Climate change
Impacts of mitigation and adaptation measures on biodiversity

Edited by
Pam Berry

Minimisation of and Adaptation to Climate change Impacts on biodiverSity
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PENSOFT

Climate change: Impacts of mitigation and adaptation measures on biodiversity

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INTRODUCTION to MITIGATION, ADAPTATION and BIODIVERSITY

Pam Berry

Climate change

In Europe, by 2100 climate change could increase annual mean temperatures between 2.5 to 5.5°C under a high and 1.0 to 4.0°C under a low greenhouse gas emissions scenario. This warming would be greatest in winter in Eastern Europe and in summer in western and southern Europe. Projected precipitation changes are more variable, but most scenarios suggest an increase in mean annual precipitation in northern Europe and decreases further south. Extreme events, such as heatwaves and intense rainfall events are likely to increase in some regions.

Observations show that many natural ecosystems are responding to current changes, by poleward and elevational range shifts of biota, phenological changes (e.g. earlier onset of spring events, migration and lengthening of the growing season), changing species' abundance and community composition. It is also projected that the resilience of many species and ecosystems will be exceeded in the 21st century with climate change being one of the responsible factors.

Climate change is projected to lead to an increase in heavy rainfall events. ©**FreeFoto.com**

Mitigation and Adaptation

There are two main approaches to addressing the impacts of climate change: mitigation and adaptation. Both aimed at reducing the vulnerability of humans and ecosystems to climate change and are necessary and complementary strategies for dealing with climate change impacts.

Mitigation involves the net reduction of greenhouse gas emissions and the protection and promotion of carbon sinks, through land-use and habitat management, e.g. forests and wetlands can significantly contribute to carbon sequestration and storage. Mitigation also involves the use of non-carbon or carbon-neutral energy sources.

Adaptation can occur as part of natural adjustment of systems to climate change or can be planned and undertaken by humans to avoid unwanted impacts. Actions are often local and sector-specific, but there can be important interactions between them.

Mitigation and adaptation interactions can be positive, for example afforestation with native species increasing carbon capture and storage, reducing flooding and aiding adaptation of biodiversity or negative, such as air conditioning requiring greater energy usage. Mitigation and adaptation are also relevant to development and many measures could be part of sustainable development, although conflicts are possible too.

Interactions also extend to sectors other than the targetted one and this booklet highlights some of those between sectoral adaptation and mitigation measures and biodiversity, identifying those which are most beneficial or harmful[1].

[1] A full report can be obtained from http://www.macis-project.net/MACIS-deliverable-2.2-2.3.pdf

AGRICULTURE

James Paterson

Climate arguably affects agriculture more than any other sector and is a major factor in what, how and where farmers grow and rear their crops and animals. The predicted changes in climate across Europe will have varying degrees of impact on agriculture throughout the region: in the south, a greater occurrence of hotter, drier summers will reduce crop yields and may even increase livestock mortality; however in the north crop and grassland growth is likely to improve and crops will be grown at higher latitudes than before.

In comparison to many other sectors, agriculture has an enviable capacity to cope with climate change by altering farming practice each year (e.g., by choosing more suitable crops species or increasing irrigation in dry summers). Some strategies have the added bonus of providing both mitigation and adaptation – for example, the adoption of drought-tolerant crop cultivars.

Although there are myriad opportunities to achieve mitigation and adaptation in agriculture there is a concern that it may come at a cost to Europe's biodiversity. Modern agricultural practice – through greater intensification and use of agrochemicals – has been responsible for a major loss of agri-environment biodiversity over the last 60 years and a number of the mitigation and adaptation strategies available to European farmers may exacerbate these losses under certain circumstances. For example:

Stone curlew *(Burhinus oedicnemus)* could be adversely affected by an increase in the use of winter cover crops as a means of enhancing carbon sequestration. **©Paul Glendell/2000 Natural England**

- **Reduction of bare fallow** – winter cover crops have been advocated as a good way of sequestering carbon (and will also improve soil structure and hence soil resilience); however, winter bare fallow is an important habitat for a range of bird species (including the IUCN Red List Burhinus oedicnemus) which would be threatened by an increase in cover crop area.
- **Adoption of biofuel crops** – most biofuel crops (except perennial grasses and trees) have similar agronomy to normal intensively grown food crops; in most cases biodiversity will not be enhanced and may even be threatened if biofuels are grown on land with high biodiversity (e.g., cereal set-aside).

However, there are examples of some strategies that could be good for biodiversity:

1. Planting tree shelter belts – provides habitat for a range of birds, insect and mammal species as well as sequester carbon and provide shade for livestock.

- **Adoption of no-till agriculture** – generally minimal or no-till cultivation will be good for soil biodiversity as disturbance is kept to a minimum. Mitigation and adaptation are achieved through carbon sequestration and improved soil resilience.

