Guidance on the maintenance of landscape connectivity features of major importance for wild flora and fauna

Guidance on the implementation of Article 3 of the Birds Directive (79/409/EEC) and Article 10 of the Habitats Directive (92/43/EEC)

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EXECUTIVE SUMMARY

Many of Europe's habitats are highly fragmented and at risk of further fragmentation as a result of ongoing developments and land-use changes. Fragmentation results in habitat loss and degradation, and constrains movements by species (e.g. for foraging, breeding, migration and dispersal). Furthermore, fragmentation impacts are likely to be exacerbated by the effects of climate change, and fragmentation will reduce the resilience of habitats and species' populations to climate change. Fragmentation may also limit the ability of some species to move to new areas that have suitable climatic conditions. It is therefore clear that fragmentation and the added impacts of climate change are major threats to biodiversity (ecosystems, habitats and species) within the EU.

Fragmentation is therefore a threat to the achievement of many of the EU's nature conservation objectives, including halting biodiversity loss by 2010. It is also constraining the effectiveness of the Habitats directive and Birds directive, in particular the establishment of a coherent network of protected areas (the Natura 2000 network) and the wider maintenance and restoration of Favourable Conservation Status of habitats and species. It also has broader implications regarding the maintenance of ecosystem functions and the provision of ecosystem services and their socio-economic benefits.

The importance of ecological connectivity amongst habitat patches and species' populations across the landscape is widely recognised. Consequently there are provisions to maintain and, where necessary, enhance ecological connectivity amongst protected areas and across the wider environment within the Habitats directive and the Birds directive. The EU Biodiversity Action Plan also calls for measures to support the sufficiency, coherence, connectivity and resilience of the broader protected area network and the need for biodiversity adaptation measures in response to climate change.

This guidance report has therefore been produced on behalf of the European Commission to assist EU Members States in halting the loss of biodiversity as a result of habitat fragmentation and the additional impacts of climate change. It aims to help develop and implement integrated ecological connectivity related measures that contribute to the maintenance or restoration of the Favourable Conservation Status of species and habitats of Community interest in accordance with requirements of the Habitats and Birds directives. In particular it provides guidance on implementation of Article 10 of the Habitats directive and Article 3 of the Birds directive. It also aims to support the connectivity and climate change objectives in the EU Biodiversity Action Plan. This guidance covers all terrestrial, freshwater and inter-tidal habitats in Europe, but does not cover marine habitats and species.

This guidance has primarily been developed through a review of scientific literature and an examination of connectivity conservation practices in a selection of EU Members States. It has also been produced in close cooperation with the European Commission and drafts have been commented on by the Scientific Expert Working Group and the Habitats Committee.

Key findings from the scientific review and case studies indicate that connectivity conservation measures should:

- Have clear biodiversity conservation objectives, with a high priority given to ensuring the coherence of the Natura 2000 network and the wider maintenance and restoration of Favourable Conservation Status of habitats and species, whilst also contributing to other EU, national, regional and local biodiversity strategy frameworks and targets.
- Assess the need for, and plan measures on the basis of functional connectivity (rather than simple structural connectivity) bearing in mind that this is species-specific.
- Focus on species that are most at risk from fragmentation, especially if they are also threatened by the added impacts of climate change.
- Be based on well-founded ecological science and supporting evidence. Particular care should be taken when using models to guide the design of ecological networks.
- Be integrated with other necessary conservation measures to ensure that other significant threats are reduced as necessary.
- Only increase connectivity where it is necessary (because landscape connectivity is inherently neither good nor bad) and carefully consider the possible risks from such actions (e.g. facilitating the spread of alien species, pests, predators and diseases, and reductions in genetic diversity and fitness).
- Consider all options for increasing functional connectivity and take their cost-effectiveness into account, remembering that the effectiveness and efficiency of measures will vary according to the habitats and species being targeted and the landscape configuration that is present.
- Apply the precautionary principle when there is significant doubt over the connectivity value of existing habitat corridors and other landscape features.
- Treat landscape connectivity as a dynamic property, and therefore follow an adaptive management approach, which responds to future changes in climate and land-use etc.

On the basis of these findings, a framework is proposed for assessing functional connectivity needs, and planning, integrating and implementing necessary actions. This framework suggests that Members States should:

1. Identify species and habitats of Community interest that are already impacted by or vulnerable to fragmentation and/or changes in suitable climate space (using a proposed risk assessment framework).
2. Assess the functional connectivity requirements of vulnerable species and habitats, taking into account likely habitat fragmentation and climate change impacts where necessary.
3. Integrate functional connectivity requirements into ecological networks and generic habitat measures across the wider environment.
4. Implement connectivity measures through existing mechanisms, such as protected area management processes, planning regulations and policies, land-use policies, and EU funding mechanisms.

Finally it is recognised that further ecological research needs to be carried out to increase the effectiveness and efficiency of connectivity conservation measures, especially regarding the longer-term needs for adapting to climate change. A number of research priorities are therefore identified to support connectivity conservation measures.

ACRONYMS

AEM .... Agri-environment measures
AES .... Agri-environment schemes
CAP .... Common Agricultural Policy
CBD.................... Convention on Biological Diversity
CFP..................... Common Fisheries Policy
CMS.................... Convention on the Conservation of Migratory Birds
COM .... Commission Communication
EAFRD .... European Agricultural Fund for Rural Development
EAGGF............... European Agricultural Guidance and Guarantee Fund
EC....................... European Community
EEA .... European Environment Agency
EFF .... European Fisheries Fund
EIA .... Environmental Impact Assessment
ECCP .... European Climate Change Programme
ERDF.................. European Regional Development Fund
ESF .... European Social Fund
EU....................... European Union
FCS..................... Favourable conservation status
GAEC .... Good Agricultural and Environmental Condition
IA........................ Impact assessment
ICPR .... Commission for the Protection of the Rhine
ICZM .... Integrated Coastal Zone Management
IPCC .... Intergovernmental Panel on Climate Change
LIFE.................... Financial Instrument for the Environment
MEA .... Multilateral Environmental Agreements
PEEN .... Pan-European Ecological Network
PELBS .... Pan-European Biological and Landscape Diversity Strategy
SAC .... Special Areas for Conservation
SCI...................... Sites for Community Interest
SEA .... Strategic Environmental Assessment
SPA..................... Special Protection Areas
TSES................... Territorial system of ecological stability
UN .... United Nations
WFD .... Water Framework Directive
Y2Y .... Yellowstone-2-Yukon initiative

1 INTRODUCTION

1.1 Background - why maintaining ecological coherence and connectivity is important

It is now widely acknowledged that habitat fragmentation is an existing and growing cause of habitat degradation and biodiversity loss in the EU and elsewhere. The fragmentation of habitats by infrastructure developments, urbanisation and land-use changes etc. leads to habitat loss and degradation (e.g. by creating smaller habitat patches that are dominated by edge-habitats, and greatly affected by disturbance and other external influences). Small habitat patches may also be insufficient for species that require large areas of habitat (such as many higher predators) or may only be able to support small populations that are susceptible to extinction as a result of chance events. Fragmentation also restricts the natural movement of species, e.g. for foraging, breeding, migration and dispersal.

Consequently IUCN recently noted that 'the loss and fragmentation of natural habitats and the implications for the conservation of flora and fauna are of global significance' (Bennett 2003). Wilcove et al. (1986) consider it to be 'the principal threat to most species in the temperate zone', whilst Noss (1991) has said that it is the 'single greatest threat to biological diversity'.

Furthermore, the need to address the fragmentation of ecosystems and landscapes has been given added urgency and importance as a result of climate change (e.g. IPCC 2002, Thomas et al. 2004a, Thomas et al. 2004b, De Rios et al 2007). Fragmentation exacerbates the impacts of climate change by reducing the resilience of species populations, habitats and ecosystems to the effects of climate change. Fragmented landscapes can also present significant barriers to the colonisation of new areas with suitable climatic conditions. Measures to restore connectivity are therefore increasingly required to increase ecosystem resilience and to enable habitats and species to move in response to climate change.

Changes in species diversity, abundance and composition due to fragmentation may have cascading impacts on the structure and functioning of habitats and ecosystems, and therefore the provision of ecosystem services. The value of ecosystem services has become widely recognised and they also form a cornerstone of current EU biodiversity policy (COM 261/2006). Continued habitat fragmentation, exacerbated by the impacts of climate change, could therefore result in socio-economic impacts, for example due to the cost of replacing lost ecosystem services (e.g. water purification and retention, flood/erosion prevention) (see for example Kettunen & ten Brink 2006, Birdlife International 2007).

The threat that habitat fragmentation poses to the EU's nature conservation and sustainable development policies and objectives has been recognised. Measures to maintain and restore ecological connectivity have therefore been included in EU nature conservation legislation. In this respect the establishment of a coherent network of protected areas (the Natura 2000 network – see Section 1.2.2 below) is considered to be of particular importance together with other connectivity conservation measures in the wider environment. The Commission Communication on Halting the Loss of Biodiversity by

2010 and Beyond (COM 216/2006) also calls for actions to address habitat fragmentation and climate change.

These guidelines have therefore been prepared to support connectivity conservation measures by EU Member States that aim to reduce the impacts of fragmentation and climate change on biodiversity (i.e. ecosystems, habitats and species). Further background information on the need for these measures is provided below and the specific objectives of these guidelines are provided in Section 3.1.

1.2 The legal and policy framework supporting the maintenance of ecological coherence and connectivity

1.2.1 International and pan-European level

Several Multi-lateral Environmental Agreements (MEAs) have recognised the importance of maintaining ecological coherence and connectivity as a contribution to biodiversity conservation. Related actions have also been identified as being necessary to support climate change adaptations. This section therefore briefly outlines the principal measures for maintaining and restoring ecological connectivity, and related climate change adaptation measures, within MEAs that apply to the EU. EU Member States that are contracting parties to these MEAs are obliged to apply these measures and support the maintenance of ecological connectivity in addition to requirements under EU legislation and other initiatives described in the following Section 1.2.2.

At the international level, the Convention on Biological Diversity[1] (CBD) provides the main framework for conserving the world's biodiversity. Although the Convention's text does not explicitly mention ecological coherence or the concept of ecological networks, many references are made to the need for the maintenance of viable populations in sufficiently large areas inside and outside statutory protection (e.g. CBD Article 8 on in-situ conservation). The CBD Programme of Work on Protected Areas, adopted in 2004, specifically emphasises the need for ecological connectivity. One of the targets of the Programme of Work is to ensure that all protected areas and protected area systems are integrated into the wider land- and seascape by 2015. This should be achieved, *inter alia*, by taking into account ecological connectivity and, where appropriate, the concept of ecological networks[2].

In addition, other international and European MEAs also support maintenance of connectivity. For example, the conservation of wetland habitats and species within the Ramsar Convention[3] takes place in the context of broader land- and seascapes and supports measures that aim to maintain connectivity between wetlands and neighbouring ecosystems. Similarly, the Convention on the Conservation of Migratory Species[4] (CMS or Bonn Convention) provides a framework for a series of more specific taxonomic based

[1] Convention on Biological Diversity: www.biodiv.org

[2] Goal 1.2 of the CBD Programme of Work on Protected Areas: http://www.biodiv.org/decisions/default.aspx?dec=VII/28

[3] The Ramsar convention on Wetlands: http://www.ramsar.org/

[4] The Convention on the Conservation of Migratory species: http://www.cms.int/

agreements between relevant parties that aim to protect the network of habitats required by migrating species throughout their range.

At the pan-European level, the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, adopted in 1979), developed and adopted by the Council of Europe, binds contracting parties to the protection of habitats and species of European concern and promotes cooperation between countries for the protection of migratory species. The Recommendation on the conservation of natural areas outside protected areas adopted within the Convention specifically addresses these issues (Recommendation 25, adopted in 1991)[5]. The Recommendation encourages the conservation and, where necessary, the restoration of ecological corridors, habitats types and landscape features that are important for wildlife conservation. Additionally, the European Landscape Convention[6], adopted in 2000 by the Council of Europe, provides a European-wide framework for sustainable planning, management and protection of landscapes. Even though the Landscape Convention does not explicitly address ecological coherence and connectivity, it provides an integrated framework that supports actions for such issues through landscape planning and management.

The need for connectivity conservation measures has been given added importance and urgency as a result of the recognition that habitat fragmentation may exacerbate the potential impacts of climate change (see Chapter 4). Climate change adaptation measures for biodiversity under existing MEAs should therefore include actions to counter habitat fragmentation. The requirement to take actions that can help biodiversity adapt to climate change has been included in a number of MEAs and subsequent decisions, some examples of which include:

- UN Framework Convention on Climate Change[7] (UNFCCC) National Adaptation Programmes of Action (UNFCCC Decision 28/CP.7, 1 and UNFCCC Decision 28/CP.7, Annex on).

- CBD Decision VII/15 (Biodiversity and climate change) which amongst other things '*Encourages Parties to take measures to manage ecosystems so as to maintain their resilience extreme climate events and to help mitigate and adapt to climate change*'.

- CBD Decision VIII/30 (Biodiversity and climate change: guidance to promote synergy among activities for biodiversity conservation, mitigating or adapting to climate change and combating land degradation), which amongst other actions '*Encourages Parties and other Governments to cooperate regionally in activities aimed at enhancing habitat connectivity across ecological gradients, with the aim of enhancing ecosystem resilience and to facilitate the migration and dispersal of species with limited tolerance to altered climatic conditions*'.

- Ramsar Convention Resolution VIII.3 (Climate change and wetlands: impacts, adaptation, and mitigation) which calls upon contracting parties to '*Manage*

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5 Bern Convention Recommendation No. 25 (1991) on the conservation of natural areas outside protected areas proper , adopted by the Standing Committee on 6 December 1991: http://www.coe.int/t/e/cultural_co-operation/environment/nature_and_biological_diversity/nature_protection/Rec25(1991).asp#TopOfPage

6 The European Landscape Convention: http://www.coe.int/t/e/Cultural_Co-operation/Environment/Landscape/

7 UN Framework Convention on Climate Change: www.unfccc.int

wetlands to increase their resilience to climate change and extreme climatic events and to reduce the risk of flooding and drought in vulnerable countries'.

- Bonn Convention Resolution 8.13 (Climate change and migratory species) which instructs the Secretariat to produce '*guidance that would help CMS Parties introduce adaptation measures to help counteract the effects of climate change on migratory species*' and '*calls on Parties and non-Party range states to implement, as appropriate, adaptation measures that would help reduce the foreseeable adverse effects of climate change on Appendix I species*'.

1.2.2 The EU legal framework

The Habitats directive[8] and Birds directive[9] form the main legal framework for protecting nature and biodiversity in the EU and implement some of the international requirements outlined above, including the Bern Convention. The overall aims of both directives are indicated in Box 1.1. In order to achieve their objectives both directives include two main types of action. Firstly the protection of important sites, these constitute Special Areas of Conservation (SACs) designated under Articles 4 and 5 of the Habitats directive (for habitats and species of Community interest) and Special Protection Areas (SPAs) designated under Article 4 of the Birds directive (for birds listed in Annex I of the directive and for migratory species). These are combined under Article 3 of the Habitats directive to form 'a coherent ecological network' referred to as the Natura 2000 network.

The second type of actions are provisions for species protection that apply to the whole of each Member State's territory and concern the physical protection of listed species as well as their breeding sites and resting places.

Box 1.1. The aims of the EU Birds and Habitats directives

Birds directive

Article 1

1. This Directive relates to the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States to which the Treaty applies. It covers the protection, management and control of these species and lays down rules for their exploitation.
2. It shall apply to birds, their eggs, nests and habitats.
3. This Directive shall not apply to Greenland.

Article 2

Member States shall take the requisite measures to maintain the population of the species referred to in Article 1 at a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level.

8 Council Directive 92/43/EEC on the conservation of natural habitats of wild fauna and flora (the Habitats directive): http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm

9 Council Directive 79/409/EEC on the conservation of wild birds (the Birds directive): http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/birds_directive/index_en.htm

Habitats directive

Article 2

1. The aim of this Directive shall be to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States to which the Treaty applies.
2. Measures taken pursuant to this Directive shall be designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest.
3. Measures taken pursuant to this Directive shall take account of economic, social and cultural requirements and regional and local characteristics.

Both directives include various connectivity conservation measures for protected areas and the wider environment. Firstly, connectivity measures are required to maintain or restore the coherence of the Natura 2000 network. In particular, paragraph 3 of Article 3 of the Habitats directive states that '*where they consider it necessary, Member States shall endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora, as referred to in Article 10*.' In addition, Article 6.4 stipulates that if a plan or project with negative impacts on a site is to take place (due to 'imperative reasons of overriding public interest') the Member States are to take '*all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected*'.

The directives also include more general connectivity provisions that relate to land use planning and development policies. These are set out in the Article 10 of the Habitats directive and Article 3 of the Birds directive.

It is important to note that all these provisions unequivocally subject the decision how and where to implement connectivity measures to the full discretionary power of the Member States.

<u>Article 10 of the Habitats directive</u>
'Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora. Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.'

<u>Article 3 of the Birds directive</u>
'…Member States shall take the requisite measures to preserve, maintain or re-establish a sufficient diversity and area of habitats for all the species of birds referred to in Article 1. 2. The preservation, maintenance and re-establishment of biotopes and habitats shall include […] (b) upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones…'

It is clear from the texts of the Habitats directive that the interpretation of 'coherence' is a key issue affecting the implementation of directives. When considering the ecological coherence of Natura 2000, it is important to note that the completed Natura 2000 network, defined by the Habitats directive as the sum of all areas designated for conservation under the Birds and Habitats directives (Article 3.1 of the Habitats directive), is a collection of individual protected sites (COM 2005)[10]. In order for these protected sites to actually form an ecologically coherent network then necessary functional connections amongst the sites and their surroundings must be maintained. Therefore management measures may need to go beyond the designated sites' boundaries and apply to the wider environment. Consequently, even though the Habitats directive's definition of a completed Natura 2000 network appears to be synonymous with a 'coherent ecological network' (see Article 3.1) it is important to distinguish between the established Natura 2000 network (i.e. all the protected areas) and establishing/maintaining overall ecological coherence of the Natura 2000 network (which includes the necessary functional connections amongst the designated sites). Further guidance on the interpretation of the overall coherence of the Natura 2000 network has been provided by the European Commission with respect to Article 6(4) of the Habitats directive[11].

It is important to note that Article 10 suggests that conservation of landscape features is of particular importance as a means of supporting the coherence of the Natura 2000 network. However, it also implies that such measures should also be taken elsewhere where necessary. Article 3 of the Birds directive clearly indicates that habitat conservation and restoration measures should be taken inside and outside protected areas.

Enhancing the movement and existence of species outside the sites designated for their protection is also supported by the Articles 4.3 and 4.4 of the Birds directive. According to the Article 4.3 of the Birds directive, *'Member States shall send the Commission all relevant information so that it may take appropriate initiatives with a view to the coordination necessary to ensure that the areas provided […] form a coherent whole which meets the protection requirements of these species in the geographical sea and land area where this Directive applies.'* In addition, the Article 4.4 stipulates that *'[…] Outside these protection areas, Member States shall also strive to avoid pollution or deterioration of habitats.'*

A key issue to consider is when connectivity measures are deemed to be necessary. In this respect measures should be taken when Member States regard them as necessary to achieve the overall objectives of the directives (Box 1.1), especially for the maintenance or restoration of the species and habitats at favourable conservation status (FCS). A European Commission paper[12] considers that '*FCS can be described as a situation where a habitat type or species is prospering (in both quality and extent/population) and with good prospects to do so in future as well*'.

[10] Habitats directive Article 3.1: 'A coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000. This network, composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range.'

[11] Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC (http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/specific_articles/art6/index_en.htm)

[12] Assessment, monitoring and reporting of conservation status – Preparing the 2001-2007 report under Article 17 of the Habitats Directive (DocHab-04-03/03 rev.3) (http://circa.europa.eu/Public/irc/env/monnat/library?l=/reporting_framework/dochab-04-03-03/_EN_1.0_&a=d)

The Commission's paper also notes that '*Member States are expected to take all requisite measures to reach and maintain the objective of FCS*' (COM 2005). Therefore, in principle Article 10 measures, and other connectivity provisions, should be implemented whenever they are necessary to maintain or restore FCS of habitats or species of Community interest. Furthermore, the Commission states that '*The concept of FCS is not limited to the Natura 2000 network'.* It therefore follows from this that Members States should promote the implementation of connectivity measures where these are required to maintain or restore FCS, irrespectively of their contribution to the coherence of the Natura 2000 network.

The assessment of FCS in accordance with Article 17 of the Habitats Directive is complex and therefore guidelines for assessment, monitoring and reporting are being developed by the European Commission. These should be referred to and used as the basis for establishing whether connectivity measures are required in order to maintain and restore FCS. The requirement to maintain FCS, including its connectivity related obligations, does not apply directly to the Birds directive. However, there are somewhat analogous, though rather less specific, obligations to maintain populations under Article 2 of the directive (see Box 1.1). Therefore, as in the case of the Habitats directive, it can be interpreted that connectivity measures under Article 3 should be implemented whenever they are required to maintain populations in accordance with Article 2 of the directive.

In addition, it should be remembered that SPAs designated for conservation under the Birds directive form an integral part of the Natura 2000 network (e.g. Article 7 of the Habitats directive). Therefore, in practice the conservation objectives for these areas are often closely associated with the FCS concept (e.g. FCS is used for setting conservation objectives and undertaking surveillance in the designated sites).

In summary, the protection and restoration of important landscape features and other connectivity measures should be implemented if they are necessary to:

- support the coherence, including functional connections, of the Natura 2000 network;
- maintain or restore FCS in habitats and species of Community interest; or
- maintain or restore populations of birds in accordance with Article 2 of the Birds directive.

It is recognised that the implementation of connectivity measures may be constrained by the current lack of detailed knowledge of the ecological requirements of many species and habitats. Article 18 of the Habitats directive, therefore calls for research and exchange of information and specially states that '*Particular attention shall be paid to scientific work necessary for the implementation of Articles 4 and 10, and transboundary co-operative research between Member States shall be encouraged*'.

Conservation actions under other EU legislation may also help to deliver connectivity measures required under the Birds and Habitats directives. In particular, the Water Framework Directive[13] (WFD) includes measures, such as the development of river basin management plans that will help to maintain and restore connectivity in the wider environment (see Section 6.4. for further information).

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[13] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (http://ec.europa.eu/environment/water/water-framework/index_en.html)

The Environmental Liability directive,[14] which establishes a framework of environmental liability based on the 'polluter-pays' principle, to prevent and remedy environmental damage, includes measures that will support ecological connectivity. It also includes a requirement to monitor and report on the conservation status of habitats and species according to the FCS framework, which also applies to birds.

1.2.3 The EU policy framework

The need to promote the implementation of Articles 10 and 3 of the Habitats and Birds directives forms an integral part of the current EU biodiversity policy. These aspects have been supported by the recently adopted Commission Communication '*Halting the loss of biodiversity by 2010 – and beyond*' and the new EU biodiversity Action Plan (COM 2006/216). The Action Plan places a high priority on enhancing the coherence and connectivity of the protected areas network (e.g. both Natura and non-Natura areas) (Objective 1 of the Action Plan, see Box 1.2). In particular, it recognises that in addition to 'structural tools' (such as flyways, stepping stone and corridors), enhancing the coherence, connectivity and resilience of the Natura 2000 network requires actions that support biodiversity in the wider environmental matrix (see Section 5.3).

The Action Plan also includes a specific set of actions related to supporting biodiversity adaptation to climate change (Objective 9 of the Action Plan). The aim of these actions is to substantially reduce the damaging climate change impacts on biodiversity. One of the listed actions specifically addresses the coherence, connectivity and resilience of the Natura 2000 network (See Box 1.2).

The Council of the European Union endorsed the biodiversity Communication and related Action Plan in the Environment Council meeting on 18 December 2006[15]. As regards the Natura 2000 network, the Council particularly emphasised strengthening the coherence, connectivity and resilience of the network. In this context, the importance of regional and local land-use planning, in particular the related responsibilities of the Member States, was stressed.

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[14] Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0035:EN:NOT)

[15] Environment Council Conclusions, 18 December 2006 (http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/envir/92249.pdf)

Box 1.2. Actions outlined in the biodiversity Action Plan related to the ecological coherence and connectivity of Natura 2000 (COM 2006/216)

OBJECTIVE 1: TO SAFEGUARD THE EU's MOST IMPORTANT HABITATS AND SPECIES.

TARGET (A1.2): Sufficiency, coherence, connectivity and resilience of the protected areas network in the EU substantially enhanced by 2010 and further enhanced by 2013

ACTION (A1.2.1): Carry out [in 2008, following next reports] scientific review of habitat types listed in annexes of nature directives, informed by 'shadow lists' of priority habitats; add to annexes any missing habitat types of Community interest, and ensure all habitat types of Community interest are sufficiently represented in the Natura 2000 network [by 2010].

ACTION (A1.2.2): Accelerate efforts to place other designated protected areas (non-Natura 2000) of national, regional and local biodiversity importance under effective conservation management [by 2010, 2012 in marine].

ACTION (A1.2.3): Assess [by 2008] and substantially strengthen [by 2010] coherence, connectivity and resilience of the protected areas network (Natura 2000 and non-Natura protected areas) by applying, as appropriate, tools which may include flyways, buffer zones, corridors and stepping stones (including as appropriate to neighbouring and other third countries), as well as actions in support of biodiversity in the wider environment (see also actions under objectives 2, 3 and 9).

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OBJECTIVE 9: TO SUPPORT BIODIVERSITY ADAPTATION TO CLIMATE CHANGE.

TARGET (A9.4): Resilience of EU biodiversity to climate change substantially strengthened by 2010.

ACTION (A9.4.2): Assess [by 2008], on the basis of available scientific evidence, and substantially strengthen [by 2010] coherence, connectivity and resilience of the protected areas network (Natura 2000 and non-Natura protected areas) in order to maintain favourable conservation status of species and habitats in the face of climate change by applying, as appropriate, tools which may include flyways, buffer zones, corridors and stepping stones (including as appropriate to neighbouring and third countries), as well as actions in support of biodiversity in the wider environment (cf action 1.2.3).

2 OVERVIEW OF THIS GUIDANCE

2.1 Objectives and scope

The overall objective of this guidance document is to assist EU Members States in halting the loss of biodiversity as a result of habitat fragmentation and the additional impacts of climate change. Specifically it aims to help develop and implement integrated ecological connectivity related measures that:

- Contribute to the maintenance or restoration of Favourable Conservation Status (FCS)[16] of species and habitats of Community interest[17] in accordance with requirements of the Habitats and Birds directives In particular it provides guidance on implementation of Article 10 of the Habitats directive and Article 3 of the Birds directive, taking into account the necessity to support the adaptation of biodiversity to climate change.

- Support the EU Biodiversity Action Plan, in particular Objectives 1 and 9 relating to the sufficiency, coherence, connectivity and resilience of the broader protected area network (i.e. including sites outside the Natura 2000 network) and the need for biodiversity adaptation measures in response to climate change (see Box 1.1).

This guidance is intended to be bound by and faithful to the texts of the Habitats and Birds directives and the wider principles underpinning Community environmental law. It is not legislative in character, but provides non-binding guidance on the application of existing legal provisions. It is in compliance with the previous advice given by the Commission on the implementation of the Habitats and Birds directives, including other relevant Commission guidance documents[18].

This document also aims to provide guidance that is:
- Based on well-founded ecological principles and scientific evidence;
- Practical and feasible within existing policy, legislation and funding frameworks and within foreseeable socio-economic and political development scenarios;
- Non-prescriptive, so that it can be improved and adapted as necessary by Members States according to their specific needs and circumstances;
- Flexible so that it can be refined in response to likely improvements in our understanding of future climate change and its impacts on biodiversity.

This guidance covers all terrestrial, freshwater and inter-tidal habitats in Europe, but does not cover marine habitats and species. Within these habitats it focuses on measures of particular relevance to habitats and species of Community interest especially those considered to be at particular risk from habitat fragmentation and climate change (see Chapter 5).

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[16] Or its equivalent as defined under the Birds directive as described in Section 1.2.

[17] Natural habitats of Community interest and species of Community interest as defined in Article 1 of the Habitats directive and bird species referred to in Article 4 of the Birds directive (i.e. listed in Annex 1 and other migratory species).

[18] Methodological guidance on the provisions of Article 6 (3) and (4) of the Habitats Directive 92/43/EEC; Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC; Guidance document on the strict protection of animal species of Community interest under the ‘Habitats’ Directive 92/43/EEC

2.2 Structure of the guidance document

The guidance is divided into the following chapters:

Chapter 3 outlines the main concepts and issues concerning fragmentation, and ecological connectivity. This chapter defines and briefly summarises some of the key landscape ecology principles related to these issues and summarises the impacts of fragmentation and lack of connectivity on species, landscapes, ecosystems and ecosystem services.

Chapter 4 summarises recent evidence of global climate change and outlines climate change projections for Europe. It also briefly reviews evidence of the impacts of climate change on biodiversity and ecosystems, including effects on both habitats and species.

Chapter 5 identifies factors that increase the vulnerability of species to habitat fragmentation, climate change and the combined synergistic impacts of climate change and habitat fragmentation. It then outlines a suggested framework for Members States to use to identify habitats and species that are at high risk of impacts from habitat fragmentation and climate change, both separately and in combination.

Chapter 6 summarises some key ecological connectivity principles from scientific studies of fragmentation and climate change impacts, and identifies some lessons from previous connectivity conservation initiatives. These are used as a basis for a proposed decision framework that can be used to plan and implement priority measures for maintaining and restoring connectivity, to overcome fragmentation impacts and facilitate adaptation of biodiversity to climate change. The framework includes three key components involving connectivity conservation measures: assessments of connectivity requirements (and other required conservation measures) for species and habitats at particular risk from habitat fragmentation; the design and development of ecological networks; and measures to improve the ecological quality of the wider landscape (habitat matrix). Recommendations are given for the implementation of each of these components.

Chapter 7 describes recommended practical measures that can be used to maintain and restore ecological coherence and functional connectivity. These measures have been divided into the following sections: protected area legislation and management; land-use planning and development controls; agricultural policies, regulations and agri-environment measures; forest strategies; measures related to inland water and coastal management; and European Community and national funding instruments.

Annexes are included which provide examples from Member States of measures that have been used to maintain and increase ecological connectivity.

2.3 Methods used to develop the guidance

This Guidance document was developed in 2006-2007 as a part of a project, titled 'Guidelines: adaptation, fragmentation', for the European Commission (ENV.B.2/ETU/2006/0042R). It has been developed in close cooperation with the European Commission and representatives from EU Member States. Drafts of these guidelines and associated working reports have been distributed for comments to the members of the Scientific Expert Group and the Habitats Committee. In addition, a number of national experts have provided information for the country case studies and examples.

The selection of terms and definitions used in this Guidance document (summarised in Annex 1) is based on an analytical review of key terms and their definitions, which was carried out specifically for this project. The review considered the most relevant international, European and national references (e.g. legal, policy-relevant and scientific texts). These included relevant European Community legislation, guidance and policy documents, as well as standard texts on ecology and landscape ecology, scientific papers and reports (such as by the Intergovernmental Panel on Climate Change (IPCC)) and documents produced under the auspices of international conventions/agreements (e.g. CBD and the Ramsar Convention). In cases where identified key terms appeared to have differing definitions then most relevant, up-to-date and, if possible, generally applied/accepted definitions were adopted. Many of the definitions used in the guidance have been adopted from previous guidance documents developed to facilitate implementation of the Habitats directive. Although these definitions are not legally binding their scope has been agreed between the Commission and the Member States. Some of terms are also used in accordance with definitions agreed by the Member States experts workshop organized on the island of Vilm by the Netherlands and Germany in May 2005 (COM 2005).

The identification of species traits associated with habitat fragmentation and climate change was carried out through an extensive literature review of primary ecological research. A number of demographic and life history traits were described that have been identified as increasing the vulnerability of species primarily to habitat fragmentation. The analysis started with the premise that climate envelope models or climate parameters give an indication of whether a species will be impacted by climate change under current scenarios. The second stage is to identify those species that may have difficulty responding due to the identified life history and demographic traits. To attempt an initial empirical test the ability to generalise from these traits, climate envelope models were used to identify the top 50 most threatened bird species in Europe, based on changing climate conditions, and these were scored for the traits they showed. Following this a review was made of the extensive literature covering species responses to climate change. The current knowledge of species responses was compared with possible measures to improve connectivity at different spatial scales and a series of scenarios was developed to link species traits to connectivity measures.

Chapter 7 describes practical measures that can be used to improve ecological coherence and connectivity. This takes into account a review, carried out as part of this project, of Community level and Member States practices that aim to establish ecological networks and enhance ecological coherence and connectivity within ecosystems/landscapes. Measures reviewed included: legislative tools; policy instruments and their implementation, instruments for land-use planning and management, and the use of different incentives to improve landscape connectivity. The review also included a number of more detailed case studies of connectivity measures in the following Member States: Belgium, Finland, Germany, Lithuania, the Netherlands, Slovakia, Spain and the UK. These accounts were used as the basis of the example measures described in Annex 3 of this guidance document.

3 LANDSCAPE ECOLOGY AND THE IMPACTS OF FRAGMENTATION

3.1 Key landscape ecology principles and terms

This chapter outlines some of the principles and key terms associated with landscape ecology, including the definition and structure of landscapes and the interrelationships between landscape and biodiversity. The aim of this chapter (and the following chapter on climate change) is to provide sufficient information to support and explain the rationale for the strategic and practical guidance given in subsequent chapters of this report. It is beyond the scope of this document to provide a more comprehensive introduction to landscape ecology and climate change science.

Definitions of key terms (highlighted in the text) can also be found in Annex 1, together with definitions of other technical terms used in this document.

3.1.1 Landscapes and their structure

In the context of these guidelines **Landscapes** are defined as one of the lower levels of ecological organisation within regional ecosystems (i.e. **biomes**) (Wiens 2002). Alternatively, landscapes may be defined according to human perceptions of the predominant land-use (e.g. a farmland landscape).

Landscapes are typically made up of discrete elements commonly termed **patches**, which can be defined as relatively homogeneous areas that differ from their surroundings (Forman 1995, Dennis et al. 2003). In general, patches have discernable boundaries and distinct spatial properties that can be described compositionally by internal variables (e.g. the density, species composition and height of trees within a woodland patch). The arrangement and number of different patches creates heterogeneity within landscapes (Wiens 2002). This **landscape heterogeneity**, in particular the spatial distribution and arrangement of patches within landscapes (i.e. landscape pattern), is important because it affects interactions between/within species both within and between patches (see Section 3.1.2 below) (Wiens 2002).

3.1.2 Interrelationships between landscape pattern and biodiversity

The definition given above considers landscapes from a 'physical' perspective. From the perspective of biodiversity within landscapes, the maintenance of species and ecological functioning of landscapes is determined by what role patches play for different species. In this context, patches are defined in terms of the habitats and/or resources used by a species (Hanski & Simberloff 1997, Dennis et al. 2003). Patches vary in the roles they play in a species' ecology, e.g. some patches might be used for foraging and some as breeding sites. The interstitial environment between patches is called the **environmental or habitat matrix** (Dennis et al. 2003). Patches and the habitat matrix are species-specific, and therefore a forest patch for one species may be the habitat matrix for another. The spatial configuration of habitats within a landscape formed by patches arranged within a matrix is generally called a **landscape mosaic** (Hanski & Simberloff 1997).

The existence of a species within a landscape is dependent on both the existence of adequate habitat/resource patches and the ability to move amongst them either for foraging, breeding or migration etc, or for dispersal and colonization (e.g. as individuals, seeds or spores). It is important that the area and quality of available patches fits the needs of the species in question. In this context, the term **habitat continuity** is used to describe the permanent and long-term stock of all habitat requirements for a species within a given landscape or ecosystem (COM 2005). In addition, both the quality of the matrix and distribution of individual patches, in particular the distance between patches, plays an important role in enabling the movement of a species between patches. In this context it is also to be noted that the patch and matrix quality are attributes that are strongly species specific, i.e. they are always to be defined according to the needs of individual species (e.g. Ricketts 2001, Dennis et al. 2003).

Connectivity is a measure that describes how connected or spatially continuous the environmental matrix is (Forman 1995). In this context, **landscape connectivity** is the degree to which the landscape facilitates or impedes movement among different patches. Landscape connectivity is a combined product of **structural and functional connectivity**, i.e. the effect of physical landscape structure and the actual species use of the landscape (Tischendorf & Fahrig 2000). In short, connectivity within the matrix enables the movement of species between patches and the functioning of the ecological system within a landscape.

