-Pui National Park (DSPNP), northwest of Chiang Mai in the Northern Thailand region (Blakesley and Elliot, 2003).

Continues

Box 23 continued

The area experiences a monsoon-like climate with pronounced wet and dry seasons. The natural regeneration of native vegetation is not enough to reverse forest degradation processes, which include not just logging, but also diverse climatic conditions and fire exposure during dry seasons (Blakesley and Elliot, 2003).

The Forest Restoration Research Unit (FORRU) of Chiang Mai University, in collaboration with DSPNP Headquarters and the United Kingdom of Great Britain and Northern Ireland's Horticulture Research International, has adapted the framework species method to restore seasonally dry forests in degraded watershed sites in the mountains of Northern Thailand. The basic structure and function of the forests are rapidly re-established by planting a mixture of 20–30 carefully selected native forest tree species (both pioneer and climax), including fruiting species that attract frugivores, mainly birds and mammals. When the planted trees yield fruit, they attract seed-dispersing animals from nearby natural forests and biodiversity starts to recover. The animals' droppings contain the seeds of additional plant species, thereby adding to the diversity of the restored sites (Blakesley and Elliot, 2003).

Experiments were designed in the nursery to develop horticultural practices that optimize seedling vigour and health. Since 1998, experimental plots have been established annually in partnership with a Hmong hill-tribe community living in DSPNP. FORRU helped the villagers to establish their own community tree nursery to test, in a village environment, the practicability of the new methods developed on the research plots (Blakesley and Elliot, 2003).

The project showed that forest cover can be returned to highly degraded hillsides at 1 300 m elevation within 3–4 years. Canopy closure starts to occur by the end of the second year after planting and is nearly complete by the end of the fourth. Increasing numbers of insects in the planted plots also attract potential seed-dispersing birds and mammals with mixed diets. In this way, the degraded sites gradually return to the tree species composition of the original native forest (Blakesley and Elliot, 2003).

5.3.4 Savannah and grassland restoration

Grasslands and savannahs often survive through achieving a delicate balance of grazing, fire and climatic conditions: changes to any of these can disrupt the ecosystem and thus both ecosystems are likely to require frequent restoration activities under conditions of climate change.

Restoration falls into three main types:

1. *To counter degradation:* Restoring grassland and savannah in areas where they have degraded, in extreme cases, into semi-desert or desert.
2. *To counter alteration:* Restoring native species mixtures and ecosystem functioning to grasslands that have been radically altered by overgrazing, incursions by invasive species or deliberate planting of non-native species.
3. *To counter invasion:* Restoring grassland and savannah where either deliberate planting or the removal of herbivores has resulted in scrub or woodland invasion.

In the long term, restoring soil biomass may be as important as restoring living plants in terms of stabilizing the system. It is likely that climate changes resulting in greater droughts and more unstable weather patterns, which in arid areas increase the risk of dust storms and sand storms, will increase the need for restoration. In practical terms, restoration often involves reducing grazing pressure, which can create the need for careful negotiations with farmers and herders. Focusing restoration on key areas, for example along the migration pathway of birds or mammals, can help to maximize returns on investment.

The cork oak savannahs in the Mediterranean (see Box 8) are an example of how beneficial well-managed cultural ecosystems can be for a variety of wildlife. Cork oak savannahs are threatened by a combination of management and environment related factors throughout their range. Management factors include poor policy and governance, a lack of technical capacity and inadequate investment in sustainable management and restoration practices. These are exacerbated by the impacts of climate change: increased vulnerability of oak trees to diseases, pests and large scale forest fires, which ultimately lead to further biodiversity loss.

BOX 24

Grassland and herbivore recovery after drought in Amboseli

The Amboseli Basin of southern Kenya, comprising Amboseli National Park at its core and the wider Amboseli ecosystem, is a seasonal refuge for herbivores during the dry season. Melt water from Mount Kilimanjaro feeds the basin and provides a permanent water source in the form of large swamps in Amboseli National Park, while seasonal rains fill the floodplain of Lake Amboseli. Migratory herbivores, whose movements are directly linked to seasonal rainfall and water availability, congregate at these water sources during the dry season (Ogutu *et al.*, 2008; Western, 2007).