It is important to realise that all the strategies above could have different outcomes: a strategy outlined for a farmer in one region may be beneficial to local biodiversity; applied in another region though and it may have the opposite effect. The diversity of landscapes, farm types, soil types and management styles means simple pan-European strategies cannot always be prescribed as a panacea for all.

Biofuels could have neutral to negative impacts on biodiversity depending on where and how they are cultivated.
©FreeFoto.com

Minimal or no-tillage is better for soil biodiversity and will encourage carbon sequestration.
©FreeFoto.com

FORESTRY

Mar Cabeza, Laura Jäätellä and **James Paterson**

Forests are potentially very sensitive to climate change although impacts will vary between climatic zones. In southern Europe forests are expected to suffer from productivity loss, weakened competitive ability and hindered sexual reproduction; in the north, the productivity of forests is likely to increase, although they may be more affected by storms, pests and disease. There is significant climate change mitigation potential in forest management and five main options are highlighted: (1) reduce deforestation and forest degradation; (2) increase afforestation and reforestation; (3) increase carbon density of existing forests at stand and landscape scales; (4) maximise the life-span of harvested wood products; and, (5) increase the substitution of fossil-fuels with forest product alternatives. On the whole, mitigation offers many opportunities for biodiversity conservation although there are are risks for biodiversity loss (e.g. afforestation using exotic species; converting other semi-natural habitats to forest; greater use of pesticides).

Adaptation to climate change can take three main forms: (1) resistance options which entail maintaining a relatively constant state in the face of stress; (2) resilience options (promotion of rapid recovery after a disturbance); and, (3) response options (facilitation of transition of ecosystems from current to new conditions). Although resistance options are expensive and only a

Avoided deforestation will contribute to climate change mitigation.
©Liana Anderson

short-term solution, they are often a necessary response. They include the reduction or prevention of fires, and control of insect outbreaks and diseases; their effects on biodiversity can be mixed (e.g. removal of undergrowth to reduce fuel load can reduce species diversity but controlling large-scale fires may maintain biodiversity). Resilience strategies are designed to allow the forest to tolerate disturbances and recover quickly and include improving connectivity, heterogeneity and diversity at the landscape level (e.g. creating forest tracts between existing semi-natural forests will improve the migration capacity of forest taxa like birds, plants, insects and mammals). Response options assist or enable ongoing natural adaptive processes such as species dispersal and migration, population mortality and colonisation, changes in community composition or species dominance and changing disturbance regimes. Examples include using different species' provenances from lower latitude populations for planting (i.e. provenances with greater tolerance for warmer climates) or controlling other threats to natural woodland processes (e.g. excessive browsing from deer; eutrophication from agricultural herbicide drift). Generally these measures should be beneficial to biodiversity and are likely to be most cost-effective long-term solutions.

Many adaptation and mitigation strategies in the forestry sector are likely to be beneficial for biodiversity and some are potential win-win-win scenarios (e.g. reduced deforestation). However, the diversity of forest management methods throughout Europe highlights possible risks to biodiversity; without appropriate management, mitigation or adaptation strategies may have detrimental effects. Of greatest concern are issues relating to land-use change (e.g. afforestation on other biodiversity-rich habitats), fire control (preventing natural fire regimes and poor design of anthropogenic fire regimes) and the possible deleterious effects of tree breeding on the genetic diversity of tree populations (which may reduce their adaptive capacity).

Control of pest outbreaks will reduce loss of carbon sequestration in forests.
©Paul Wakeley/Natural England

The prevention of forest fires will help reduce the loss of carbon storage.
©Kate Parr

ENERGY

James Paterson

There is no single panacea for climate change mitigation in the energy sector; many renewable energy forms offer low or zero carbon potential but the picture is complicated by environmental impacts (e.g., land-use, pollution, impact on species), cost, public acceptance and adaptation capacity.

Today's main energy suppliers (oil, coal and gas) will continue to be the dominant global energy sources until at least 2030 and efforts to reduce their GHG emissions are apace. Along with nuclear and hydropower, their adaptation capacity will encompass a number of factors: the viability of renewable sources (e.g., water for hydropower); availability of cooling water; disruption by extreme weather events (offshore structures); location of physical infrastructure (e.g., power stations in low-lying areas like coastal zones). Other renewable sources (wind, wave, solar, geothermal) are perhaps better equipped to adapt to climate change.

Biodiversity impacts in the energy sector vary enormously and no energy mitigation measure is completely biodiversity friendly but among the better options are:

- **Solar power** – apart from land-use in large-scale operations and water demand in water scarce regions, solar power is relatively benign.
- **Wind power** – large wind turbines are known to affect bat and certain bird species but their overall impact is minimal. Careful choice of location is imperative to avoid the worst impacts (e.g., in bird migration zones).