Of the two forms of connectivity, functional connectivity is the most important in providing ecologically valuable connectivity within landscapes. It has been acknowledged that physical structural connections between patches (e.g. connecting areas that are physically similar to patches) do not necessarily guarantee that a functional relationship between individual patches exists (i.e. that the physical connections enable the movement of species between patches). This has been demonstrated, for example, by a number of studies analysing the effectiveness of ecological corridors and stepping stones within ecological networks (see Box 6.1 and for example Simberloff & Cox 1987, Beier & Noss 1998, Simberloff et al. 1992). Nor do gaps between habitat patches necessarily indicate that the patches are functionally separated.

Movement between patches can only be ascertained by analysing landscapes from the perspective of individual species and making sure that the landscape elements that allow each species to move exist in the required spatial scale and pattern. The nature and scale of these elements can differ significantly between species (for some illustrating examples see Box 3.1).

The term **'Ecological networks'** is widely used to describe one of the main practical conservation measures for protecting core areas of high quality habitat and maintaining and enhancing connectivity amongst them across the landscape (Bennett 2003, Bennett & Mulongoy 2006, Jongman & Kristiansen 2001)(see also Section 6.3). Typically connectivity within an ecological network is established by defining and protecting **ecological corridors**. Such corridors may consist of large areas of habitat or linear strips of habitat, which physically connect patches, or patches of habitat that act as 'stepping stones' in the wider habitat matrix. An alternative approach is to maintain **landscape**

permeability by avoiding land-use practices that increase the hostility of the habitat matrix to a species.

The term 'ecological coherence' is often used to describe the ecological status of a network and is of particular importance to these guidelines because several references are made to ecological coherence in the EU Habitats directive (see Section 1.2.2). No commonly agreed generic definition for this term exists. However, the following definition was developed by the expert workshop in 2005 in Vilm for the specific case of the **ecological coherence of the Natura 2000** network: '*A sufficient representation (patch quality, total patch area, patch configuration, landscape permeability) of habitats / species to ensure favourable conservation status of habitats and species across their whole natural range*' (COM 2005). The participants of the Vilm workshop agreed also that ecological coherence should in the first instance be considered in relation to functional rather than physical connectivity. In general, the definition agreed in Vilm can also be used as a basis for considering ecological coherence in a broader context than the Natura 2000 network.

It is important to note that there are several cases where protected area systems are called 'ecological networks' even though there may be little effective ecological connectivity amongst the sites. This is also the case with the Natura 2000 network because it is currently mainly a collection of unconnected protected sites designed to serve a certain conservation purpose (i.e. conservation of a selected set of species and habitats)(see Section 1.2.2).

The findings described above have important implications for measures that aim to increase ecological connectivity and the coherence of protected area networks. In particular, the starting point for establishing connectivity amongst protected areas within a network should be based on functional, rather than structural connections between individual habitat patches. Consequently, the purpose of connectivity conservation measures (such as ecological networks) should not necessarily be to link individual patches with physical structures (such as corridors of similar habitat) but to ensure the existence of required functional connections.

Box 3.1. Species specific requirements for functional connectivity

Functional connectivity within landscapes is a result of a species' use of the landscape. For functional connectivity to exist, landscape elements allowing the species' use of the landscape, including movement of species within the landscape, need to be in place. The nature and scale of these elements can differ significantly between species and consequently species-specific requirements need to be carefully considered, for example, when developing suitable management/conservation strategies for species at a broader landscape level.

For many species the requirements for moving between habitat/resources patches and establishing themselves in new habitats are rather broad (e.g. generalist species). However, there are also many species that require more specific conditions for movement and dispersal within landscapes. For example, the existence and dispersal of forest species that depend on dead wood (such as some beetles, fungi and lichens), requires a sufficient amount of standing or fallen dead wood and stumps to be present. However, given that the majority of forests in the EU are managed for forestry purposes, the amount of dead wood in forests has significantly decreased. Therefore, specific management practises securing the maintenance of dead wood in forest ecosystems need to be established to guarantee the spread of these specialised species within landscapes.

The spread of species can also be dependent on the occurrence of natural disturbances such as storms, avalanches and local forest fires. These disturbances create light gaps and openings that allow species to spread and exist within the landscape. This requirement can be typical, for example, for pioneer species that colonise open spaces as the first stage in primary or secondary succession and go extinct on a site when the succession continues. The natural disturbances have, however, often negative forestry impacts, and as a result forestry management practises have traditionally aimed to minimise the occurrence of such disturbances. In addition, there is a difference between natural and manmade disturbances (e.g. different forest management practices), hence the latter cannot replace the role of the former in forest ecosystem dynamics. Therefore, integrating natural disturbances into forest management practises (e.g. maintaining or replicating natural disturbances) is crucial for securing the movement of disturbance dependent species within landscapes.

On the other hand, there are a number of species whose existence and spread requires very stable and homogenous ecological conditions and whose survival is therefore particularly threatened by escalating anthropogenic disturbances (e.g. forest management practises). These species are often characterised by a high ability to maintain stable populations within the patches they inhabit but have a low capacity for colonising new habitats. Ensuring the maintenance of these species therefore requires specific management measures, such as guaranteeing sufficient availability of the required habitats within a landscape.

References: Kuuluvainen et al. 2004, Siitonen & Hanski 2004, Ahlroth 2003 and Toivanen & Kotiaho 2007.

Landscape pattern, species diversity and species population dynamics

The number of species (i.e. richness) in a patch may be influenced by patch size and its isolation from other patches, because this affects the balance between extinction and immigration. In other words, there is a connection between the size of a patch and its species diversity, and between the distance of a patch from other patches. The commonly accepted connection between species diversity and patch size and isolation is based on the theory of island biogeography developed by MacArthur and Wilson (1967). This theory has since been applied to non-island settings as it has been acknowledged that, in some sense, patches act like islands for species within heterogeneous landscapes. The island biogeography theory has been used to guide the selection and design of nature reserves because to some extent they form islands of suitable habitats within seas of human modified landscapes. However, there is much debate about the usefulness of applying island biogeography theories to protected area issues (see Boxes 3.2 and 3.3).

Patch size and connection between individual patches within landscapes also affect species population dynamics. Population dynamics depend on interactions between individual and spatially separated populations of a species that, often as a result of the fragmentation, exist in discrete habitat patches. Rather than stable and homogeneous populations, species can therefore be seen as dynamic entities that are distributed unevenly across landscapes in habitats of varying quality. Small local populations of species inhabiting individual patches are generally considered vulnerable to extinction as a result of chance events etc. The **minimum viable population size**, i.e. the smallest size that an isolated population can be and survive in the long-term differs between species (Schaffer 1981). However, if sufficient numbers of individuals from other local populations can re-colonize empty habitat patches after extinctions then the species can continue to survive. In such a situation the species exists as a **metapopulation** as originally defined by Levins in 1970 and further developed by Hanski & Gilpin in 1990s (Levins 1970, Hanski & Gilpin 1991, 1997).

A metapopulation can be defined as a set of local populations within a larger area where migration from one local population to at least some other patches is possible (Hanski & Simberloff 1997). Metapopulations exist at a spatial scale where individuals can occasionally disperse among different patches but do not make frequent movements because the patches are separated by substantial expanses of unsuitable habitat (Hunter 2002). This intermediate rate of movement is usually sufficient to avoid long term genetic differentiation among patches, but low enough to allow each patch to be quite independent demographically. At high rates of interchange, there is effectively only one population occupying all the patches; thus it is important to note that not all species that are distributed in habitat patches are composed of metapopulations.

Consequently, the long-term survival of many species is strongly dependent on the movement of individuals (e.g. dispersal and migration) between different habitat patches. In addition, the movement of individuals is also necessary to guarantee genetic exchange between different populations and secure the capacity of a species and its individual populations to adapt to changing environmental conditions. As a result, both landscape pattern and the quality of the matrix play an important role in enabling the long-term survival of species within landscapes.

Box 3.2 Island biogeography theory by MacArthur and Wilson

The application of MacArthur and Wilson's island biography theory to non-island settings has also been criticised by being over simplistic. For example, terrestrial patches, including protected areas, are often indistinct from their surrounding ecosystems and they are not surrounded by totally inhospitable habitat. In addition, island biogeography theory only predicts species richness for single sites. By focusing on species richness the theory also does not address a number of factors that might be of high importance from the perspective of conservation planning and management. These aspects include, for example, the ratios of exotic and native species and population level considerations of extinction and colonization (see below). The theory also makes no predictions about diversity across multiple sites, or how that diversity will compare to other regions.

Nevertheless, despite problems with the theory, island biogeography can be considered to have had a significant contribution to conservation. Above all, the theory has expanded the focus of scientists and conservationists to landscapes and got them thinking about the effects of habitat area and isolation on biodiversity.

References: MacArthur, R. H., and E. O. Wilson 1967. The theory of island biogeography. Princetown University Press, Princetown, New Jersey, USA.

3.2 Impacts of habitat fragmentation on biodiversity

Fragmentation normally encompasses two components, the loss (or change) of habitat and the breaking up of the remaining habitat into smaller units (although the term is commonly used to describe only the latter process). Figure 3.1 illustrates a hypothetical situation where habitat fragmentation progresses initially as a result of the construction of a simple road (with negligible habitat loss), followed by habitat loss (conversion from woodland to semi-natural grassland) and finally habitat deterioration, which reduces functional connectivity across the habitat matrix.

Impacts resulting from fragmentation vary amongst habitats and species, but generally start to appear when around 70 per cent of the original habitat has been lost (Andrén 1999)[19]. Such impacts can include changes in species composition, community structure, population dynamics, behaviour, breeding success, individual fitness and a range of ecological and ecosystem processes (e.g. Doherty & Grubb 2002, Huitu et al. 2003, Opdam & Wascher 2004).

In many cases the greatest biodiversity impacts resulting from habitat fragmentation are the result of habitat loss (Fahrig 2003). This is because there is a well documented species-area relationship; species richness invariably increases with the size of the area measured (Schoener 1976; Wiens 1989). Consequently smaller fragments tend to support fewer species (Henle et al. 2004a, Henle et al. 2004b, Miller & Cale 2000). There are considered to be three main causes for this species-area relationship (Huston 1994). Firstly, at small scales, it may often be a sampling artefact. Secondly, and importantly, as sample areas increase then the diversity of habitat types (and variations in habitat) will increase as a result of environmental heterogeneity. Thirdly, the relationship may result from an equilibrium between extinction rates and immigration rates as postulated by the theory of island biogeography (MacArthur & Wilson 1967).

Small populations have been shown by many studies to be likely to suffer extinctions through a number of different mechanisms (e.g. chance events, see Section 3.1.2). This effect increases with increasing isolation from other patches of similar habitat. For larger species, the minimum core of habitat block necessary to prevent extinction can be extremely large.

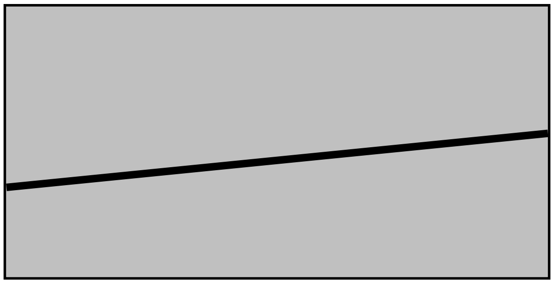
These island biogeography theories and population persistence observations started a debate as to whether it is preferable to have small numbers of very large nature reserves, or large numbers of smaller ones (e.g. Burkey 1989). This became known as the 'single large or several small', or SLOSS, debate (see Box 3.3), which has still not been resolved to the satisfaction of many conservation biologists. As a result there is no consistent or agreed best practice on the application of island biogeography principles to protected area design. Nevertheless, although the consideration of SLOSS factors often remains appropriate, it is increasingly recognised that other factors may be of equal or greater importance.

[19] This value is likely to differ greatly between species and habitats, and other estimates suggest fragmentation effects become apparent when as much as 60 per cent of original habitat remains

Figure 3.1. A diagrammatic representation of a hypothetical progression in habitat fragmentation

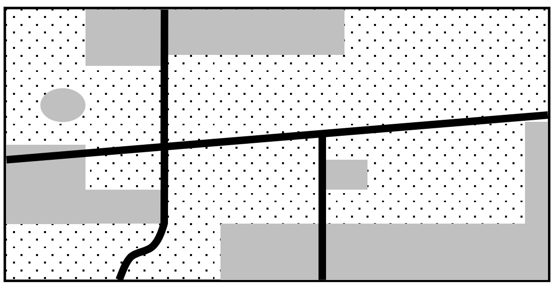
Key: Shaded = semi-natural forest. Hatched = Intensive managed forest. Stippled = semi-natural grassland with scattered trees (i.e. parkland). Unshaded = agriculturally improved grassland.

a. Construction of a road across an area of continuous semi-natural ancient forest



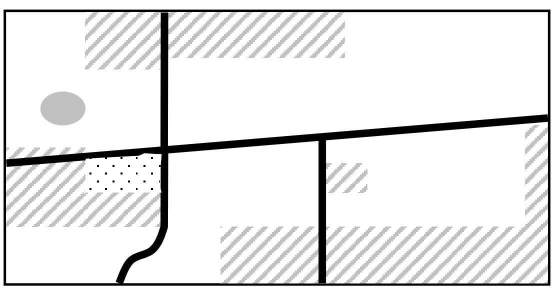
Impacts: No significant direct habitat loss, but creation of some edge habitat. Fragmentation of forest habitat for some species (e.g. some invertebrates) that cannot cross roads. Some disturbance impacts may reduce effective habitat size for some disturbance sensitive species.

b. Clearance of some forest and conversion to semi-natural parkland (grassland with scattered trees). Some further road construction



Impacts: Substantial habitat loss and fragmentation. Likely loss of disturbance sensitive species and species requiring large forest areas, and/or interior habitats. Connectivity between forest areas now much reduced, but many species can move through semi-natural parkland landscape matrix. New habitats created and benefits for forest edge species leading to an overall increase in species diversity.

c. Intensification of forest and agricultural management



Impacts: Widespread habitat degradation leading to habitat loss for many species. Reduced connectivity between forest fragments due to reduced permeability of the surrounding matrix. Only small isolated patches of semi-natural forest and parkland remain. Overall impact: substantially reduced species diversity.

Box 3.3 Reserve designs and biogeography

Based on biogeographical studies some basic rules of thumb have been proposed, and widely referred to, for the selection of nature reserves (Diamond 1975). These are simply that:

1. Larger areas are better than smaller areas
2. One large area is better than separated areas of the same total area
3. Adjacent areas are better than isolated areas
4. Linkages ('corridors') between areas are better than completely isolated areas
5. Clusters of areas are better than areas in a line
6. Compact areas are better than linear areas

However, there have been many erroneous and inappropriate applications of these island biogeographical based theories to site evaluation and the selection of protected areas (Bibby 1998). Opdam and Wiens (2002) have also pointed out that the analogy between nature reserves and islands is flawed because they are not counterparts in an inhospitable ocean. Insights on nature reserve design from the theory of biogeography are therefore likely to be misleading.

Furthermore, in practice many other factors need to be taken into account in considering the optimal size, distribution and shape of nature reserves. Indeed, in many cases these other factors will be more important. For example, in some circumstances, small isolated reserves might be appropriate, for instance for safeguarding plants with minute ranges that may be susceptible to competition from invasive species.

Factors that increase a species' sensitivity to habitat fragmentation are examined in Section 4.3.

3.3 The role of connectivity in maintaining ecosystem resilience and securing the delivery of ecosystem services

The maintenance of connectivity is important for the proper functioning of **ecosystems**, which can be defined as dynamic complexes of plant, animal and micro-organism communities and their non-living environment interacting as functional units (see Annex 1 for broader definition). Ecosystems are formed of different ecosystem components, including plants, wildlife, climate, landforms and human activities. The organisation and composition of these components is called **ecosystem structure** whereas the dynamic interactions between the components are generally called **ecosystem processes**.

Much of the complexity of an ecosystem (its structure and processes) can be reduced to a number of ecosystem functions. An ecosystem function is defined as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (de Groot 1992, de Groot et al. 2002). It is important to note from this definition that ecosystem functions themselves do not need to convey direct benefits or value to humans. Indirectly many processes that humans never see or use remain essential for the proper functioning of an ecosystem. Therefore the full range of functions provides the capacity of ecosystems to deliver ecosystem services, which are those ecosystem functions that have observable benefits to human society. It is therefore not possible to protect the delivery of ecosystem services without protecting the broader range of ecosystem functions.

Currently, the most commonly used categorization of ecosystem services is the classification developed by the Millennium Ecosystem Assessment in 2005 (MEA 2005A). The MEA definition of ecosystem services divides the services into four different categories, namely *provisioning services* such as food, water, timber, and fibre; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling.

Biodiversity underpins the provision of all ecosystem services and can be defined as the sum of variation in genes, species and ecosystems (MEA 2005A). In this context, the key feature of biodiversity is the functional relationships amongst species within an ecosystem. Within an ecosystem there maybe several species, or assemblages, that perform similar functions, such as nitrogen fixation. The loss of one of these species may be deemed as acceptable as other species may perform the same function and therefore there is redundancy in the system. Conversely there will be some species that have an important and unique function within the ecosystem (**keystone species**) and their loss will have highly damaging effects. With greater redundancy there is a greater 'insurance' that an ecosystem can function in the face of change.

Thus, even though some goods and services might continue to be delivered with less biodiversity, keeping as many species as possible is of significant importance. This is because our limited knowledge of ecosystem functions means that it will never be possible to identify which species we can afford to lose, and because diverse ecosystems will provide the best insurance against future environmental change.

In conclusion, maintaining biodiversity will help to maintain **ecosystem resilience**. Resilience in this context is defined as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004). Ecosystem resilience is closely linked to the assessment of the role of biodiversity within ecosystems and the ability of ecosystems to cope with human induced impacts (e.g. habitat destruction and fragmentation). Consequently, understanding the role of biodiversity within ecosystems (e.g. trophic relations between species, functional traits, abundance and distribution) is more important than solely assessing species richness. Much of this information is lacking and as yet, there have been few studies into the relationship between biodiversity, ecosystem services and human wellbeing (MEA 2005A). It is important to note that within an ecosystem, the capacity only to buffer negative effects is not enough (ecosystem resistance). The ecosystem must be able to reorganize after disturbance, adapt to the new situation, and sustain important ecosystem services. A non-resilient ecosystem facing disturbance will degrade or even flip into less desirable states (Holling 2001).

Ensuring the existence of species within their respective natural ecosystems by enabling the movement and spread of species within landscapes can increase ecosystem resilience. Consequently, securing ecological connectivity within landscapes can reduce the negative impacts of fragmentation and climate change. Thus connectivity conservation measures can help to support the functioning of ecosystems and the provisioning of ecosystem services and their socio-economic benefits.

4 BIODIVERSITY IMPACTS OF CLIMATE CHANGE

4.1 Climate change projections

The Inter-governmental Panel on Climate Change (IPCC) has stated in its Fourth Assessment Report (IPCC 2007b) that the 'warming of the global climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level'. The observed temperature increases are also rapid and significant, and as a result 11 of the last 12 years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850). Overall, the total temperature increase from 1850 – 1899 to 2001 – 2005 is 0.76°C (from 0.57 to 0.95°C). The IPCC also notes that 'at continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones'. Changes have been greatest in Arctic regions, where the average temperatures increased at almost twice the global average rate over the past 100 years.

There is also further evidence of continuing and possibly accelerating sea-level rise. Global average sea level rose at an average rate of 1.8 mm (1.3 to 2.3 mm) per year over 1961 to 2003, but at 3.1 mm (2.4 to 3.8 mm) per year between 1993 and 2003 (IPCC 2007b).

Furthermore the IPCC (2007a) considers that 'most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentration'.

The IPCC (2007a) projections for future climate change are now considered to be more reliable as a result of improved models, increased numbers of simulations and accumulated climate change data that have been used to test model predictions. As a result the IPCC considers that 'for the next two decades a warming of about 0.2°C per decade is projected for a range of SRES[20] emission scenarios. This rate of increase falls within previous projections made in the IPCC's Third Assessment Report (IPCC 2001a).

The IPCC also has higher confidence of the following climate changes:

1. Projected warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean.
2. Snow cover is projected to contract.
7. Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios.
8. It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.

[20] Special Report on Emission Scenarios (IPCC 2000)

9. It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures.
10. Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century.
11. Increases in the amount of precipitation are very likely in high-latitudes, while decreases are likely in most subtropical land regions.
12. Based on current model simulations, it is very likely that the meridional overturning circulation[21] of the Atlantic Ocean will slow down during the 21st century. However, temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases.

Although there is less certainty over projected regional climate changes, there has been broad consensus on the likely general pattern of change in Europe. These are summarised in Box 2.5, although they may now need to be updated in response to more recent studies by the IPCC and others.

Box 4.1 Climate change projections for Europe

Temperature

Annual temperature change between 0.1 and 0.4°C per decade, with greatest warming over southern Europe and northeast Europe and least along the Atlantic coastline of the continent.

In winter, the continental interior of eastern Europe and western Russia warms more rapidly (0.15–0.6°C per decade) than elsewhere. In summer, the pattern of warming displays a strong south-to-north gradient, with southern Europe warming at a rate of between 0.2 and 0.6°C per decade and northern Europe warming between 0.08 and 0.3°C per decade.

Winters currently classified as cold (occurring 1 year in 10 during 1961–1990) become much rarer by the 2020s and disappear almost entirely by the 2080s. In contrast, hot summers become much more frequent. Under the 2080s scenario, nearly every summer is hotter than the 1-in-10 hot summer as defined under the present climate.

The agreement between models about these future temperature changes is greatest over southern Europe in winter, but this region shows the greatest level of disagreement between summer model simulations. All model simulations show warming in the future across the whole of Europe and in all seasons.

Precipitation

A 1–2 per cent increase per decade in annual precipitation in northern Europe and an up to 1 per cent per decade decrease in southern Europe (in summer, decreases of 5 per cent per decade may occur). (EEA 1999)

There is marked contrast between winter and summer patterns of precipitation change. Most of Europe gets wetter in the winter season (between +1 and +4 per cent per decade); the exception is the Balkans and Turkey, where winters become drier. In summer, there is a strong gradient of change between northern Europe (wetting of as much as +2 per cent per decade) and southern Europe (drying of as much as –5 per cent per decade).

Weather extremes

The scenarios do not explicitly quantify changes in daily weather extremes. However, it is very likely that frequencies and intensities of summer heat waves will increase throughout Europe; likely that intense precipitation events will increase in frequency, especially in winter, and that summer drought risk will increase in central and southern Europe; and possible that gale frequencies will increase.

[21] Also known as the North Atlantic Drift and North Atlantic Oscillation

Sea-level rise

Global-mean sea level rises by the 2050s by 13–68 cm. These estimates make no allowance for natural vertical land movements. Owing to tectonic adjustments following the last glaciation, there are regional differences across Europe in the natural rates of relative sea-level change.

Source: Based on a key features of climate scenarios for Europe (IPCC 2001b), unless indicated as EEA (2004).

4.2 Climate change impacts on ecosystems and habitats

There is already convincing evidence that climate change is resulting in biodiversity impacts, such as changes in wild species' distributions, phenology and survival rates (e.g. IPCC 2002 - see also Section 3.3 below). So far these have not been globally significant, but several studies project profound ecosystem impacts as a result of possible climate changes, such as the loss of the Amazon rainforest (Cox et al. 2004) and the possible global extinction of 18-35 per cent of species (Thomas et al. 2004a, Thomas et al. 2004b). Thus it is becoming increasingly apparent that climate change is likely to be the most profound threat to global biodiversity, leading to new impacts and exacerbating existing pressures (IPCC 2002). These impacts are expected to degrade many vital ecosystems, particularly in the polar regions, where climate changes will be greatest.

An assessment of the effects of climate change on ecosystems in Europe by the IPCC concluded that there will be many significant and detrimental impacts (IPCC 2001b). These are likely to include declines in the extent of permafrost with resulting encroachment of trees and shrubs into the northern tundra, and broad-leaved trees into coniferous forests. In mountain regions, higher temperatures will lead to an upward shift of biotic and cryospheric zones and perturb the hydrological cycle. The reductions in area of such habitats, as well as some wetlands and isolated special habitats, will threaten some species, including rare/endemic species and migratory species (see below).

The IPCC (2001b) report also provides evidence that climate change impacts may be exacerbated by increasing pressures on remaining semi-natural habitats as a result of impacts on agriculture and forestry. Although agriculture may benefit form increased crop yields as a result of increasing atmospheric CO2 concentration, this will probably be counteracted by the risk of water shortages in southern and eastern Europe and by a shortening of growth duration in many grain crops as a result of increasing temperature. Similarly, although timber harvest will probably increase in commercial forests in northern Europe, the IPCC has high confidence that reductions will occur in the Mediterranean, as a result of increased drought and fire risk. Such impacts may increase the pressures for expanding, intensifying and relocating agriculture and forestry at the expense of protected areas and other ecologically valuable habitats. Furthermore, the need for plant protection will also grow and the use of pesticides and fungicides may increase as a result of climate changes (Parry 2000).

A more recent, but less detailed, summary of projected climate change impacts in Europe by the IPCC confirms these likely general impacts (IPCC 2007a). It also notes, with respect to Europe, that 'The great majority of organisms and ecosystems will have difficulties adapting to climate change'.

Reviews of information on climate change impacts on biodiversity in Europe, and Europe's vulnerability and adaptation to climate change have also recently been carried out by the European Environment Agency. These have concluded that projected climate change is expected to lead to considerable losses of species and habitats throughout Europe. The most vulnerable ecosystems are the European arctic and mountains, coastal wetlands and ecosystems in the Mediterranean region.

Associated sea-levels rises are also likely to have major long-term impacts because 9 per cent of all European coastal zones (12 per cent for EU Member States), which can be defined as a 10 km strip, are potentially vulnerable to sea level rise and related inundations, being below 5 m above sea-level (EEA 2005b). The most threatened coastal environments within Europe are deltas, low-lying coastal plains, islands and barrier islands, beaches, coastal wetlands, and estuaries. Large areas of such habitats in north-west Europe will be vulnerable to sea-level rise. Some coastal ecosystems in the Baltic, Mediterranean and Black Seas may be particularly threatened because of the low tidal range in these areas and the limited scope for onshore migration resulting from the intense human use of the coastal zone.

4.3 Climate change impacts on species

There is now sufficient evidence to support the hypothesis that anthropogenic climate change is already having a direct and measurable impact on species (see reviews in Parmesan & Yohe 2003, Root et al. 2003, Root & Hughes 2005, Parmesan 2005, 2006). This impact is expected to increase the number of species threatened with extinction (Thomas et al. 2004).

Climate change is expected to affect species in a number of ways (Harrison et al. 2006, Huntley et al. 2006), and may already have overtaken habitat loss as the main threat to biodiversity in some regions (Lemoine et al. 2007), though not yet all (Jetz et al. 2007). Responses can be separated into two broad categories: range changes (Pearson & Dawson 2003, Huntley et al. 2004, Beaumont et al. 2005, Harrison et al. 2006) and phenological changes (Durant et al. 2007, Luo et al. 2007, Thorup et al. 2007). In a meta-analysis of 99 bird, butterfly and alpine shrub species ranges and 172 species for phenological events, Parmesan & Yohe (2003) show that on average species' range limits have moved 6.1 km (± 2.4 km) per decade towards the poles and that spring timings are 2.3 days earlier per decade. Climate change will result in increased climate space for some species, and reduced space for others. In a review of 32 species in the UK, the MONARCH project projected that climate space would increase for 15 species, decrease for 8, and change little for 9 (Walmsley et al. 2007). However, even species for which climate space is predicted to increase might need to undergo significant shifts in their current ranges to occupy newly available climate space.

While fragmentation might increase species' vulnerability to climate change in many ways, it is likely that a major impact will be on species attempting to track shifting climate envelopes. Evidence from the palaeontological record and current studies indicate that as conditions change the response of most species will be to colonise new areas as they become suitable and abandon ones (through local extinctions) where conditions deteriorate, leading to range shifts. The general pattern of observed or predicted shifts in Europe is for species in warming regions to show movements northwards (Hill et al. 2002, Battisti et al. 2005, Harrison et al. 2006) or increases in altitude (Hill et al 2002, Battisti et al 2005, Battisti et al 2006, Truong et al 2007). For European tree species, climate envelope models predict that boreal deciduous and coniferous species will experience range reductions, being replaced by temperate deciduous and coniferous species, which will increase the functional species diversity of boreal areas (Thuiller et al. 2006). This move is also matched by a predicted northern expansion of Mediterranean evergreen and deciduous species, which are currently limited by winter temperature and growing season length (Thuiller et al. 2006).

The ability of species to track these changes depends on the availability of suitable habitats within transitional and new ranges, and their ability to reach them (Donald 2005). Therefore, the ability to track moving climate envelopes will rely partly on characteristics of the species (e.g. ability to disperse across unsuitable habitats, ability to persist in marginal habitats) and partly on landscape structure (e.g. the size and distribution of habitat islands, the properties of the habitat matrix). The potentially synergistic effects of landscape structure and climate change are poorly understood (Honnay et al 2002, Opdam and Wascher 2004), though it has been suggested that modifying landscapes, by increasing connectivity or redesigning the distribution of protected areas, might provide a mechanism to help species adapt to climate change (Araujo et al 2004, Hulme 2005, del Barrio et al 2006, Donald & Evans 2006, Gaston et al 2006, Davies & Pullin 2007).

Changes in distribution or phenology resulting from climate change will have knock-on effects for the composition of ecological communities and therefore the functioning of ecosystems. These changes will be mediated by local extinctions and/or replacement by new species (Nielson et al. 2005). This then will place both ecological and evolutionary pressures on species as they are faced with new competitors, predators and prey (Thomas 2005); resulting in either positive or negative feedback relationships that will either ameliorate or exacerbate the impacts of climate change. The ability of an ecosystem to buffer these impacts and maintain certain functions is likely to be closely related to its connectivity. Therefore the effects of fragmentation may have a greater impact on the ability of species to persist under climate change than their internal ability to track changing climate space (Mora et al 2007). Alternatively, fragmentation might serve to reduce certain threats predicted under climate change, such as the spread of new diseases or invasive species (Condeso & Meentemeyer 2007).

5 ASSESSMENT OF SPECIES AT RISK FROM FRAGMENTATION AND CLIMATE CHANGE

5.1 Impacts of habitat fragmentation on species

Habitat loss and change can break up continuous habitat into a series of smaller fragmented patches, which exacerbates habitat loss (because some patches may be too small for some species), increases the proportion of habitat edge and increases the isolation of remaining habitat patches. Isolation between patches is a function both of the distance between habitat patches and the permeability of the landscape matrix to the movement of species. The conditions found within this broader landscape matrix have a significant effect on the remaining habitat patches (Ewers & Didham 2005). As fragmentation is a spatially explicit process, the impacts need to be considered at a spatial scale relevant to the species and habitats of concern. This means that resulting connectivity measures used as responses to fragmentation also need to be viewed at spatial scales relevant to the species in question.

The ability of a species to persist within a fragmented landscape is related to its ability to exist in a series of local patches and to re-colonise these patches over time (Hanski 1998). This ability depends on a suite of morphological, behavioural and ecological traits within individuals that interact with the abiotic conditions encountered within the habitat (Swihart et al 2003). Variation in these traits means that the ability to persist in fragmented landscapes will vary within and between species (Henle et al 2004b, Ewers & Didham 2005).

Separating the impacts of habitat loss and fragmentation on species can be complex as fragmentation necessarily contains elements of loss. Habitat loss has well documented effects, including reductions in trophic chain length, changes to species interactions, reductions in the number of specialists, reductions in breeding success and dispersal success and increases in predation rates (see review in Fahrig 2003). However, identifying the additional impacts of fragmentation is more difficult. Fragmentation impacts include reduced population density, reduced population persistence, reduced reproduction, reduced individual fitness and increased disease incidence (Farhig 2003).

Movement between patches in a fragmented landscape is partly dependent on the spatial distribution of the population and patches within the landscape. The permeability of the matrix between habitat patches affects the ability of individuals to move between patches. For example, understory forest species are usually averse to crossing open areas, but heterogeneous matrix areas can alleviate this effect. Forest birds artificially translocated to forest patches of differing isolation were equally able to use forest corridors or scrub matrix habitats, whereas they would not cross open areas (Castellón & Seiving 2005). The way in which individuals move through the landscape is likely to change with landscape structure (Goodwin & Fahrig 2002). Changes to this movement ability have resulting impacts on a host of species interactions such as predation, parasitism, competition, and herbivory. Possibly due to the need for increased mobility, fragmentation adversely affects predators more than herbivores (Zabel & Tscharntke 1998, Tscharntke et al 2002). Also specialists such as parasitoids suffer more from fragmentation effects than generalists, which tend to be better able to exploit the surrounding habitat matrix (Steffan-Dewenter & Tscharntke 2000).

As populations become smaller and more isolated, they become more prone to the loss of genetic variation through factors such as random genetic drift, increased self fertilisation in plants, and increased inbreeding in animals (Honnay & Jacquemyn 2007). Although most studies have focussed on the deleterious genetic effects of small populations on rare species, common species can be equally as susceptible to the population genetic consequences of habitat fragmentation (Honnay & Jacquemyn 2007).

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5.2 Species traits increasing sensitivity to fragmentation

There are a number of observable and measurable traits that may be used to predict the response of a species to external events, such as habitat fragmentation (Diaz et al 2004). Several studies have reviewed traits or characteristics of species that may make them more sensitive to habitat fragmentation (Davies et al 2001, Henle et al 2004b, Swihart et al 2003, 2006, Donald 2005, Donald & Evans 2006). In a review of 12 traits associated with vulnerability to habitat fragmentation, Henle et al (2004b) identified the following as being important: rarity (low natural abundance), high individual area requirement, high population fluctuation, low reproductive potential, low storage effects, intermediate or low dispersal power and specialist habitat requirements.

There is a strong interaction between different traits, with high levels of correlation and co-dependence between them. For example Davies et al (2004) showed that specialisation and rarity acted synergistically to make beetle species more vulnerable to extinction in forest fragments. Thus a series of traits is needed to make predictions concerning species vulnerability. Environmental conditions will also affect the degree to which these traits determine species' vulnerability to fragmentation, with some only having an effect under certain conditions. In the following sections a series of the key traits associated with fragmentation are considered in more detail.

1. **Rarity** is a condition of species that naturally occur at low densities, have been historically depleted, or have suffered recent population declines (Henle et al 2004b, Honnay & Jacqemyn 2007). Low abundance exacerbates a species' sensitivity to the removal of links between individuals or populations and the subsequent exposure of remaining populations to extinction through demographic and environmental stocasticity. Such extinctions are particularly likely when population fluctuations in fragments are large relative to the overall population size.

2. **Niche breadth and habitat specificity** relate to the range of different resources utilised by a species (Swihart et al 2003, 2006). Generalist species can exploit a wide range of resources and have a broad niche; whereas specialists are more limited in the resources they exploit and are less able to switch if these resources become depleted or fragmented. Generalists are therefore able to exploit fragmented and successional habitats better than specialists, and are less likely to be impacted by the loss of particular food items due to fragmentation (Swihart et al 2003, 2006).

3. **Individual area requirement or home range size** is the area individuals within a population require for foraging and reproduction. Species with large area needs, i.e. species with large home ranges, which are primarily those at high trophic

levels, are more vulnerable to fragmentation (Woodroffe & Ginsberg 1998, Henle et al 2004b).

4. **Dispersal ability** describes the ability of individuals to move through the landscape. As a sensitivity factor this is scale-dependent and will be most beneficial when it extends beyond the range of environmental fluctuations affecting a patch (Henle et al 2004b, 2004c, Donald 2005). Furthermore, dispersal can occur at different scales for the same species, e.g. plants can undergo regular short distance dispersal and rare long distance dispersal events. Dispersal ability is highly variable between and within taxonomic groups and there may be behavioural adaptations that limit the dispersal ability of species into seemingly suitable habitat. For example, some forest bird species are unwilling to break forest cover when moving between forest patches (Komdeur et al 2004). Dispersal ability, as a sensitivity factor, can also be confounded by the means of dispersal, rate of dispersal and colonisation ability shown by the species (Henle et al 2004b), for example plants that rely on animal dispersal are more vulnerable to fragmentation than those relying on wind dispersal.

5. **Reproductive potential and longevity** have an important effect on sensitivity to habitat fragmentation by determining the number of individuals able to colonise new areas and by buffering against fluctuations in population size (Henle et al 2004b). Longevity and reproductive output are closely correlated. Species with high mortality usually have a high reproductive output and are therefore expected to be able to cope better with changes caused by fragmentation, whereas species with long life-spans generally have a low reproductive output and have been shown to be sensitive to fragmentation.

6. **Storage effects** refer to the ability, particularly of plants, to store reproductive potential across time and generations for example in seed banks or through clonal propagation (Henle et al 2004b). Examples for animals include species that can remain dormant during periods of unfavourable conditions. Species with high storage potential should be able to delay the negative impacts of fragmentation.