The Amboseli Basin has undergone great changes in recent decades: the previous woodland–grassland mosaic habitat has shifted to open grassland and daily maximum temperatures have increased dramatically (Altmann *et al.*, 2002; Western and Maitumo, 2004). More importantly, rain patterns have become more stochastic, with annual rainfall varying more than four-fold and the long dry season often preceded by a period of drought (Altmann *et al.*, 2002).

The most recent severe drought, for example, was the result of poor rains in 2008 and a total failure of the main rainy season in 2009. The shrinking water sources attracted high aggregations of herbivores, which promptly overgrazed the area. This resulted in an exceptionally rapid population collapse over the course of the drought. The overall mortality rate of over 75 percent was nearly four times higher than recorded levels dating back to 1967, which never exceeded 20 percent of herbivore populations. Wildebeest (*Connochaetes taurinus*) populations dropped by 92 percent between September and November 2009 and zebra (*Equus quagga*) populations by 71–85 percent, leaving only 312 wildebeest and 1 828 zebra surviving in the Amboseli

Continues

Box 24 continued

Basin. Other species affected by the drought include the African buffalo (*Syncerus caffer*) and Grant's gazelle (*Nanger granti*), which decreased by 65 percent and 66 percent, respectively, as well as large numbers of elephants (*Loxodonta africana*) and hippopotamuses (*Hippopotamus amphibius*) (Kenya Wildlife Service *et al*., 2010; Western, 2010; Western and Amboseli Conservation Program, 2010; Worden, Mose and Western, 2010).

Heavy and prolonged rains broke the drought in December 2009 and began restoring the ecosystem. Vegetation recovered quickly, benefiting from the rains and the lower grazing pressure as a result of drought mortality. Herbivore populations soon began to recover, aided (in the case of the wildebeest) by immigration from neighbouring ecosystems, such as Tsavo National Park. By July 2010, the wildebeest population had reached 1 667. Still, this is nowhere near the species' population of 7 000 in 2007 (Western and Amboseli Conservation Program, 2010).

The natural restocking of Amboseli herbivores from neighbouring populations illustrates the importance of maintaining wildlife corridors. Had the Amboseli ecosystem been isolated, the herbivore population may have been too low to recover, particularly given the high predation pressure in the basin. The dependence of herbivore populations on Amboseli National Park's swamps as permanent water sources in times of drought again stresses the need to maintain ecosystem connectivity.

The Kenya Wildlife Service is contributing to the restoration of Amboseli National Park in two ways. To restock herbivore populations, it plans to relocate 3 000 wildebeest and 4 000 zebra from neighbouring ranches in phases (Kenya Wildlife Service, 2010b). A first phase began in February 2010 with the capture and translocation of 137 zebra (Wildlife Extra, 2010).

The Kenya Wildlife Service further endorsed a plan to create restoration plots in woodland and swamp areas, while existing restoration plots and enclosures have been rebuilt (Kenya Wildlife Service *et al*., 2010; Western and Amboseli Conservation Program, 2010). Fencing off areas has been shown to be a cost-effective way to encourage the regeneration of vegetation (Western and Maitumo, 2004).

5.4 ADOPTING INTEGRATED AND LANDSCAPE APPROACHES

Adaptation to climate change is already occurring, although in a reactive way, since most societies are not yet well prepared to adapt to changes and cope with extreme weather events. Given that land use and climate change both contribute to the major environmental changes we are currently experiencing (Costa and Foley, 2000; Pielke, 2005), the best way to adapt to different climatic conditions and mitigate their effects is through a preventative approach and by integrating the environmental effects of changing climate into land use planning. Such approaches are particularly useful in addressing events that affect ecosystems on a large scale, like wildfires and invasive species. Proper resource planning should be part of this planning process.