Solar energy has little direct effect on biodiversity apart from land-use in large-scale operations and water demand in water scarce regions. ©**Chris Jardine**

- **Wave power** – although a very new technology, no known negative impacts have been reported so far.
- **Geothermal** – generally minor impacts compared to other energy providers if potential problems are mitigated and controlled.

The most damaging measures for biodiversity include:

- **Hydro-power** – Large-scale hydroelectric schemes destroy habitats in mountain areas (by creating dammed reservoirs), they affect the upstream and downstream ecology of rivers, fragment landscapes, increase fish mortality and prevent migration and change nutrient loads even as far as estuaries.
- **Tidal barrage** – barrage schemes can have major detrimental impacts on biodiversity: fish mortality from turbine collision is common, fish migratory patterns can be affected and aquatic and terrestrial habitats in estuaries can be severely impacted.
- **Coal/Gas/Oil** – new Carbon Capture and Storage systems are very energy-use intensive which may lead to further environmental degradation; although some pollutant emissions will be reduced some will increase (e.g., ammonia); there will be an increased need for land for conversion sites, transport (pipelines) and location of terrestrial storage entry points; and the effects of CO2 leakage on ocean biodiversity are increasingly worrying (e.g., calcification of coral reefs, trophic disturbance).
- **Nuclear** – apart from land-use, effects stemming from the operation of power plants commonly include mortality of fish larvae as well as juvenile and adult fish through entrainment in the water intake systems, disturbance stemming form water discharge (temperature differences and increased turbidity), and pollutants and escape of radionuclides.

The effects on biodiversity of many energy mitigation and adaptation measures can be softened through careful (and often costly) design and implementation. Nevertheless, the knowledge of current and potentials impacts is an important part of any planning process

Wind turbines can have negative impacts on birds and bats, but this may be avoided by careful siting. **©FreeFoto.com**

Tidal barrages can have major negative impacts especially on species such as fish. Thames Barrier. **©FreeFoto.com**

BUILT ENVIRONMENT

Jake Piper and **Elizabeth Wilson**

Impacts of climate change upon the built environment

The major consequences of climate change upon urban areas and built infrastructure are expected to increase impacts of and vulnerability to: flooding (by rivers, urban surface water or at the coast); erosion and landslip; damage associated with storms, as well as impacts of higher summer temperatures and drier soils.

Mitigation and adaptation options and their impact on biodiversity

Responses to climate change may be made at the strategic level (on choice of location, nature of land-use and settlement pattern), but also at the level of urban design and of building design. In extreme cases climate change may lead to settlements being moved away from flood-risk locations. Adapted design at the strategic level may include decisions on urban sprawl and urban extensions – intensifying the use of space and reducing urban sprawl, with the aim of reducing use of transport energy, for example: a “modal shift” to public transport.

The redesign of urban areas to adapt to climate change may, on the other hand, see an increase in green space to maintain more comfortable temperatures, as well as changes to the design and management of green spaces and parks, to increase and adapt the planting of trees and shrubs and the management of water spaces (including the restoration of natural water-courses within urban areas). Other actions affecting urban design which respond to other pressures may interact with climate change impacts – for instance increases in impermeable surfaces to provide car parking or built space will interact with increased rainfall to exacerbate flooding.

Building design for climate change may be concerned with better ventilation and heat management – such as by using green walls, shading and greater thermal mass. Within buildings and

Award-winning design for Dordrecht International Competition: Floodproof Homes Pilot.
Source: BACA Architects, London

infrastructure, energy efficient technologies and practices may be introduced for both buildings and the appliances or equipment they contain.

Many mitigation and adaptation measures have consequences for biodiversity. In some cases new spaces may become available which may be designed for habitats; in others newly urbanized areas may either occupy sites previously available to biodiversity, or they may fragment such sites, leading to loss of value for wildlife species. Then, sites may suffer changes to their exposure or water supply, also changing their characteristics as habitats. A change to local renewable energy generation (using wind, water, solar, or biomass) may also mean habitats are lost or obstacles to wildlife movement are introduced. An attempt to improve resilience to storm effects via removal of trees would adversely affect urban biodiversity and possibly increase urban heat island effects.

Major risks to biodiversity (and opportunities)

Biodiversity in the built environment is at particular risk of any measures that take up or fragment green spaces and habitats, or where flows of water (and nutrients) into habitats are significantly changed. However, there are opportunities to introduce new areas of green space and enhance existing ones as part of an approach to reduce energy use or in order to make urban areas more resilient to climate change – e.g. via sustainable urban drainage systems.