7. **Trophic level** describes the position of a species within the food web. Species at higher trophic levels (e.g. secondary or tertiary consumers) are expected to have a higher extinction risk from habitat fragmentation because they need either larger areas of habitat or are sensitive to disruptions to the trophic levels below them (Valladares et al 2006). Zabel & Tscharntke (1998) showed reductions in predator abundance with increasing fragment isolation in insect communities. However, the degree of impact of trophic level may be tempered by the complexity of the food web involved (Henle et al 2004b).

8. **Colonisation ability** refers to the ability of a species to colonise new areas. Species with a high colonisation ability tend to be short lived, have a high reproductive output, a small body size, short generation time and high fecundity and are pioneers within a new area. A useful proxy for this measure is age at first breeding.

5.3 Species traits increasing sensitivity to climate change

The effects of habitat fragmentation are likely to become more severe under patterns of global warming, as species try to adapt to changing conditions by tracking moving climate envelopes. Climate change is a pervasive environmental disturbance that affects all areas and populations at the same time (although to differing extents); an effect which is less well studied in metapopulation theory (Opdam & Wascher 2004).

Many assessments of species' sensitivity to climate change have taken a bio-climate envelope (or niche-based) modelling perspective and define sensitivity by the degree to which a species' distributions is affected (Thuiller et al 2005). These modelling studies usually assume either total dispersal or zero dispersal to reflect the ability of species to respond to changing conditions. However, very few studies have tried to compare ecological properties, species characteristics and climate projections to provide a more realistic understanding of which species are sensitive to change and whether they will be able to respond (see Thuiller et al 2005, Broennimann et al 2006). Such assessments are necessary to identify whether simple ecological metrics can indicate which species may be most sensitive to climate change. In general, characteristics that describes the range of habitat conditions a species can tolerate (niche breadth) and where these conditions are on bio-climatic gradients (i.e. hot and dry conditions or cold and wet conditions) give an indication of the sensitivity of species to climate change. These associations are discussed in more detail below.

1. **Species at the ends of a temperature or precipitation gradient** are found in areas that are either colder or hotter, or wetter or dryer, than the mean. This measure has been quantified by describing the mean conditions used by a particular species and the mean conditions for the area (Thuiller et al 2005). It can also be estimated through expert judgment of existing knowledge on the species. It is generally the case that species inhabiting these more extreme environments are likely to lose more climate space than species adapted to more average conditions (Thuiller et al. 2005).

2. **Relative altitudinal distribution** is widely regarded as an important factor affecting a species' vulnerability to climatic warming. As noted in Section 4.3, it is predicted that species' ranges in warming regions will increase in altitude where this is possible, and there is some evidence of this happening already (e.g. Hill et al. 2002, Battisti et al. 2005, Truong et al. 2007). But species that are restricted to altitudinal ranges that are close to the maximum altitude of the land within their area of distribution may be constrained in their ability to move upwards. Consequently species that inhabit the tops of hills and mountains may completely lose their suitable climate space. It is important to note that this trait relates to relative altitude, and therefore species inhabiting hill tops in relatively low countries may be at risk as well as high altitude alpine species etc.

3. **Niche breadth** was identified as a sensitivity trait for habitat fragmentation, and it can also act as a sensitivity trait for climate change. Specialist species, i.e. those that tolerate a narrow range of conditions, are predicted to be able to respond least to changing climates (Thuiller et al 2005, Broennimann et al 2006). To some extent, this effect will be moderated by the position of the niche along temperature and precipitation gradients.

4. **Range size** was found during the development of these guidelines to be a strong predictor of the relative loss of climate space in European breeding birds (see Donald et al. 2007). Species with restricted ranges were most vulnerable in terms of projected loss of climate space and the lack of overlap between current climate envelopes and future predicted envelopes (this expresses the extent to which a species range will have to move to track climate change). Similar results have been found for European plants (Thuiller et al 2005).

As with the traits discussed for habitat fragmentation, a greater relative loss of climate space can be expected in species showing a combination of the traits mentioned above. European plant species with small ranges, narrow niches and that were marginal on a temperature or precipitation gradient were identified as most at risk from loss of climate space (Thuiller et al 2005). For example, boreo-alpine plant species (species in boreo-subapline and artico-apline biogeographic areas) have narrow niches and are marginal on the temperature gradient and are therefore predicted to lose climate space due to climate change.

5.4 Framework for identifying species at risk from fragmentation and climate change

Fragmentation represents a serious threat to biodiversity, and one that is likely to become more serious in the future, as global climate change takes effect. One of the ways that species will attempt to adapt to climate change is to track moving climate envelopes. Their ability to cross landscapes at the same speed as their climate envelopes, which is likely to exceed anything in their evolutionary history, will depend in part on the connectivity of those landscapes. In Europe, many natural habitats occur as fragments in an increasingly hostile landscape matrix. The species likely to be most impeded by fragmentation are likely to be those exhibiting one or more of the traits described in the previous section, though it may be difficult to identify such species in practice (Vos et al 2001, Henle et al 2004b). Based on their review of the impacts of habitat fragmentation on species, Henle et al (2004b) developed the following series of fragmentation vulnerability profiles:

1) **Highly vulnerable species have**: low natural abundance and/or high individual area requirement, high population fluctuations, low reproductive potential, low storage effects, intermediate or low dispersal power, and specialised habitat requirements.
2) **Vulnerable species**: low population size and density, large area requirements, and high mobility. Such species may have difficulties responding to even moderate habitat loss if reproductive output is low. However, these species should cope fairly well if remaining habitat is concentrated in a few more distant but larger remnants.
3) **Less vulnerable species**: high density and low population fluctuations. Such species should be relatively insensitive to the spatial effects of fragmentation.

These profiles, together with the review of traits described above, have been used in these guidelines as the basis for the habitat fragmentation risk assessment framework described below. It is suggested that this can be used as a tool for initially identifying species of Community interest (which, for the purpose of these guidelines, are considered to be all species currently listed under Annex 2 or 4 of the Habitats directive, Annex 1 of the Birds directive and migratory bird species relevant to Article 4 of the Birds directive) that are vulnerable to habitat fragmentation, with and without the potential impacts of changes in suitable climate space. Species that are considered vulnerable to fragmentation should then be subject to a detailed assessment of their connectivity requirements at an appropriate biogeographic scale in relation to existing and potential habitat fragmentation and changes in climate space (see Section 6.2). The framework has a hierarchical approach to the treatment of information, such that scientific evidence of fragmentation impacts or significant changes in climate space triggers the requirement for a detailed assessment, irrespective of the number of fragmentation and climate change vulnerability traits that the species exhibits.

The overall risk assessment process is presented in Figure 5.1 and described in more detail below.

5.4.1 Description of the fragmentation and climate change risk assessment steps

1) For each species of Community importance: does the species have an unfavourable conservation status AND is fragmentation considered to be a contributory factor?

Member States are expected to periodically assess the conservation status of species of Community importance in accordance with the requirements of the Habitats directive and Environmental Liability directive. Such assessments of conservation status should normally identify the main threats faced by a species and also provide life history or demographic data that can be used to assess the species' vulnerability to fragmentation.

1.1 **If YES:** Go to Step 4.
1.2 **If NO:** Go to Step 2.

2) Have scientific studies indicated that the species is vulnerable to the effects of habitat fragmentation?

Species that may be in FCS could be undergoing widespread but shallow declines (or be constrained) due to changes in habitat quality, quantity and fragmentation. Is there existing information in peer-reviewed literature or technical reports to indicate that the species is vulnerable to habitat fragmentation?

2.1 **If YES**: Go to Step 4.
2.2 **If NO:** Go to Step 3.

3) Is the species at risk from fragmentation according to an assessment of the following vulnerability traits?

Using existing knowledge concerning the demographic parameters and life history traits of the species compare the species traits against the risk categories in Table 5.1..

Table 5.1. Fragmentation risk categories associated with species' traits

Trait	Risk category		
	Low	Medium	High
Abundance	Common	Medium	Rare
Individual Area requirement	Low-medium	Medium	High
Niche Breadth (habitat specificity)	Broad (Generalist)	Narrow (Specialist)	Narrow (Specialist)
Dispersal ability/Mobility	High	Moderate-High	Low -Moderate
Reproductive potential	High	Low	Low
Population Fluctuation	Low	High	High

Does the species fall within the moderate or high risk categories (i.e. columns) for three or more traits OR fall within the high risk category regarding individual area requirements and dispersal ability?

3.1 **If YES**: The species is at risk from fragmentation. Go to Step 4.

3.2 **If NO:** the species is unlikely to be at risk from habitat fragmentation. However, the effects of climate change may act to increase its vulnerability to fragmentation in the future. Fragmentation may constrain a species' ability to adapt to climate change by following moving climate space. Therefore go to Step 5.

4) Carry out a detailed assessment of connectivity requirements in relation to existing and potential habitat fragmentation and climate change impacts

The assessment should include consideration of the potential synergistic impacts of climate change and fragmentation on the species, irrespective of the species' vulnerability as assessed under Steps 5 and 6 below. The assessment should be carried out at an appropriate biogeographical scale (through collaboration between Members States if necessary) and used as a basis for identifying and planning required connectivity conservation and restoration measures (see Section 6.2).

5) Have scientific studies indicated that the species is vulnerable to changes in suitable climate space (e.g. there is likely to be little overlap between the current and future projected ranges)?

Although the species is unlikely to be vulnerable to habitat fragmentation, we need to know whether the effects of climate change are going to act synergistically with fragmentation and potentially exacerbate fragmentation impacts and constrain climate change adaptation.

5.1 **If YES**: Go to Step 7.
5.2 **If NO:** Go to Step 6.

6) Is the species at risk from changes in climate space according to an assessment of the following vulnerability traits?

Using existing knowledge assess the species' climate change vulnerability traits against the risk categories in Table 5.2.

Table 5.2. Climate space change risk categories associated with species' traits

Traits	Risk		
	Low	**Medium**	**High**
Deviation from mean temperature	Low	Moderate	High
Deviation from Mean Precipitation	Low	Moderate	High
Relative Altitude	Low	Medium	High
Niche Breadth	Broad (Generalist)	Narrow (Specialist)	Narrow (Specialist)
Range size	Large	Small	Small

Does the species fall within the medium or high risk category for 2 or more of the traits?

5.1 **If YES**: The species is at risk from changes in climate space. Go to Step 7.
5.2 **If NO:** The species is unlikely to be of immediate concern from fragmentation. Therefore other species should be considered as priorities for connectivity conservation and an assessment of connectivity requirements is not required at the moment. However, the species should be re-evaluated at appropriate timescales and immediately if new information becomes available that is likely to change the species' assessment.

7) Carry out a detailed connectivity needs assessment in relation to climate change adaptation requirements

Although the species does not appear to be impacted by, or vulnerable to, habitat fragmentation at the moment, this may change as a result of the effects of climate change on the species. Existing and potential fragmentation may also constrain the species' ability to adapt to changing climate space. The assessment should be carried out at an appropriate biogeographical scale (through collaboration between Members States if necessary) and be used as a basis for identifying and planning required connectivity conservation and restoration measures (see Section 6.2).

5.4.2 Risk assessment examples

Table 5.3 provides a worked example of the application of the fragmentation and climate space risk assessments outlined in Tables 5.1 and 5.2. These include a selection of species that were studied as part of the Modelling Natural Resource Responses to Climate Change (MONARCH) project in the UK (Walmsley et al 2007). Data concerning the habitat fragmentation sensitivity traits and the climate associations are included for comparison.

For species projected to gain habitat in the UK under climate scenarios (Table 5.2a), Stone Curlew (*Burhinus oedicnemus*) and the Heath Fritillary (*Mellicta athalia*), would be of concern from a fragmentation perspective, but the climate associations indicate that all species should prosper under climate change. Both species were identified in the supporting analysis for this guidance as having a low vulnerability to changes in their climate envelopes (see Terry 2007).

For species projected by the MONARCH project to lose climate space (Table 5.3b), both the Black Grouse (*Tetrao tetrix*) and the Twinflower (*Linnaea borealis*) are at high risk according to several fragmentation and climate change vulnerability traits. In contrast, the Song Thrush (*Turdus philomelos*) is currently a widespread species that appears to be at low risk from fragmentation in responding to climate space changes. However, according to the MONARCH results it is projected to lose suitable climate space (Walmsley et al 2007).

Table 5.3. Fragmentation risk categories associated with species traits

Trait risk categories are indicated as follows: High risk = Red fill, bold and capitals; Moderate risk = orange fill and underlined; Low risk = Green fill and normal type. SPEC = Species of European Conservation Concern (BirdLife International 2004).

a.

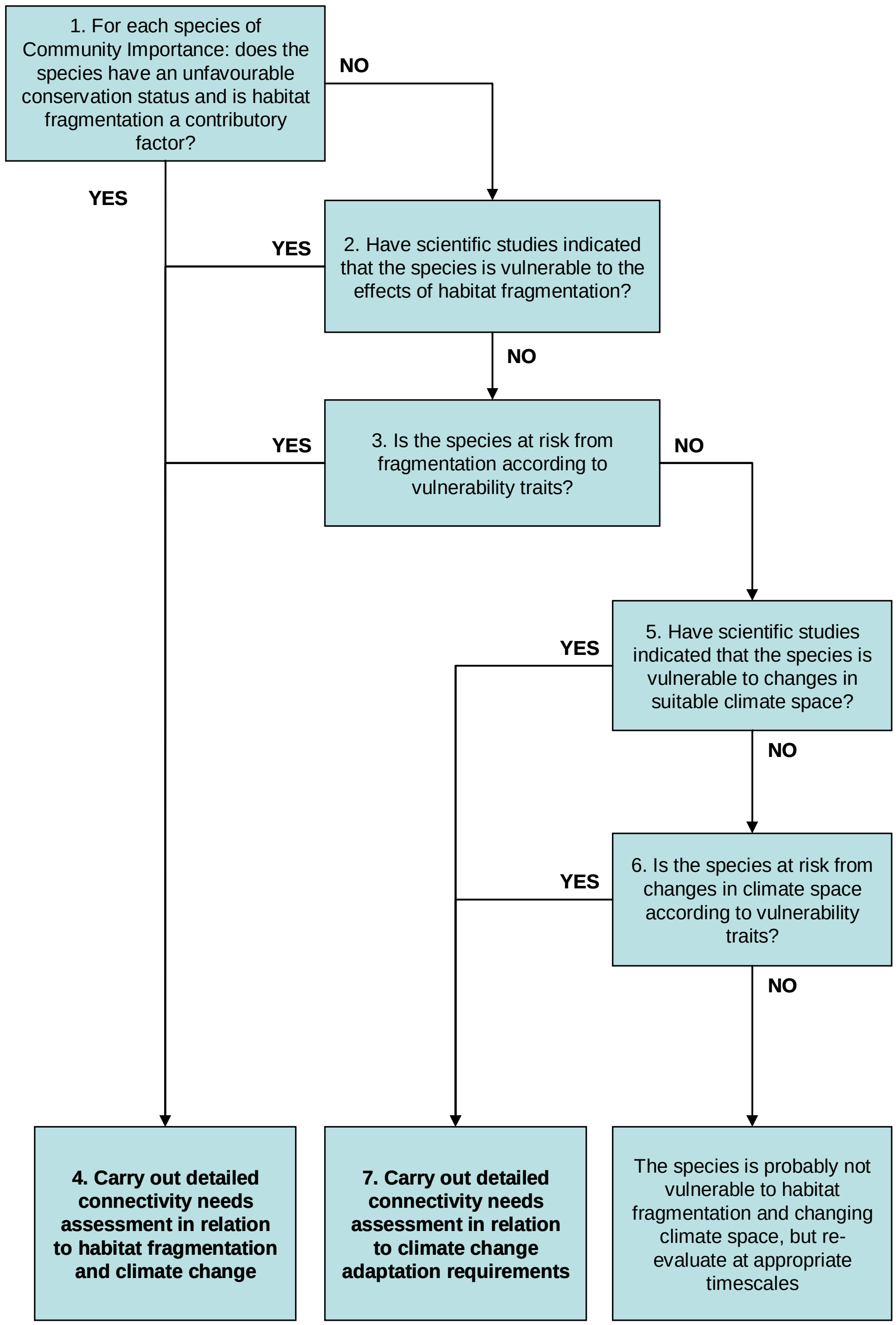
	Species		
	Stone Curlew *Burhinus oedicnemus*	**Corn bunting** *Miliaria calandra*	**Heath fritillary** *Mellicta athalia*
MONARCH Projection	Gain	Gain	Gain
Fragmentation vulnerability traits			
Conservation Status	**SPEC 3/ANNEX 1**	**SPEC 2/ANNEX 1**	
Abundance	**LOW**	**LOW**	High
Individual Area requirement	**HIGH**	Low	Low
Niche Breadth (habitat specificity)	**NARROW**	Broad	**SPECIFIC**
Dispersal ability/Mobility	High	High	**LOW (NORMALLY LESS THAN 100M)**
Reproductive potential	**LOW**	High	**LOW (SINGLE BROOD)**
Population Fluctuation	Low	Low	Low
Climate change vulnerability traits			
Deviation from Mean Temperature	Warm	Average-Warm	Average
Deviation from Mean Precipitation	Moderate (Arid)	Average	Average
Mean Altitude	Low	Low	Average
Niche Breadth	**NARROW**	Broad	**NARROW**
Range size	High	High	High

b.

	Species		
	Black grouse *Tetrao tetrix*	**Song thrush** *Turdus philomelos*	**Twinflower** *Linnaea borealis*
MONARCH Projection	Loss	Loss	Loss
Fragmentation vulnerability traits			
Conservation Status	**SPEC 3/ANNEX 1**	Non-**Spec**	
Abundance	**LOW**	High	**LOW**
Individual Area requirement	**HIGH**	Moderate	Low
Niche Breadth (habitat specificity)	**SPECIALIST**	Generalist	**SPECIALIST**

Dispersal ability/Mobility	High	High	**LOW**
Reproductive potential	**LOW**	High	**LOW**
Population Fluctuation	?	Low	?
Climate change vulnerability traits			
Deviation from Mean Temperature	**COLD**	Average	**COLD**
Deviation from Mean Precipitation	Moderate	Moderate (moist areas)	Moderate (shallow rooted needs moist areas)
Mean Altitude	Average to High	Low	**HIGH**
Niche Breadth	**SPECIALIST**	Generalist	**SPECIALIST**
Range size	**LOW**	High	

Figure 5.1. Framework for fragmentation and climate change risk assessment



6 A FRAMEWORK FOR ASSESSING, PLANNING AND IMPLEMENTING ECOLOGICAL CONNECTIVITY MEASURES

This Chapter outlines a framework that can be used by Member States to assess, plan and implement connectivity measures to reduce the impacts of fragmentation and climate change. The primary aim of these measures (as stated in Chapter 2) is to contribute to the maintenance of FCS amongst habitats and species of European Community interest and to support the EU Biodiversity Action Plan.

6.1 General principles and rationale

Previous chapters of these guidelines have demonstrated a clear need for urgent measures to reduce and reverse the impacts of habitat fragmentation. Furthermore such impacts are being increasingly exacerbated by climate change. Fragmentation is also likely to constrain the ability of many species to move in response to changing climatic conditions.

There is therefore a clear justification for taking actions, in accordance with the provisions of the Birds and Habitats directives, to maintain and restore ecological connectivity. However, some of the results from research studies and previous attempts to manage habitat connectivity indicate that such measures must be carefully considered if they are to be effective. In particular, current scientific knowledge indicates that all adopted ecological connectivity and climate change adaptation measures should:

- Have clear biodiversity conservation objectives, which should include contributing to the implementation of the Birds and Habitats directives and other EU environmental objectives, as well as wider EU, national, regional and local biodiversity strategy frameworks and targets.
- Only be carried out where there is a real need because landscape connectivity is inherently neither good nor bad (Taylor et al 2006). Through its effects on ecological processes, connectivity may positively influence population persistence for some organisms in some situations and negatively influence them in others (see Table 6.1). Risk assessments should therefore be carried out of the potential detrimental impacts of increasing connectivity through the creation of new habitat corridors.
- Be integrated with other necessary conservation measures to ensure that other significant threats are reduced as necessary – connectivity measures alone will be ineffective if other factors (such as habitat quality) are more important constraints on movement and survival.
- Be carefully targeted and cost-effective because funds and other means of biodiversity are limited. All means of increasing connectivity should therefore be considered and their cost-effectiveness taken into account. For example, managing the matrix can offer an effective means of managing the landscape to preserve or restore functional connectivity (Taylor et al. 2006).
- Give a high priority to maintaining, expanding and enhancing existing key habitats and species populations in large multiple reserves (Noss & Daly 2006).
- Be based on well-founded ecological science and supporting evidence.

- Assess the need for, and plan measures on the basis of functional connectivity (rather than simple structural connectivity) bearing in mind that this is species-specific (Taylor et al. 2006).
- Take care when using simple mathematical models to guide the management of complex, heterogeneous landscapes. Multi-faceted approaches for landscape planning are likely to be more robust and defensible, especially when a combination of modelling and empirical approaches is used to predict the effects of alternative landscape configurations or management actions on populations (Noss & Daly 2006).
- Notwithstanding the need for making decisions on the basis of good science, the precautionary principle[22] should be applied when there is significant doubt over the connectivity value of existing habitat corridors and other landscape features.
- Remember that landscape connectivity is a dynamic concept. It needs to be assessed and managed in the context of human land-use change, and it will change over both short and long time-scales (Taylor et al. 2006). An adaptive management approach should therefore be used to manage connectivity, which takes into account projected future impacts of climate change and likely land use changes (including land abandonment).
- Be implemented in accordance with the principles of the ecosystem approach, which is the primary framework for action under the CBD (http://www.biodiv.org/programmes/cross-cutting/ecosystem/default.shtml).

Table 6.1. Potential advantages and disadvantages of the use of corridors as conservation tools to facilitate connectivity. Source: Crooks & Sanjayan (2006), modified from Noss and Soulé (1987)

Potential advantages	Potential disadvantages
1. Increase immigration rate, which could: • Increase or maintain species diversity • Provide a 'rescue effect' to small, isolated populations by augmenting population sizes and decreasing extinction probabilities • Permit recolonization of extinct local populations, potentially enhancing persistence of metapopulations • Prevent inbreeding depression (i.e. reduced fitness in a given population as a result of breeding of related individuals) and maintain genetic variation within populations	1. Increase immigration rate, which could • Facilitate the spread of infectious diseases • Facilitate the spread of alien species, e.g. exotic predators and competitors • Facilitate the spread of weedy or pest species • Decrease the level of genetic variation among subpopulations • Cause 'outbreeding suppression'(i.e. situation where crosses between offspring of individuals from different populations have lower fitness than offspring from crosses between individuals from the same population) by disrupting local adaptations and co-adapted gene complexes
2. Permit daily or seasonal movements for foraging, breeding, migration, or other behaviours	2. Facilitate spread of wildfires and other catastrophic abiotic disturbances
3. Facilitate dispersal of animals from natal	3. Create a 'mortality sink' by increasing exposure of

[22] Principle 15 of the Rio Declaration which states that:
'*In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*'.

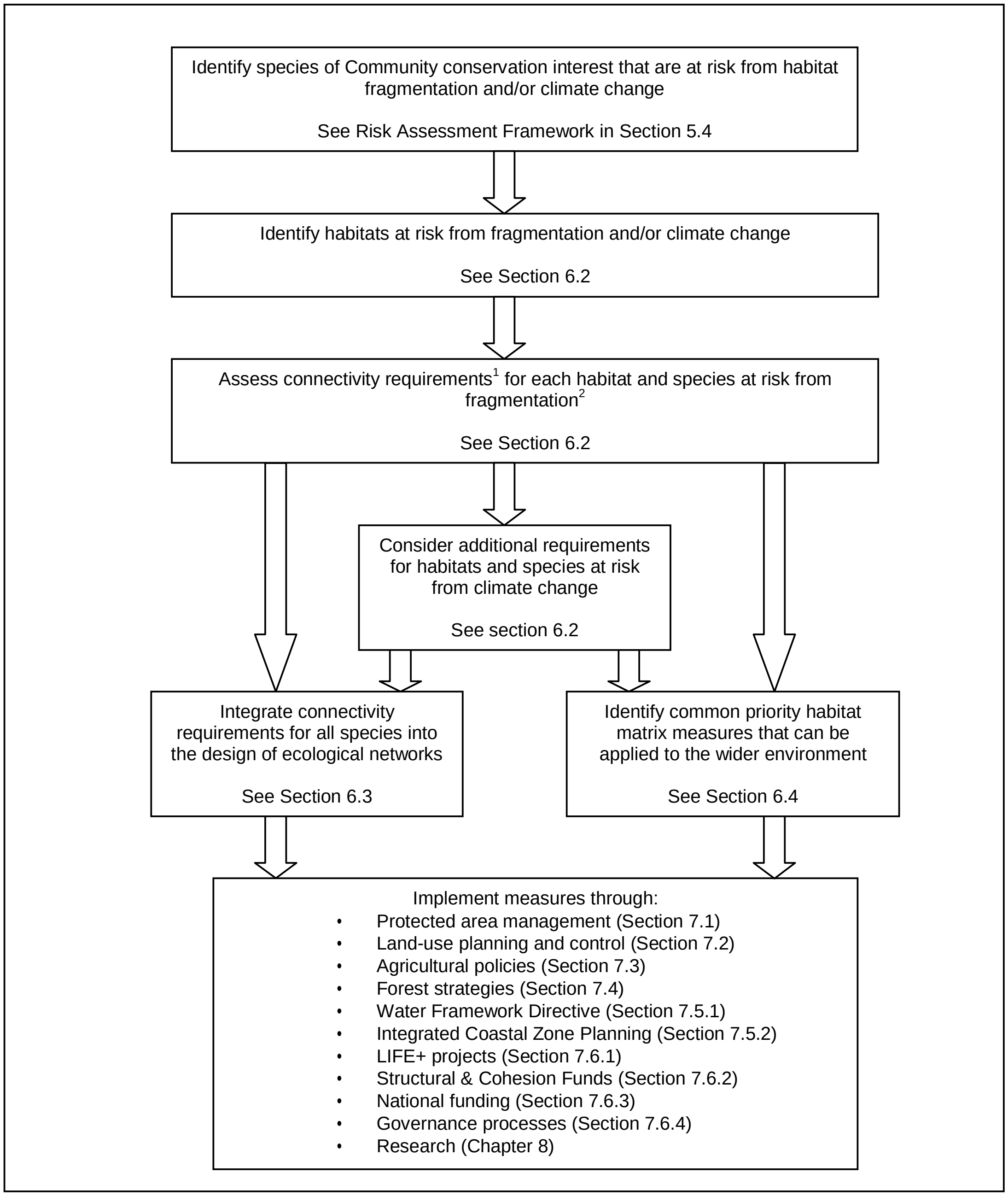
ranges to adult breeding ranges	animals in corridors to humans, native and exotic predators and competitors, pollution, and other deleterious ‘edge effects’
4. Accommodate natural range shifts due to global climate change	4. Riparian strips, often recommended as corridors might not enhance dispersal or survival of upland [i.e. non-wetland] species
5. Provide predator-escape cover for movement between patches	5. High economic cost to purchase, design, construct, restore, maintain and protect corridors
6. Provide wildlife habitat for transient or resident animals within corridors	6. Trade-off costs and conflicts with other conservation acquisitions, including conventional strategies for enlarging core areas and preserving endangered species habitat
7. Provide alternative refuges form large disturbances (a ‘fire’ escape)	7. Political costs from altering human land-use patterns
8. Continuance of ecological processes and ecosystem services such as succession, seed dispersal, and flow of water, nutrients, and energy	
9. Provide ‘green belts’ to limit urban sprawl, abate pollution, provide recreational opportunities, and enhance scenery and land values	

On the basis of these important principles and other considerations discussed earlier, the framework outlined in Figure 6.1 is proposed as a means of assessing, planning and implementing connectivity measures to reduce the impacts of fragmentation and climate change. This framework includes consideration of a number of issues other than connectivity as connectivity needs to be considered in relation to other potential conservation actions (e.g. improvement in the quality of existing habitat patches). However, the framework includes three key connectivity conservation components:

- Identification of required connectivity measures for species and habitats at particular risk from habitat fragmentation.
- The design and development of ecological networks.
- Measures to improve the ecological quality of the wider landscape (habitat matrix).

It is important to note that each of these should be carried out to meet to the overall objectives of these guidelines (as stated in Chapter 2). It is recommended that these components are carried out by Member States, but on a biogeographical basis through cooperative actions, where necessary and feasible. These key connectivity components are further described below and specific recommendations are given for their implementation. Practical measures that can be used to implement the components are described in Chapter 7.

Figure 6.1. A framework for assessing connectivity and climate change adaptation needs.



Notes:

1. Carried out on an appropriate biogeographical basis by Member States through collaborative assessments where necessary.
2. Assessments and the implementation of actions should be prioritised according the following factors: Priority Status in the Habitats directive or equivalent status for birds; the overall conservation status of the species in the biogeographical area being assessed, evidence of fragmentation impacts.

6.2 Identification of required connectivity measures for species and habitats at risk from fragmentation

6.2.1 Identification of species and habitats at risk from habitat fragmentation

One of the key lessons from scientific studies of ecological connectivity is that functional connectivity is a species-specific and a landscape-specific property (Noss & Daly; Taylor et al 2006). This is because a species' connectivity requirements depend on a number of factors that are species-specific, including their spatial distribution and population dynamics, and movement, dispersal and colonisation abilities. These requirements will also vary from place to place according to the configuration of habitat patches and the properties of the surrounding landscape matrix.

Because functional connectivity is species-specific, general connectivity measures (such as simple strategies of physically connecting habitat patches with habitat corridors), may be ineffective and inefficient. For example, some apparently isolated habitat patches may in fact be functionally connected and part of a habitat network for those species that can cross the intervening habitat matrix. In such cases new connectivity measures may not required and may in fact be detrimental, e.g. by increasing predator access to habitat patches (see Box 6.1). As Noss and Daly (2006) point out, 'if corridors are created or protected in the wrong places and prove ineffective, populations could become locally extinct, funds will have been wasted, and conservationists will lose credibility'.

It is therefore clear that effective and efficient connectivity conservation measures for threatened species need to be assessed and planned on a species-specific basis. A similar conclusion was reached at the Vilm Workshop (COM 2005). However, it is also clear that it would be impossible to assess and plan connectivity measures for all species of Community interest, let alone for other species of wider concern. It is therefore proposed that connectivity measures should be targeted (at least initially) to those species and habitats of Community interest that are known, or suspected, to be at risk from fragmentation, especially if they are also threatened by the added impacts of climate change. In practice the provision of necessary connectivity for such species and habitats is also likely to provide connectivity benefits for a wide range of ecosystems, habitats and species.

A proposed framework for identifying species at risk from fragmentation and the additional impacts of climate change is described in Section 5.4 (and outlined in Figure 5.1). It is not appropriate to carry out such an assessment at the EU level because some of the risk factors (e.g. association with fragmented habitats) vary considerably across the region. It is therefore suggested that these assessments should be carried out by Member States on a biogeographical basis where necessary and feasible. They might also be carried out as part of the development of species actions plans and site management plans.

It is also important and necessary to identify habitats of Community interest (i.e. listed in Annex II of the Habitats Directive) that are at potential risk from fragmentation and climate change and to assess their connectivity requirements. However, it has not been within the scope of this study to produce a framework for identifying habitats at risk from fragmentation and climate change. Nevertheless, some of the elements of the species risk assessment framework can be applied to habitats of Community interest. It is therefore suggested that habitats of Community interest are considered to be at risk if:

- The habitat is in unfavourable conservation status and there is evidence that this is due, at least in part, as a result of fragmentation; or

- Existing scientific knowledge indicates that the habitat is vulnerable to the effects of habitat fragmentation; or

- Existing scientific knowledge indicates that the habitat is vulnerable to the effects of habitat fragmentation in combination with climate change.

The fragmentation risk assessments are likely to produce a long list of habitats and species that require detailed assessments of their connectivity requirements. Connectivity assessments and necessary measures may therefore need to be prioritised for action. Such prioritisation should take into account whether a species or habitat is given Priority in the Habitats directive (or equivalent status for bird species), whether they are in FCS and whether there is evidence of current fragmentation and climate change impacts. In practice though some flexibility may need to be used in following priority actions. For example, in some cases it may be appropriate to take advantage of opportunities to combine connectivity conservation measures with unrelated but beneficial events (e.g. land abandonment).

6.2.2 Assessment of connectivity requirements

As outlined in Figure 6.1, the connectivity requirements of species and habitats at risk from fragmentation should be assessed. In particular, in accordance with Articles 3 and 10 of the Habitats directive, it is recommended that a high priority should be given to assessing the coherence of the Natura 2000 network with respect to such species and habitats. This should include the identification of current functional connectivity amongst the network for these species and habitats on the basis of empirical evidence where available.

Wherever feasible expert-based approaches to assessing functional connectivity should be complemented by more rigorous empirical studies and modelling. Functional connectivity models should take into account the properties of the intervening landscape and each species ability to move through it, such as through ‘least-cost’ analysis (Adriaensen et al 2003; Bunn et al 2000). The functional connectivity of habitats can also be assessed using ‘least-cost’ approaches, e.g. by using ‘generic focal species’ (*sensu* Lambeck 1997) for each habitat type to represent typical movement costs; a method used to develop ecological networks in England (Catchpole 2006).

Particular care should be taken in assessing the functional importance of landscape features that appear to be of high connectivity value. Many narrow habitat corridors and linear features, such as hedgerows, may provide valuable habitat but have limited functional connectivity value (Davies & Pullin 2007; Dawson 1994; Donald 2005; Donald & Evans 2006; Hobbs 1992; ITE 1994; Spellerberg & Gaywood 1993). Nevertheless, as noted in section 6.1 the precautionary principle should be applied so that in cases of doubt such features should be retained.

The assessment of connectivity requirements should be completed with an evaluation of the adequacy of existing connectivity. Typically this may consider the species' demographic ecology, current conservation status and possible future threats from fragmentation. For example, the carrying capacity or actual population size within each identified functional network should be assessed in relation to recommended minimum habitat areas or minimum viable population sizes. Such assessments may often need to be carried out by expert evaluations. However, as before these should take account of all available empirical data and expert approaches should be complemented by modelling analysis where feasible and appropriate. The use of spatially explicit population models and stochastic patch occupancy models may be particularly useful in this regard (Carroll 2006). However, in practice such models are often unsupported by empirical data. Furthermore, sensitivity analysis of spatial population models such as LARCH indicate that they are highly sensitive to small alterations in parameter values (Verboom & Pouwels 2004). The outputs of such model should therefore be treated cautiously and expert evaluations, and ideally some field validations, should be carried out before they are used as a basis for defining ecological networks or other connectivity conservation decisions.

6.2.3 Assessment of options for maintaining and increasing connectivity

Once an assessment of functional connectivity requirements has been completed then options for maintaining and increasing connectivity, if it is inadequate, can be considered. Assessments of options for alleviating inadequate connectivity should take into account all factors that affect the conservation status of the species or habitat in question, because connectivity measures need to be considered as part of a range of possible actions (Bennett 2003). Increasing connectivity *per se* may not be the most appropriate solution.

In particular, increasing connectivity should not be seen as a substitute for the conservation of large core areas of habitat (Noss & Daly 2006). Instead connectivity features such as corridors should complement extinction-resistant core areas because these areas are likely to hold key populations that play a major role in maintaining metapopulations (see Chapter 3).

A high priority should, therefore, be given to assessing the coherence of the Natura 2000 network for species that are considered to be at risk from fragmentation. Thus the relationship between Natura 2000 sites and their wider ecological networks (if present) should be established and their viability evaluated. As described later (Section 7.1) the management of these sites should then take into account their wider ecological network, as for example suggested by Opdam et al (2002).

The first conservation options that should be considered for any habitat patch relate to improving the quality of the existing habitat and the viability of their species' populations. This may alleviate requirements for increasing connectivity. In particular, increasing the area of small habitat patches may increase population sizes, thereby reducing the risk of chance extinction and other threats associated with small populations. Such populations will become less dependent on functional connectivity and may be more resilient to fragmentation. Similarly, improvements in habitat quality may increase survival rates and reproductive productivity such that sink populations, which are dependent on immigration from functionally connected source populations, become source populations themselves.

This may in turn benefit other functionally connected populations, especially where they operate as a metapopulations (see Chapter 3).