Public policies and legislation play an important role in facilitating adaptation to climate change. Land use planning should be regulated by policies that take steady changes as well as likely extreme events into consideration (FAO, 2011b). The integration of information on climate and changing ecosystems into resource use planning is now being implemented in countries around the world, with national and international funds being allocated for this purpose (Parry *et al*., 2007). When putting such integrated land use plans into place, the direct causes of climate change should be considered, together with its immediate and long-term effects. Hazard mitigation can only be successful if land use planning takes into consideration the impacts of changed climatic conditions, particularly with respect to the displacement of human activities and development. Plans also need to address how existing hazards may change in frequency and extent, and whether new hazards are likely to emerge.

Planning usually involves the integration of various approaches. Under conditions of increasing drought, for example, the management of grazing permits for livestock are not always effective on their own to avoid land degradation. In such cases, enhanced land use planning should also address the restoration of degraded land and sustainability as well as human livelihood benefits (Curtin, 2002).

A number of studies have modelled the future effects of climate change at both local and regional scales and the results can be used for improved land use planning (e.g. Colls, Ash and Ikkala, 2009). Some of these studies have resulted in successful land use planning, although costs can be high and international funding may be needed, particularly in developing countries. New technological tools have made it possible to integrate information on different land characteristics in computer models to predict vulnerability to climate change. Such models can help identify the best management practices for specific areas. They not only make it possible to predict the potential effects of climate change, but also the activities (and their extent) that the land can sustain without incurring ecosystem loss.

The application of enhanced land use planning should include participatory approaches that engage local communities in the process of planning, informing them about predicted changes in their area and taking into consideration the interests of the whole community. In the Sudan, for example, a management plan was adopted that expands the traditional techniques for harvesting and conserving water and foresees the development of wind barriers to counter the effects of decreased precipitation on land degradation and drought (Osman-Elasha *et al*., 2006). In Florida, the United States of America, a workshop involving local communities focused on the need for increased community resilience to storm-surge hazards and identified strategies to combat the widening storm-surge hazard zones (Frazier, Wood and Yarnal, 2010).

The Ethiopian Government developed a Climate Change National Adaptation Programme of Action (National Meteorological Agency, 2007). The programme was part of a GEF-funded project developed with the assistance of UNDP as a consequence of the detected increase in mean annual temperature of 0.37 °C every ten years from 1961 to 2005, leading to an increased frequency of droughts. The plan included a list of 37 adaptation actions, ranging from the institution of crop-insurance to increasing capacity-building for small scale irrigation systems, the establishment of a natural reserve in the Great Rift Valley and the enhancement of land resource use in rangelands.

These integrated plans will become increasingly important and complex as we learn more about the likely impacts of and possible responses to climate change. From a wildlife management perspective, such integration implies, for example, that different species groups are addressed equally. There is still much to be learned about how integration can work in practice. Integrated approaches are described below, with respect to the key issues of fire and invasive species, although the principles can be applied to other situations as well.

5.4.1 Wildland fire management

Fires have been identified as critical change factors in an altered climate. Responses cannot be limited to individual site management, but rather require a wider landscape approach. Fire regimes have changed over the course of the last century and continue to change (Dale *et al.*, 2001). This change has led to some significant environmental responses, including shifts to more fire-adapted species, shifts in forest type to either non-native species or lower value forests or conversion to scrublands, grasslands and even deserts. Many of these environmental changes have led to water quality deterioration and quantity reduction, the reduction of the carbon sequestration potential of forests (potentially exacerbating the speed of climate change) and the loss of livelihoods for local communities. Adapting forests to a changing climate and the increasing impacts of fire will be technically challenging and may incur significant costs. On the other hand, failure to confront this challenge will mean an even greater cost to society and the environment.