The types of habitat most at risk of impacts of climate change (and, perhaps, interaction with other urban pressures) are parks and gardens including semi-natural woodlands or grasslands and bodies of open water in urban environments. The species most affected include urban mammals and birds, invertebrates, amphibians and reptiles, as well as plants, especially trees of parks and streets. Aquatic and wetland wildlife may also be affected in urban river and canal corridors and ponds.

POLICY

Both existing and new policy needs to be reviewed to address climate change. Policy affecting both biodiversity and the environment is being updated, but review is also needed for areas which interact in complex ways with climate change and with socio-economic change. These areas include: development and regeneration, services such as transport and water supply, as well as the use of energy. It is important that sectoral policy (strategies and measures), are inte-

Urban square – Manchester
ASCCUE project: Adaptation Strategies for Climate Change in an Urban Environment
www.b4cc.org/asccue

Urban flooding: system overflow
IUCD: 11th International Conference on Urban Drainage
www.icud.org/

Green walls: aesthetics and biodiversity (Paris and Madrid)
Paris: Musee du Quai Branly

Madrid: Caixa Forum

grated with both biodiversity and climate aims, so that maladaptation is avoided and negative impacts and vulnerability are not simply displaced to affect other ecosystem components.

Review and assessment will be the principal means to achieving policy integration, and a further set of policy options will need to be considered to find those that will be most effective in different circumstances and sectors. Policy options take various forms, including regulation/legislation, market based instruments to preserve and extend choice; "soft" options which include guidance, communications and governance, as well as research and development to identify effective approaches for the future.

Before any new policy instruments are introduced they would need to be assessed for criteria such as sustainability, effectiveness and feasibility as well as policy integration, the precautionary principle, and equity. Where synergies exist between mitigation and adaptation policies and measures leading to opportunities for biodiversity (such as green roofs) these may merit special research and measures.

Sustainable drainage systems: Wetland during construction
Hopwood Motorway Services Area, Bromsgrove, UK
CIRIA SUDS web: www.ciria.org/suds/index.html

Functioning SUDS wetland: Hopwood Motorway Services Area, Bromsgrove, UK
Hopwood Motorway Services Area, Bromsgrove
CIRIA SUDS web: www.ciria.org/suds/index.html

Green roofs on commercial buildings (Karlsruhe Germany and Warsaw, Poland)
International Green Roof Association
http://www.igra-world.com

RIVER and COASTAL FLOODING

Pam Berry

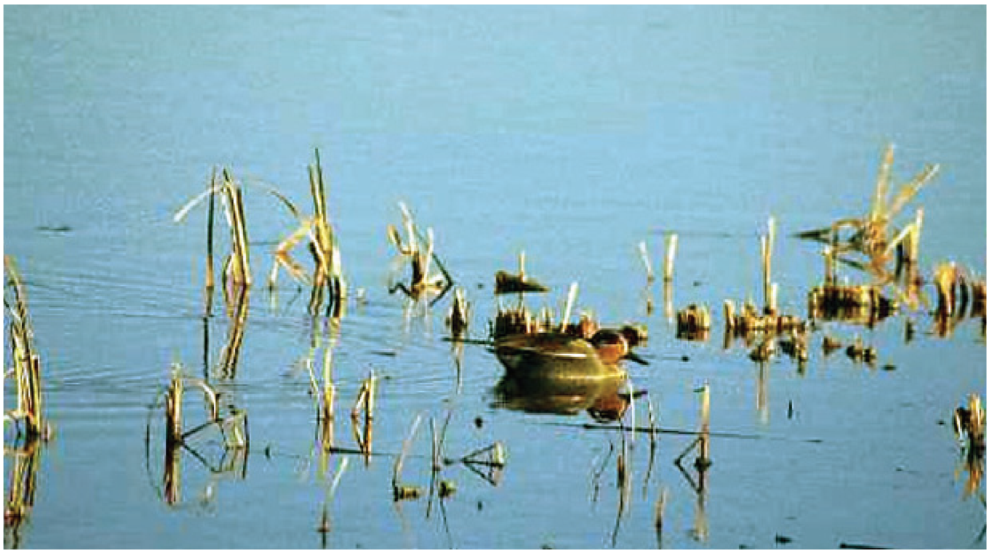
Floods are a natural part of the functioning of rivers and coasts, but due to human modifications of rivers and the coast the likelihood of flooding has increased. In addition, climate models project higher precipitation extremes in warmer climates and precipitation intensity increases almost everywhere, but particularly at mid- and high latitudes where mean precipitation also increases. All enhance flood risk, as does sea level rise.