Measures to improve the quality of existing habitat patches include:

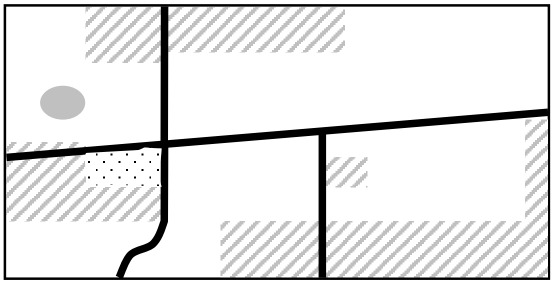
- Increasing the size of core areas, or amalgamating core areas with high quality habitats, to increase population sizes and habitat heterogeneity;
- Improving habitat and species management within core areas; and
- Reducing environmental pressures on core areas (e.g. from disturbance or pollution) by regulating land management practices within buffer areas (zones) and, where necessary, beyond.

If connecting structures are needed to increase functional connectivity between core areas (such as Natura 2000 sites) and other habitat patches then careful consideration needs to be given to the selection of options. As illustrated in Figure 6.2 and noted by many landscape ecologists, there are often many options for increasing habitat connectivity (Bennett; Opdam & Wiens 2002). The effectiveness and efficiency of connecting structures will vary according to the habitats and species being targeted and the landscape configuration present (i.e. the spatial distribution and quality of habitat patches, the properties of the surrounding habitat matrix and the possible presence of barriers to movement). For example, some woodland species may not use narrow woodland corridors because they are dominated by edge habitats, which they avoid. However, they may be able to utilise large stepping stones of habitat that are within their dispersal distance. Other species may benefit from wider scale measures that aim to increase the permeability of the intervening habitat matrix (i.e. to reduce its hostility), through measures such as reductions in agricultural intensity (use of fertilisers and pesticides), predator numbers and water pollution.

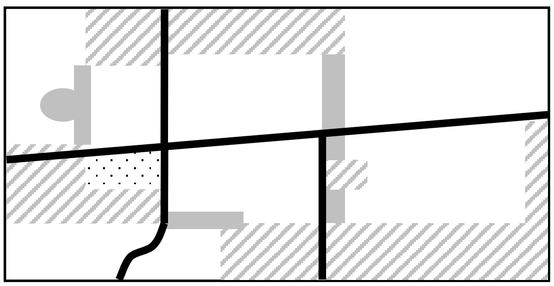
Figure 6.2. Options for improving connectivity within a fragmented landscape

Key: Shaded = semi-natural forest. Hatched = Intensive managed forest. Stippled = semi-natural grassland with scattered trees (i.e. parkland). Unshaded = agriculturally improved grassland.

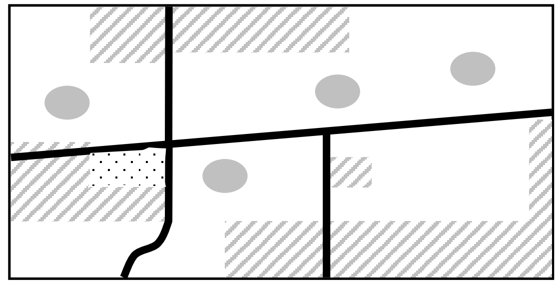
a. Current fragmented landscape



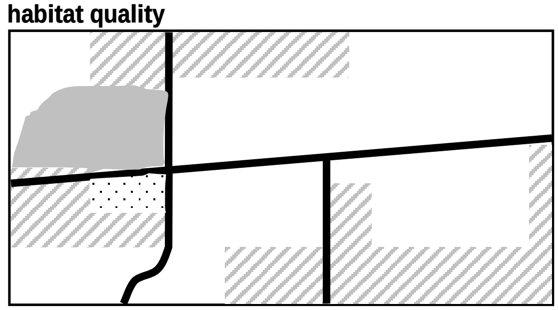
b. Link habitats with linear forest corridors



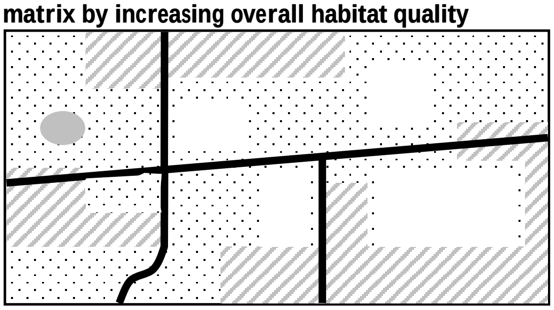
c. Increase habitat density and create stepping stones



d. Amalgamate habitat patches and improve habitat quality



e. Increase the permeability of the surrounding matrix by increasing overall habitat quality



6.2.4 Assessment of connectivity requirements for species that need to move in response to climate change

Consideration of future connectivity requirements should also be carried out for species that may need to move as a result of climate change (see Figure 6.1 and Chapter 5). These species may initially benefit from connectivity measures, as described above, that aim to reduce current impacts from fragmentation. Such measures may increase the resilience of habitats and species populations to climate change (e.g. by improving habitat quality and improving the viability of populations) such that they remain in their current locations.

However, the scope for increasing resilience is likely to be limited for habitats and species in many locations. Therefore, as climate change pressures grow the long-term survival of a habitat patch or species population may become unsustainable in its current location. It may therefore become extinct if it does not move, at least in part, to another more suitable location. Connectivity measures may, therefore, be increasingly required to facilitate adaptation by allowing habitats and species to move in response to movements in suitable climate space. In this situation the population relocates (in part or wholly) to another place.

Allowing and encouraging species to move in response to climate change will require some greater flexibility in protected area management. In particular, greater emphasis may need to be given to maintaining habitats and populations across biogeographic areas, rather than preservation of species and habitats within specific fixed locations.

In accordance with the general principles discussed above, connectivity measures that aim to facilitate habitat and species movements in response to climate change should be assessed and planned on a case-by case basis, taking into account the latest projections of climate change and response models etc. Nevertheless, the following generic measures to assist movements in response to climate change have been suggested (Bennett 2003; Hobbs & Hopkins 1991; Noss & Daly 2006) and should be considered, in addition to conserving currently unfragmented landscapes:

- Maintaining habitat linkages parallel to latitudinal, altitudinal and coastal-inland gradients.
- Minimising barriers to dispersal.
- Maintaining the continuity of species' populations across their present geographical ranges.

However, large-scale measures which aim to create extensive networks of habitat corridors aligned with anticipated climate changes are unlikely to be effective or realistic, particularly in already highly fragmented landscapes.

6.2.5 Integration of connectivity measures

As described above, the most cost-effective means of meeting functional connectivity requirements vary according to the species and habitats involved and the location. Connectivity measures therefore need to be initially planned on a species-by-species and location-specific basis. However, the results of these assessments and plans for species-specific action can be amalgamated (e.g. by GIS over-lays) so that integrated measures can be identified and implemented. This can be achieved through the development of a combined ecological network (see Section 6.3 below), which incorporates the connectivity needs of all key species, or by identifying common measures that can be applied to the wider habitat matrix (see Section 6.4).

Recommendations

To be effective, connectivity conservation measures for species and habitats of Community interest need to be based on species-specific or habitat-specific specific plans, which incorporate assessments of existing and required functional connectivity and options for overcoming inadequate connectivity. It is recommended that these connectivity plans should

1. Target those species and habitats of Community interest that are known, or suspected, to be at a high risk from fragmentation, especially if they are also threatened by the added impacts of climate change.

2. Evaluate functional connectivity on the basis of the best available information complemented by additional rigorous scientific studies and modelling where necessary and feasible, rather than purely expert-based approaches. Functional connectivity models should be based on empirical data and take into account the properties of the intervening landscape and each species ability to move through it.

3. Consider connectivity measures as part of a range of possible actions. Increasing connectivity should not be seen as a substitute for the conservation of large core areas of habitat. Instead connectivity features such as corridors should complement extinction-resistant core areas. A high priority should therefore be given to assessing the coherence of the Natura 2000 network for species that are considered to be at risk from fragmentation.

4. Firstly consider options for improving the quality of the existing habitat and the viability of species' populations. This may alleviate requirements for increasing connectivity and increase emmigration, which may help support connected metapopulations.

5. Carefully consider the optimum means of increasing functional connectivity where this is necessary. The effectiveness and efficiency of connecting structures will vary according to the habitats and species being targeted and the landscape configuration present.

6. Evaluate the likely future connectivity requirements of species that may need to move as a result of climate change. This should include consideration of connectivity measures that increase the resilience of the existing habitat and species *in situ*. But longer term measures may need to focus on enabling species and habitats to move in response to changing climatic conditions.

7. Be amalgamated (e.g. by GIS over-lays) and integrated so that common measures can be identified and potentially conflicting requirements resolved. Although connectivity measures need to be initially planned on a species-by-species and location-specific basis, they need to be combined, e.g. through incorporation into ecological networks (see section 6.3 below), so that they can be implemented efficiently.

6.3 Ecological networks

6.3.1 The conceptual basis for ecological networks

The ecological network as a concept and a tool has been developed over the past 30 years with the broad aim of maintaining the integrity of environmental processes (Bennett and

Mulongoy 2006). Although such networks vary in concept and implementation etc, they share two generic goals, namely:

- ‘maintaining the functioning of ecosystems as a means of facilitating the conservation of species and habitats; and
- promoting the sustainable use of natural resources in order to reduce the impacts of human activities on biodiversity and/or to increase the biodiversity value of managed landscapes (Bennett & Wit 2001)‘.

The following elements characterize all ecological networks (after Bennett & Mulongoy 2006):

- a focus on conserving biodiversity at the landscape, ecosystem or regional scale;
- an emphasis on maintaining or strengthening ecological coherence, primarily through providing for connectivity;
- ensuring that critical areas are buffered from the effects of potentially damaging external activities;
- restoring degraded ecosystems where appropriate;
- promoting the sustainable use of natural resources in areas of importance to biodiversity conservation.

It is important to note here that maintaining connectivity within an ecological network does not necessarily require physical connections between all its components. As discussed previously in this document, it is now widely recognised that the key requirement is the maintenance of functional connectivity. Functional connectivity may be enhanced by a number of means (see Section 6.2.3) such as improving habitat quality, reducing inter-patch distances or (as described in the next section) and increasing the permeability of the landscape matrix.

Typically ecological networks comprise the following components (Bennett & Mulongoy 2006; Jongman & Pungetti 2004), which reflect their existing and potential ecological importance and functions (and the terminology descriptions in Section 3.1):

- **Core areas**, are areas of high ecological quality and conservation interest, and therefore should be where the conservation of biodiversity takes primary importance. They normally include all protected areas, but often other areas of high ecological quality as well.
- **Corridors**, which aim to maintain vital functional ecological connections between the core areas. These are often physical linkages, and may vary from narrow linear corridors (such as watercourses or hedgerows) to broad landscape corridors. But they may also consist of functionally connected corridors of habitat patches that act as stepping stones in the wider landscape (habitat matrix). The term ‘Connecting Structures’ is also often used to refer to linear structures and stepping stones in the landscape that have a connectivity function (COM 2005). Corridors may sometimes be referred to as ‘greenways’, especially when they link urban areas with the wider countryside.
- **Buffer zones**, which aim to protect the network from potentially damaging external influences by limiting acceptable landuses.
- **Sustainable-use areas**, which according to Bennett and Mulongoy (2006) are ‘where opportunities are exploited within the landscape mosaic for the sustainable use of natural resources together with maintenance of most ecosystem services’. However, this is misleading as many core areas, corridors and buffer zones will also be under some form of natural resource use (e.g. agriculture or forestry), which should also be sustainable (though it may not be). Sustainable-use areas may

perhaps be better described as areas with less important ecological values (including functions) that should be primarily managed for broader ecosystem services rather than traditional nature conservation needs. Nevertheless, it should be borne in mind that such areas often contain important populations of threatened or declining species of conservation importance (e.g. farmland birds and rare arable plants) that require conservation measures in such areas (i.e. the wider environment). Furthermore, as described in the next section, measures which improve the quality of the overall landscape, including sustainable-sue areas as defined here, can help maintain and restore functional connectivity.

Another common component of ecological networks is provided by 'nature restoration/creation areas' which can be defined as areas with a high potential to develop into valuable habitats (COM 2005). They are often identified as a means of increasing, amalgamating or connecting core areas, such as in the National Ecological Network in the Netherlands (Jongman & Kristiansen 2001).

Much of the rationale for the development of ecological networks is derived from scientific studies of population dynamics and island biogeography (as described in Chapter 3.1.2). Subsequently the concept has moved from scientific research to a conservation policy planning tool and consequently there are few scientific studies of the efficacy of ecological networks *per se* within the scientific literature. Although considerable data exist on how species use habitats and the impacts of landscape structure on population dynamics, data concerning the use of corridors as connective structures is equivocal (see Box 6.1). Species need to be able to move through landscapes either for dispersal or migration and this movement is undoubtedly important for maintaining viable populations. However functional connectivity is species-specific (Taylor et al 2006), and therefore the structures that can provide connectivity for one species may be functionally useless to others. As discussed previously, there are also potential risks from increasing connectivity through the creation of new corridors (see Box 6.1).

In becoming a policy and planning tool, ecological networks have provided a framework for the integration of sectoral land (and sea) use policies to support and enhance ecological integrity. This framework is inherently scale-free and has therefore been applied from local to pan-European levels. However, the challenges of implementation increase as the scale of the concept is increased. Thus an open question remains as to how the vision of a series of inter-connected landscape elements can be transformed into reality on the ground.

Box 6.1. Evidence of the effectiveness of corridors and stepping stones as measures for increasing connectivity

The evidence that corridors provide benefits by increasing connectivity, rather than simply by providing additional habitat, are equivocal, largely because of the practical difficulty of distinguishing between these two effects and because of methodological shortcomings in previous research. From a review of the published literature up to 1994 it was found that many studies demonstrated that animals and plants prefer to move along corridors rather than cross the matrix habitat, but an approximately equal number found no detectable effects and few, if any, showed that recolonisation would not have occurred without corridors (Dawson 1994). Dawson could find no studies that conclusively demonstrated that corridors act as conduits that prevent extinctions in patches, possibly because few were sufficiently rigorous to demonstrate unambiguous advantages. Overall, Dawson concluded that corridors:

1. 'Sometimes allow individual animals to survive by allowing them access to sufficient habitat to meet their needs;
2. May maintain populations of some animal and plant species by replenishment; however, most species probably fail to use a corridor or can cross the gaps between patches of habitat adequately without its aid; and.
3. Can serve the needs of some migratory animals in their seasonal movements'.

Others have come to similar conclusions (Davies & Pullin 2007, Donald 2005, Donald & Evans 2006, Hobbs 1992, Spellerberg & Gaywood 1993). For example (Wiens 1995) suggested that the 'evidence that species do depend on corridors for their movements or that corridors have clear conservation value … is limited and equivocal'. Little evidence was also found of the potential benefits of corridors in relation to movements required as a result of climate change (Davies & Pullin 2007, ITE 1994, Wiens 1995).

Some studies have found some evidence of benefits from corridors. For example, Gonzalez et al. (1998), have demonstrated significant effects of corridors in preventing metapopulation extinction by providing an immigration 'rescue effect', and Mech and Hallet (2001) used genetic methods to argue that corridors increase connectivity for specialist mammals. Beier and Noss (1998) found convincing connectivity benefits of corridors, but in only around half of all published studies, largely because too few studies have included all the necessary demographic parameters. More recently a review by Debinski and Holt (2000) suggested that although the predicted positive relationship between species richness and fragment size is rarely apparent in empirical data from patches of natural habitat in fragmented landscapes, there is a consistent agreement across many studies that increasing connectivity increases species richness, and that movement is related to connectivity.

Despite these studies, it still remains unclear whether increases in movements and species richness are the direct result of connectivity, or simply because corridors provide additional habitat area. Furthermore, Haddad and Tewksbury (Haddad & Tewksbury 2006) note that the effects of corridors on population viability is little studied and the empirical understanding of the effects of corridors on community structure and diversity is still in its infancy. Although they find that support for corridor effects on population is growing, especially for smaller taxa with short generation times (because these are easier to study), there are many caveats.

Although there is little clear evidence that corridors directly provide clear population benefits, it might be prudent to assume that corridors should be maintained in accordance with the precautionary principle. This seems particularly prudent given the difficulties associated with demonstrating their impacts. Consequently Beier and Noss (1998), reviewing the complexity and intractability of this issue, suggest that 'those who would destroy the last remnants of natural connectivity should bear the burden of proving that corridor destruction will not harm target populations'. On the other hand, in the absence of conclusive evidence of the functional benefits of corridors, the costs of establishing them need to be compared critically against the costs and potential benefits of alternative conservation approaches (Simberloff et al. 1992).

There are a number of MEA and other policy initiatives that support the use of Ecological networks as a conservation tool, particularly in Europe, as listed below (some of which have been outlined in Section 1.2):

- Global: Convention on Biological Diversity, Ramsar Convention, Bonn Convention
- European: Pan-European Biological and Landscape Diversity Strategy (PEBLDS) governed by the Council of Europe, European Union Habitats Directive, Bern

Convention, European Landscape Convention, Alpine Convention, Carpathian Convention, Barcelona Conventions
- National: national legislation and policy
- Sub-national: regional legislation and policy (e.g. Federal States).

6.3.2 How have ecological networks been identified?

A wide variety of methods have been used to develop ecological networks (e.g. see Bennett 2003; Hilty et al. 2006; Jongman & Kristiansen 2001; Noss & Daly 2006) and it is beyond the scope of this report to review them in detail. The major differences in methodology tend to appear with the scale at which the ecological network is identified and with the immediate objectives of the ecological networks which can vary between Member States. In general terms there are two broad approaches based either on landscape structure (or metrics) or species' landscape ecology, which can be characterised as the difference between structural and functional connectivity respectively. Approaches that are based on structural connectivity are generally easier to implement but make fundamental assumptions which in many cases artificially inflate the importance of structural elements in maintaining functional connectivity. The negative impacts of this approach become more apparent the more detailed and site specific the network becomes. A further result is that networks based on structural components tend to identify one ideal type of ecological network, whereas this is biological speaking unrealistic (Watts et al. 2005, Catchpole 2006). Therefore structural approaches may have a role in the identification of networks at a regional to continental scale, but at the sub-national level approaches should be based on functional connectivity (Humphrey et al. 2005).

Approaches to identifying networks based on structural elements include the Dutch ecological network and the Flemish ecological Network. In Germany, the Federal Agency of Nature Conservation has coordinated a project to identified nationally important areas based on both habitat characteristics and the needs of a series of focal species (i.e. those most in need of connectivity) (see also Annex 2).

Within the UK a common approach amongst England, Northern Ireland, Scotland and Wales has been developed to produce a pan-UK ecological network based on functional connectivity as assessed by 'least-cost path analysis' (Adriaensen et al. 2003; Bunn et al. 2000; Catchpole 2006; Watts et al. 2005).

Approaches to identify networks based on functional connectivity tend to develop quantitative models based on a focal species approach that use generic characteristics derived from a series of focal species. As described in Chapter 5, the ability of a species to move through a fragmented landscape depends on a suite of traits such as dispersal ability and individual area needs (Vos et al. 2001). The focal species approach uses these traits to model the permeability of a landscape to different species as measured by the 'ecological cost' of movement, which is the probability of movement through the surrounding landscape matrix of a particular structure (Humphrey et al. 2005). The models then try to minimise the cost of moving through the landscape. Importantly these approaches do not advocate a single optimal landscape structure. Examples of this approach include the LARCH model developed in the Netherlands. LARCH uses landscape indices which are scaled according to the spatial requirements of a species. Bruinderink et al. (2003) used this tool to identify an ecological network for red deer (*Cervus elephus*) in Belgium, Netherlands and adjacent areas of France and Germany. The resulting maps identify core areas, areas suitable for recolonisation (i.e. those that could support viable populations) and the degree of connectivity between sites. Similar approaches have been applied in a number of cases in the UK including the development of a habitat network in Cheshire (Van Rooij et al. 2003), Wales (Watts et al. 2005) and Scotland (Ray et al. 2004).

Possibly the most data intensive approach to the identification of ecological networks is to create spatially explicit population models which simulate the lifecycles of individuals or populations in specified areas (Humphrey et al. 2005). Although these approaches provide a more realistic representation of the modelled habitats, the methods have outstripped the field data required to build them (Humphrey et al. 2005). In a recent review of such approaches, Noss and Daly (2006) concluded that initial, opportunistic or subjective approaches based on expert opinion and current knowledge are not always inferior to more technical approaches (e.g. modelling) but they are less reliable and more open to criticisms. Noss and Daly therefore suggest that more use should be made of quantitative habitat and population modelling, combined with extensive field studies, to make corridor design more reliable and scientifically defensible.

6.3.3 How have ecological networks been implemented in practice?

Despite the scientific challenges, the implementation of ecological networks is often constrained by practical and socio-political issues. In particular, securing adequate organisational capacity, human resources, funding, land ownership and access is often a major challenge to the implementation of ecological networks (Bennett 2003; Bennett & Mulongoy 2006).

Not surprisingly, given the above, the methodologies used vary greatly between countries and even regions (Jongman & Kristiansen 2001). For example, the Belgian Regions of Flanders, Wallonia and Brussels have different ecological network processes, making it difficult to compare ecological networks or to even embed networks at one level with those at a higher level. Some countries view their Natura 2000 network as analogous to an ecological network (e.g. Sweden) and others have developed separate ecological network processes (e.g. Germany). There are also sometimes different proposals for ecological networks for the same regions, for example as a result of separate statutory and NGO initiatives.

Some countries, (e.g. Germany and the Czech Republic), have established the basis for ecological networks within national legislation and others through national and/or sub-national policy, (e.g. the Netherlands and the Flanders region of Belgium). Although legislation provides a ‘hard’ legal basis for the implementation of measures, in reality it does not provide a guide to the countries with effective and implemented ecological networks. This is then followed by legislative or policy documents that set out the strategic objectives of the network, for example the Slovak Act on Nature and Landscape Protection introduced a system called the ‘Territorial System of Ecological Stability’ (TSES), defined as ‘an integrated structure interconnected to other ecosystems, their components and elements, which ensure a diversity of life conditions and forms in the landscape’ (UNEP, 2000). This introduced the concept of ‘biocorridors’ as one of three landscape elements essential to biodiversity conservation. In Lithuania, the Law on Protected Areas introduced the National Nature Frame that would include an ecological network. At this stage the planning process starts where the core areas and connective structures are identified. Most of the countries that have declared an intention to develop ecological networks have got to this stage. However implementing networks on the ground has proven more difficult. (See Annex 2 for more information).

Depending how the ecological network concept is implemented, the length of time required to establish the structure and regulations for implementation at the local level can be extensive. For example Estonia implements its national Green Network through the framework of the Planning and Building Act. This required schematic maps at the national level and then the definition of environmental conditions for the development of land-use and settlement structures at the county level. By 2006, all 15 counties of Estonia had prepared a map of ecological networks to a scale of 1:50,000 as one of the layers of thematic spatial planning. Also larger towns (Tallinn, Tartu, Pärnu) are compiling a spatial plan of the Green Network.

Therefore few countries in Europe are yet to extend implementation of the concept beyond priority setting and indicative maps and the degree of implementation of ecological networks varies considerably. The National Ecological Network of the Netherlands was initiated in 1990 and has been supported by national funding mechanisms since. The network has to be completed by 2018 and involves the integration of the network into national spatial planning policy. However the pace of implementation has slowed in recent years. Other networks are at an earlier stage of development, a ecosystem based network along the eastern bank of the Meuse river in the Netherlands has been planned and should eventually consist of approximately 1,975 ha of land, of which about 35% will be under stewardship agreements with local landowners. The province of Barcelona provides one of the few examples of an ecological network that was developed and integrated with spatial planning regulations to determine where infrastructure developed within the region can take place. The SITxell system of the provincial administration of Barcelona currently protects up to 70% of land from development, identifies habitats for restoration and aims to make transport infrastructure more permeable. Some areas have been specially protected because of their key role for connectivity in the region. (See Annex 2 for more information).

In Germany the ecological network is currently under development. However as nature conservation is implemented at the federal state level (Länder), the aim of the national tool is to provide a tool that can guide infrastructure development at a national level and assist federal states to identify areas of national and regional importance. But in most other regions ecological networks either remain as maps, guidance documents or are currently under development. There is therefore an urgent need to review the different implementation of ecological networks within Europe and compare their designation either side of borders. (See Annex 2 for more information).

6.3.4 Transboundary cooperation for ecological networks

Relatively few species have their entire range within one country in Europe. Therefore most species populations cross national or federal borders, however many conservation initiatives stop at these administrative barriers. Increasingly in Europe an emphasis is being place on transboundary cooperation for nature conservation. Importantly connectivity needs should be assessed in border regions and cooperation should be established when there it is clear that populations need measures that cross borders. Most transboundary or transnational initiatives involve shared ecosystems which in Europe are predominantly associated with mountain (e.g. Pyrenees, Alps and Carpathians) or river (Rhine, Danube, Sava) systems. Some such as the Commission for the Protection of the Rhine (ICPR) respond to specific threats, which for the Rhine was extreme pollution and degradation of the river quality. The current implementation plan, Rhine 2020 focuses on the continued restoration of the main stream as a backbone of the Rhine ecosystem and its main tributaries, the functioning of the Rhine as a habitat for migratory fish and the preservation and extension of areas of ecological importance along the Rhine and in the Rhine valley for autochthonous plant and animal species (ICPR 2001).

Another example is provided by the tri-partite cooperation between Belgium, the Grand Duchy of Luxembourg and Netherlands, which agreed a common basic transboundary ecological and landscape plan. The plan is being implemented by local authorities and aims to apply the concepts developed in the Pan-European Biological and Landscape Diversity Strategy to this transboundary area. It also aims to develop a joint approach to transboundary environmental issues in Belgium, Luxembourg and the Netherlands. By doing this it should provide scope for generating practical projects that can strengthen environmental relationships between the three partners. On this basis, two drafts are being prepared simultaneously, one involving the Flemish Region and the Netherlands, and the other involving the Walloon Region.

The Pan-European Ecological Network (PEEN) developed under PEBLDS aims to develop a ‘physical network of core areas and other appropriate measures, linked by corridors and supported by buffer zones, thus facilitating dispersal and migration of species’ (PEBLDS Strategy text). In reality PEEN, which has developed overview maps for Central, Eastern and South Eastern Europe (with Western Europe soon to be completed) provides the basis for a unifying framework to promote synergies between national and sub-national approaches. One of the important functions that PEEN can serve is to draw attention to the need for transboundary cooperation between connectivity measures. National and sub-national initiatives tend to limit their focus to national boundaries, whereas the dispersal of species across borders is obviously an important consideration.

6.3.5 Examples of connectivity initiatives from outside Europe

The development of ecological networks has been driven within in Europe as a response to the extreme levels of habitat fragmentation found in the continent. In other regions of the world landscape connectivity measures have primarily focussed on large-scale corridor or greenway initiatives (Bennett & Mulongoy 2006). Greenways are differentiated by having multi-use objectives such as conservation and recreation. Examples of such initiatives include the WildCountry Initiative established by the Wilderness Society in Australia in 1997, the American Wildlands Project launched in North America in 1992, and the Northwest Florida Greenway Project.. In most cases these initiatives have acted as over-arching strategic tools that steer a range of different measures and activities to support conservation and habitat connectivitiy on the ground. For example the Gondwanaland Link, which forms part of the WildCountry Initiative has implemented specific measures including the preservation of large intact areas of core habitat, the re-vegetation of degraded areas, land purchases, mixed production land use with restoration of native vegetation, and communications and awareness-raising with local communities and the private sector.

An important lesson from these large-scale initiatives is that they provide an overview of the different landscape elements within their range to support the targeting of specific projects. This provides a coherent understanding of where projects which may have different primary objectives could be placed. Such an approach is missing at the European level, although this framework role could be provided by PEEN for connectivity. A further benefit of this coordinated approach is that these initiatives can highlight the importance of transboundary cooperation.

Greenways are a concept more commonly utilised in the USA. These are continuous corridors linking specific sites or ecosystems and can vary considerably in scale but are usually managed for both conservation and recreation. In the US this approach is most often applied to land surrounding urban areas. The initiatives are often accompanied by targeted land acquisition programmes that purchase the land to be protected and managed. Examples include the Northwest Florida Greenway Project which is a cooperation between the Nature Conservancy, the US Department of Defence and the government to protect a corridor that connects Eglin Air Force Base and the Apalachicola National Forest. This initiative forms part of Florida's land acquisition programme 'Florida Forever' which since its inception in 2001 has used $1.8 billion (1.4 billion EUR) to protect 216,713 hectares of land.

Other examples include the Confluence Greenway, which aims to protect a 500 km2 area between Missouri and Illinois, the Maryland Greenprint Program and the Hudson River Valley Greenways. Although these initiatives use a range of tools including those widely applied in Europe through management projects, restoration, communication and education; there is an interesting difference in that US projects often place a focus on land acquisition and easements. Easements are the transfer of usage rights between actors. For conservation they represent the transfer of rights to manage land in a certain way, i.e. from economic use to conservation, from the owner to another organisation. The landowner retains legal ownership and usually continues to manage the land. The organisation that receives the easement is responsible for monitoring this management. The owner can receive significant tax incentives for making an easement but the land value can be negatively affected.

Recommendations

It is recommended that ecological networks should aim to maintain functional connectivity (and not necessarily just structural connectivity), and where necessary increase it, whilst avoiding potentially significant detrimental impacts. To achieve this it is suggested that ecological networks should:

1. Ensure that they have clear objectives, agreed with all key stakeholders, which should include contributing to the ecological coherence of the Natura 2000 network and the wider maintenance and restoration of FCS amongst habitats and species of Community interest.

2. Give a high priority to reducing impacts on Natura 2000 sites by improving habitat conditions within them and by reducing impacts from surrounding areas (e.g. upstream in river catchments).

3. Take into account and support other nature conservation policy drivers, including the EC Biodiversity Communication and the recommendations contained within its Annex 'EU Action Plan to 2010 and Beyond', national, regional and local biodiversity action plans.

4. Indicate priorities for actions such as habitat corridor creation measures, which go beyond existing legal obligations (e.g. protection of Natura 2000 sites), to facilitate the effective and efficient targeting of resources. Prioritisation should reflect global, EU, biogeographic, national and local priorities for habitats and species, taking into account the conservation status of habitats and species and the biogeographic importance of habitats and species populations within the network.

5. Contribute to the conservation of habitats and species populations in the wider environment (i.e. outside Natura 2000 sites), in order to help deliver the overall objectives of the Birds and Habitats directives. Ecological networks should not lead to polarised nature conservation planning where ecological considerations are restricted to part of the landscape.

6. Focus on the maintenance and enhancement of functional connectivity (see Chapter 31) where this is necessary to maintain or deliver FCS for both habitats and species. The requirements for, and location of increased connectivity measures should take into account the key principles outlined in Section 6.1 and be ascertained through scientific studies that are based on the best available data. In particular, they should:
   a) avoid assumptions that habitat patches are not functionally connected if they are not structurally connected;
   b) take into account the differences between dispersal distances of key species groups and how these differ according to the landscape matrix surrounding patches.
   c) identify, if feasible, functional networks with species populations that are too small to be viable, such that they require measures to increase their quality or connectivity.

7. Consider all options for increasing connectivity (see Section 6.2.3 and Figure 6.2) and select the most effective and efficient means of increasing connectivity. Networks should not focus exclusively on physically connecting habitats, but should also consider improving the size and quality of core habitats, the creation of new habitat patches as stepping stones and increasing the permeability of the landscape matrix (see Section 5.3 below).

8. Give careful consideration to the effectiveness and efficiency of developing new ecological corridors (see Table 6.1 and Box 6.1). General policies of connecting habitat blocks with relatively narrow linear corridors of moderate quality habitat (e.g. hedgerows, forest or grassland strips) may be ineffective in increasing functional connectivity for many species of conservation importance. Their efficiency and cost-effectiveness should therefore be considered with respect to priority nature conservation objectives

9. Identify areas of existing habitat that may be of high connectivity importance, irrespective of their direct biodiversity importance. For example parks, disused railways, canals and rivers in urban areas may hold few species or habitats of importance, but may provide important migration, dispersal or foraging routes.

10. Carefully consider the potential risks (see Table 6.1) of increasing connectivity during the development of ecological networks. Proposals to connect sites of high nature conservation importance that have been isolated for long periods of time should be treated with particular caution as immigration may cause 'outbreeding suppression' and lead to the loss of genetic variation among subpopulations.

11. Involve all key stakeholders from an early stage and provide clear and costed action plans for implementing and sustaining the network in long-term. Care should be taken to avoid the development of overly ambitious networks that may cause concern amongst affected communities or which are likely to be difficult to implement as a result of costs and land acquisition requirements.

12. Be integrated with national, regional and local spatial planning systems, so that areas that are identified as having an important connectivity function are identified in planning documents and protected accordingly. Priority areas for increasing connectivity through nature restoration / creation areas should also be clearly identified and incorporated into spatial plans so that they may be targeted for suitable development compensation schemes identified in EIAs and appropriate assessments.

13. Identify priority areas in ecological networks that may be targeted for habitat management, enhancement and restoration through agri-environment schemes and forest schemes under the European Agricultural Fund for Rural Development (see Sections 7.3 and 7.4) and other EU funding schemes (e.g. LIFE nature, European Fisheries Fund and the Structural Funds) and national and regional funding.

14. Include clear quantified performance targets (directly linked to their objectives) that are objectively and systematically monitored over the long-term and reported to all stakeholders.

6.4 Improving the ecological quality of the overall landscape

Whereas ecological networks advocate a targeted planning approach that focuses on defined core areas and connectivity features, an alternative, or complementary approach to increasing connectivity, is to implement measures that improve the general ecological quality of the overall landscape. This view is based on the concept that a landscape is a mosaic of habitat patches that are utilised by a species, within a matrix of surrounding habitat that is, to some degree, unsuitable or inhospitable to the species (see Section 3.1). In the past theoretical studies and island biogeographic theory made a clear distinction between homogenous areas of high quality patches surrounded by inhospitable matrix. However, this is not reflected in reality where both habitat patches and the surrounding matrix are rarely homogenous and where there distinctions between habitat patches and the surrounding matrix are often unclear (Donald & Evans 2006, Ewers & Didham 2006, see Box 3.2). It is now recognised that the structure of the surrounding matrix affects many factors such as movement between patches (Ricketts 2001, Stevens et al. 2004, 2006), colonisation rate (Bender & Fahrig 2005), edge effects (reviewed in Ewers & Didham 2006), breeding success (Lahti 2001), as well as species composition, abundance and persistence (Tubelis et al. 2004). Within this context improving the ecological quality of the overall landscape refers to management actions that increase the permeability of the surrounding habitat matrix for species in order to increase functional connectivity.

As discussed above, species show significant differences in their preferences for using connective structures and matrix habitat (e.g. Ricketts 2001). In terms of matrix structure, both the permeability of the patches themselves and the permeability of the boundaries between patches will determine the degree of impact the matrix has on species (Stevens et al. 2004). In this context we can therefore consider how management actions can be directed to matrix habitat to improve its permeability to species and combat the effects of fragmentation.

Most studies of the effects of matrix habitat on species have been based on forested landscapes where there can be dramatic changes between forested and de-forested or afforested areas. However in Europe, the most widely felt impacts came from the conversion of natural grasslands to agriculture and then the subsequent intensification of agricultural practices on those areas, which had more severe impacts than the initial conversion (Donald 2004). Agri-environment Schemes (AES) provide possibly the most important approach that can be used to 'soften' or improve the permeability of the agricultural matrix to species (Donald & Evans 2006, see Section 7.3.2). Actions undertaken within AES generally improve plant species diversity, extensify production, conduction biodiversity friendly management and improve connective elements (e.g. hedgerows and ditches). However, for these to provide a truly effective tool for functional connectivity they have to allow for targeted actions within a broader landscape. This approach has been adopted within the National Ecological Network in the Netherlands where protected areas are integrated with important agricultural areas and wetlands. More information on these examples is provides in Chapter 7 and in country case studies included in Annex 2.

As climate change causes range changes in species (see Chapter 4), focussing management attention and schemes such as AES on matrix habitat is likely to improve the ability of species to adapt to shifting conditions. For species this type of action is most likely to benefit those with intermediate dispersal ability, i.e. small to medium sized mammals, amphibians, reptiles and some invertebrates (e.g. butterflies; Ricketts 2001, Sutcliffe et al. 2003, Donald & Evans 2006).

Recommendations

It is clear from recent scientific studies and experiences gained from conservation initiatives (e.g. ecological networks and agri-environment schemes) that the potential for using habitat matrix management to improve functional connectivity should be further explored within Europe. However, although there is a good understanding of the impacts that the surrounding habitat matrix can have on species, there is less knowledge concerning relative differences between matrix configurations on individuals and how they move between patches. Furthermore, greater knowledge is needed concerning landscape features that can improve landscape permeability for broad taxonomic groups.

Despite these limitations on knowledge, some recommendations for improving functional connectivity in the wider environment could be given. These principally involve increasing the sustainability of land-use management, therefore it is recommended that Member States should:

1. Reduce the use of fertilisers and pesticides (especially broad-spectrum persistent pesticides), e.g. by promoting integrated farm management, agri-environment measures and organic farming.