Fire-sensitive ecosystems

The crux of the problem in fire-sensitive ecosystems is not so much the introduction of fires, but their frequency. Historical records and charcoal in soil profiles show that tropical forest fires, even in wetter forests, are not unprecedented. Fire can be considered endemic in some areas, but usually only occurs in tropical rainforests at intervals of hundreds if not thousands of years. Wetter forests burn less frequently, but are more vulnerable to fire than drier forests because they have thinner protective layers of bark and suffer much higher mortality rates. Periodic disturbances by fire in these ecosystems may also be important in favouring the reproduction and abundance of some important tropical timber species and maintaining biodiversity (Otterstrom and Schwarts, 2006; Snook, 1993).

One of the key adaptation strategies for wildland fires is to use Integrated Fire Management, a comprehensive framework for managing fire, and emissions from fire, in both fire-sensitive and fire-dependent ecosystems (FAO, 2006; Myers, 2006).

This framework involves:

- Assessment and analysis of context.
- Definition of fire management goals and desired ecosystem condition.
- Assessment of laws, policy and institutional framework.
- Fire prevention and education.
- Fire preparedness and response.
- Ecosystem restoration, recovery and maintenance.
- Adaptive management, research and information transfer.
- Promotion of secure land tenure and community-based solutions.

Land tenure issues are as critical to successful fire management as they are to other land management issues. Landholders sometimes tend to avoid the use of fire as a land-management tool and invest more in the prevention of accidental fire, as a result accumulating fire-sensitive species on their properties (Nepstad *et al.*, 2001). In some situations, the overuse of regular fires causes other kinds of problems. Successful fire management strategies, within an Integrated Fire Management framework, engage the local stakeholders who are causing forest-degrading fires in fire-sensitive systems. Local communities are logical partners in fire suppression and management because they are both the first line of attack and the most affected by unwanted fires (Ganz, 2001; Ganz *et al.*, 2007; FAO and FireFight South East Asia, 2002). Such communities should be given incentives for preventing escaped agricultural fires and putting out unwanted fires in a timely manner. Successful strategies require plans and procedures that link local and regional fire-fighting support for large fire suppression as a function of expected size, duration and complexity. The mobilization of local communities is further enhanced by providing training in early detection, initial attack and decentralized communications. As with fire suppression and management, local communities are logical partners for rehabilitating degraded landscapes and reducing fire susceptibility before conversion to agricultural or degraded non-forested lands (Ganz *et al.*, 2007).

Fire-dependent ecosystems

As with fire-sensitive systems, Integrated Fire Management also offers a similar framework for ecosystem-based adaptation in fire-dependent ecosystems. Ecosystem-based adaptation entails the use of biodiversity and ecosystem services as part of an overall adaptation strategy, in order to help people adapt to the adverse effects of climate change. The distinction for fire-dependent systems is that fire itself is used as a tool in fire management (Myers, 2006; FAO, 2006).

There are many forest and savannah/grassland ecosystems that have evolved positively in response to frequent fires from both natural and human causes, maintaining high biodiversity and a changing steady state for low intensity disturbance regimes. The practice of fire-suppression in these fire-adapted environments results in the decline of fire-maintained habitats and the wildlife species that depend on them, such as the migratory woodland caribou (*Rangifer tarandus caribou*) (Canadian Forest Service, 2005; van Lear and Harlow, 2002; see

Box 25). Another major side effect is the accumulation of fuel on the forest floor, which increases the threat of fires of a scale and intensity for which the forests have not been adapted (Bancroft *et al.*, 1985). This effect of fire-suppression in fire-dependent systems is well-established in the literature (Agee and Skinner, 2005; Baeza *et al.*, 2002; Grady and Hart, 2006; Liu, 2004; Myers, 2006; Perry, 1994; Piñol, Beven and Viegas, 2005; Pollet and Omi, 2002; Stocks, 1991).