Nearly all river and coastal flooding measures are concerned with adaptation and any mitigation is incidental and usually minimal. For example, the protection or re-creation of wetlands and salt marsh or grazing marsh may increase local carbon sequestration and such measures are also beneficial for biodiversity. Adaptation measures can be divided into managing rural and urban landscapes, managing the flood event and losses and engineering (Thorne et al., 2007). There is most information on (and probably interaction with) impacts on biodiversity for the first two and last groups.

Among the positive measures for biodiversity are: restoration of flood plains, wetlands and washlands, green roofs, coastal realignment and afforestation with native species. For example:

- **Wetland and washland restoration** could enable the creation of important habitats, such as hay and flood meadows, reedbeds and swamps. Depending on the flood regime it can benefit wading birds, such as snipe (*Gallinago gallinago*);
- **Green roofs** can increase habitat availability, provide homes to trampling-sensitive plants and ground-nesting birds, increase ecological connectivity and provide undisturbed soil, which can increase insect diversity;

Waders and dabbling ducks such as teal (*Anas carolinensis*), could benefit from increased habitat availability through wetland and washland recreation.
©Paul Glendell/English Nature



• **Coastal realignment** can allow the inland movement of habitats e.g. salt marsh and beaches, but this may squeeze coastal grazing marsh. Any increase in inter-tidal habitats could lead to gains in associated specialist plants, invertebrates and molluscs, bird roosting and feeding areas, and expansion of fish nurseries.

Measures which can be negative for biodiversity include flood control infrastructure, channelisation, large dams and beach nourishment. For example:

• **Flood control infrastructure**, including dams may disrupt vegetation and adversely affect aquatic flora and fauna through altering flow patterns and flooding regimes and disrupting migration;
• **Channelisation** can disconnect wetlands from rivers and lead to effective habitat fragmentation. It can also lead to the decline of species associated with slower flowing water and reduced fish abundance;
• **Beach nourishment** can result in the smothering of shallow reefs, all species, and the degradation of beach habitats. It can reduce species diversity, density of invertebrate prey for shorebirds, surf fishes and crabs and nesting frequency. It can benefit endangered and threatened sea turtles and some nesting shore birds by restoring habitat along eroded beaches (Greene, 2002).

There are many opportunities for appropriately implemented flood adaptation measures to also enhance biodiversity and these win-win situations should be sought, in order to maximise the efficient use of resources.

Hard engineering coastal management schemes (e.g. sea walls) to reduce flooding will prevent the inland migration of biodiversity.
©Peter Wakely/Natural England

It is important that coastal habitats are allowed to adapt by moving inland. The picture on the left shows Tollesbury on the Blackwater Estuary, UK before the sea wall was breached to allow managed re-alignment and movement inland and on the right, sluice flooding before the wall was breached.
©Peter Wakely/Natural England

HUMAN HEALTH

Martin Musche and **Ingolf Kühn**

Air conditioning, is an adaptation that will reducing heat stress, but will increase energy use and thus greenhouse gas emissions.

Impacts of climate change upon human health

Climate change is expected to have two major implications for human health. First, human beings may increasingly be exposed to extreme weather events, such as heat waves or floods. Second, altered climatic conditions are expected to change the distribution and seasonality of allergenic pollen species, human pathogens and their vectors.

Mitigation and adaptation options and their impacts on biodiversity

Public investments in education, early warning systems and health systems represent an indispensable precondition to lower the vulnerability of individuals to both, extreme weather events and the transmission of vector borne diseases. Such investments may also prevent the implementation of other adaptation measures which may be more expensive and /or may cause negative effects on biodiversity.

A reduction of indoor temperatures to prevent heat stress may be achieved either by energy-intensive air conditioning or by improving the insulation of buildings (passive cooling strategies). Actions to reduce the urban heat island effect including the creation of green spaces, green roofs and the use of light surface materials may also lead to a reduction of temperature outside and inside buildings.

The spread of vector borne diseases may be prevented by several vector control strategies. Mosquitoes may be controlled most efficiently by targeting their larval habitats. These measures include the drainage of breeding sites and the application of chemical and biological control agents. The latter options also apply to ticks which may also be controlled by vegetation management.

Mosquitoes may become more of a problem in some areas. They could be controlled by draining wetlands or using chemical or biological agents. All these options are likely to be negative for biodiversity.
©http://free-stock-photos.com/animal/mosquito-1.html

Strategies to mitigate and to adapt to the effects of climate change differ in their potential impact on biodiversity. Increased energy use associated with active cooling of buildings is expected to cause mainly negative effects depending on the energy source. In contrast, all active cooling strategies including measures to reduce the urban heat island effect may be beneficial if implemented appropriately. Apart from vaccination programmes most currently available options to control pathogens and their vector species affect biodiversity to some extent. Negative impacts may be prevented by establishing integrated control schemes.