2. Retain patches of semi-natural habitat in the landscape (e.g. semi-natural grassland and scrub within farmland habitats, deadwood and boggy patches in forests).

3. Promote wildlife-friendly management of connectivity elements (e.g. hedgerows, ditches) as a means of improving general landscape permeability.

4. Identify priority areas of matrix habitat for restoration to increase the permeability of the landscape to species movement.

5. Identify species most in need of matrix restoration and the resources they will need in matrix landscapes and prioritise measures to support this restoration.

6. Identify options for the adaptation of agri-environmental schemes (AES) and the mechanisms used to target them to improve the continuity between farmed and non-farmed habitats (see further recommendations in Section 7.3).

7. Integrate predictions resulting from habitat fragmentation and climate change projections into the deployment strategies for AES (Donald & Evans 2006).

8. Implement sustainable forest management approaches to soften the matrix between highly managed forests and semi-natural and natural forests.

7 MEASURES THAT CAN INCREASE CONNECTIVITY

This Chapter provides a description of key practical measures, at EU and national levels that have been or can potentially be used to prevent fragmentation and improve connectivity within landscapes. They can contribute to the creation of ecological networks and their components or to otherwise increase functional connectivity. The Chapter demonstrates how different sectoral measures can be applied to implement the approaches described in Chapter 5 above. In this context, the chapter also provides information on practical examples at place in Member States. In addition, a number of recommendations are provided to support the application of identified measures.

7.1 Designation and management of protected areas, including buffer zones and ecological corridors

The designation and management of protected areas clearly provides an important means of conserving sites of high conservation importance (i.e. core areas) and ecological corridors and other features that provide functional connectivity (irrespective of whether or not they are identified within a proposed ecological network).

As described in Section 1.2.2, the Habitats and Birds directives provide the legal basis for the designation and management of protected areas of EU nature conservation importance (i.e. as Natura 2000 sites). The directives are implemented through transposing national legislation in each Member States'. In addition to Natura 2000 sites, Member States' national and regional legislation enables the designation of protected areas of national, regional, and local importance, including sites that may be of broader environmental and cultural interest.

Once designated as SACs and SPAs Member States must establish necessary conservation measures, e.g. appropriate management plans, to maintain or to restore FCS of the site (Article 6(1) of the Habitats directive). Additionally, according to the Habitats directive's provisions the Member States are already obliged to prevent any deterioration of sites and disturbance of species from the time of their initial proposal by the Members State's as Sites of Conservation Interest (SCIs) through out the designation process (Articles 6(2), (3) and (4)). These provisions also apply to the sites designated under the Birds directive.

The Habitats and Birds directives do not include any specific provisions for the establishment of buffer zones around Natura 2000 sites. However, the requirements related to the prevention of deterioration of sites and disturbance of species provide for a number of measures to be carried out outside Natura 2000 sites. In particular, according to the Habitats Directive any plan or project not directly connected with the management of the site but likely to have a significant effect thereon is to be subject to appropriate impact assessment of its implications for the site in view of the site's conservation objectives (Article 6(3)) (for impact assessments, see also Section 6.1.3 below). In this context, the outcomes of an impact assessment might point towards the establishment of buffer zone around a Natura 2000 site in order to protect the site from disturbances caused by planned activities.

As for corridors and other connecting elements, a number of Habitats and Birds directives Articles (e.g. Articles 10 and 3, respectively) provide for the establishment of specific measures improving connectivity within the network. See Section 1.2.2 for more detailed information.

As regards the implementation, the establishment of national or regional ecological networks and/or development of connective structures as way of improving connectivity between protected areas have been adopted by a number of Member States. See Section 6.3 and Annex 2 for more information (e.g. Belgium, Germany, Lithuania, Slovakia and the Netherlands)

In general, the Habitats and Birds directives provide limited flexibility for Member States regarding the designation of the sites. Consequently, the directives and the Member States instruments transposing the provision of the directives into national legislation provide a solid basis for the establishment of protected areas in the EU. However, the directives provide a considerable amount of flexibility for selecting the management measures both for individual Natura sites and the whole network on national, regional and local levels. As a result, the Member States have the main responsibility in establishing and implementing measures that maintain connectivity within the network. According to the review of the Member States' practises, carried out as part of the development of these guidelines, there appears to be insufficient measures (e.g. legal provisions), for conserving and increasing connectivity within and between protected areas. In addition, even when legal measures are in place their implementation is often inadequate or lacking.

Recommendations

In order to improve ecological connectivity as a part of the designation and management of protected areas, buffer zones and ecological corridors it is recommended that the Member States should:

1. Where necessary, provide appropriate legal protection for connecting elements between nature conservation areas (e.g. corridors or stepping stones identified in ecological networks). An improved legal basis for addressing connectivity would support the current provisions of the Habitats and Birds directives.

2. Ensure that during the management planning process for Natura 2000 sites connectivity and climate change risks are appropriately assessed and addressed. Such assessments should establish the sites' need for functional connectivity with respect to its designated habitat and species features and its role in supporting other sites (e.g. as a key site supporting smaller less viable populations). For example, the management of individual sites can benefit from landscape scale approaches, which take into account the site's relationship with wider habitat networks, as proposed by Opdam et al. (2002). The risk assessment should take into account the likely impacts of future climate change and assess potential threats to designated features from existing and potential habitat fragmentation following possible land use changes etc. Potential threats from increasing connectivity (e.g. invasive species) should also be identified and acted on accordingly. Plans should finally identify actions that should be taken to alleviate threats from existing levels of connectivity as well as from possible land-use changes and likely climate change impacts.

3. Ensure that functional connectivity requirements are fully taken into account when the boundaries of protected areas are considered during the designation of new protected areas. Habitats that have an important connectivity function should be included within the protected area or given some other appropriate form of protection.

4. When necessary, investigate the possibility of enlarging protected sites and amalgamating individual sites to increase connectivity amongst them and to increase their overall resilience (e.g. by increasing the population sizes of vulnerable species). Alternatively, explore the potential of establishing buffer zones around protected areas. Where a site itself cannot be enlarged, or it would be a poor use of resources, buffer zones could be an effective method of offering limited protection to a larger area.

5. Ensure that functional connectivity requirements are fully taken into account in Appropriate Assessments of plans and projects that may affect Natura 2000 sites (under the Article 6(3) of the Habitats directive) and consideration of compensation measures (under Article 6(4) of the Habitats directive). Particular attention should be paid to possible negative effects on the movement of species and the role that the site plays in the context of wider functional networks and, especially, the overall coherence of the Natura 2000 network. Further guidance on appropriate assessments is provided on the European Commission's webpage[23] on Article 6 of the Habitats Directive (European Commission 2000, 2001, 2007).

6. Consider how the establishment of protected areas for landscape, archaeology and other aspects of cultural heritage, could contribute to the maintenance of connectivity between protected areas (e.g. within the protected areas network). For example, old buildings protected for their cultural heritage value might function as resting and/or nesting sites for some species, such as bats.

7. Ensure that appropriate levels of protection are given to sites outside the Natura 2000 network that play an important supporting role in maintaining the coherence of the network and FCS amongst its habitats and species (see for example Opdam et al. 2002 for further guidance. These may include sites of national, regional and local ecological importance that maintain functional connectivity between Natura 2000 sites, e.g. by extending the area of habitat patches, joining habitat patches or acting as stepping stones for migration or dispersal between sites. The role that such sites play in maintaining the coherence of the Natura 2000 network should be evaluated and taken into account in decisions on their protection and management (e.g. in site management plans, Appropriate Assessments and EIAs).

8. Integrate the management of protected areas into broader local/regional socio-economic development. Even though conservation of species and habitats is the main goal of protected area management in a number of occasions well-managed conservation areas also play an important role in providing and maintaining ecosystem services in the area. Ecosystem resilience and the connectivity within landscapes and between protected areas play an important role in this context (See Section 3.3).

9. Develop and implement effective and innovative financial measures for establishing nature restoration/creation areas and connecting structures, where these are required to

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23 http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/specific_articles/art6/index_en.htm

support protected areas. These could include different compensation and land acquisition mechanisms (when needed and appropriate) and funding mechanisms supported by the private sector.

7.2 Land-use planning and control

7.2.1 Spatial planning policies and regulations

Spatial planning policies, regulations and processes play an important role in conserving protected areas, such as Natura 2000 sites, as well as nationally and regionally protected sites. These include proactive processes such as the preparation of spatial plans, which implement planning policies by identifying favoured areas for developments (e.g. residential expansion) and areas where developments should be avoided or limited. For example, the designation of green belts around towns and cities is a common practice for protecting green space for amenity, landscape and environmental purposes. Planning regulations can also provide an effective mechanism for protecting specific landscape features that have connectivity functions (e.g. the Hedgerow Regulations in England and Wales – see Annex 3 for the UK).

In the EU the issues related to land-use and spatial planning fall under the exclusive competence of Member States. This means that the Community has no legislative powers over Member States' land-use practises. The Community can, however, provide specific guidelines and recommendations that aim to support Community-wide approaches on certain land-use related issues. In the context of nature conservation, the Habitats and Birds directives provide some limitations on the land-use outside the Natura 2000 areas (Article 6 (3) of the Habitats directive, see Section 6.1.1 above).

As regards land-use planning and nature conservation, the EU Biodiversity Action Plan for 2010 and Beyond (COM 2006/216) provides specific targets that aim to improve the integration of aspects related to biodiversity into land-use planning and management practises in the EU. The Action Plan states that from 2006 onwards the negative impacts of territorial plans on biodiversity should be prevented or minimised (Target A4.2). It also specifically stipulates that from 2006 spatial planning should actively contribute to strengthening ecological coherence and functioning (Target A4.3). In this context the Action Plan urges Member States to develop and implement spatial and programmatic plans that support the coherence of the Natura 2000 network and also maintain and/or restore the ecological quality of wider landscapes.

Supporting connectivity through land-use planning strategies and polices can in principle take place two different ways. Firstly, land-use planning processes can be used to actively support the maintenance and establishment of landscape features that improve connectivity, e.g. ecological networks and their different elements. This includes integrating the creation and management of protected areas, buffer zones, corridors and other connecting structures as integral parts of an area's land-use planning strategy (see Annex 3 for Spain, Finland and Slovakia). Secondly, land-use planning and management processes can help to maintain general landscape quality by preventing further fragmentation of landscapes (e.g. preventing construction in existing uniform green areas).

Land-use planning in the Member States can be based on both legislative instruments (i.e. binding instruments, such as Acts and Regulations) and different planning and management approaches adopted at national or regional level, e.g. generally non-legally binding instruments (although some may also have a legal basis). In addition to spatial land-use approaches, maintaining and enhancing connectivity can also be integrated into a number of different sectoral strategies influencing land-use, e.g. transport (see Section 6.2.2 below). In general, spatial plans and regulations provide an opportunity to integrate connectivity related issues into land-use planning and management at different local and regional scales (e.g. establishing and managing ecological networks and their elements and/or addressing issues related to landscape quality).

Spatial plans and associated policies normally indicate the type and boundaries of protected areas and provide guidance on development restrictions that may apply to such areas. Thus they provide policy makers and developers with information that can be used to explicitly identify development opportunities and avoid potential conflicts. Some spatial plans identify areas that may be protected for connectivity functions (e.g. green corridors in urban areas) and may incorporate outputs from ecological network studies (see Chapter 5.2.2). Thus functional corridors may be protected by planning restrictions on areas identified as being important for connectivity in ecological networks. In practice, however, the protection given to such corridors is often relatively low. This may be because it is often difficult to provide evidence of such corridor functions, and thus their importance and efficacy may be questioned by project proponents during planning enquiries etc.

Planning also contributes to the maintenance of connectivity through development control regulations. These include measures such as Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) which help to guide large scale projects and programmes, and individual projects respectively. These are described in Section 6.2.3.

Public participation and consultation play an integral role in land-use planning processes. Stakeholder involvement can also be beneficial for preventing fragmentation and maintaining connectivity within landscapes. For example, enhancing communication between different stakeholders allows the establishment of a joint vision on the local/regional development potential and objectives. This can provide important support for the integration of nature conservation related aspects into land-use planning and management. However, in practice proactive measures are often needed to raise public awareness and their capacity for contributing to planning processes (see Annex 3 Finnish Ruuhka Suomi project).

During the development of these guidelines a review was carried out of land-use planning and management measures in place in Member States. This revealed that, in addition to restrictions on land-use activities influencing Natura 2000 sites included in national laws on nature conservation (e.g. the Habitats and Birds directives' provisions), some Member States had also adopted other legislative instruments that support the maintenance of connectivity within landscapes. For example, in Belgium (Flanders) a specific Decree prevents any further development (urbanisation, camping, tourism etc.) of all dune areas along the coast (see Annex 3 for Belgium Dune Decree). This Decree effectively prevents the use of coastal areas for development projects and allows the government to purchase these areas for restoration. Consequently, the Decree limits fragmentation of the coastal zone and averts further degradation of coastal ecosystems. Similarly, in England and Wales the Hedgerow Regulation prevents the removal or destruction of ecologically valuable hedgerows. This measure helps to maintain valuable habitats and at the same time promotes connectivity for a number of species within the rural landscape (see Annex 3 for the UK Hedgerow Regulation).

Issues related to connectivity, including maintaining and establishing connections between protected areas, play an integral role in a number of land-use planning approaches adopted by Member States. For example, in Slovakia an integrated land-use planning approach has been adopted to guide land-use planning and management at a national level (see Annex 3 for Slovakian LANDEP approach). This approach aims to improve the ecological situation in urban areas and enhance connectivity between small fragmented areas. Similarly, an integrated land-use planning approach has been developed for the Barcelona region in Spain (see Annex 3 for Spanish SITxell project). In Finland the use of all state-owned land is guided by an integrated approach aimed at sustainable use of natural resources. This includes a specific method for landscape ecological planning that also incorporates aspects related to ecological networks (see Annex 3 for Finnish Landscape Ecological Planning approach).

It is to be noted, however, that in order to truly improve ecological connectivity within landscapes, land-use planning approaches should specifically address the functional, rather than structural connections between protected areas. Therefore, general land-use planning approaches, which for example focus on increasing a landscape's ecological stability and resilience, might not actually improve the movement of species in the area. This has been the case, for example, in the Czech Republic where a territorial system of ecological stability (TSES) has been adopted. The TSES objective has been to establish biocentres and –corridors to improve the ecological stability of the landscape. As a consequence, the country's patchy and mosaic landscape pattern, which was largely lost during the second half of 20th century has been, to a certain extent, restored. This has also provided for the creation of landscape elements which are supposed to support ecological connectivity across landscapes. However, instead of aiming at specifically improving functional connectivity with respect to specific species or habitats that need it (see Section 6.2), the TSES has followed a general approach of physically connecting core areas. As a consequence, it is not clear how effective the TSES biocorridors have been in supporting functional connectivity.

Recommendations

Spatial planning policies, regulations and processes are one of the most important tools for avoiding biodiversity losses through habitat loss and fragmentation and other development related impacts. Moreover, planning agreements can provide a number of opportunities to increase connectivity and they may become an increasingly important tool for integrating different connectivity requirements, including maintenance or restoration of landscape permeability, into spatial planning. It is therefore recommended that Member States should:

1. Consider establishing a coherent and comprehensive national framework (e.g. legal and policy instruments) in order to ensure that issues related to ecological connectivity are effectively addressed as an integral part of land-use planning.

2. Integrate EU, national and regional biodiversity conservation objectives and targets into planning policies and regulations and aim to actively contribute to the delivery

of these targets, i.e. clear biodiversity conservation objectives should form an integral part of planning policies.

3. Give a high priority to providing appropriate levels of protection to sites of nature conservation importance (global and EU level to national, regional and local importance) within planning policies and regulations.

4. Incorporate the results of ecological network studies into regional and local spatial plans and similar planning tools. Plans should protect core areas and recognise the ecological value of buffer areas, corridors and other habitats and features that provide functional connectivity between core areas. The location, extent and type of buffers and connectivity features should be carefully considered and should be based on ecological networks (Section 6.3) that incorporate species-specific or habitat-specific assessments of functional connectivity requirements (Section 6.2), and have been identified using sound ecological principles and evidence.

5. Identify (e.g. from ecological network maps and initiatives, when available) areas where enhanced functional connectivity is required and where habitat restoration and creation should be targeted to increase connectivity. This information may then be used to guide habitat compensation measures (planning gain schemes etc), where this is appropriate.

6. Develop and strengthen polices and regulations that reinforce the protection of important ecological features in the wider landscape (such as ponds or areas of semi-natural vegetation) that may have important connectivity functions (e.g. as linear corridors or stepping stones). For example, the UK Hedgerow Regulation and the Belgium Dune Decree are examples of effective mechanisms for protecting important landscape features (see Annex 3).

7. Improve and support the use of existing land-use planning and management tools and/or develop new tools so that nature conservation objectives can be further integrated into land-use planning processes.

8. Enhance and support the participation of stakeholders and the general public in land-use planning processes. In this context, actively support capacity building in relation to the importance and value of biodiversity and ecosystems, including issues related to connectivity. Stakeholder participation enables all relevant aspects and interest, including the ones related to nature conservation, to be taken into account in the planning process. In addition, stakeholder involvement can create synergies that avoid further fragmentation of landscapes and/or improve connectivity. For example, establishing mechanisms for stakeholder participation can assist in coordinating land-use practises carried out by several small private landowners.

9. Recognise that biodiversity conservation requirements will change as a result of climate change, and that planning processes can contribute to climate change adaptation. Therefore, land-use planning should take account of likely future climate changes and ensure that appropriate measures are taken to increase the resilience of ecosystems and species populations. The adopted measures should respond to latest scientific advice that may include, for example, increasing

resilience by enlarging or amalgamating sites and, where necessary, allowing the movement of species in response to future climate change.

7.2.2 *Land-use and management within the transport sector*

In the context of land-use planning and management, the transport sector has a significant impact on landscape ecology within the EU. Roads and railways lead to conspicuous and mostly permanent habitats losses and fragmentation, alter habitat conditions (e.g. hydrological regimes), disrupt patterns of wildlife movement and can be major causes of disturbance and mortality; all of which have connectivity impacts (Canters 1997; Forman & Alexander 1998; Forman et al. 2003; Spellerberg 2002; Trombulak & Frissell 2000). For many species, and particularly invertebrates, roads and railways are insurmountable barriers to movement. Consequently, the transport sector has a major role to play in avoiding further fragmentation of landscapes.

To some extent fragmentation of landscapes due to transport infrastructure can be avoided or mitigated by environmentally sensitive planning, at national, regional and local scales and by implementing specific measures that reduce the barrier effects of roads and railways etc. (Clevenger & Wierzchowski 2006). In the former case, Member States can introduce legal or policy measures that specifically guide the development of transport networks away from areas that are important in the context of biodiversity and nature conservation, e.g. Natura 2000 areas. In particular, transport regulations or guidelines can be used to avoid fragmentation by preventing the development of roads and railways within large areas of contiguous ecologically valuable habitat. Strategic Environmental Assessments (SEAs) provide a particularly good tool for addressing these issues (see Section 7.2.3 below).

As regards the specific measures, artificial pathways (e.g. wildlife bridges and tunnels) and other measures to reduce collision risks can be used to improve 'the permeability' of transport networks. Such measures can reduce mortality rates and enable some species to cross roads and railways that would not otherwise be able to. However, artificial passages need to be well-designed, located in appropriate positions (according to scientific studies of connectivity needs) and appropriately managed and monitored if they are to effectively support the movement of species within fragmented landscapes.

To some degree roads and railways can provide connectivity functions themselves, particularly where roadside verges contain appropriately managed semi-natural habitats (Noss & Daly 2006). However these benefits are likely to be limited and many roadside habitats may be populations sinks (Trombulak & Frissell 2000). In addition, it should be noted that encouraging movement of species along transport corridors can have a negative impacts for nature conservation if they facilitate the spread of alien species.

The review of Member States' measures carried out for this report revealed a number of attempts to mitigate the negative effects of transport infrastructure as a part of activities carried out by the transport sector (e.g. in Belgium, Finland and the Netherlands). These initiatives included, for example, providing specific guidelines on nature-friendly development of transport networks, constructing artificial passages to enable the movement of species within national transport networks, using nature-oriented management of transport networks, including for example roadside and waterside verges.

Artificial passages and wildlife crossings (e.g. bridges and tunnels) are used in a number of the Member States. For example, artificial passages form an important element of the Dutch ecological network (see Annex 3 for Dutch wildlife passages). Studies from Finland show that the artificial passages are actively used by animals (e.g. elks) (e.g. Vare et al. 2003). Nature-oriented management of roadsides had been applied, for example, in Belgium (Flanders) and Finland (see Annex 3 for roadside verges in Belgium and Finland). In both cases nature-friendly management of roadside verges has been shown to contribute to the conservation of flora and fauna (e.g. insects) in the area (e.g. Jantunen et al. 2004, Saarinen et al. 2006). In Flanders the road side management is also controlled through a Decree (Wegbechermenbesluit), such that nature-friendly management practises are legally required.

Despite some of the observations mentioned above, and other evidence that wildlife bridges and tunnels are actively used by many of the species they were designed for, their efficacy in providing necessary functional connectivity and supporting broader ecosystem processes (e.g. in maintaining metapopulations or migrations) remain unclear (Clevenger & Wierzchowski 2006). Therefore, further studies are needed to clarify and improve the effectiveness of artificial passages in mitigating fragmentation impacts from roads and railways. The findings also indicate that artificial pathways, engineering designs, verge management and other similar mitigation measures should been seen as a second-best option to impact avoidance measures such as sensitive routing or project alternatives.

Recommendations

1. Develop and/or support the take-up and implementation of sector specific instruments (regulations, recommendations and guidelines) that aim to enhance the integration of nature conservation aspects into the development and management of national transport planning and management. In particular, ensure that the transport sector actively contributes to both preventing fragmentation and, where appropriate, improving landscape connectivity.

2. Introduce legal or policy measures that specifically guide the development of transport networks away from areas that are important in the context of biodiversity and nature conservation, e.g. Natura 2000 areas.

3. Adopt transport regulations or guidelines that avoid fragmentation by preventing the development of roads and railways within remaining large areas of contiguous habitat of conservation importance.

4. Introduce specific measures, such as environmentally sensitive routing, that aim, in the first instance, to prevent or reduce fragmentation impacts from transport networks and, in the second instance, to enhance the permeability of transport networks and infrastructure (e.g. artificial wildlife passages, nature-friendly management of transport network land). In the case of artificial passage, their design and location should be based on appropriate scientific studies and their effectiveness in maintaining functional connectivity should be appropriately monitored.

5. When ecologically justified and otherwise feasible (e.g. cost-effective), convert the abandoned elements of transport network, including road- and railway lines and

channels, back into their natural state and/or alternatively develop innovative ways to reuse the abandoned infrastructure in a nature-friendly way.

6. Control and mitigate the possible negative effects of facilitating the movement of species via transport corridors, in particular the spread of alien species.

7. Minimise disruptions to surrounding habitats, such as from disturbance or hydrological changes, which can reduce habitat quality. This is particularly important from a connectivity point-of-view where roads and railways etc pass alongside habitats and connectivity structures that are important for functional connectivity. For example, many roads and railways follow rivers, mountain passes and coasts; habitats in such areas can be of major importance for migrating and dispersing wildlife.

7.2.3 Strategic Environmental Assessments and Environmental Impact Assessments

Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) are intended to be preventative mechanisms that avoid or pre-empt adverse environmental effects that might be associated with proposed programmes, developments or new activities. EIAs aim to identify, quantify and assess the potential impacts of individual projects (such as road, rail, port and large-scale industrial and residential construction or extraction projects). There have been long established EIA procedures in most EU countries, but these have been standardised to some extent with the EU Environmental Impact Assessment Directive (85/337/EEC, as amended by Directive 97/11/EC).

Comprehensive project EIAs typically involve the following key steps (Glasson et al. 1999):

1. Project screening
2. Scoping
3. Consideration of alternatives
4. Description of the project and environmental baseline
5. Identification and prediction of main impacts
6. Evaluation and assessment of impact significance
7. Recommendations for mitigation
8. Public consultation and participation
9. Production and review of an Environmental Impact Statement
10. Decision making
11. Post-decision monitoring, auditing and follow-up

Although this implies a linear process, EIA in practice is iterative, with feedback and interaction amongst the various stages. EIA is also more effective if it includes frequent public consultations and participation with key stakeholders throughout (not just at the end).

SEA is becoming increasingly important as a mechanism for ensuring that environmental concerns are integrated with the development planning process and also provides a mechanism for reducing uncertainty earlier in the planning process. This has been given added impetus through the EU SEA Directive (Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment), which became effective in July 2004. The SEA Directive has many references and requirements relating to the conservation of biodiversity and implementation of other EU nature conservation directives. For example, one of the criteria for determining whether or not a plan may have significant environmental effects is if it has ‘effects on areas or landscapes which have a recognised national, Community or international protection status’.

If adverse environmental effects cannot be avoided, the EIA process generally triggers measures to reduce or control adverse effects on the environment (‘mitigation’) or to provide compensation (also known as ‘offsets’, see ten Kate *et al.* 2004) for unavoidable impacts.

One of the main constraints on SEAs and EIAs is that there is often limited information available on biodiversity and the effects of proposed projects to carry out comprehensive ecological evaluations or to undertake reliable assessments of potential impacts. As functional connectivity is particularly difficult to assess this is likely to be overlooked or over-simplified in impact assessment studies.

Despite some of the limitations associated with EIAs and SEAs, the processes provide many opportunities for maintaining and enhancing connectivity, where this is required, and for assisting with climate change adaptation. If carried out according to the best practice they can:

- Guide development programmes through SEA so that environmentally sensitive areas are avoided.
- Avoid fragmentation and other biodiversity impacts at the project level (through alternative projects, mitigation and if necessary project refusal).
- Provide connectivity and other biodiversity benefits through well designed project compensation (planning gain) measures (e.g. habitat restoration, which might contribute to the implementation of ecological networks).
- Improve understanding of connectivity impacts through research and post-project monitoring.

Recommendations

1. Ensure that connectivity and climate change adaptation issues are fully considered in screening, scoping, impact assessment and other stages of SEAs and EIAs (including the risk associated with increasing connectivity where appropriate).

2. Ensure that all public data on species and habitats and the latest scientific information is accessible and used in EIA and SEA process.

3. EIAs should follow the precautionary principle such that the onus should be on project proponents, to show that adequate functional connectivity is maintained as a result of their proposed project (taking into account realistic mitigation measures). This should apply to all species, areas and landscapes, but connecting elements identified as being important for connectivity in spatial plans etc. should be given special attention.

4. SEAs and EIAs need to take into account the latest available scientific advice on likely future climate changes and ensure that project impacts do not reduce the resilience of existing biodiversity resources or the capacity to adapt to climate

change. Proposed mitigation and compensation measures should be shown to be 'climate-proof' (e.g. restored habitats should be viable under likely future climate changes) and allow movement of species in response to future climate change.

7.3 Agricultural policies, regulations and agri-environment measures

The management of agricultural habitats in the EU has a major impact on EU conservation measures for habitats and species, including the effectiveness of the Natura 2000 network. This is in part because a significant number of semi-natural habitats have developed as a consequence of low intensity traditional farming methods. Extensive livestock grazing is a particularly important requirement (in the absence of their wild herbivore counterparts) for the maintenance of semi-natural habitats of high ecological value, such as heathlands, dry grasslands and montane grasslands. Although arable farmland is an artificial habitat of low ecological value in itself, it can support species of high conservation importance. For example, many rare arable weeds are entirely depend on low intensity arable cultivation systems, which are becoming increasingly rare. Such arable farmland can also provide import habitats for threatened birds, such as the Great Bustard (*Otis tarda*) and Little Bustard (*Tetrax tetrax*) (Tucker & Evans 1997). According to preliminary estimates (EEA 2004) approximately 15-25 per cent of European countryside consists of high natural value farmland, largely comprising habitats such as semi-natural grasslands, dehesas/montados and steppe areas.

Agriculture also has a major impact on functional connectivity, and hence the coherence of the Natura 2000 network, and other areas of nature conservation importance. This is because agricultural land makes up the majority of land outside protected areas in most countries (with the exception of some predominantly forested northern EU countries). In total, agricultural land covers about 50 per cent of the total European land surface. Therefore agricultural landscapes usually make up the habitat matrix through which most species need to move if they are migrating or dispersing between protected areas and other habitat patches. It is therefore clear that the quality of agricultural habitats and their external impacts on other habitats is of profound importance in terms of maintaining and enhancing connectivity in the landscape (Donald & Evans 2006).

There are two main trends to be observed in rural areas within the EU: intensification and land abandonment (EEA 2005). Intensification has occurred over most of the EU as a result of new agricultural technology combined with supportive agricultural policies, in particular the Common Agricultural Policy (CAP). This has resulted in considerable increases in fertiliser inputs, pesticide use, water use and drainage, crop specialisation, stocking density, pollution and habitat loss. As a result the most intensive farm systems, particularly in lowland Western Europe, are now highly productive large-scale monocultures with low biodiversity. The biodiversity impacts of these agricultural changes have been well documented and have for example included major population declines in many farmland birds across most of Europe (Donald et al. 2001, Tucker & Heath 1994).

At the other extreme are many of the high natural value farming systems, such as in southern Europe, with low stocking densities, little or no chemical inputs and labour-intensive management such as shepherding. Many of these extensive farming systems are under severe socio-economic pressure and are subject to the abandonment of agricultural management. In general the cessation of agricultural management (i.e. grazing and/or cultivation) enables natural processes to take over leading to successional habitat changes. These habitat changes vary but typically start with the growth of rank grassland and shrubs, followed by scrub and eventually forest (although the final climax stage may be prevented by disturbances such as fire). Thus the overall impact of land abandonment is a reduction in grassland and arable habitats (particularly in low intensity marginal farming areas) and an increase in scrub and forest in the landscape.

Landscape changes from land abandonment can have diverse impacts on ecological connectivity and other biodiversity conservation issues. Whether these are beneficial or detrimental largely depends on local conservation priorities. In predominantly agricultural areas small-scale abandonment can lead to increases in habitat and species diversity that can be beneficial. In fragmented landscapes abandonment may provide opportunities for managed habitat restoration projects, which could help connect isolated habitat patches.

On the other hand, large scale abandonment can lead to declines in habitat heterogeneity and species diversity across the landscape. This will be particularly detrimental where it affects areas of high natural value farming, as many species of high conservation value depend on such semi-natural habitats. Moreover, in many areas the species associated with such high natural value farming habitats are likely to be of higher conservation importance than most of the generalist species that are likely to benefit from scrub and young forest habitats. In the longer term, i.e. centuries, naturally regenerated forests may gain high ecological values, though these may be impacted by climate change. Therefore, the impacts of land abandonment on functional connectivity and other biodiversity conservation issues need to be evaluated on a case-by-case basis, taking into account short-term and longer-term conservation goals at local, regional, national, EU and global levels.

In summary, agricultural changes can have several impacts on the coherence of the Natura 2000 network and its potential for adaptation to climate change, including:

- Inappropriate management (i.e. intensification), or in some cases abandonment of agricultural management, of farmland habitats of high natural value, which reduces their resilience to fragmentation and climate change.
- Reduced functional connectivity amongst farmland and other habitats, as a result of habitat loss and general deterioration in the ecological quality of the farmland habitat matrix (e.g. as result of increased pesticide use).
- Impacts on other habitats, such as forests, rivers and other wetlands (e.g. from water abstraction, pollution and disturbance), which reduces their resilience and the capacity for their component species to adapt and disperse.

The EU Biodiversity Action Plan for 2010 and Beyond (COM 2006/216) includes an action to '*[optimise] the use of available measures under the reformed CAP, notably to prevent intensification or abandonment of high-nature-value farmland, woodland and forest and supporting their restoration*'. An EEA project has been set up to support this action, and includes analysis of spatial and ecological aspects of the network's coherence. This work will examine two aspects of Natura 2000: the role of agricultural management of designated sites, and within the wider countryside; and the potential effects of climate change on the network (see Chapter 7 on research requirements).

It is clear that a high priority needs to be given to conservation measures that ensure the appropriate management of Natura 2000 sites and other areas of high natural value. This in itself will help to maintain and enhance connectivity in the agricultural landscape and facilitate habitat's and species' adaptation to climate change. However, this will not be sufficient alone. The appropriate management of the wider agricultural landscape is also necessary, particularly in the most fragmented and degraded areas. In such circumstances, measures will be often required to enhance functional connectivity. As described in Section 6.2, the most efficient and effective approach for increasing resilience and connectivity in rural landscapes will vary considerably depending on the spatial structure of the landscape and its management system, the target habitats and species involved and their conservation importance. The selection of measures therefore needs to be carefully considered, and appropriately targeted to ensure real and long-term functional connectivity benefits. As described below some existing environmental measures provide opportunities for implementing practical connectivity actions in agricultural landscapes.

7.3.1 Cross-compliance measures

As a result of the CAP reforms in 2003 all farmers receiving direct payments are now subject to compulsory cross-compliance (according to Council Regulation No 1782/2003 and Commission Regulation No 796/2004). Farmers are now obliged to keep land for which they claim single payment support in Good Agricultural and Environmental Condition (GAEC). These conditions are defined by Member States, and should include standards for soil protection, maintenance of soil organic matter and soil structure, and maintenance of habitats and landscape, including the protection of permanent pasture. In addition, Member States must also ensure that there is no significant decrease in their total permanent pasture area, if necessary by prohibiting its conversion to arable land.

These cross-compliance measures therefore provide a minimum standard of environmental protection (which may be improved upon by agri-environment measures below). As some of these standards must include the maintenance of habitats and landscapes, then some basic connectivity features may receive some protection. The protection of permanent pasture may also be beneficial as such habitats can serve as connecting elements especially in areas dominated by arable land. However, it appears that in some cases the added value of cross-compliance may be limited.

Recommendations

Cross-compliance measures provide a mechanism for giving a basic level of protection to connectivity features in farming landscapes. It is therefore recommend that Member States should:

1. Incorporate habitat connectivity objectives in the development of cross-compliance policies and regulations. For example, consideration could be given to the development of a minimum standard for landscape connectivity as part of GAEC requirements. Such a standard could define a minimum amount of semi-natural habitat that should be retained within particular types of farmland. This could help alleviate the likely loss of set-aside (see below).

2. Consider cross compliance measures that go above and beyond existing regulations where farmland habitats have become highly degraded or farming has caused severe fragmentation of remaining non-farmed habitats.

7.3.2 Agri-environment measures

Agri-environment measures (AEM) have been one of the most important mechanisms developed under the Common Agricultural Policy (CAP) to mitigate the impacts of agricultural intensification in the EU. They started in 1985 under Council Regulation (EEC) No 797/85[24] and have been further developed through Regulation (EEC) No 2328/91[25], Regulation 2078/92 (known as the agri-environment Regulation), Council Regulation on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) ((EC) No 1257/1999) and most recently the Council Regulation on rural development for the period 2007-2013, i.e. the European Agricultural Fund for Rural Development (EAFRD) (1698/2005).

Under the current EARD regulation AEM remain compulsory for Member States, which underlines their ongoing importance. In addition, according to the current Community co-financing arrangements a significant proportion of the costs of the management of the Natura 2000 network should come from existing Community funding instruments, including EAFRD (Miller, Kettunen & Torkler 2006). Therefore, the EAFRD Regulation is to provide an increasing number of possibilities for managing Natura 2000 sites, including the option to use EAFRD funding for AEM and for other measures that enhance/support connectivity within the Natura network and wider landscape scales (see Table 7.1).

In response to the various regulations and national priorities, a wide variety of AEM schemes have now been implemented. However, two broad approaches have typically been taken:

- A 'broad and shallow' approach, offering relatively simple, low-cost management options over a very wide area.
- A 'narrow and deep' approach with more targeted, possibly higher maintenance and management options to fewer farmers.

A recent European Commission review of AEM across Europe found that the schemes have had a number of beneficial impacts on biodiversity, including the maintenance and restoration of habitats of high ecological value and increases in habitat / landscape diversity (Oréade-Brèche 2005), which it is anticipated will enhance ecological connectivity. However, more detailed studies have found that schemes have been variable in their biodiversity conservation achievements (Berendse et al. 2004; Kleijn et al. 2006; Kleijn et al. 2001; Kleijn & Sutherland 2003). Furthermore the appraisal of AEM has often been hindered by a lack of proper monitoring (Kleijn & Sutherland 2003).

Nevertheless, some well monitored national schemes have shown a variety of biodiversity benefits, such as the Environmentally Sensitive Areas scheme and Countryside Stewardship scheme in the UK (Reid & Grice 2001, Tucker et al. 2003, Aebischer 2000).