Natural variability within species and their differing capacities to respond, which is evident in different species of trees, provide opportunities to maintain forests in the face of changing disturbance regimes. The intentional usage of important disturbance types in forest management, such as fire, can build resistance, resilience and gradually lead to forest transitions. Gradually increasing the frequency of prescribed burning could help prepare forests for the increased fire frequency predicted in climate change models. Natural selection can be intense and rapid among seedlings and prescribed fire can quickly promote species and genotypes that are appropriate for altered fire regimes (Galatowitsch, Frehlich and Phillips-Mao, 2009). The use of fire and other disturbances should be used in controlled research settings to aid in the identification of climate-ready genotypes to be used in replanting efforts following catastrophic fire.

Financial calculation of fire-related losses

High-intensity wildfires often lead to a loss of benefits for ecosystems and people, including, but not limited to, those dependent on wildlife habitat, especially in the area of forage production. The owners of large properties in Mato Grosso, Brazil, report that undesired fires cause losses of at least US$11 000 per year (per landholding) in lost cattle forage and fencing. Additional losses from fire include timber, wildlife, buildings and livestock (Nepstad *et al.*, 2001). In the forest concessions of East Kalimantan, Indonesia, the loss of 23 million m^3 of harvestable timber – due to the 1997–1998 fires – was estimated to be worth approximately US$2 billion (Hinrichs, 2000). Economic costs were estimated at more than US$9.3 billion in the same fires (Asian Development Bank and National Development Planning Agency, 1999; Barber and Schweithelm, 2000). The value of these losses has been estimated based on the replacement costs or the value of the market resources that were burned (Merlo and Croitoru, 2005) and may include lost income-generating capacity, lost recreation opportunities, airport closures and degradation of ecosystem services, such as clean water and wildlife habitat (Asian Development Bank and National Development Planning Agency, 1999; Dunn, Gonzalez-Caban and Solari, 2005).

Accounting for ecosystem goods and services is rarely comprehensive, but will nonetheless be necessary if we are to understand the true costs of unwanted fires and the impacts of long-term site degradation on wildlife and ecosystem services (TSS Consultants and Spatial Informatics Group LLC, 2005). Such calculations are an important first step in the overall evaluation of environmental costs, so that the appropriate incentives can be factored into fire-management strategies.

BOX 25

Protecting the winter habitat of reindeer through fire management

The reindeer (*Rangifer tarandus*), known as caribou in North America, is an Arctic and Subarctic deer species with both migratory and resident populations ranging across the tundra, taiga and boreal forests of Asia, Europe and North America. The species is widespread and numerous and is categorized in the IUCN Red List as being of least concern with stable population trends (Henttonen and Tikhonov, 2008), although some subspecies are considered endangered (e.g. woodland caribou, *R. t. caribou*) or of special conservation concern (e.g. barren-ground caribou, *R. t. groenlandicus*) by regional committees (e.g. COSEWIC, 2010).

Ground-dwelling lichens constitute the primary winter forage for migratory populations of reindeer and this dependence makes the species highly vulnerable to fire disturbance. The destruction of lichen by fire has been the major cause for population declines in barren-ground and woodland caribou across North America (Cumming, 1992). After a fire, it takes 20–40 years for the first lichen species to return, 40–60 years for the species favoured by caribou to recover, 60–80 years for a suitable grazing cover of lichen to develop and up to 150 years for preferred lichen species such as *Cladonia mitis*, *Cladonia rangiferina* and *Cetraria nivalis* to reach pre-fire peak levels (Thomas, D.C., Barry, S.J. & Alaie, 1995). Caribou distribution was found to match lichen abundance, with very limited distribution in areas burned less than 50–60 years ago (Joly, Bente & Dau. 2007) and extensive occurrence in old forests (150–250 years post-fire) (Thomas, 1998).

Wildfires are expected to increase in number, extent and intensity throughout the tundra ecosystem (Joly, Bente and Dau, 2007). This will reduce the availability of the preferred winter habitat of the species. Simulations predict that an increased frequency of wildfires will result in an immature forest age structure (i.e. few areas older than 100 years), which is at the lower end of the range of the reindeer's preferred winter habitat (Rupp *et al.*, 2006).