Major risks to biodiversity (and opportunities)

The use of air conditioning represents the adaptation strategy most detrimental to all components of biodiversity and types of habitat. Passive cooling strategies may be suitable to mitigate the negative effects associated with air conditioning and if conducted appropriately, may be beneficial for urban biodiversity.

Vector control strategies which involve the drainage of wetlands and the large scale application of chemical control agents are considered to express the most negative effects on wetland biodiversity, in particular on arthropods and their predators.

TOURISM and LEISURE

Anne Dubuis, Antoine Guisan and **James Paterson**

Climate has always had a considerable effect on tourism and recreational activities and future climate change is likely to impact on them further. The main anticipated climate change effects on tourism will be: a reduction in tourism in the traditional hot summer destinations (e.g., the Mediterranean) due to hotter and drier conditions; an increase in winter storm damage and sea-level rise at low-lying seaside locations which may result in land (and hence amenity) loss; and, a loss of snow cover in mountainous regions resulting in a reduction in ski tourism.

The tourism industry is mainly concerned with adapting to climate change and many of the most popular holiday destinations are already anticipating this. In some circumstances adaptation will involve relocation of activities (e.g. summer and winter tourism may increase in Scandinavia and other northern European countries at the expense of southern countries) or in timing of visits (e.g. more summer visits to the Alps in place of winter trips or more spring and autumnal trips to Mediterranean countries). The two types of tourism that will be affected most will be beach holidays and skiing. The outlook is not positive for either and efforts to ameliorate the effects of climate change will either be costly or impossible; furthermore, many adaptation measures are likely to be harmful to biodiversity. The ski industry faces a difficult challenge and many low-altitude resorts may not be able to offer skiing in a few decades; higher altitude resorts may have to increase snow-making, develop new piste or diversify into summer tourism – all of which can have detrimental impacts on biodiversity. Beach resorts may have greater potential to adapt: new sea-level rise defences and desalination plants may be created and sun-seekers will be able to avoid the hot months by favouring spring or autumn holidays. There is a high risk of biodiver-

Loss of snow leads to the need to move to higher slopes or to use snow-making equipment.
Kranska Gora, Slovenia. ©Pam Berry

sity loss if coastal engineering projects are built in or near protected marine ecosystems. Some coastal defence systems, however, may protect habitats from detrimental climate change effects.

The most effective mitigation strategy in the tourism sector will involve reducing carbon emissions from travel. This may entail replacing air travel with rail or coach travel, reducing the number of trips each year (e.g. fewer weekend breaks) and improving transport efficiency across all transport forms. Other mitigation activities include adopting renewable energy sources in resorts (e.g. hydropower in mountain resorts) and greater offering of carbon offset schemes with holiday packages. The impacts on biodiversity will mainly be positive (e.g. an increase in rail travel is likely to reduce pollution caused by other forms); however, some negative outcomes may result from inappropriate implementation (e.g. building hydropower plants in conservation areas).

Generally, adaptation strategies are likely to be more detrimental to biodiversity than mitigation but the outcome of both types of strategy will depend greatly on local environments and the sensitivity of implementation.

Summer beach holidays in more northern countries may increase as temperatures warm.
©FreeFoto.com

Reductions in air travel would contribute to climate change mitigation.
©FreeFoto.com

CONSERVATION

Mar Cabeza and **Guy Midgely**

The EU is committed to the Convention on Biodiversity's target "to halt biodiversity loss by 2010". This can only be achieved by sound conservation practices which minimise the loss of habitat, species and genetic variation. By definition, conservation should be a sector with actions that are positive for biodiversity. The main conservation strategy has been the establishment of geographically fixed networks of protected areas (PAs). These are now affected by climate change and the challenge for conservation is to enhance the ability of current strategies to provide a basis for future biodiversity persistence. In particular, allowing species to adapt to climate change through species adapting on site, moving to new sites or a combination of these.

Potential adaptation strategies include: a) take no action through informed choice b) adaptable conservation areas, c) sound conservation outside PAs d) prevention of invasion by alien species e) management of disturbance regimes, such as fire and grazing, f) expand or identify new PAs g) connect PAs (corridors and stepping stones) h) conserve genetic diversity, and as extreme solutions, i) develop ex-situ conservation (e.g. seed banks, captive breeding) j) translocate species in order to assist migration.

Captive breeding in zoos may be necessary to enable some species to adapt to climate change.

Some of these, while benefiting certain species, may have secondary consequences affecting biodiversity negatively, such as assisted migration, and thus are associated with higher risks. Benefits are more likely with other strategies (e.g. expanding PAs, alien species management, seed banks), but all are associated with a great degree of uncertainty. Also, some strategies may be of general application (e.g extending PAs, buffers around PAs) while others can be applied only in critical situations or for particular taxa (e.g. translocate species to assist distribution shifts).