[24] Council Regulation (EEC) No 797/85 on improving the efficiency of agricultural structures
[25] Council Regulation (EEC) No 2328/91 on improving the efficiency of agricultural structures

These included some major conservation successes such as for the Cirl Bunting (*Emberiza cirlus*) under Countryside Stewardship Special Projects (Peach et al. 2001). This was achieved through a partnership between governmental agencies and NGOs and landowners, and provides a convincing case for targeted implementation of AEM schemes that 'fit' well with existing farm practices and deliver conservation results (Evans et al. 2002). Part of this success was related to their practicality and attractive financial incentives and the projects also benefited from their ability to target resources to relatively small areas. Provision of advisers with specific conservation knowledge was also important in the success of the recovery programmes (see Annex 3 on UK AEM).

Overall it appears that AEM schemes can provide biodiversity benefits, especially when they are appropriately targeted and designed. However, as noted by Whittingham (2007), performance may be limited by a number of factors, including:

- Application to small patches of land (which may not provide all of a species' ecological requirements, are effected by surrounding management practices such as drainage, or may be beyond the dispersal distance from uninhabited patches).
- Placement in inappropriate areas (e.g. where target species are absent or where ecological conditions are unsuitable).
- Application of generalised national habitat management measures, which are not always suited to local conditions.

Despite some of the problems and limitations described above, there is little doubt that AEM provides one of the most important mechanisms for conserving biodiversity in farmland landscapes (as well as reducing impacts on non-farmed habitats). To date, AEM habitat management and restoration actions have been carried out for a variety of biodiversity conservation purposes. But, there is now an increasing recognition of the role that AEM can play in maintaining and enhancing functional connectivity (Donald & Evans 2006). The actual impacts of such measures will, however, depend on their scale and spatial arrangements. Some recommendations that may help AEM maintain and enhance functional connectivity are outlined below.

Table 7.1. Examples on how the European Agricultural Fund for Rural Development (EAFRD) could support management of Natura 2000 areas in the context of agriculture and forestry, including enhancing connectivity within ecosystems / between individual sites. Table adopted from Miller, Kettunen & Torkler 2006, please see this document for more examples.

EAFRD Article	Description	Possible application in the context of Natura 2000
36(a)(i)	natural handicap payments to farmers in mountain areas	Payments could be used to support traditional extensive sustainable agricultural practice in areas where this is necessary for maintenance of valuable habitat - eg grazing of alpine meadows or open steppe.
36(a)(ii)	payments to farmers in areas with handicaps other than mountain areas	
36(a)(iv)	agri-environment payments	There are many options open to Member States and agri-environment schemes can be designed to be adaptable to differing regional requirements. Fro example, agri-environment schemes could be targeted at agricultural land between key Natura 2000 sites in order to develop wildlife corridors linking important habitats.

36(a)(vi)	support for non-productive investments [agricultural land]	Temporary fencing for grazing management aimed to habitat maintenance, restricting public access or other agricultural activities.
36(b)(i)	first afforestation of agricultural land	Could fund restoration of native forests where these have been lost; could link to other restoration projects to facilitate creation of a continuous network of Natura 2000 sites.
36(b)(ii)	first establishment of agro-forestry systems on agricultural land	Could enable restoration of traditional agro-forestry systems such as Mediterranean dehesa/montado in areas where these have been lost.
36(b)(iii)	first afforestation of non-agricultural land	Could facilitate the restoration of native forests in areas where these have been cleared.
36(b)(iv)	Natura 2000 payments; [forests]	Restoring old growth forest: creation and management of large reserves (greater than 50ha) without any forest management.
36(b)(v)	forest-environment payments	Creation and maintenance of biodiversity supporting structures
36(b)(vi)	restoring forestry potential and introducing prevention actions;	Prevention actions could include planting of native tree habitats where these are fire-resistant.
36(b)(vii)	support for non-productive investments [forests]	Support establishment of small vegetated ponds in forest areas that could also contribute to increasing connectivity within the landscape.
52(b)(iii)	conservation and upgrading of the rural heritage	Restoration of local wetland habitats through modification of waterways and restorative planting.
63	Leader	Management of local habitats to facilitate objectives of local development plans related to nature conservation (e.g. increasing ecological connectivity).

Recommendations

Members States should ensure that AEM schemes have clear biodiversity conservation objectives, which include contributing to the management and coherence of the Natura 2000 network, the maintenance and restoration of FCS in habitats and species of Community interest, as well as wider biodiversity objectives such as EU and national biodiversity action plans. Such schemes should:

1. Ensure close integration with other policies, plans and initiatives concerned with connectivity issues and climate change adaptation. Furthermore, consider using AEM schemes as a primary mechanism for addressing issues related to connectivity in the rural/agricultural context.

2. Have sufficient levels of uptake to have significant beneficial biodiversity impacts. Payment levels therefore need to be sufficient to encourage target levels of uptake for specific measures, especially where these may have significant socio-economic risks and require substantial changes to farming practices (e.g. whole field measures). Flexible, locally adaptable schemes and awareness campaigns may help to increase uptake efficiently.

3. Ensure that connectivity measures are required and appropriately targeted if AEM funding is limited. For example, competitive schemes may allocate points according to the value for money provided by the proposed measures. In this respect targeting could be linked to implementation of Natura 2000 management plans, connectivity requirements for species of Community importance at risk from fragmentation (see Section 6.2), species action plans or proposed Ecological Networks (see Section 6.3).

4. Consider targeting AEM connectivity measures to areas where there are sufficient areas of semi-natural habitat of high natural value remaining to benefit from such actions. Although the restoration of habitats in highly degraded and fragmented agricultural landscapes may be highly desirable, very high levels of AEM scheme participation are likely to be required to reverse biodiversity declines and fragmentation impacts.

5. Ensure that broad and simple AEM schemes that aim to deliver high levels of participation have significant beneficial biodiversity impacts that address conservation priorities. Base AEM scheme prescriptions for increasing connectivity on species and habitat requirements as ascertained from the best available empirical evidence and scientific studies (see Section 6.2). Such measures should focus on delivering functional connectivity where it is needed and select the most effective and efficient means of increasing connectivity.

6. Adopt an adaptive management approach so that AEM schemes and prescriptions can be revised as necessary as information improves on habitat and species connectivity requirements and the impacts of climate change. Flexibility also needs to be allowed to create agreements that are more adapted to local circumstances, agricultural practices and objectives.

7. Include clear quantified biodiversity performance targets in all schemes that are directly linked to their objectives. These should be objectively and systematically monitored and reported on to all stakeholders.

7.3.3 Set-aside

Although set-aside was not designed as an environmental policy it has resulted in significant biodiversity benefits (Buskirk & Willi 2004; Colston & Perring 1995; Firbank 1998; Hansson & Fogelfors 1998; Henderson & Evans 1999; Henderson et al. 2000; Hodge et al. 2006; Poulsen et al. 1998; Sotherton 1998; Vickery & Buckingham 2001). This is primarily because it reintroduces into the arable landscape fallow land (which reduces overall agricultural activity) and maintains habitats of relatively high ecological value over a large area. For example, naturally regenerated set-aside provides suitable habitat for a variety of invertebrates, small mammals and birds. The fact that it is compulsory, if CAP support is to be claimed, is particularly important in relation to connectivity issues because it ensures an even spread of set-aside habitat, including in the most intensively farmed areas. It is in such areas that set-aside significantly contributes to habitat heterogeneity. It is therefore likely to be of critical importance in providing non-farmed habitat refuges in the largely hostile habitat matrix of arable farmland landscapes in Western Europe. These may help to support dynamic metapopulations as well as providing habitat stepping stones for wider dispersal, migrations and climate change driven range changes.

At the time of writing these guidelines, it is anticipated that set-aside will be abolished following the proposed CAP 'Health Check' in 2008, because it no longer provides a useful supply-control function (Hodge et al. 2006). However, the environmental benefits of set-aside have been widely recognised and it is likely that policy measures will be introduced to mitigate the loss of these benefits. At this time it is not possible to predict the policy mechanisms that may be used to achieve this. But it is clear that policy options for retaining the environmental benefits of set-aside are constrained by the overall CAP policies of reducing regulations and administrative burdens and the overall cost of the CAP. Furthermore, any scheme that aims to compensate for the biodiversity impacts of set-aside reversion would need to be over a very large total area to be effective.

The most likely policy options for retaining set-aside benefits are incorporating some basic requirements into cross-compliance (such as retention of a minimum non-cropped area) and/or including other more demanding habitat management elements (e.g. retention of over-winter stubbles) into AEM schemes. However, other policy drivers such as the need for energy crops may also affect the use of what is now set-aside land.

It is therefore not possible to currently provide recommendations on how connectivity issues may be addressed following the likely withdrawal of set-aside. However, it is clear that Members States should take connectivity issues into account during the development of related CAP policies and their implementation at national levels.

7.4 Forest strategies and support to forestry sector

Approximately 30 per cent of Europe's land area is covered by forest, most of which is semi-natural forest (EEA 2005c). Most forests are, at least to some extent, economically productive and about 25 per cent of the forest area is subject to more or less extensive protection. The protected forests in Europe cover some 37 million hectares and are designated for the protection of biodiversity, soil or water supply. In the Natura 2000 network, forests currently cover almost half of the total number of designated areas. However, reflecting the long tradition of forest use and management, the proportion of forest 'undisturbed' by human activities in most European countries is less than 1 per cent (EEA 2003).

Consequently, in addition to agriculture, forestry plays an important role in shaping the landscapes within the EU. Management of forest habitats also has a major impact on EU conservation measures for habitats and species, including the effectiveness and coherence of the Natura 2000 network. The main causes of fragmentation of forest ecosystems in Europe include industrial forest management, forest fires, agricultural use and road construction. In addition, forest management in many parts of Europe during the past two centuries has often favoured the planting of single-species stands, particularly of conifer. This has tended to reduce habitat and species diversity and overall biodiversity within many forest areas. However, currently there is a general trend, especially in western and central Europe, to increase the share of mixed forests by converting monoculture introduced species stands to mixed stands with native species (Bengtsson et al. 2000). Natural regeneration is also becoming a more common forest management practice and often increases the amount of mixed forests (Bartelink & Olsthoorn 1999). According to UNECE/FAO (2000), however, only about 13 per cent of forests in the EU are considered to be mixed (whilst in Europe as a whole 17 per cent are mixed).

Issues related to forest policy fall under the full competence of the Member States. Therefore, the EU's contribution in the area is mainly limited to supporting the implementation of sustainable forest management through common policies and strategies to be implemented jointly by the EU and the Member States. One of the main current policy documents guiding the forest policy at the EU level is the EU Forest Action Plan (COM(2006)30) adopted in 2006. The Action Plan focuses on four main objectives: 1) improving long-term competitiveness of the forest sector, 2) improving and protecting the forest environment, 3) contributing to the quality of life, and 4) fostering coordination and communication within the sector. The Action Plan introduces eighteen key actions that are to be implemented jointly between the Commission and the Member States during the period of five years (2007–2011). These include actions aimed at contributing towards achieving the EU's biodiversity objectives for 2010 (and beyond) and enhancing the protection of EU forests.

The Action Plan does not directly address issues related to ecological coherence and connectivity. However, measures aimed at maintaining/improving connectivity can fall under the scope of several activities endorsed by the Action Plan. For example, the Action Plan supports restoration and afforestation initiatives with environmental objectives and it also promotes the use of EAFRD for Natura 2000-forest measures. The Action Plan puts a lot of emphasis on monitoring forest ecosystems in the EU and it proposes monitoring of the impacts of forest fragmentation on biodiversity. In addition, the Action Plan strongly supports improving coordination and cooperation within the forestry sector. Improving coordination can further support and facilitate initiatives aimed at preventing fragmentation and/or improving connectivity. However, such practical actions depend largely on the implementation of Community level provisions and recommendations at the national level.

The EU Biodiversity Action Plan for 2010 and Beyond (COM 2006/216) includes a number of actions aimed at supporting the conservation and sustainable use of biodiversity in the context of forest policy. For example, the Action Plan urges Member States to assess the effects of afforestation (and should the case arise deforestation) plans on biodiversity and, depending on the results, adjust the plans to avoid any negative biodiversity impacts (Action A2.1.15). In addition, the Action Plan emphasises the role of 'high nature value' forest areas and lists several actions to be taken jointly by the Commission and the Member States to address this issue (e.g. Actions A2.1.2., A2.1.3 and A2.1.7). For example, according to the Action Plan the high-nature-value forest areas threatened by the loss of biodiversity are to be identified by 2007. Furthermore, appropriate measures to maintain or restore the conservation status of these areas are to be implemented (2007 onwards) (Action A2.1.3).

During the current 2007-2013 funding period the Member States have the opportunity to use Community co-financing for forestry through the European Agricultural Fund for Rural Development (EAFRD) (Council Regulation (EC) No 1698/2005) (see also Section 7.3.2. above). In general, the EAFRD funding emphasises investment and competitiveness in the private sector and less focus is given to provide funding opportunities for public owners. Support for forest plantations is also not strongly supported by EAFRD, however agroforestry can receive support under the fund.

There are also opportunities for funding management actions for the Natura 2000 network under the EAFRD Regulation, including measures that can enhance/support connectivity within the network/wider landscape scale. However, the programming of EAFRD funding gives Member States a lot of freedom to develop policies and measures that suit their national and regional priorities. For example, it is not obligatory for the Member States to allocate any EAFRD funding for forestry related measures. Consequently, the actual level and types of funding in support of Natura 2000 and ecological connectivity in individual countries depend on decisions taken at a national level. Opportunities provided by EAFRD at the Community level Natura 2000, are outlined in Table 7.1 above (Section 7.3.2).

The support provided in the context of EAFRD could have important implications for preventing forest fragmentation and supporting connectivity in forest systems. A number of recommendations connected with the use of EAFRD for forestry related measures are provided below. In this context, see also the recommendations for agri-environment measures listed in Section 7.3.2 above.

Recommendations

1. Include aspects related to preventing fragmentation and enhancing connectivity as integral parts of national forestry strategies and regional forestry management plans. In this context, highlight the value of naturally functioning ecosystems and their ecosystem services (e.g. carbon sequestration) and pay particular attention to a) issues related to maintaining and enhancing functional connectivity and b) the impacts of and need for adaptation to climate change.

2. Enforce the implementation of measures listed in the EU Forest Action Plan paying particular attention to measures that can enhance connecting elements within forest areas and restoration and afforestation initiatives, monitoring of forest fragmentation on biodiversity, and improving coordination and cooperation within the forestry sector.

3. Where appropriate, support re-afforestation and afforestation initiatives that aim to create diverse forest ecosystems e.g. by natural regeneration, maintenance or restoration of structures supporting forest biodiversity (wetlands, dead wood, bushes). In this context, consider using EAFRD afforestation payments to contribute to restoration of forest habitats, where this is required to improving functional connectivity between forest habitats. However, the impacts of afforestation schemes on biodiversity must be carefully considered as they can lead to detrimental impacts, for example if diverse agricultural grasslands are replaced with a forest monoculture.

4. Allocate EAFRD funding specifically for forestry related measures that support the maintenance and enhancement of connecting elements within forest areas and ecosystems. In this context, targeted national EAFRD forestry measures could provide opportunities to connect isolated forest habitats, particularly if uptake of measures in blocks of land or zones is encouraged.

5. Where feasible, consider taking forest areas out of management (especially forests with low economic value) so that they can develop naturally and be used for scientific studies of forest ecology and the impacts of the climate change.

6. In order to prevent fragmentation and improve connectivity synchronise the forest-environment annual payments (EAFRD Article 47) and the linked grants (e.g. EAFRD Articles 49 and 44) at the national level. In doing so, and in determining the remaining eligibility requirements for planting and management grants, the national EAFRD strategies and regional grant approval processes should identify the types and location of planting sites, geographical areas and types of planting (species, provenance, density, open spaces within woodland etc) which would best meet the biodiversity related targets in the area. These could include, for example, biodiversity action plan targets for woodland habitats and species, requirements for buffering and enhancing Natura 2000 sites, habitats used by species of Community interest, and woodland networks in the wider countryside.

7. Improve the ecological quality of forests outside the Natura 2000 network in order to help maintain and restore FCS amongst forest species, e.g. by practicing continuous-cover forestry.

7.5 Measures related to inland water and coastal management

7.5.1 The Water Framework Directive and catchment management

The 'Directive establishing a framework for the Community action in the field of water policy' (Directive 2000/60/EC), i.e. the EU Water Framework Directive (WFD), sets up the current basis for the protection of inland and coastal waters and groundwater resources in the EU. The Directive requires all inland and coastal water bodies to reach, as a minimum, 'good status' by 2015. This 'good status' takes into account aspects related to both ecological and chemical characteristics of the water body. In this context, the ecological status refers to the quality of the structure and functioning of aquatic ecosystems.

The goals of WFD are to be reached through the establishment of an integrated EU-wide river basin management structure within which environmental objectives for inland water bodies, including ecological targets, will be set. A key component of this structure is the development of river basin management plans (e.g. covering rivers, lakes, wetlands and coastal zones) that are to be finalised by the Member States by 2009.

The Water Framework Directive also takes fully into account the provisions of the Habitats directive. Therefore, WFD has been seen to provide important support to the management and monitoring of the Natura 2000 network in the future. The Directive does not contain any particular requirements for implementing the Habitats directive's provisions. However, the WFD definition of good ecological status includes aspects related to maintaining or restoring morphological characteristics and the structure of inland water bodies, including preserving river continuity and enabling natural migration of species. There are therefore good opportunities to maintain and enhance ecological coherence and connectivity of inland water ecosystems, including river basins.

The establishment and implementation of integrated river basin management plans also requires active participation of stakeholders. Enhancing communication between different stakeholders allows the establishment of a joint vision on the local/regional development potential and objectives. This can provide important support for the integration of nature conservation related aspects, including preventing fragmentation and increasing connectivity between sites, into river basin and inland water management (see Annex 3 on BE river contracts). In addition, the river basin management plans create a good framework for addressing cross-border issues.

Recommendations

As the implementation of the Directive is still at an early stage it still remains to be seen how Member States will include connectivity related issues as an integral part of river basin management plans. In this context, a number of recommendations can be identified.

1. Integrate issues related to connectivity into river basin management plans. This could include identifying important elements for enabling the movement of species (e.g. migrating routes) and maintaining them in or restoring them to their natural state. In this context, the value of naturally functioning inland water ecosystems and their ecosystem services (e.g. socio-economic benefits), should be highlighted.

2. Explore the possibility of using the framework provided by the WFD to prevent fragmentation and enhance connectivity between Member States. The WFD provides a good opportunity to manage river basins at transnational scale.

3. Address issues related to fragmentation and connectivity as a part of public and stakeholder participation processes. In particular, actively support capacity building in relation to the importance and value of inland water ecosystem biodiversity, including issues related to the maintenance of ecosystems services and climate change.

4. Explore the possibility of using the WFD monitoring framework to monitor the status of inland water protected areas paying particular attention to aspects related to movement of species between water bodies and wetlands.

7.5.2 Integrated Coastal Zone Management

The management of coastal zones within the EU is subject to an EU recommendation on integrated coastal zone management (ICZM) (Recommendation (2002/413). As a consequence, Member States are recommended to formulate and adopt national ICZM strategies aimed at ensuring the protection of their coastal environment. The ICZM introduces a strategic approach and principles that Member States should follow in undertaking national ICZM stocktaking and national ICZM strategies. These strategies should be based on the application of the ecosystem approach and they should also take into consideration the implementation and management of protected areas as a part of the overall management of coastal areas.

The development and implementation of ICZM strategies by Member States was reviewed in 2006[26]. The review concluded that none of the 24 EU coastal Member States and Accession Countries had implemented an ICZM National Strategy as proposed by the EU. Furthermore, even where an ICZM National Strategy, or equivalent, had been developed in a number of countries its implementation was often still pending. Nevertheless, the review concluded that conservation of coastal biodiversity played a significant role in a number of coastal areas. For instance, the national coastal zones of Poland, Latvia, Lithuania and Estonia have significant areas, which are designated as Natura 2000 sites. For example, 45 per cent of the Latvian coastal zone is protected under the Habitats directive.

According to the review, a number of Member States appeared to have incorporated aspects related to the conservation of natural coastal systems and processes in the context of their ICZM regulatory framework. However, specific references to biodiversity conservation were somewhat limited. Protection of biodiversity and nature seemed to play a prominent role in only a few national ICZM approaches.

In the future it is likely that coastal zones will be one of the areas most affected by climate change. According to the IPCC, coasts are expected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise (IPCC 2007b). These effects will be exacerbated by increasing human-induced pressures on coastal areas. In addition, coastal wetlands including salt marshes and mudflats are projected to be negatively affected by sea-level rise especially where they are constrained on their landward side, or starved of sediment. In Europe, the foreseeable negative impacts of climate change on coastal zones include increased risks of inland flash floods, and more frequent coastal flooding and increased erosion due to increases in storminess and sea-level rise (IPCC 2007b).

The above mentioned impacts might reduce future development pressures on coastal areas, including further fragmentation of coastal ecosystems. In addition, it has been recognised that healthy coastal ecosystems, such as saltmarshes, can play an important role in physically buffering the effects of climate change (MEA 2005b). Therefore, the conservation of coastal habitats is an important element of adaptation to climate change. In fact a number of coastal realignment projects are now underway in Europe, e.g. in England (Dixon et al. 1988; French 2001), that are designed to allow the natural regeneration of saltmarsh as a means of coastal flood defence, whilst also providing habitats of high ecological value and other ecosystem services.

Holistic ICZM management plans can provide a good framework for maintaining and enhancing connectivity within coastal areas and ecosystems (both terrestrial and marine coastal systems). The ICZM plans can also provide a suitable tool for incorporating the effects of climate change into coastal management. In order to do so, however, Member

[26] An evaluation of Integrated Coastal Zone Management (ICZM) in Europe, a report by the Rupprecht Consult GmbH (Germany) and the International Ocean Institute (Malta) finalised in 2006 (http://ec.europa.eu/environment/iczm/home.htm)

States need to increase the establishment and implementation of ICZM strategies and include issues related to nature conservation, including fragmentation and connectivity, as an integral part of these plans.

Recommendations

1. Increase the establishment and implementation of ICZM strategies and integrate issues related to connectivity into these strategies. Particular attention needs to be given to the potential ecological impacts of urbanisation and other developments along the coastline. In this context, careful consideration should be given to the impacts of developments on the value of naturally functioning coastal ecosystems and their ecosystem services, including the socio-economic benefits arising from flood, storm and coastal erosion protection.

2. Ensure the compatibility of the ICZM strategies and coastal ecological networks, for example by integrating the management of coastal ecological networks as an integral part of the ICZM.

3. Address issues related to fragmentation and connectivity as a part of the ICZM public and stakeholder participation processes. In particular, actively support capacity building in relation to the importance and value of coastal ecosystem services, including the issues related to maintenance of ecosystems services in the context of climate change.

4. Use opportunities from coastal realignment schemes to create and enhance coastal habitats as a means of restoring functional connectivity along fragmented coastal ecosystems and to facilitate climate change adaptation.

7.6 Relevant Community and Member States funding instruments in the context of enhancing the maintenance of connectivity within landscapes

As a general principle of the EU Member States are responsible for the implementation of European law. Therefore costs arising as consequence of implementation should be covered by national budgets based on the principle of subsidiarity. However, the Habitats directive Article 8 provides for the possibility of Community co-financing. The provisions in the new 2007-2013 Community funds open up the possibility of available funds for nature conservation projects.

As described in Section 7.2, the European Agricultural Fund for Rural Development (EAFRD) provides support for a number of measures (e.g. forestry) that can be used to promote connectivity within rural landscapes. In addition to EAFRD there are also a number of other Community funding instruments that provide opportunities for maintaining and/or actively improving connectivity within landscapes. This section provides an overview of the most relevant of these instruments for the 2007-2013 funding period, namely the European Financial Instrument for the Environment (LIFE and LIFE+) and the Structural and Cohesion Funds. In addition, some general insights and recommendations on the national funding possibilities are given.

Even though marine ecosystems fall outside the scope of this Guidance Document it is to be noted that, in addition to the Community funds mentioned above, the European Fisheries Fund (EFF) for 2007-2013 (Council Regulation (EC) No 1198/2006) offers a number of possibilities for supporting the management of marine (e.g. coastal marine) Natura 2000 sites. In this context, support can also be provided for enhancing connectivity between protected areas. In general, a number of Regulation's provisions can also help to maintain coherence and connectivity in marine and coastal areas by supporting non-damaging fishing and aquaculture methods. However, the programming of EFF funding gives Member States a lot of freedom to develop policies and measures that suit their national and regional specificities. Consequently, the actual level and types of funding in support of Natura 2000 in individual countries will depend on decisions taken at a national level.

7.6.1 The European Financial Instrument for the Environment (LIFE)

The EU LIFE programme which was introduced in 1992 aims to contribute to the implementation, development and enhancement of the Community's environmental policy and legislation as well as the integration of the environment into other EU policies. LIFE-nature projects have included a range of approaches and measures for increasing connectivity between habitats and species populations. The most common actions taken to connect populations appear to be:

- Increasing the size and productivity of source populations through habitat improvements and habitat expansion (e.g. for Capercaillie and Fire-bellied Toad).
- Reconnection and consolidation of fragmented habitats (e.g. for the Marsh Fritillary and Iberian Lynx).
- Creation / restoration of habitat patches as stepping stones for dispersal (e.g. for Bitterns and Great Crested Newts).
- Creation / restoration of linear corridors of habitat to allow for dispersal, migration and gene-flow between populations (e.g. for Brown Bears).
- Removal of dispersal and migration barriers (e.g. for fish).
- Protection and enhancement of migration staging posts (e.g. along the Gulf of Finland flyway).

One LIFE-environment project also carried out innovative research and pilot projects to define and develop ecological networks in Cheshire (United Kingdom) and Abruzzo and Emilia-Romagna (Italy).

Although the LIFE programme's overall impacts on connectivity cannot be quantified, the instrument has undoubtedly made important contributions to maintaining and increasing connectivity between habitats and species populations. It also has the potential to do so in the future, however, the current LIFE programme has now closed to new applications.

The LIFE programme has now closed to new applicants. However, a new programme called 'LIFE+' has been developed and will carry out similar biodiversity conservation actions (amongst others). The agreement and implementation of the LIFE+ programme has been delayed, but it is anticipated that applications for projects will be invited in 2007.

Although the regulation for LIFE+ had yet to formally come into force at the time of writing these guidelines the draft regulation had been approved by Parliament (http://ec.europa.eu/environment/life/funding/lifeplusdraft_en.pdf).

LIFE+ shall consist of three components: LIFE+ Nature and Biodiversity; LIFE+ Environment Policy and Governance; and LIFE+ Information and Communication. Of these LIFE+ Nature and Biodiversity provides the principal means of supporting connectivity conservation projects. However, connectivity measures could be taken under the other LIFE+ components (e.g. as forest measures under LIFE+ Policy and Governance).

The specific objectives of LIFE+ Nature and Biodiversity shall be:

(a) to contribute to the implementation of Community policy and legislation on nature and biodiversity, in particular the Habitats and Birds directives, including at local and regional level, and to support the further development and implementation of the Natura 2000 network, including coastal and marine habitats and species;

(b) to contribute to the consolidation of the knowledge base for the development, assessment, monitoring and evaluation of Community nature and biodiversity policy and legislation;

(c) to support the design and implementation of policy approaches and instruments for the monitoring and assessment of nature and biodiversity and the factors, pressures and responses that impact on them, in particular in relation to the achievement of the target of halting biodiversity loss within the Community by 2010 and the threat to nature and biodiversity posed by climate change;

(d) to provide support for better environmental governance by broadening stakeholder involvement, including that of NGOs, in consultations on, and the implementation of, nature and biodiversity policy and legislation.

LIFE+ has the potential to support a wide range of connectivity conservation measures (including land purchase), particularly with respect to objective a). Indeed, Annex 1 specifically lists 'site and species management and site planning, including the improvement of the ecological coherence of the Natura 2000 network', as one of the nature and biodiversity measures that are eligible for funding.

However, it should be noted that funding will not be provided for projects that can be supported by existing community funds, such as the ERDF, EAFRD and Cohesion Fund etc. Funding shall also only be provided for projects related to the implementation of the Birds directive and Habitats directive that are best practice or demonstration projects.

Unlike the previous LIFE programme, LIFE+ has indicative annual national allocations and will allocate funding for action grants in accordance with its multi-annual strategic programme. It will also take into account national priorities for action identified by Member States from the Commission's multi-annual strategic programme. The priority areas of action listed in the multi-annual strategic programme for nature and biodiversity are:

- contributing to implementing Community policy and legislation on nature and biodiversity, in particular the Birds and Habitat directives, and promoting their integration with other policy areas;
- supporting the further development and implementation of the Natura 2000 network, including coastal and marine habitats and species;
- supporting the design and implementation of policy approaches and instruments for monitoring and assessing nature and biodiversity and the factors, pressures and responses that impact on them, in particular in relation to achieving the target of halting biodiversity loss within the Community by 2010; and
- improving knowledge of the impact of genetically modified organisms on ecosystems and biodiversity: risk assessment methodologies.

The scope of these actions is very broad and provides many opportunities for Member States to develop LIFE+ projects that aim to maintain and restore connectivity to reduce fragmentation and climate change impacts, on the Natura 2000 network and in the wider environment.

Recommendations

It is clear that LIFE+ has the potential to support a wide range of connectivity conservation measures. It is therefore recommended that Members States should:

- Recognize the importance of maintaining and restoring connectivity, to reduce fragmentation and climate change impacts on the Natura 2000 network and in the wider environment, and include such projects in their list of national LIFE+ priorities. Such projects could include the assessment and provision of functional connectivity requirements for species and habitats at high risk from fragmentation (see Section 6.2) and the implementation of ecological networks, or key components of such networks, e.g. through habitat restoration projects.

- Promote the LIFE+ programme to a wide range of potential project proponents, including statutory conservation agencies, institutes, universities and NGOs, and encourage and support the preparation of connectivity projects in accordance with the priorities and examples listed above.

7.6.2 The Structural and Cohesion Funds

The aim of the EU regional policy is to promote coherent development within the EU and reduce gaps between the wellbeing of different regions within the Community area. Traditionally, the Community's regional policy has paid little attention to issues related to nature conservation and biodiversity. Furthermore, the initiatives supported by Structural and Cohesion Funds have frequently been criticised for having negative impacts on biodiversity (see for example WWF 2006). These negative effects include issues related to the fragmentation of landscapes, for example, as a consequence of the development of transport networks and construction of infrastructure for irrigation (e.g. dams and channels). For example, the development of roads, dams and railways supported by the EU Structural and Cohesion Funds has contributed to the loss and fragmentation of Iberian Lynx populations in Spain, by creating barriers between the different populations and obstructing the exchange of individuals among them. Similarly, in Greece the construction of the Egnatia Highway is predicted to lead to fragmentation of the Greek population of Brown Bears. Promoting sustainable development has, however, improved the inclusion of environmental issues, including biodiversity, into EU regional policy.

The EU regional policy is supported by three specific funding instruments: the European Regional Development Fund (ERDF), the European Social Fund (i.e. the Structural Funds) and the Cohesion Fund. Of these funds the ERDF and the Cohesion Fund are the most relevant in the context of this guidance document. The Community co-financing for managing Natura 2000 during the 2007-2013 period will come from a mixture of existing funds (COM/2004/431), including also the Structural and Cohesion Funds. This will increase possibilities for implementing measures that also support ecological coherence and connectivity in the context of regional development. These measures can be linked, for example, with risk prevention and the development of transport networks. In addition, support is also provided for transnational initiatives. A number of the possibilities provided by ERDF and the Cohesion Fund are illustrated in Table 7.2 below.

The programming of Structural and Cohesion Funds gives Member States a lot of freedom to develop policies and measures that suit their national and regional needs. Consequently, the actual level and types of funding in support of Natura 2000 and ecological connectivity in individual countries will depend on decisions taken at a national level. It is therefore important to ensure that these types of activities are or can be addressed in Member States' priorities for ERDF and Cohesion funding, i.e. in the national strategic plans and operational programmes for these funds. In this context, a number of recommendations can be identified.

Recommendations

1. Ensure that activities that aim to enhance connectivity form an integral part of national priorities for ERDF and Cohesion funding. This means that the national strategic plans and operational programmes for ERDF and the Cohesion Fund should include these issues. In this context, special attention should be given to the value of naturally functioning ecosystems and their ecosystem services for regional development, including the socio-economic benefits.

2. Ensure that initiatives supported by ERDF and the Cohesion Fund have minimum adverse effects on biodiversity and landscape connectivity. For example, it is important that further fragmentation of landscapes and ecosystems as a consequence of regional development initiatives is avoided as much as possible. In this context, it is to be noted that plans and projects with negative implications on the Natura 2000 network or individual sites are in principal prohibited by the EU Habitats and Birds directives.

3. Promote regional initiatives that also actively support the maintenance and enhancement of connectivity within landscapes. This could include, for example, habitat creation and/or restoring natural ecosystems and vegetation for risk prevention (e.g. preventing and mitigating floods and forest fires).

4. In the context of the development of transport networks, support initiatives that firstly aim to avoid or minimise the further fragmentation of landscapes and secondly ensure that adequate mitigation measures are incorporated into approved

schemes to enable the necessary movement of species (e.g. by the use of road tunnels or wildlife passages and corridors). In the case of Natura 2000, the Article 6 of the directive provides a legal requirement for implementing these mitigations measures.

Table 7.2. Examples on how European Regional Development Fund (ERDF) and the Cohesion Fund could support management of Natura 2000 areas, including enhancing connectivity within ecosystems / between individual sites. Table adapted and updated from Miller, Kettunen & Torkler 2006. Please see this source for more examples.

ERDF Article	Description	Possible application in the context of Natura 2000
4(4)	Environment, including investments connected with water supply and water and waste management; waste-water treatment and air quality; prevention, control and fight against desertification; integrated pollution prevention and control; aid to mitigate the effects of climate change; rehabilitation of the physical environment, including contaminated sites and land and brownfield redevelopment; promotion of biodiversity and nature protection, including investments in NATURA 2000 sites; aid to SMEs to promote sustainable production patterns through the introduction of cost-effective environmental management systems and the adoption and use of pollution-prevention technologies	Could fund one-off sediment removal and deepening from a river delta area to enable long-term habitat restoration.
4(5)	Prevention of risks, including development and implementation of plans to prevent and cope with natural and technological risks	Creating natural habitats patches though large-scale tree planting of native species that have low fire risk.
4(8) and 5(3)a	Transport investments	Where there is existing transport infrastructure (e.g. roads, rail corridors) improvements could be made to reduce its fragmentation effects (e.g. through addition of underpasses/overpasses).
5(2)a and 5(2)b	Environment and risk prevention, and specifically: stimulating investment for the rehabilitation of contaminated sites and land, and promoting the development of infrastructure linked to biodiversity and investments in Natura 2000 contributing to sustainable economic development and/or diversification of rural areas	Could fund one-off sediment removal and deepening from a river delta area to enable long-term habitat restoration.
6(1)b	Development of cross-border economic, social and environmental activities through joint strategies for sustainable territorial development: encouraging the protection and joint management of the natural and cultural resources, as well as the prevention of natural and	Could fund cross-border initiatives that also support ecological connectivity within landscapes, including river-basin restoration including sediment removal, removal of large infrastructure such as dams.

	technological risks.	
6(2)b	Establishment and development of transnational cooperation: actions may include protection and management of river basins, coastal zones, marine resources, water services and wetlands; fire, drought and flood prevention; the promotion of maritime security and protection against natural and technological risks; and protection and enhancement of the natural heritage in support of socio-economic development and sustainable tourism, water management, with a clear trans-national dimension, including protection and management of river basins, coastal zones, marine resources, water services and wetlands.	
8	Sustainable urban development: strengthening economic growth, the rehabilitation of the physical environment, brownfield redevelopment, and the preservation and development of the natural and cultural heritage, the promotion of entrepreneurship, local employment and community development, and the provision of services to the population taking account of changing demographic structures.	Within urban areas, could support redevelopment of Natura sites to promote local use and community development.
Cohesion Fund Article	**Description**	**Possible application in the context of Natura 2000**
2(b)	Environment within the priorities assigned to the Community environmental protection policy under the policy and action programme on the environment, in this context also including areas related to sustainable development which clearly present environmental benefits, namely energy efficiency and renewable energy and, in the transport sector outside the trans-European networks, rail, river and sea transport, intermodal transport systems and their interoperability, management of road, sea and air traffic, clean urban transport and public transport.	Construction of infrastructure for water treatment in order to improve water quality (and therefore habitat quality) at Natura 2000 sites.