Given this strong effect of wildfires on reindeer and the dependence of rural communities on the species for everything from food, clothing and shelter to tools and transportation, it is not surprising that fire management is an important conservation tool (see Cumming, 1992; Joly, Bente, and Dau, 2007; Stevenson *et al.*, 2003; Thomas, 1998). Most management measures aim to maintain mature and old-growth (> 100 years old) vegetation through fire-suppression in order to safeguard winter-forage habitat. Such measures include: 1) defining minimum areas of mature habitat (> 55 years old), 2) defining maximum burn areas of winter range, 3) identifying optimum burn rates (about 0.25–0.5 percent annually), 4) annually mapping burned winter range areas over 1 000 ha and 5) suppressing fire in winter ranges to maintain adequate forest age distribution. Rather than a single-species approach tailored towards reindeer alone, however, fire management should be based on an ecosystem approach that considers the effects of fire regimes on a broad number of species (Thomas, 1998).

5.4.2 Management of invasive species and wildlife diseases

The effects of the interactions between global warming and biological invasions are alarming and more effective conservation policies are urgently required. These should not only aim to respond to invasions, but also to explore proactive measures to counteract predicted climate changes.

In general, it is crucial that governments enforce coordinated strategies to mitigate the impacts of invasions. These should be based, in the first instance, on the prevention of new incursions, but also should ensure prompt and effective management of invasive species when prevention fails. As a general principle, it is globally acknowledged that prevention should be the first line of defence because preventing the arrival or introduction into the wild of a potentially invasive species, is far more cost-effective than dealing with the problem afterwards. It is clear, however, that a prevention framework will not entirely halt the occurrence of new introductions, and so it is important to enforce a hierarchical approach: prevention is the first priority, then early detection and rapid response when prevention fails, followed by the eradication of invasive species and, finally, control as the last option.

It must be stressed that all of the measures required to mitigate the impact of invasions are potentially affected by climate change, and it is therefore urgent that we develop our strategies with this in mind. Rapid response, for example, is by far the most effective management approach to invasions; in general, the removal of a species is easiest – and often only feasible – immediately after the introduction has occurred, when populations are still small and are confined to restricted areas (Genovesi *et al.,* 2010). The successful eradication of the American beaver (*Castor canadensis*) from France, for example, or of the Indian porcupine (*Hystrix indica*) from the United Kingdom of Great Britain and Northern Ireland were made possible by a prompt reaction, which started before these species became widely established in the wild (Genovesi, 2005). Rapid response also requires the prediction of which species are more likely to invade. The potential of a species to arrive and to become established depends largely on the climatic conditions of the invaded area. Many tropical species now arriving in Europe find temperatures that may permit them to establish in that region.

Rapid removal is not the only response to invasions: there are many examples of the successful eradication of well-established populations of invasive species. Globally, 1 129 eradication programmes have been recorded, targeting alien species of plants or animals in all environments, with outstanding results in terms of biodiversity recovery (Genovesi, 2011). The successful eradication of the coypu (*Myocastor coypus*) from East Anglia in the United Kingdom of Great Britain and Northern Ireland, for example, was facilitated by cold winters that reduced the population before the removal campaign started (Gosling, 1981; Panzacchi *et al.*, 2007; see Box 26). Climate warming, however, could facilitate a rapid expansion of this neotropical invasive rodent to a large portion of Europe. It is already causing huge economic losses in Italy. The encouraging results also depend on the great advancements in the science of eradications; in recent years a number of sophisticated techniques and protocols have been developed, which allow highly selective removal methods that minimize undesired impacts on the environment. Many techniques have been used in eradications – often in an integrated manner – from trapping or shooting vertebrates, to poisoning invertebrates, as well the use of toxicants, pesticides and herbicides for targeting weeds. There are also a growing number of coordinated programmes that target multiple species at the same time, reducing overall costs and multiplying the positive outcomes of the campaigns (Genovesi, 2007).