Some of these conservation actions, such as increase in protected area, sustainable management of the matrix, or management of processes, such as fire, can also have important climate change mitigation potential. All the measures, however, need careful implementation and monitoring to ensure that they achieve their objectives.

Some species may be able to adapt to climate change, but others will require assistance through specific measures will may include greater habitat provision, special breeding or, in extreme cases translocation.
©Pam Berry

MITIGATION, ADAPTATION and BIODIVERSITY: threats and opportunities

Pam Berry

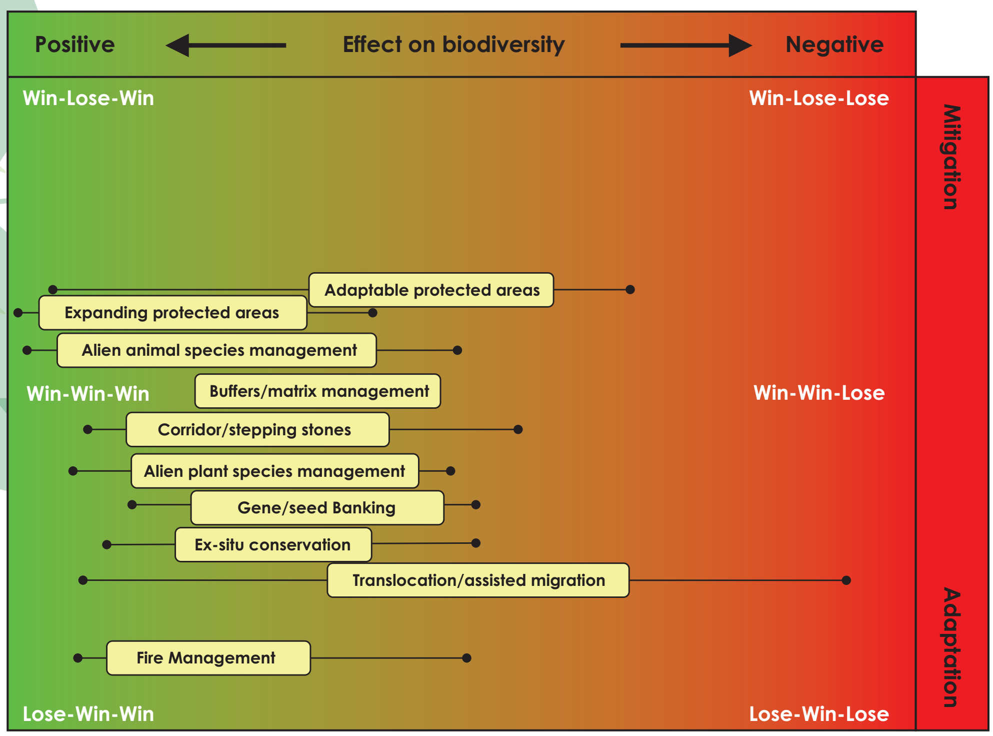
Many climate change mitigation and adaptation measures are implemented with little regard for their wider impacts. This review has highlighted those which may complement or conflict with biodiversity and thus represent risks or opportunities for conservation.

Major risks and opportunities for biodiversity

The mitigation and adaptation measures have a number of possible impacts on biodiversity (Figure 1):

neutral – no recorded effect on biodiversity e.g. many of the animal husbandry and breeding measures and some management of flood losses, such as insurance;

Figure 1. Known and potential relationships between mitigation and adaptation measures and their impacts on biodiversity. The position of the boxes on the biodiversity axis is based on the literature review of the biodiversity impacts of various mitigation and adaptation schemes and represents the typical outcome; the whiskers demonstrate the potential range of impacts. (from Berry et al., 2008; Paterson et al., 2008).



positive for mitigation, neutral or negative for adaptation and positive for biodiversity – e.g. avoided deforestation, slurry management;

positive for mitigation, neutral or negative for adaptation and negative for biodiversity – e.g. dams and tidal barrages, some renewable woody biomass;

neutral or negative for mitigation, positive for adaptation and negative for biodiversity – e.g. control of mosquitoes by draining of wetland, snow-making in ski resorts;

neutral or negative for mitigation, positive for adaptation and for biodiversity – e.g. conservation measures, such as *ex situ* conservation, restoring connectivity;

positive for mitigation, adaptation and biodiversity to varying degrees – e.g. urban green spaces, restoration of wetlands.

These impacts can vary though according to the manner of their implementation, habitats and species of concern and the temporal and spatial scale under consideration.

Those with negative impacts on biodiversity should be avoided and remedial measures implemented, while measures with positive outcomes represent opportunities which should be sought and promoted.