7.6.3 National funding instruments

As described in previous sections of this chapter there appear to be a wide range of potential EU mechanisms with associated funding that can help to implement required connectivity and related climate change adaptation measures. For example, AEM schemes can be used to maintain or restore habitats, such as in the Netherlands, where agri-environment schemes have been used to help establish the National Ecological Network. However, it is expected that many Member States will find that the requirements for maintaining and enhancing connectivity will require more funding than is available from the EU, especially in the future as measures to adapt to climate change become increasingly important and urgent. There may also be requirements for specific habitat maintenance or restoration measures that cannot be easily addressed through existing mechanisms and funding streams.

Recommendations

It is suggested that Member States should consider the need for future national funding instruments to implement the connectivity measures needed to ensure the coherence of the Natura 2000 network and necessary biodiversity adaptation measures for climate change. In particular it is recommended that:

1. Member States should calculate the costs of achieving adequate coherence across the Natura 2000 network and FCS amongst habitats and species within their country (taking into account necessary trans-boundary coherence). This should draw on overall assessments of the coherence of the national Natura 2000 network as well as plans for ecological networks and connectivity measures identified in Biodiversity Action Plans etc. Funding opportunities should be identified for required connectivity actions and gaps in funding identified and costed.

2. Where necessary a national funding strategy should be developed for establishing ecological networks and implementing other required connectivity measures (including those related to climate change). This may involve the establishment of a specific fund to draw together and promote a wide range of connectivity and climate change adaptation actions as one brand identity for publicity and fund raising purposes.

3. Members States should consider establishing and promoting a range of funding mechanisms to support the national funding strategy and/or specific connectivity measures where required. Possible funding mechanisms that might be considered could include:
    - Direct national or regional government funding (or via statutory conservation bodies)
    - Lottery schemes
    - Use of environmental taxes (e.g. the Landfill Tax as developed in the UK)
    - Business and public appeals, possibly in partnership with NGOs
    - Use of mitigation banking funds or credits.

7.7 Governance and decision-making processes

As the sections above indicate, a number of different sectors play a role in maintaining and enhancing connectivity within landscapes. This creates challenges for coherent decision-making that is crucial to ensure that different sectoral actions and measures actively support and/or do not jeopardise landscape connectivity. Consequently, ensuring effective governance and decision-making processes, both at the Community and Member States level, is of high importance. This includes guaranteeing efficient cooperation and coordination between different sectors, including biodiversity conservation, land-use planning, regional development and agricultural sectors. In addition to the horizontal coordination between sectors, vertical coordination and communication between the Community and Member States' national, regional and local levels is also important to assure that the Community and national level measures that aim to prevent fragmentation and/or increase connectivity are mutually supportive. It is also important to note that the administrative boundaries rarely coincide with the natural boundaries of ecosystems and their functioning. Therefore, the creation of mechanisms for cross-border cooperation is also essential.

Since 2002 the Commission has been committed to carrying out impact assessments of all its major initiatives, i.e. those which are presented in the Annual Policy Strategy or later in the Work Programme of the Commission[27]. At present, these Commission impact assessments are one of the main mechanisms in place for facilitating coordination between different policy sectors at the Community level. In principle, the Commission impact assessment procedure can also provide opportunities for improving the consideration of connectivity related issues in decision-making. For example, the consultation processes carried out in the context of these impact assessments, includes a consultation within the Commission (inter-service consultation) and a wider public consultation. These offer opportunities for different stakeholders (e.g. relevant Commission Directorate Generals, representatives of the civil society) to address any negative effects the suggested policy/legal proposal might have on ecosystems and landscapes, including on ecological coherence and connectivity. In addition, it is possible to point out any relevant considerations that might have not been addressed by the impact assessment. In addition to the impact assessment procedure, there are also examples of the establishment of inter-Commission (e.g. inter-Directorate General) working groups on an ad-hoc basis in order to address certain thematic issues with clear cross-sectoral implications (e.g. invasive alien species). In principle, similar mechanisms could also be used to address issues related to ecological coherence and connectivity.

As for the communication between the Community and Member States level, a number of permanent committees, including the Habitats Committee and the Ornis Committee have been established as part of decision-making process in the EU and to facilitate the implementation of Birds and Habitats directives. These committees may provide potential fora also for addressing the implementation of the connectivity related provisions of the directives between the Community and Member States level (e.g. coordinating the implementation efforts).

At the transnational level there are also some examples where enhancing ecological connectivity between neighbouring states has been taken up by a specific transnational

[27] Commission's Communication COM(2002)276 of 5 June 2002 on Impact Assessment; Commission Impact Assessment Guidelines (15 June 2006): http://ec.europa.eu/governance/impact/docs/key_docs/sec_2005_0791_en.pdf

governing body, such as the Commission for the Protection of the Rhine (see Chapter 5.2.2).

In addition to coordination, it is also vital that considerations of connectivity related issues are well integrated into all sectoral decision-making processes. In this context, there is still scope for improvements both at the Community and Member State level. One of the identified reasons for the low level of integration of biodiversity related issues into sectoral decision-making (e.g. the impacts of policy and legislative decisions on landscape connectivity and biodiversity), is the lack of awareness on the importance of these issues at different sectoral levels. For example, the implications of biodiversity impacts on a number of socio-economic benefits arising from ecosystem services are poorly known. Consequently, raising the profile of connectivity related aspects in governance processes is of high importance.

As regards climate change, the Intergovernmental Panel on Climate Change (IPCC) and the European Climate Change Programme (ECCP) are mechanisms that, in addition to providing authoritative information on climate change, can be also seen to support the integration of climate change issues into policy- and decision-making at international and European levels. The work of these initiatives has traditionally focused on the prevention of climate change and the mitigation of its impacts (e.g. by addressing energy and emissions). However, current work by the IPCC and ECCP is increasingly addressing the need for adaptation to climate change and the role of biodiversity in mitigating the effects of climate change. In this context, the issues related to ecological connectivity and climate change should be addressed and highlighted in order to further support the integration of these issues into policy- and decision-making in the near future.

Recommendations:

In order to help governance and decision-making mechanisms prevent fragmentation and support the maintenance and enhancement of ecological connectivity, it is recommended that Member States should consider:

- Improving coordination and communication between different sectors on issues relevant to ecological connectivity, both at Community and national level. In this context, an improved use of the existing impact assessment processes and/or establishment of permanent and/or semi-permanent mechanisms that assist decision-making processes (such as thematic experts groups, working parties and advisory committees), could be considered.

- Improving coordination and communication between different decision-making levels in the EU, including the Community, national, regional and local levels, by using existing, and/or establishing new mechanisms to assist in decision-making processes (see above).

- Where necessary, improving cross-border/transnational coordination and communication on issues related to ecological connectivity. Connectivity issues could be integrated into the mandate of existing cross-border/transnational governance bodies (e.g. river basin organisations) or, where appropriate and feasible, the establishment of new mechanisms could be considered.

- Clarifying the roles that different players (e.g. at the Community level and within Member States governmental sectors), have in developing and implementing measures that aim to prevent fragmentation and improve ecological connectivity. It may also be necessary to ensure that the responsible sectors have sufficient power and authority to implement any required measures. Responsibilities for decision making regarding climate change impacts upon biodiversity should also be clarified in this respect.

- Increasing the profile of ecological connectivity related issues in the governance processes (e.g. government strategies) and raising awareness amongst all governmental sectors of the importance of maintaining ecological connectivity. In this context, the value of biodiversity and related ecosystem services, including its socio-economic benefits, should be highlighted.

- Providing necessary guidance and capacity building support for different governmental sectors on how issues related to fragmentation and ecological connectivity, in particular its functional aspects, should be addressed. This would be particularly appropriate in improving addressing connectivity in the context of land-use planning (e.g. transport). In particular, provide guidance on how to address issues related to ecological connectivity and climate change.

8 FUTURE RESEARCH REQUIREMENTS

This guidance document has shown that a considerable amount of research has been conducted within the scientific disciplines of landscape ecology and population dynamics that underpin the rationale for maintaining connectivity amongst the Natura 2000 network of sites and other habitats of conservation value. Nevertheless, further work needs to be conducted on these subjects, especially regarding large-scale and long-term processes. For example, eight key questions on connectivity and landscape structure were recently identified as being amongst the 100 most important ecological questions of high policy relevance in the UK (Sutherland et al. 2006). Although these relate to the UK, they are relevant to much of Europe and are therefore included below. Further work is also urgently required concerning the likely impacts of climate change on ecosystems, habitats and species, and the need for habitats and species to move in response to climate changes. These climate change related issues are currently being investigated under an EEA research project as described below in Box 7.1.

However, the greatest immediate need for research in the context of the objectives of the Habitats and Birds directives considered in this guidance is on the efficacy and efficiency of practical connectivity measures. It is therefore recommended that Member States should urgently consider undertaking research and monitoring projects (in collaboration where this is feasible) that aim to:

1. Increase our understanding of the interrelationships between connectivity and landscape structure and role in maintaining FCS amongst habitats and species. For example, the following questions as identified by Sutherland etc al. (2006) should be considered.
   - What are the lag times between habitat fragmentation and the loss of species of different taxonomic and functional groups?
   - Is it better to extend existing habitat patches or create further patches within the landscape?
   - How should we manage landscape mosaics for the conservation of diverse taxa that operate on different spatial scales?
   - What are the relative merits of different indices of habitat connectivity? Which of them best predict conservation value?
   - What is the value of linear habitats, such as hedgerows, railways, road verges and riparian strips, as corridors for dispersal between fragmented habitat patches?
   - For species where the concept is applicable, how can 'source' and 'sink' populations be identified and how should their status affect conservation management?
   - How important are core versus peripheral areas in the conservation strategy of a species?
   - How reliant are animal and plant populations in small nature reserves on the maintenance of habitat in surrounding non-protected areas?

2. Identify and quantify the cost-effectiveness of practical measures that can be take to increase matrix permeability.

3. Establish which habitats and species of Community importance are particularly at risk at a national and biogeographic scale from habitat fragmentation and the likely impacts of climate change (building on the results of the EEA study – see Box 7.1).

4. Examine the relationships between landscape permeability and the provisions of ecosystem services.

5. Develop and implement monitoring schemes that aim to measure the actual impacts of ecological networks and other connectivity measures in relation to specific quantifiable biodiversity related objectives (including the coherence of the Natura 2000 network and the wider maintenance and restoration of FCS in habitats and species of Community interest).

Box 7.1. Understanding the Natura 2000 network's vulnerability to projected climate change impacts

The European Environment Agency launched a project in 2006 which includes analysis of spatial and ecological aspects of the Natura 2000 network's coherence. This work will examine two aspects of Natura 2000: the role of agricultural management of designated sites, and within the wider countryside; and the potential effects of climate change on the network.

The climate change project centres on the bringing together of data and information from the Natura 2000 database (housed by the EEA at its Topic Centre on Biological Diversity), and relevant data and information from research projects in this area. In particular it aims to:

1. Investigate the Natura 2000 network's connectivity and fragmentation via the wider landscape.
2. Identify habitats and species most likely to be affected by climate change impacts in specific regions (including Arctic regions, mountain regions, coastal wetlands, and the Mediterranean region).
3. Map these habitats and species within the Natura 2000 network.
4. Explore the use of policy tools to address these risks.

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ANNEXES

Annex 1. Glossary and definitions of technical terms

Term	Definition	Source
Category: Ecosystem characteristics		
adaptive capacity	The ability of a system / individuals to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.	Corresponding definitions from different sources: IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
biodiversity	Variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems	Convention on Biological Diversity (CBD) (Article 2) (http://www.biodiv.org/convention/articles.shtml?lg=0&a=cbd-02) Corresponding definition also, for example, by: Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.

biomass	General definition: The total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass In the context of EC energy policy: the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.	**General definition:** IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Secretariat of the Convention on Biological Diversity. 2003. Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10) **EC energy policy context:** Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market
biome	A large, regional ecological unit, usually defined by some dominant vegetative pattern.	Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.
carbon sequestration	The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through land-use change, afforestation, reforestation, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing fossil fuels to produce hydrogen- and carbon dioxide-rich fractions and long-term storage in underground in depleted oil and gas reservoirs, coal seams, and saline aquifers.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)

connectivity – structural and functional	Structural connectivity is equal to habitat continuity and is measured by analysing landscape structure, independent of any attributes of organisms. This definition is often used in the context of metapopulation ecology. Functional connectivity is the response of the organism to the landscape elements other than its habitats (ie the non-habitat matrix). This definition is often used in the context of landscape ecology. See also: *landscape connectivity; habitat continuity, wildlife corridors, stepping stones, connecting structures*	*According to*: Tischendorf, L. and Fahrig, L. 2000. On the usage and measurement of landscape connectivity. Oikos 90: 7-19.
ecological coherence of Natura 2000	Sufficient representation of habitats / species to ensure favourable conservation status of habitats and species across their whole natural range. 'Sufficient representation' is a function of patch quality, total patch area, patch configuration and landscape permeability.	COM (2005) Note to the Scientific Working Group: Conclusions of workshop 'Ecological networks and coherence according to article 10 of the Habitats Directive', Vilm, Germany, May 2005; and Ssymank, A., Balzer, S. and Ullrich, K. 2006. Biotopverbund und Kohärenz nach Artikel 10 der Fauna-Flora-Habitat Richtlinie. Natur und Landschaft 38(2): 45-49.
ecological stability	Ability of a community or ecosystem to withstand or recover from changes or stress imposed from outside. Within the concept of stability there are a number of terms and types that warrant further discussions. Generally ecologists have included the concepts of resilience and resistance of communities within the concept of stability. In this case resilience is the speed with which a community can return to its original state after being perturbed and resistance is the ability to avoid the perturbation in the first place (See '*ecosystem resilience*' and '*ecosystem resistance*' below). These two ideas are now generally subsumed with the definition of ecosystem resilience.	Lawrence, E. (ed.). 2002. Henderson's dictionary of biological terms (12th edition). Pearson Education Limited, Essex, England. Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.

	Stability can be further divided into local and global stability. Local stability describes the tendency of a community to return to its original state when subjected to a small perturbation, whereas global stability describes this ability when faced with large perturbations. Furthermore, the stability of a community depends on the ecological conditions within which exists. If a community is stable within a narrow range of conditions it is said to be dynamically fragile whereas if it is stable within a broad range of conditions it is dynamically robust. Previously it was thought that stability was a function of the community complexity, i.e. the more species that occurred within a community and the more interactions between them led to a more stable community. However this was shown to not be the case and has been shown to vary dramatically with community (Begon et al. 1996).	
ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. The ecosystem boundaries are defined by the dynamic interactions, sometimes termed ecosystem processes, among the components of an ecosystem (i.e. plants, wildlife, climate, landforms and human activities). The ecosystem boundaries are irrespective of scale or location for ecosystem processes occur at a multitude of scales. Generally ecologists take a pragmatic approach that looks for assemblages of strong links between components within an ecosystem compared to weak interactions with components outside them. As biological diversity relates to the sum of the variability within species (e.g. genetic), between species and between ecosystems, it can be seen as a key structural feature of	Convention on Biological Diversity (CBD) (Article 2) (http://www.biodiv.org/convention/articles.shtml?lg=0&a=cbd-02) Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)

	ecosystems.	
ecosystem functions / functioning[28]	Ecosystem functions are defined as the capacity of natural [ecosystem] processes and components to provide goods and services that satisfy human needs, directly or indirectly. These functions have been broadly grouped into four categories: 1) regulation, 2) habitat, 3) production and 4) information (de Groot et al. 2002). In short, ecosystem functions can be seen as an observable outcome (a subset) of *ecosystem processes* and *ecosystem structure*. Out of the group of ecosystem functions, a set of *ecosystem services* having visible benefits to human society can be identified.	de Groot, R. S., Wilson, M. A., Boumans, R. M. J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services Ecological Economics, 41/3: 367-567
ecosystem services	Ecosystem services are the benefits people obtain from ecosystems. These include four different categories, namely *provisioning services* such as food, water, timber, and fibre; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling. Please note: provisioning ecosystem services can also be referred to as *ecosystem goods.* Therefore, the term '*ecosystem goods and services'* is also often used in literature (particularly prior to the Millennium Ecosystem Assessment (MEA)). The term '*ecosystem goods and services'* is equivalent to the MEA four-category	Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) This definition also adopted by the European Commission 'Halting the loss of biodiversity by 2010 – and beyond' (COM/2006/216) (http://ec.europa.eu/environment/nature/biodiversity/current_biodiversity_policy/biodiversity_com_2006/index_en.htm)

[28] Depending on the source, the definition/classification of following terms differs slightly: ecological processes and ecosystem functioning / functions. The definitions / classification adopted in the context of this study is compatible with the one used by Millennium Ecosystem Assessment (2005). For different definitions / classification see, for example: Hooper, D. U., Chapin, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J. H., Lodge, D. M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A. J., Vandermeer J. and Wardle, A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs, 75/1: 3-35.

	definition of ecosystem services (above). The term '*ecosystem goods and services'* has been used by a number of pioneering scientists in the field, for example Prof. Gretchen Daily and Prof. Robert Constanza. *References:* Daily, G.C. (ed.). 1997. Nature's Services: Societal Dependence on Natural Ecosystems, Island Press, Washington, DC; Costanza, R., d'Arge, R., de Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 253–260.	
ecosystem process	An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy.	Millennium Ecosystem Assessment (MEA). 2005. Our human planet: summary for decision-makers. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
ecosystem resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004). Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.	Millennium Ecosystem Assessment (MEA). 2005. Our human planet : summary for decision-makers. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) Walker, B. H., C. S. Holling, S. C. Carpenter and Kinzig, A. P. 2004. Resilience, adaptability and transformability. Ecology and Society 9:5.
ecosystem resistance	The capacity of an ecosystem to withstand the impacts of drivers without displacement from its present state. This is an analogous definition for community resistance which is discussed under the definition for ecological stability.	Millennium Ecosystem Assessment (MEA). 2005. Our human planet: summary for decision-makers. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
ecosystem structure	Attributes related to the instantaneous physical state of an ecosystem; examples include species population density, species richness or evenness, and standing crop biomass	US Environmental Protection Agency Glossary of terms (http://www.epa.gov/OCEPAterms/eterms.html)

ecotone	Zone / transition areas between two ecosystems where these two systems overlap. Ecotones support species from both of the over lapping ecosystems and also species found only in this zone. Consequently, the species richness in ecotones might be higher than in surrounding areas. In principle, fragmentation causes an increase in habitat edges, therefore increasing the proportion of ecotones within a landscape. In this context, it has also been considered that habitat edges have a negative influence on interior conditions of habitat (e.g. through increased predation and invasion), i.e. the edge effect.	*Based on:* Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii; and Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.
habitat continuity	Permanent and long term stock of all necessary habitat requirements for an organism within a given landscape/ecosystem, including dynamic/spatial mosaics.	*Based on:* COM (2005) Note to the Scientific Working Group: Conclusions of workshop 'Ecological networks and coherence according to article 10 of the Habitats Directive', Vilm, Germany, May 2005.
habitat / landscape heterogeneity / diversity	Landscapes' quality or state of being heterogeneous, eg being composed of parts of different habitats.	*Based on:* Franklin, A., B. Noon and George, T. 2002. What is habitat fragmentation? Studies in Avian Biology 25: 20-29 and Murphy, H. T. and Lovett-Doust, J. 2004. Context and connectivity in plant metapopulations and landscape mosaics: does the matrix matter? Oikos 105: 3-14.
landscape	Landscapes can be defined as one of the lower levels of ecological organisation within regional ecosystems (i.e. biomes). Alternatively, landscapes can also be considered as areas defined by different resource management such as forestry and agriculture. The latter definition strongly corresponds to human perceptions.	Wiens, J. A. 2002. Riverine landscapes: taking landscape ecology into the water. Freshwater Biology 47:501-515.

landscape connectivity	The degree to which the landscape facilitates or impedes movement among patches. Landscape connectivity is a combined effect of structural and functional connectivity, i.e. effect of landscape structure and the species' use, ability to move and risk of mortality in various landscape elements on the movement rate among habitat patches in the landscape. See also: *connectivity - structural and functional*	Tischendorf, L. and Fahrig, L. 2000. On the usage and measurement of landscape connectivity. Oikos 90: 7-19 (*and the references within*).
landscape pattern	The spatial distribution and arrangement of patches within landscape.	*Based on:* Forman, R.T.T. and Godron, M. 1986. Landscape ecology. John Wiley & Sons, NewYork. 620 pp; Forman, R. T. T. 1995. Land mosaics. The ecology of landscapes and regions. - 632 p.; Cambridge.
primary production	Rate of biomass produced by an ecosystem, generally expressed as biomass produced per unit of time per unit of surface or volume. Net primary productivity (NPP) is defined as the energy fixed by plants minus their respiration. Global terrestrial NPP is estimated to be 110-120 x 10^9 tonnes dry weight per year, and 50-60 x 10^9 tonnes in the seas. Therefore although marine ecosystems cover two-thirds of the Earth's surface, they provide one third to one half of its production. There is a general latitudinal trend where productivity is concentrated in tropical and temperate regions and is primarily constrained by solar radiation (as a resource) and temperature (as a condition). Other factors also limit productivity within more narrow bounds including availability of nutrients, water availability and altitude. It should also be remembered that measures of NPP are biased towards above-ground NPP in terrestrial ecosystems due to the difficultly of measuring below ground NPP.	Millennium Ecosystem Assessment (MEA). 2005. Our human planet: summary for decision-makers. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.

succession (ecological)	The more or less predictable changes in the composition of communities following a natural or human disturbance. As an ecological concept, succession can be defined as the non-seasonal, directional and continuous pattern of colonisation and extinction on a site by species populations (Begon et al. 1996). This definition encompasses a range of different sequences that occur over widely varying time scales and often as a result of different mechanisms. A number of different forms of succession can be identified: Degradative succession These events can occur over a relatively short time scale and occur when a degradable resource (e.g. dead organic matter) is utilised successively by a number of species. As the matter continues to degrade the conditions tend to favour one group of species over another. Ultimately this process terminates as the resource is used up. Allogenic succession This involves the creation of new habitat that is opened up for invasion by green plants or other sessile organisms. In this case the new habitat does not degrade but becomes occupied. This form of succession is caused by changing external geophysicochemical forces. Autogenic succession This occurs when species occupy newly exposed areas in the absence of abiotic influences. If this exposed area has not previously been influenced by a community the sequence of species is referred to primary succession. Whereas cases where substrate becomes exposed due to the removal of species, but seeds	IUCN / World Conservation Monitoring Centre Glossary of Biodiversity Terms (http://www.unep-cmc.org/reception/glossaryA-E.htm) Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.

	or spores remain – the subsequent sequence of species is termed secondary succession.	
Category: Pressures on ecosystems (including those of climate change)		
coral bleaching	The paling in colour of corals resulting from a loss of symbiotic algae. Bleaching occurs in response to physiological shock in response to abrupt changes in temperature, salinity, and turbidity.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
deforestation	Conversion of forest to non-forest land.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
desertification	Land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Further, the United Nations Convention to Combat Desertification defines land degradation as a reduction or loss in arid, semi-arid, and dry sub-humid areas of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)

disturbance	A discrete event, either natural or human induced, that causes a change in the existing condition of an ecological system. In community ecology, disturbance generally relates to the interruption of, or interference with, interspecific competition and the settled state the community structure would assume if the conditions remained constant. Therefore a disturbance is a discrete event in time that removes organisms or otherwise disrupts the community by influencing the availability of space and/or food resources, or by changing the physical environment. A general consequence of this is that space or resources become available to new individuals. The most commonly identified causes of disturbance are predators, parasites, disease, temporal heterogeneity and changes to physical structures. Changes to each of these factors can be naturally occurring or anthropogenically induced (Begon et al. 1996). However this term becomes more vague when applied to conservation issues. Habitat disturbance is identified as one of the three ways in which habitats can be disrupted (destruction and degradation being the others). In this sense disturbance refers to discrete events that cause minor but accumulating impacts on a species. For example repeated visits to caves have been shown to disrupt grey bat (*Myotis grisescens*) populations leading to declines in the USA (Begon et al. 1996).	Kaufmann, M. R., Graham, R. T., Boyce, D. A., Jr., Moir, W. H., Perry, L., Reynolds, R. T., Bassett, R. L., Mehlhop, P., Edminster, C. B., Block, W. M., and Corn, P. S. 1994. An ecological basis for ecosystem management. Gen. Tech. Rep. RM 246. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 pp. Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.
disturbance regime	Frequency, intensity, and types of disturbances, such as fires, insect or pest outbreaks, floods, and droughts.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm)
erosion	The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Secretariat of the Convention on Biological Diversity. 2003.

		Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10)
eutrophication	Increase in the amount of nutrients in the soil and waterbodies, with an impact on ecological processes. The most important nutrients causing eutrophication are phosphorus and nitrogen.	Dumortier, M., De Bruyn, L., Hens, M., Peymen, J., Schneiders, A., Van Daele, T., Van Reeth, W., Weyemberh, G. & Kuijken, E. 2005. Natuurrapport 2005. Toestand van de natuur in Vlaanderen: cijfers voor het beleid. Mededelingen van het Instituut voor Natuurbehoud nr. 24, Brussel. (Translation provided by the Flemish Research Institute for Nature And Forest (INBO).
extinction	The complete disappearance of an entire species. Extinction can happen at different spatial scales and relates to the complete disappearance of a species from a specified area. Local extinctions of small populations in insular habitats are common events for a diverse range of taxa. In most cases local extinctions can be countered by recolonisation of the area from a larger 'mainland' population. A local extinction of an endemic species is the same as a global extinction since recolonisation is impossible. Remote islands with high species diversity and many endemics are there also the centres for high rates of extinction. The most pervasive factors associated with extinction are habitat or island area (Begon et al. 1996)	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Secretariat of the Convention on Biological Diversity. 2003. Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10) Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.

fragmentation / habitat fragmentation	The breaking up of extensive landscape features into disjunct, isolated, or semi-isolated patches as a result of land-use changes. Fragmentation has two negative components for biota: loss of total habitat area and the creation of smaller, more isolated, remaining habitat patches (Meffe and Carroll 1997). Fragmentation can be seen as a landscape-scale process involving both habitat loss and the breaking apart of habitat with a net increase in the area of habitat edges (i.e. habitat fragmentation). (Fahrig 2003) Direct habitat loss has large, consistently negative effects on biodiversity, while process of habitat fragmentation has weaker effects which may be negative (increased exposure to external pressures; reduced migration; higher local extinction rates) or positive (enhanced persistence of predator-prey system by providing refugia for prey species; enhanced stability of two-species competition) (Fahrig 2003). Populations caught in a non-equilibirum metapopulation dynamic are also referred to as fragmented. This occurs when there is too little migration between metapopulations to maintain the overall population.	**General definition:** European Community Biodiversity Clearing House Mechanism Glossary of Terms (http://biodiversity-chm.eea.europa.eu/nyglossary_terms/) Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates, inc. Publishers, Sunderland, Massachusetts. 729 pp; and Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34: 487-515.
invasive alien species	An alien species whose introduction and/or spread threaten biological diversity. See also: *alien species*	Convention on Biological Diversity, CBD Guiding Principles (CBD Decision VI/23) (http://www.biodiv.org/decisions/default.aspx?dec=VI/23)
Category: Responses		

adaptation	Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
afforestation	Planting of new forests on lands that historically have not contained forests. **Please note:** in practise the term 'afforestation' in Europe is often defined as planting of new forest on lands where the land-use has been different for a certain number of year, e.g. at least one forest generation. For example, in the context of the Kyoto Protocol the 'afforestation' has been defined as the human-conversion of land that has not been forested for a period of at least 50 years to forested land (FCCC/KP/CMP/2005/8/Add.3). See also: *reforestation*	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) UNFCCC. 2005. Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its first session, held at Montreal from 28 November to 10 December 2005. Addendum. Part Two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol at its first session (FCCC/KP/CMP/2005/8/Add.3). http://unfccc.int/documentation/documents/advanced_search/items/3594.php?rec=j&priref=600003823&data=&title=&author=&keywords=&symbol=FCCC%2FKP%2FCMP+&meeting=&mo_from=01&year_from=2005&mo_to=&year_to=&last_days=&anf=0&sorted=date_sort&dirc=DESC&seite=1#beg
agro-forestry (system)	Mixed systems of crops and trees providing wood, non-wood forest products, food, fuel, fodder, and shelter.	Millennium Ecosystem Assessment (MEA). 2005. Our human planet : summary for decision-makers. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)

ecological network	A coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources (Bennett 2004). Ecological networks are, therefore, a tool to support the maintenance, restoration or reestablishment of functional ecological relations between different elements of a landscape (Finck & Riecken 2001, Riecken et al. 2004). Actions to maintain or restore these interactions include: conserving a representative array of habitats allowing species populations access to a sufficient surface area; allowing seasonal migration, permitting genetic exchange between different local populations, allowing local populations to move away from degrading habitats; and securing the integrity of vital environmental processes (Bruszik et al. 2006). By focusing on the ecological interactions across landscapes, ecological networks explicitly include relations between semi natural to natural areas and cultivated areas and therefore identify appropriate opportunities within the landscape matrix for the sustainable use of natural resources - agriculture, forestry, fishing, human settlements, recreation, etc. (Finck & Riecken 2001, Bennett 2004, Riecken et al. 2004). Typically ecological networks are implemented through a planning approach that identifies core areas (protected areas), buffer zones of mixed landuse and connective structures that enable the movement of organisms between core areas (e.g. ecological corridors and/or permeable landscapes) (Bruszik et al. 2006, Bennett 2004).	Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 55 pp. Bruszik, A., Rientjes, S., Delbaere, B., van Uden, G., Richard, D., Terry, A. and Bonin, M. 2006. Assessment of the state of affairs concerning the Pan-European Ecological Network (Final draft - 31 August 2006) 79 pp. Finck, P. & Riecken, U. (2001): Nationaler Biotopverbund aus Bundessicht. Flächenpool-Lösungen - ein Fortschritt für den Vollzug der Eingriffsregelung? : Tagungsband zur Oppenheimer Arbeitstagung ; 2. Teil: Planung vernetzter Biotopsysteme - Umsetzung und Konsequenzen : Tagungsband. - Oppenheim - (2001), Bd. 5: S. 4-12. Riecken, U., Ullrich, K. & Finck, P. (2004): Biotopverbund. - In: Konold, W., Böcker, R. & Hampicke, U.: Handbuch Naturschutz und Landschaftspflege. Handbuch Naturschutz und Landschaftspflege: Kompendium zu Schutz und Entwicklung von Lebensräumen und Landschaften. - 13. Erg. Lfg. 9/04. ecomed, Landsberg: 1-20 (Teil XI-4; Stand: 2004).

favourable conservation status	Habitats: The conservative status of a natural habitat will be taken as ‘favourable’ when: its natural range and areas it covers within that range are stable or increasing, and the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and the conservation status of its typical species is favourable as defined below (as in Habitats directive Article 2 (i)). Species: The conservation status of a species means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the territory referred to in the habitat Directive’s Article 2. The conservation status will be taken as ‘favourable’ when: population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis. Please note: favourable conservation status was initially introduced by the Habitats directive, i.e. its origins are in political, not ecological, literature.	Article 2 of the habitat Directive (92/43/EEC)
landscape permeability	The quality of a heterogeneous land area to provide for passage of organisms. In contrast to focusing on the identification of corridors or connected habitat patches, the landscape permeability considers more broadly the resistance to organism movement and aims to provide a consistent estimate of the relative potential for organisms' passage across entire landscapes. This measure therefore considers the permeability of the matrix habitat as well as the degree of	Singleton, P. H., Gaines, W. L. and Lehmkuhl, J. F. 2002. Landscape Permeability for Large Carnivores in Washington: A Geographic Information System Weighted-Distance and Least-Cost Corridor Assessment. Unites States Department of Agriculture, USA, 74 pp.; and Tischendorf, L. and Fahrig, L. 2000. On the usage and measurement of landscape connectivity. Oikos 90: 7-19 *(and the references within)*.

	structural connectivity.	
land-use planning	The systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land-use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses. Land-use planning may be at international, national, district (project, catchment) or local (village) levels. It includes participation by land users, planners and decision-makers and covers educational, legal, fiscal and financial measures.	FAO. 1993. Guidelines for land use planning. FAO Development Series 1 (via European Environmental Agency (EEA) glossary of terms (http://glossary.eea.europa.eu/EEAGlossary)
minimum viable population	A minimum viable population for any given species in any given habitat is the smallest isolated population having a 99per cent chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental and genetic stochasticity and natural catastrophes (Schaffer 1981). Schaffer emphasised that the specific survival probabilities and time periods were almost subjective in their designation, but what was important was the development of a quantitative estimate for the population size required to ensure long term survival. This approach has been increasingly taken over by population viability analysis as a means to model and predict extinction risk as a more accurate way of predicting population viability.	Schaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience. 31(2): 131-134.

mitigation	An anthropogenic intervention to reduce negative or unsustainable uses of ecosystems or to enhance sustainable practices. In the context of climate change: an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.	**General definition:** Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) **Definition in the context of climate change:** IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Secretariat of the Convention on Biological Diversity. 2003. Inter-linkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10);
reforestation	Planting of forests on lands that have previously contained forests but that have been converted to some other use. For the definition of 'reforestation' in the European context, see also: *afforestation*	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx).
Category: Ecosystem management		
adaptive management	A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning.	Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
buffer zone	Zone / area around the network (ie around core areas and, if necessary, around linkage elements) which protects the network from potentially damaging external influences and which are essentially transitional areas characterized by compatible land uses.	Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 55 pp.