The efficacy of the different techniques depends heavily on the climatic conditions; for example, precipitation can deeply alter the effect of toxicants, change the vulnerability of the target species and influence the response of invaders to removal. The potential effect of climate change on removal methods is even more notable in the case of permanent control, which is the only remaining management alternative when eradication is not feasible.

Global warming poses new challenges for the management of invasions, affecting the potential for new incursions and the manageability of species and altering the effectiveness of control measures. It is therefore critical to consider such effects when formulating response strategies for biological invasions at all scales, from the global to the local level. Population modelling should consider the possible effects of global changes. The development of more effective early warning and rapid-response frameworks to guide and support responses carried out by countries is urgent, and the management methods currently used to combat invasions should be tested with regard to the possible effects of climate change (US Environmental Protection Agency, 2008).

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Climate change facilitates the spread of invasive species such as the coypu (Myocastor coypus).

Similarly, climate conditions also affect the management of pathogens entering new environments and niches, with the potential for changes in disease dynamics related to climate change. In areas affected by increases in temperature and rainfall as well as other shifts in climatic factors, there should be increased vigilance in monitoring for change in current endemic disease patterns, as well as recognition of newly emerging pathogen trends. Epidemiological studies to model the climactic factors associated with disease outbreaks can help identify triggers for increased surveillance or preventative measures. The identification of risk factors associated with pathogen exchange between wildlife, domestic animals and people can assist in developing response plans when disease outbreaks occur. This process requires the cooperation and sharing of information between public health, veterinary and wildlife officials in a region. The health of ecosystems and wildlife is directly related to the health of people and the livestock on which they depend. It is critical that we develop the capacity within countries to monitor, recognize and respond to unusual disease events using a multidisciplinary "One Health" approach (FAO, 2011c; Newman, Slingenbergh and Lubroth, 2010).

BOX 26

Coypu invasion and eradication in Europe

The coypu or nutria (*Myocastor coypus*) is a large semi-aquatic rodent native to South America, which has been introduced in many areas of the world for its fur. As a consequence of escapes and releases, the species is now established in many countries of Asia, Europe and North America where it impacts natural vegetation as well as crops through overgrazing and causes significant damage to riverbanks and dykes because of its burrowing behaviour. The coypu can also negatively affect insect, bird and fish species and alter the functionality of freshwater ecosystems. The economic losses caused by the coypu can be severe. In Italy, for example, average yearly costs of coypu damage exceed €4 million, and are expected to rise to over €12 million in the future (Panzacchi *et al.*, 2007). The species is listed among the world's 100 worst invasive species by IUCN's Species Survival Commission Invasive Species Specialist Group (Lowe *et al.*, 2000).

To mitigate its impacts, the coypu is intensively controlled in many areas of the world and has been the target of several eradication programmes. Its eradication from West Anglia, United Kingdom of Great Britain and Northern Ireland, in the 1980s is one of the most successful removal programmes ever carried out on a mainland area (Gosling and Baker, 1989; Genovesi, 2005). The success of that eradication was facilitated by the coypu's susceptibility to cold winters, when mortality rate can exceed 80 percent of the population (Carter and Leonard, 2002). Some populations completely collapse during harsh winters (Doncaster and Micol, 1990). On the contrary, following mild winters, coypu populations can show impressive demographic growth with increased reproduction and survival rates.

Continues

Box 26 continued

Many areas of Europe and North America where the coypu has been introduced have a continental climate, with cold winters that limit the expansion of the species. Ongoing global warming could massively increase the damage caused by this invasive rodent, by fostering the growth of populations, facilitating its spread to currently unsuitable areas and limiting the effectiveness of control programmes. The consequences could be severe, not only for the biological diversity in freshwater ecosystems, but also for the economy of many rural areas. A major invasion could even affect the safety of human communities living in proximity to rivers and streams. The coypu can weaken riverbanks by digging, causing the collapse of the banks and, in some cases, causing floods.

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Spraying of a biological insecticide as part of an eradication programme for the gypsy moth (Lymantria dispar).