Cross-sectoral interactions

This work has also shown that there are a range of interactions between mitigation and adaptation measures and biodiversity and a simple conceptual framework is shown in Figure 2. In reality a combination of them may be implemented in order to deal with a particular situation and these may be entirely within any sector or may involve cross-sectoral impacts and actions. Table 1 shows some health measures and their interaction with other sectors. Some these actions may be complementary, while others may involve trade-offs, such as between salt marsh and coastal grazing marsh when considering coastal adaptation measures.

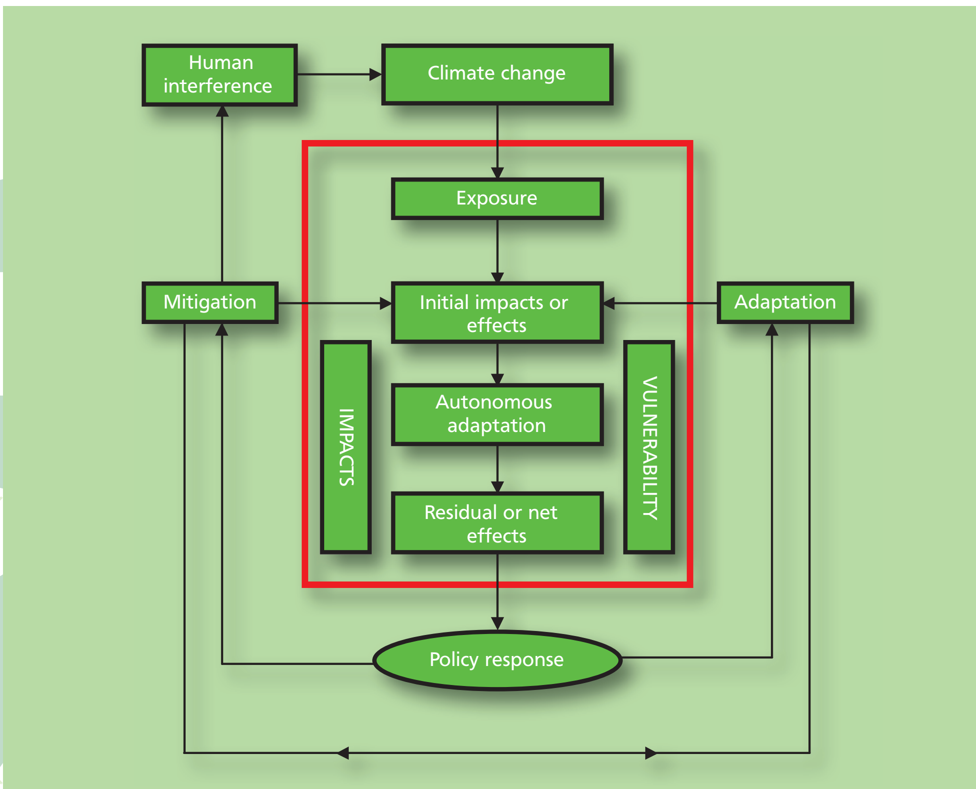
Table 1. The interactions between health mitigation and adaptation measures for climate change and other sectors.

Health	Agriculture	Forestry	Energy	Built environment	Flood management	Tourism & leisure	Conservation
	Some mosquito control measures e.g. the use of insecticides may prevent the spread of vector species which transmit human and livestock pathogens, vegetation management for tick control may lead to a loss of agriculturally used land	Afforestation may reduce the urban heat island effect, vegetation management for tick control may lead to a loss of forest area	The use of nuclear power bears the risk of radioactive contamination of humans, biofuels may be produced at the expense of food production increasing the risk of malnutrition	Urban landscape planning and building design may reduce the urban heat island effect	Dikes and embankments protect settlements from flooding and may prevent casualties, the creation of green spaces within urban areas may enhance flood protection	Mosquito control e.g. by Bt toxins may increase the attractiveness of wetlands for leisure activities	Increase of open space or afforestation to reduce the urban heat island effects on health could be beneficial. Introduction of vector control agents – benefits questionable

Conclusions

This review has shown how there are a variety of possible interactions between sectoral mitigation and adaptation measures, and between these and biodiversity. The cross-sectoral nature of mitigation and adaptation measures means that in order to have coherent responses there needs to be policy integration between in the various sectors. Those measures which are wholly positive (win-win-win) should be sought in order that cost-effective and environmentally sound action is taken.

Figure 2. The inter-relationship between adaptation and mitigation. The red box represents a sector, in this case biodiversity (Adapted from Smit et al., 1999).



Minimisation of and Adaptation to Climate change Impacts on biodiverSity
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SIXTH FRAMEWORK PROGRAMME