		Corresponding definition also, for example, by: Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.
connecting structures	Connecting areas for specific species or habitats (eg within ecological networks). Landscape mosaics may provide these functions. See also: *ecological corridors, landscape permeability*	COM (2005) Note to the Scientific Working Group: Conclusions of workshop 'Ecological networks and coherence according to article 10 of the Habitats Directive', Vilm, Germany, 2006.
core area	Area where the conservation of biodiversity takes primary importance, even if the area is not legally protected.	**General definition:** Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 55 pp.
ecological corridors	Landscape elements which serve to maintain vital ecological or environmental connections by providing physical (though not necessarily linear) linkages between the core areas. The ecological functions of corridors are to enable species dispersal, migration, foraging and reproduction. Individual corridors are not necessarily linear features, but can be grouped in several ways according to their shapes (diffuse, belt-like, line-like, etc.), structure (continuous or interrupted like stepping stones), spatial position to the core area (conjunctive corridor or blind corridors), or by their services like migration corridors, commuting corridors and dispersal corridors. In practise, ecological corridors can be established at different scales, e.g. regional, national or local. At regional and national level ecological corridors refer to continuous habitat stretches (such as river valleys and water courses) and/or mosaic of habitat types	Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 55 pp. *Further elaborated in:* Bruszik, A., Rientjes, S., Delbaere, B., van Uden, G., Richard, D., Terry, A. and Bonin, M. 2006. Assessment of the state of affairs concerning the Pan-European Ecological Network (Final draft - 31 August 2006) 79 pp. (*and the references within*); and Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.

	that allow movement of species within the landscape. At local level corridors can consist of landscape elements such as hedgerows, dikes and road verges. It is to be noted that the proper scale of implementation is to a large extent species dependent and these aspects should be, therefore, taken into consideration.	
ecosystem approach	A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.	Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
ecosystem management	An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries.	Corresponding definitions by: Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx); and Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.
integrated coastal zone management	Environmentally sustainable, economically equitable, socially responsible, and culturally sensitive management of coastal zones, which maintains the integrity of this important resource while considering local traditional activities and customs that do not present a threat to sensitive natural areas and to the maintenance status of the wilds species of the coastal fauna and flora.	Recommendation of the European Parliament and the Council concerning the implementation of Integrated Coastal Zone Management in Europe (2002/413/EC)
landscape ecology	Landscape ecology is the study of structure, function, and change in a heterogeneous land area which contains interacting ecosystems. Landscape ecology focuses on 1) the spatial	Forman, R.T.T. and Godron, M. 1986. Landscape ecology. John Wiley & Sons, NewYork. 620 pp; Forman, R. T. T. 1995. Land mosaics. The ecology of landscapes and regions. - 632 p.;

	relationships among landscape elements, 2) the flows of energy, mineral nutrients, and species among the elements, and 3) the ecological dynamics of the landscape mosaic through time. In particular, landscape ecology is concerned with the effects of both natural and human disturbances on the landscape.	Cambridge.
multiple use - sustainable-use areas / multiple use zones	Multiple use: an on-site management strategy that encourages an optimum mix of several uses on a parcel of land or water or by creating a mosaic of land or water parcels, each with a designated use within a larger geographic area. Sustainable-use areas / multiple use zones: areas within the ecological networks where sufficient opportunities are provided within the landscape matrix for both the exploitation of natural resources and the maintenance of ecosystem functions.	Multiple use: IUCN / World Conservation Monitoring Centre Glossary of Biodiversity Terms (http://www.unep-wcmc.org/reception/glossaryA-E.htm) Sustainable-use areas / multiple use zones: Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 55 pp.
precautionary principle	When dealing with environmental policy, the precautionary principle states that: 'when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically'. At the EU level, precautionary approach also includes risk to animal and plant health (COM 2000/1).	Secretariat of the Convention on Biological Diversity. 2003. Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10). At the EU level the use of precautionary principle has been defined in the Commission Communication on the precautionary principle (COM 2000/1) (http://ec.europa.eu/dgs/health_consumer/library/pub/pub07_en.pdf). Reference to the precautionary principle is also included in the EC Treaty (in the context of environmental policy); however the Treaty provides no particular definition for the term (Maastricht Treaty of 1992 and the later EC Treaty.

protected area	A geographically defined area which is designated or regulated and managed to achieve specific conservation objectives	Convention on Biological Diversity (CBD) (Article 2) (http://www.biodiv.org/convention/articles.shtml?lg=0&a=cbd-02)
renewable and non-renewable resources	Renewable resource is an energy sources that are, within a short time frame relative to the Earth's natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass. In the context of EC energy policy: Renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases). Non-renewable energy resources: resources that do not fall under the above definitions	**General definition:** IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm) **EC energy policy context:** Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market
restoration (ecosystem)	The return of an ecosystem or habitat to its original community structure, natural complement of species, and natural functions.	IUCN / World Conservation Monitoring Centre Glossary of Biodiversity Terms (http://www.unep-wcmc.org/reception/glossaryA-E.htm) The SER International Primer on Ecological Restoration. 2004. Society for Ecological Restoration International, Science & Policy Working Group (Version 2: October, 2004) (http://www.ser.org/pdf/primer3.pdf)
stepping stones	An ecological corridor formed by non-linearly connected resource/habitat patches that allow organisms to disperse between the patches (e.g. core areas within an ecological network).	*According to* Prussic, A., Rientjes, S., Delbaere, B., van Uden, G., Richard, D., Terry, A. and Bonin, M. 2006. Assessment of the state of affairs concerning the Pan-European Ecological Network (Final draft - 31 August 2006) 79 pp. (*and the references within*).

sustainable forest management	The stewardship and use of forests and forest land in a way and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil now and in the future, relevant ecological, economic and social functions, at local, national and global levels and does not cause damage to other ecosystems. Alternatively according to FAO criteria: a group of forest management practises that centre around seven globally agreed core thematic areas: extent of forest resources; biological diversity; forest health and vitality; protective functions of forests; productive functions of forests; socio-economic functions; legal policy and institutional framework. The content and structure of sustainable forest management differs between regions / countries.	**General definition:** The Pan-European Process (ie the Helsinki Process) initiated by the Pan-European Forest Council in 1993. (http://www.pefc.org/internet/html/activities/4_1137_527.htm) FAO Criteria and indicators for sustainable forest management (http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=4462&sitetreeId=16587&langId=1&geoId=0)
wilderness area	Protected area managed mainly for wilderness protection. Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.	Definitions of a protected area categories adopted by IUCN (Category 1b) (http://www.unep-wcmc.org/protected_areas/categories/index.html)
Category: Species / habitat ecology		
alien species	Alien species refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.	Convention on Biological Diversity, CBD Guiding Principles (CBD Decision VI/23) (http://www.biodiv.org/decisions/default.aspx?dec=VI/23)

carrying capacity	The carrying capacity (usually denoted by *K*) represents the equilibrium point (i.e. the point at which density dependent birth and death rates cross) where intraspecific competition acting on birth and death rates regulate a population at a stable density. The maximum number of individuals of a particular species, that a given part of the environment can maintain (or 'carry') indefinitely. This concept is easier to illustrate theoretically where a population can be characterised by a sinmple carrying capacity. In natural populations the huge range of factors affecting density means that there will be a range of values that represent the carrying capacity. Also intraspecific competition will not hold a population to a predictable level, but will contain a population within certain bounds. This concept is closely linked to the establishment of quotas for harvesting wild living resources. Often the objective is drive the population to half its carrying capacity, where population growth is identified as maximal.	Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii. *For recent discussion see:* del Monte-Luna, P., Brook, P. W., Zetina-Rejón, M. J. and Cruz-Escalona1, V. H. 2004. The carrying capacity of ecosystems. Global Ecology & Biogeography, Volume 13, 485-495 pp.
climate envelope	The range of climatic variation within which the species can persist, provided its non-climatic environmental requirements are met. Estimating the climate envelope from distribution data provides a description of the climate within which the species has been recorded, and allows prediction of where a species' climate envelope will move under different scenarios of climate change (climate envelope modelling).	Harrison, P.A., Berry, P.M., Butt, N. and New, M. 2006. Modelling climate change impacts on species' distributions at the European scale: implications for conservation policy. Environmental Science and Policy, 9: 116-128. Walker, P. A. and Cocks, K.D. 1991. HABITAT: a procedure for modelling a disjoint environmental envelope for a plant or animal species. Global Ecology and Biogeography Letters 1:108-118.

dispersal capacity / ability	The capacity / ability of an organism to move away from place of birth. In the context of connectivity: The ability of an individual or population to move through a landscape mosaic, a function of landscape permeability, functional connectivity and the individual movement characteristics of the individual or species (Steven et al. 2004).	**General definition based on**: European Community Biodiversity Clearing House Mechanism Glossary of Terms (http://biodiversity-chm.eea.europa.eu/nyglossary_terms/) Stevens, V.M., Polus, E., Wesselingh, R.A., Schtickzelle, N. and Baguette, M. 2004. Quantifying functional connectivity: experimental evidence for patch-specific resistance in the Natterjack toad (*Bufo calamita*). Landscape Ecology, 19: 829-842
dispersal success	The number of successful immigrants into habitat patches in a landscape, or as search time, the number of movement steps individuals require to find a new habitat.	Tischendorf, L. and Fahrig, L. 2000b. How should we measure landscape connectivity? Landscape Ecol. 15: 633/641.
ecological community	An assemblage of species occurring in the same space or time, often linked by biotic interactions such as competition or predation.	Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
exposure	The nature and degree to which a system is exposed to significant climatic variations.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm)
keystone species	A species whose impact on the community is disproportionately large relative to its abundance. Effects can be produced by consumption (trophic interactions), competition, mutualism, dispersal, pollination, disease, or habitat modification (nontrophic interactions).	Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) Corresponding definition also, for example, by: Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp.
landscape mosaic (mosaic, habitat mosaic)	Spatial configuration of habitats within a landscape, generally formed by patches arranged within a matrix. See also: *matrix, patch*	Hanski, I. and Simberloff, D. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. In: Hanski, I. and Gilpin, M. (eds), Metapopulation biology. Ecology, genetics, and evolution. Academic Press, pp. 5 /26.

matrix (habitat / environmental matrix)	The interstitial habitat / environment between habitat patches in a habitat mosaic, typically comprising the most extensive habitat / environment type in a landscape. See also: *patch, mosaic*	Dennis, R. L. H., Shreeve, T. G. and Van Dyck, H. 2003. Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. Oikos 102: 417 /426.
metapopulation	Sets of local populations within some larger area, where typical migration from one local population to at least some other patches is possible (Hanski & Simberloff 1997). Metapopulations exist at a spatial scale where individuals can occasionally disperse among different patches but do not make frequent movements because the patches are separated by substantial expanses of unsuitable habitat. This rate of movement is usually sufficient to avoid long term genetic differentiation among patches, but low enough to allow each patch to be quite independent demographically. (Hunter 2002).	Hanski, I. and Simberloff, D. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. In: Hanski, I. and Gilpin, M. (eds), Metapopulation biology. Ecology, genetics, and evolution. Academic Press, p. 5-26. Corresponding definition also, for example, by: Meffe, G. K. and Carroll, C. R. 1997. Principles of Conservation Biology (second edition). Sinauer Associates , inc. Publishers, Sunderland, Massachusetts. 729 pp. Hunter, M. L. Jr. 2002. Fundamentals of Conservation Biology, Second edition, Blackwell Science, ISBN 0-86542-029-7
metapopulation ecology	Field of ecology that studies the dynamics of fragmented populations in heterogeneous landscapes, eg how these populations might respond to future perturbations such as climate change.	Hanski, I. and Simberloff, D. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. In: Hanski, I. and Gilpin, M. (eds), Metapopulation biology. Ecology, genetics, and evolution. Academic Press, p. 5-26.
patch (habitat or resource)	A particulate, invariant and homogeneous entity within an ecosystem. A concept forming the basis of metapopulation dynamics.	Dennis, R. L. H., Shreeve, T. G. and Van Dyck, H. 2003. Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. Oikos 102: 417 /426.
patch configuration	The spatial arrangement of habitat patches within a mosaic, determined by patch size and isolation	Krawchuk. M. A. and Taylor, P. D. (2003) Changing importance of habitat structure across multiple spatial scales for three species of insects. Oikos 103/1: 153.

patch isolation	An attribute of a patch determined by the rate of immigration into the patch; the lower the immigration rate, the more isolated is the patch.	COM (2005) Note to the Scientific Working Group: Conclusions of workshop 'Ecological networks and coherence according to article 10 of the Habitats Directive', Vilm, Germany, May 2005.
patch quality	The quality of a patch or patches within a mosaic (from the perspective of a given organism).	Dennis, R. L. H., Shreeve, T. G. and Van Dyck, H. 2003. Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. Oikos 102: 417 /426.
patch size	The size of a patch or patches within a mosaic.	Dennis, R. L. H., Shreeve, T. G. and Van Dyck, H. 2003. Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. Oikos 102: 417 /426.
pioneer species	First species that colonise a bare site as the first stage in a primary succession. Pioneer species can also be found in secondary succession (an established ecosystem being reduced by an event such as a forest fire of a clearing), colonizing newly created open spaces.	Lawrence, E. (ed.). 2002. Henderson's dictionary of biological terms (12th edition). Pearson Education Limited, Essex, England.
population density	It is common to use the term population to describe a group of individuals of one species. However the boundaries defining that population are not always readily expressed. In cases were the limits of the population may be expressed arbitrarily, it is better to use the population density. This is usually defined as numbers of individuals per unity area. Density can be calculated in three different ways. The most common way is the ‘resource weighted density’ which assumes equal distribution of individuals per unit resource; ‘organism weighted density’ which finds the mean distribution of individuals per unit resource and the ‘exploitation pressure’ which measures the mean density experienced by the resource (see Lewontin & Levins 1989 for more details).	Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii. Lewontin, R.C. and Levins, R. 1989. On the characterisation of density and resource availability. American Naturalist. 134: 513-524.
response latency / time	The time interval between a stimulus and response.	Lawrence, E. (ed.). 2002. Henderson's dictionary of biological terms (12th edition). Pearson Education Limited, Essex, England.

sensitivity	Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (eg a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (eg damages caused by an increase in the frequency of coastal flooding due to sea-level rise). This definition can also be considered to apply to species.	IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx)
specialist and generalist species	Specialist species: Species which can survive and thrive only within a narrow range of habitat and/or climate conditions, or which can use only a very limited range of food, and is therefore usually less able to adapt to changing environmental conditions. Generalist species: Organism or species with a very broad ecological niche, which can tolerate a wide range of environmental conditions and eat a variety of foods. Specialisation is linked to the predictability of the environment in which the species are found. The main source of this predictability comes from climatic variation. Generally speaking seasonal environments (temperate areas) should contain a broader range of conditions for species than seasonally constant ones (i.e. the tropics), but constant environments allow for greater specialisation due to a stability of resource conditions. There are some studies that indicate a relationship between species richness and climate variability, with increasing variability and decreasing richness. In general when talking about predatory species, those that require a shorter handling time of the prey compared to searching time should be generalists. Whereas predators with a long handling time relative to searching, should become specialists. When either	Lawrence, E. (ed.). 2002. Henderson's dictionary of biological terms (12th edition). Pearson Education Limited, Essex, England. Begon, M., Harper, J.L., and Townsend, C.R. 1996. Ecology: individuals, populations and communities (3rd ed.). Blackwell, Oxford, UK. 1068 pp + xii.

	prey density decreases or interspecific competition increases, specialist predators are more like to switch search areas, whereas generalist predators may switch prey species. Studies from tropical forests, also found that rare plant species tended to be specialists, whereas generalists tend to be more common.	
species range (natural)	The spatial limits within which the habitat or species occurs. A natural range is not static but dynamic: it can decrease and expand.	Guidance document on the strict protection of animal species of community interest provided by the 'Habitats' Directive 92/43/EEC, European Commission (autumn 2006 draft).
vulnerability – species and ecosystems/habitats	Exposure to contingencies and stress, and the difficulty in coping with them. Three major dimensions of vulnerability are involved: exposure to stresses, perturbations, and shocks; the sensitivity of people, places, ecosystems, and species to the stress or perturbation, including their capacity to anticipate and cope with the stress; and the resilience of the exposed people, places, ecosystems, and species in terms of their capacity to absorb shocks and perturbations while maintaining function. In the context of climate change: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.	**General definition:** Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. (http://www.maweb.org/en/index.aspx) **Definition in the context of climate change:** IPCC Glossary of Terms (as used in the IPCC Third Assessment Report 2001) (http://www.ipcc.ch/pub/gloss.htm); Secretariat of the Convention on Biological Diversity. 2003. Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154 pp. (CBD Technical Series no. 10);

Annex 2. Examples on the measures in place in the Member States

Belgium

Dune Decree in Flanders

Coastal dunes are fragile habitat types that, due to their location, are under very high pressure from tourism and coastal development. In 1993, the Flemish Government accepted a piece of legislation called the Dune Decree that aimed to prevent any further development (urbanisation, camping, tourism etc.) of all dune areas along the Flemish coast. The decree covered all geomorphological landscape elements that could be classified as dunes (e.g. grasslands, meadows, forested areas, ruderal areas, decalcified fossil dunes).

The decree imposed a building ban within two types of areas:

- agricultural land important for the dune area: these areas are situated in zones with agrarian use. The agrarian use can be continued, however it is subject to restrictions on business expansion.
- protected dune area: these areas are located in zones dedicated for other land-use than agriculture. In these areas a building ban applies, except for activities benefiting nature conservation or coastal defence.

The Dune Decree has effectively stopped landowners from selling dune areas as no significant development can anymore take place in these zones. The decree has also closed some dune areas for conservation, either permanently (throughout the year) or during the brooding period for birds. When revising the current land-use plans and maps measures are taken to implement these protection schemes and extent the area of fully protected and rehabilitated dunes. As a part of the rehabilitation process thorough soil sanitation works have been carried out to restore dunes in an abandoned military domain and to extract infrastructure and rehabilitate vegetation in former camping sites. In addition, a naval base has been demolished and works have been carried out to restore a tidal marsh along the only estuary (river IJzer) on the Belgian coast. Furthermore, key dune areas are being purchased and where necessary cleared. Finally, management plans for dune areas are being developed and scientific monitoring is being set in place.

The imposed building ban has prevented further fragmentation to take place in the dune area. Additionally, the implemented restoration measures have enabled a number of dune habitats to regain their natural ecological condition. Consequently, the implementation of the Dune Decree has helped to improve ecological connectivity along the Belgium coast.

The Flemish Ecological Network

Flanders is a densely populated, dynamic region with a strongly fragmented landscape. As a result, nature is under heavy pressure. To improve environmental quality and to develop and manage nature areas the spatial development plan for Flanders (Flanders Spatial Structure Plan, 1997) provides demarcation for a natural spatial pattern, i.e. for maintaining and developing natural/green areas in the region (e.g. areas for nature conservation). The Flemish Ecological Network (Vlaams Ecologisch Netwerk, VEN) is the core component of this pattern.

The Flemish Ecological Network is one of the main elements aiming at maintaining and improving ecological coherence in Flanders. The objective of VEN is to create a coherent and functional network of nationally and internationally important ecosystems within Flanders. More specifically, VEN is to merge fragmented nature and forest reserves into larger and interconnected units of nature. In general, VEN supports and, to a large extent, fulfils obligations that Flanders has under the EU and international law, e.g. the Birds and Habitats directives and the Ramsar Convention.

VEN is formed of 125,000 ha of areas dedicated to nature conservation. The VEN network is supported by 150,000 ha of connecting structures, including nature areas with mixed functions (e.g. parks and areas subject to agri-environmental schemes) and nature corridor areas (e.g. small rivers and hedgerows). The latter two areas form a network called the Integraal Verwevings- en Ondersteunend Netwerk – IVON (Integral Interweaving and Supporting Network). The aim of this secondary network is to improve connection between fragmented areas (e.g. between areas included in VEN).

In principle the approach of identifying core areas (VEN) and connecting structures (IVON) through an integrated spatial planning perspective offers a practical method to improve connectivity within landscapes and between protected areas. In practice the process has, however, experienced some resistance and difficulties in implementation. VEM and IVON were initially to be established by 2003, however later on the deadline for completing the networks was postponed to 2007. By the end of 2006 VEM covered 87,022 ha of Flemish landscape, equivalent to 70 per cent of the target. As for IVON, by 2006 only 935 ha, i.e. 0.7 per cent of the target, had been designated.

River Contracts - integrated river basin management initiative in Wallonia

River Contracts are a tool to implement the Water Framework Directive (WFD) in Wallonia. The main objective of these contracts is to facilitate joint planning and decision-making between different stakeholders within watershed areas. Several groups can participate in these contracts, including local politicians and administration, teachers, socio-economic groups, and all the users (farmers, anglers, recreation, nature volunteers, NGOs). The main element of the River Contract process is to develop and implement a programme of actions to restore, protect, and valorise the natural and hydrological resources of the watershed.

Several national and transboundary projects have taken place within the framework of River Contracts. For example, a project carried out in the Semois-Semoy catchment area aimed at improving the coherence between river basin management plans implemented on different sides of the transboundary basin (BE & FR) (Semois-Semoy project, EC funding Interreg IIIA). In addition, the project also carried out restoration activities within the catchment and undertook actions aiming at improving communication and raising awareness in the area. Similarly, in Ardennes a LIFE-Nature project was established with a view to improve the habitats of the threatened pearl mussel (*Margaritifera margaritifera*) in three river basins. The required actions included, for example, carrying out measures to improve water quality, developing conservation plans and monitoring pearl mussel populations.

The above initiatives have contributed to reducing fragmentation and improve ecological connectivity within river basins in Wallonia. In the future, River Contracts can form an integral part of local planning processes and help protecting important habitats in the area. In addition, joint decision-making and implementation of the identified actions is likely to increase public involvement in nature protection and habitat restoration, including raising awareness on the role and importance of ecological connectivity.

Nature-oriented management of verges along roads and waterways

Nature-friendly management of verges along roads and waterways is an initiative common for both Flanders and Wallonia. The implementation of management measures, however, differs between the two regions.

Within Flanders, the nature-oriented management of roadside verges and verges along the waterways is a legal obligation carried out by local and regional road / waterway managers (legal decision in 1984). Currently some 998 km of roadside verges and 636 km of river and canal verges are under nature-oriented management by the Flemish Government. In total, Flanders possesses 17.000 km of regional roads and 20.000 km of river and canals. Although not all of them are bordered by semi-natural verges, there is still plenty of scope for further action. In addition, a significant amount of verges is managed by local authorities. These authorities are actively encouraged to take measures towards more nature-oriented management. In the Walloon Region, nature-oriented roadside management is voluntary and established through contracts with local municipalities. The contracting municipalities establish management plans that govern the mowing and cutting back of verges.

The management of verges along roads and waterways can form an important element in maintaining and increasing biodiversity within landscapes and facilitating movement of species, e.g. grasslands species. For example, initial monitoring results in Flanders confirm the effectiveness of these measures for conserving vegetation along roads and waterways. Also, monitoring studies have identified the return of several rare species to verges. Roadside management can therefore create new habitats that resemble semi-natural habitats. Consequently, well-managed verges can help to mitigate effects of habitats fragmentation by creating functional pathways for species within wider landscapes.

For more information on measure in Belgium, please contact: the Institute for Nature and Forests, the Scientific Institute of the Flemish Government (INBO), www.inbo.be

Finland

Landscape ecological planning (LEP) in Finland

Fragmentation of landscapes and ecosystems has been identified as a moderate scale problem in Finland. In order to improve integrated management of ecosystems and landscapes, including reduce habitats fragmentation, an integrated land-use planning approach, called the landscape ecological planning (LEP), has been implemented in Finland.

The LEP approach has been mainly used in the context of planning for state-owned lands, particularly forests. LEP is an approach for integrated forest management planning in which ecological goals are aligned with different forms of forest use, while bearing in mind the objectives of forestry in the area. Instead of planning the management of differently managed forest areas separately, e.g. managed forests, nature conservation areas, game areas and special areas for recreational use, LEP considers the management of these extensive forest areas in a joint manner.

The long-term ecological objective of landscape ecological planning is to assure the survival of the area's native species as viable populations. Another central goal of planning is to ensure the existence of nature-based sources of livelihood in the area, e.g. continuation of multiple forest use practises.

Establishing ecological networks and improving connectivity play an integral role in LEP process. All state owned forests are covered with landscape ecological plans, altogether 6,5 million hectares and 112 landscape ecological plans. In 2006, the area under LEP included (in managed forests, productive forest land) 150 000 hectares of ecologically valuable set aside areas, 81 000 hectares of productive forest land that had been designated as ecological corridors. Typically, the corridors followed landscape's small waterways, wet depressions and sometimes wetlands.

According to the evaluation of LEP programmes in 1996-2000, the main principles of planning ecological corridors within the LEP approach were sufficient. However, there was a lot of variation in terms of practical implementation of the approach.

LEP's is implemented by the forestry operations of Metsähallitus (Finnish state enterprise for managing state-owned land). The results of LEP are stored in the geographic information system (GIS) of Metsähallitus. The logging plans of Metsähallitus are drawn using the data of the GIS. The ecological quality of the loggings is ensured each year by control measurements based on random sample of logging sites.

Since 2000, landscape ecological plans have formed an integral part of planning and management of state-owned forests in Finland. The LEP plans are implemented and updated as part of ongoing forest management practises. LEP has an important role in reducing habitats fragmentation by planning ecological corridors as an important part in natural resource plans. Until now LEP has been used on state-owned land but efforts are being made to apply LEP on private land, i.e. planning the use of areas that have several private landowners involved.

References:

- Thematic Report on Forest Ecosystems Finland. http://www.biodiv.org/doc/world/fi/fi-nr-fe-en.pdf
- Objectives of the forest sector compiled into the Regional Forest Programmes. http://www.mmm.fi/en/index/frontpage/forests/forest_policy/regional_forest_programmes.html

Ruuhka-Suomi project – public participation and awareness rising as a tool for reducing habitat fragmentation in Finland

Uusimaa area is the growth zone of Helsinki 'metropolis' area. The constant growth within this zone is decreasing and fragmenting the remaining natural habitats, including ecological networks and corridors, in the area. In this context, the Finnish Association for Nature Conservation (FANC) and UYSP (Uusimaa regional office of FANC) have initiated a project called Ruuhka-Suomi. The project aims to support the maintenance of the network of protected areas (e.g. ecological corridors) in the southernmost Finland.

Aim of Ruuhka-Suomi project is to facilitate the participation of stakeholders in national / regional land-use planning processes, in particular from the perspective of protecting their natural environment (e.g. influencing the environmental and strategic impact assessment processes - EIAs and SEAs). The stakeholders of the project include, for example, the FANC regional and local branches, other NGOs and interested citizens. The project aims also to support participation through providing advice and capacity building for stakeholders, improving information availability and facilitating communication between stakeholders (e.g. providing information via Internet and producing fact sheets, check lists and models for complaints). The initiative also actively follows national and regional developments (e.g. development regional master plans) providing comments to land-use plans with potential impacts of nature conservation and biodiversity.

In the past Ruuhka-Suomi project has covered following activities:

- Carried out fieldworks and developed proposals for protected and recreational areas and networks;
- Activated FANC members, local branches and other regional NGOs to take part in land-use planning processes in regional and municipality level;
- Invested in establishing a position for a nature conservation officer that is leading the project;
- Created a special ecological networks working group;
- Influenced actively the regional land-use planning processes, e.g. by developing and issuing statements and complaints on planned land-use activities with negative impacts on environment and natura conservation. Has also developed press releases to raise awareness about the southern Finland ecological network;
- Arranged four public seminars on ecological networks, where all the stakeholders have taken part.

For example, Ruuhka-Suomi project has had an important role in rejecting uranium mine plans in Uusimaa. As a part of this process the project staff visited NGO and other meetings, took part in lobbying (e.g. collecting signatories for appeal to the Government and Parliament), proposed successfully an addition about uranium to EIA Act, coordinated national meetings for anti-uranium movements, and wrote and published press releases. As a result, the claims for uranium mine areas in Uusimaa have now been rejected. In addition, Ruuhka-Suomi project has also helped to prevent the loss of an important forest area functioning as an ecological corridor and recreational site for local people (due to construction of a golf course). In this case, FANC helped to carry out nature inventories in the area and assisted the local stakeholders in expressing their opinion in the planning process (e.g drafting and commenting documents and writing a complaint to courts). As a final result, the Supreme Administrative Court ruled against carrying out the planned development initiative.

The Ruuhka-Suomi project has contributed in raising public awareness in ecological networks and connectivity. Therefore, the initiative can also see as a positive example of using public participation methods as a tool to enhance ecological coherence and connectivity in land-use planning processes.

References: Ruuhka-Suomi Project
(http://www.sll.fi/luontojaymparisto/maankaytto/ruuhkasuomihanke/ruuhkasuomienglish)

Roadside transects and artificial passages in Finland

Transport networks play an important role in contributing to landscape and habitat fragmentation. The Finnish Road Administration (Finnra) has been tasked with the goal of creating an eco-efficient transport system that reduces the adverse environmental impacts of traffic.

The Finnish transport sector, Finnra in particular, has been relatively proactive in taking issues related to biodiversity into consideration. Consequently, a number of artificial passages (e.g. bridges and tunnels) have been constructed as a part of the road network. Finnra constructed ten artificial passages on the Highway 7 in the late of 1990's. In recent years Finnra has constructed four other passages: two green bridges on the Highway 1 in Lohja (2004) and on main road 51 in Kirkkonummi (2005), one waterway bridge in Nastola (2005) and one bridge for elkson the Highway 4 in Heinola (2005). On the Highway 1 Finnra will construct 20 new passages in the near future. These passages will be completed by 2008.

Artificial constructions have been shown to have a potential to reduce habitat fragmentation at local and regional level. In addition, the animal accidents have reduced. According to an assessment carried out by Finnra, the artificial passages in Pernaja on the Highway 7 had been well adopted by animals and, consequently, the related costs in road constructions have been justified[1]. According to the study, the underpasses had also become a part of the territory for local elks and they were also a part of the wandering route of elks. Follow-up studies on the Highway 4 will be carried out in the coming years.

There are more than 160,000 hectares of public road verges under regular mowing management in Finland. It has been acknowledged that nature-oriented management of verges along roads and waterways may help to create substitute habitats or refugia for several grassland species adapted to continuous grassland management[2]. According to a study by the University of Joensuu Department of Biology and Finnra (data collection carried on between 2004 and 2005) appropriately managed roadside transects can increase the abundance and diversity of several species, such as butterflies, wasps and meadow flora[3].

Building of roads and transport networks naturally increases the fragmentation of landscapes. However, carefully planned (e.g. ecologically justified, see Chapter 7 of the Guidance) artificial passages and appropriately managed verges can potentially function as corridors and stepping stones within fragmented landscapes.

References:

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2. Juha Jantunen, Kimmo Saarinen, Anu Valtonen, Timo Hugg, Sanna Saarnio: Vegetation and butterfly fauna in roadside habitats (Tienpientareet ja valtateiden liittymät kasvien ja perhosten

elinympäristönä). Helsinki 2004. Finnish Road Administration. Finnra Reports 9/2004. 57 p. + app. 4 p. ISSN 1457-9871, ISBN 951-803-225-4, TIEH 3200859. In Finnish, summary in English. http://alk.tiehallinto.fi/julkaisut/pdf/3200859-vtienpientjavaltatliittkas.pdf

3. Kimmo Saarinen, Juha Jantunen, Anu Valtonen: The effects of mowing on roadside biodiversity (Niiton vaikutus tienpitentareiden niittyeliöstön monimuotoisuuteen). Helsinki 2006. Finnish Road Administration. Finnra Reports 9/2006. 46 p ISSN 1457-9871, ISBN 951-803-672-1, TIEH 3200985. In Finnish, summary in English. http://alk.tiehallinto.fi/julkaisut/pdf/3200985-v-niini.pdf

For more information on measure in Finland, please contact:
Finnish Environment Institute (SYKE) (http://www.ymparisto.fi);
Finnish Road Administration (Finnra) (http://www.tiehallinto.fi);
Metsahallitus - Finnish state enterprise for managing state-owned land (www.metsa.fi)

Germany

Ecological networks and special protection programmes for threatened species in Germany

Germany has taken a strong position on the **ecological networks** establishment. With regard to land use planning, nature conservation legislation states that all conditions and measures for nature conservation should be elaborated for the planning area and the regions have to regulate the prohibition of disturbance and harm to ecosystems. This means that the interests of nature conservation and landscape maintenance are integrated in land use planning processes.

Establishing ecological networks in Germany occurs at the regional level (i.e. at the level of Länder). All Länder (Federal States) are obliged under the Federal Nature Conservation Act to establish a network of interlinked biotopes (Biotopverbund) covering at least 10 per cent of the total area of each Land. There is no overall implementation nationally, beyond the provision of guidance to the Länder. As regards the guidance, an indicative map showing core areas of national importance for an ecological network is currently being produced by the Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN).

The network of interlinked biotopes is designed to a) safeguard native fauna and flora species (e.g. their respective populations); b) protect the habitats and biocoenoses of these species and; c) preserve, restore and develop functioning ecological interrelationships within and between biotopes. The network consists of core areas, connecting areas and connecting elements. These include: designated national parks, legally protected biotopes, nature conservation areas, biosphere reserves or parts of such areas and other areas and elements, including parts of landscape protection areas and nature parks if they are suitable.

In addition to network of interlinked biotopes, the German Länder have also adopted specific **special protection programmes for threatened species**. These programmes are targeted measures for maintaining the threatened species, which are developed throughout the state and consist of an analysis of populations and habitat structures and risk factors in order to determine protective measures.

For example, for the endemic and threatened plants in Bavaria a special programme has been developed since 1991. In the framework of the projects by the Free State of Bavaria, successful targeted measures for protection of these species were realised, based on detailed analysis of population trends, factors of influence and risks. The loss of species was stopped and increase in populations has been established for many types of plants.

Another good example of special protection programmes is the sea eagle protection project in the Land Schleswig-Holstein. The most important species protection measures implemented are: buying of old beech stands, reconstruction of former wetlands, developing protection zones around the nesting areas, maintaining the brood areas, agreement on forest economic and hunting measures in the protected zones with the forest employees, land owners and those who have a permission to hunt, targeted support to three public observation stations.

All networks and species protection programmes which are connected with spatial planning tasks play an importing role in minimising and mitigating the effects of fragmentation. Currently, over 300 ecological network projects exist in Germany with a majority in the mountain areas. Different special protection programmes, projects and networks for threatened species are improving the larger (Länder and inter-Länder scale) ecological networks. Implementing smaller scale networks for threatened species in ecological networks may help determine weakness in larger scale ecological networks. Different kind of ecological networks is a good way to protect different habitats and reduce their fragmentation.

Habitat Fallow Land (Lebensraum Brache) Project

In Germany, a number of biodiversity related projects have been initiated to decrease habitat fragmentation and improve connectivity within landscapes. One of the interesting examples has been a project called 'Habitat Fallow Land' carried out in the Länder Hesse and Bavaria in 2003-2006[1].

The goal of the 'Habitat Fallow Land' project has been to improve the situation of wildlife in the agrarian landscape by encouraging farmers and others landowners to create and maintain set-aside areas (i.e. fallowed agricultural land) with a specific goal to host wildlife. Furthermore, the project has tried to mainstream these wildlife friendly set-asides into the basic agricultural practises. The project has been developed and carried out jointly by the key stakeholder groups, including representatives from nature protection, hunting and agriculture sectors.

During the project period, 2.200 hectares of arable farmland has been taken up for wildlife friendly set-asides. On these areas, for example, cultivation of low-cost seed mixtures as suitable cover-, breeding- and feeding habitat for wildlife has been tested. In 2004, the project produced practical guidelines for the management of wildlife friendly set-aside. This included measures for the preparation of soils, optimal sowing times, seed assortments used and cultivation required.

At present there is about 1 million hectares of arable land in Germany. There is a large potential for this land to be used and managed for biodiversity. Up to now, this potential has been under-utilised. The management of non-cultivated agricultural areas for wildlife has a potential to make significant contributions to the connectivity of landscapes in Europe.

References:

1. http://www.lebensraum-brache.de

For more information on Germany, please contact: The German Federal Agency for Nature Conservation (Bundesamt für Naturschutz) (http://www.bfn.de)

Lithuania

The Law on Protected Areas and the Nature Frame

In Lithuania, all environmentally important natural and semi-natural areas are covered by an interrelated territorial system called the Nature Frame. The purpose of the Nature Frame is a) to create a framework for maintaining and improving natural ecological system in the country; b) to ensure connections between natural protected areas; and c) to assure the conservation of natural landscape, biodiversity and natural recreational resources.

The Nature Frame consists of zones with important ecological functions, such as groundwater filtration, conservation of biodiversity, recreational resource protection and aesthetic improvements. It is based on a geo-ecological approach and managing areas at the level of watersheds and catchments. Consequently, the focus of the Frame is broader than the solely ecological focus adopted by several ecological networks. However, a country-wide network of protected areas forms one of the most important elements of the Nature Frame.

In general, the Nature Frame is composed of three meta-functional subsystems:

- *geo-ecological watersheds* – belt areas which are separate large geoecosystems and perform the function of ecological compensation between the systems;
- *geoecosystems´ stabilisation centres* – areas which perform the function of ecological compensation in geoecosystems;
- *migration corridors* – valleys and hollow valleys through which intensive geodynamic and bioinformation circulation takes place.

Lithuanian Nature Frame has been adopted by the national legislation. The Environment Protection Law adopted in 1992 legitimised the Nature Frame as a system of ecological compensative territories serving the goals of landscape stabilisation. The Law on Protected Areas adopted in 1993 created a more concrete juridical basis for the Nature Frame. The aim of the Law on Protected Areas is to regulate social relations in connection with protected areas. This is the main legal instrument for establishing protected areas, the Nature Frame and ecological networks in Lithuania.

In practise, the implementation of the Nature Frame takes place through land-use planning and management practises at national, regional or local level. According to the Lithuanian Law on Territorial Planning, the Nature Frame schemes can form a part of general spatial plans or they can be prepared separately. In spatial planning process, Nature Frame schemes are used when drafting and evaluating general master plans at national, regional and municipal level, e.g. assessing the implications intended land-use and development initiatives. In addition, the Nature Frame is also used as a basis for town and urban areas planning. In town planning, the Nature Frame determines conditions for the urban structure and functions, and reveals the natural components of landscape that should be maintained and protected. In addition, the Nature Frame is also an integrated part of urban structure and therefore in itself an object of planning.

The Nature Frame is a comprehensive framework for environmentally sustainable land-use planning. Its implementation both strengthens the connections between natural and semi-natural areas and prevents the negative effects of land-use on landscapes, ecosystems and their functioning. Consequently, the Nature Frame plays an important role in improving ecological connectivity within wider landscape (e.g. between protected areas) and reducing fragmentation in the semi-natural areas threatened by economic and urban activities.

The Netherlands

The National Ecological Network in Netherland

The fragmentation and isolation of habitats as a result of intensive agriculture, urbanization and expanding infrastructure has been long recognised as a major threat to many habitats and their associated wildlife in the Netherlands. This has shaped Dutch nature policy, which now centres on the creation of the National Ecological Network (NEN). The NEN was launched by the Dutch government in its 1990 Nature Policy Plan and consists of systematically planned national network of protected areas. It is the backbone of Dutch nature policy. When completed, NEN will include all national parks and other important nature conservation sites, as well as productive forests and some farmland areas, such as grasslands that are important for breeding waders and other birds.

The purpose of the NEN is to enlarge existing natural areas (core areas) *and* to connect them by means of connection zones. In practice the enlargement of core areas is by far the most effective as it facilitates efficient management, and improvement of environmental conditions etc. Connection zones consist of interconnected natural elements and habitats (stepping stones and key areas), which promote the exchange of one or more species. Core areas for connection occur where: the landscape in between the habitats is unsuitable; the surface area requirements of the species are not met, even when new nature has been created; the species are hardly or not at all present in the planning area and the change of natural establishment from neighbouring populations is small; and essential elements of the species' habitat are isolated form one another and are difficult to access. The national NEN policy and the European Natura 2000 requiremnts complement each other. The objectives of the NEN are broader and aim to create green buffers with better land use and environmental conditions for habitats and wildlife in general.

The ultimate goal of the NEN policy is to create a network of natural habitats of sufficient ecological quality. When the NEN is fully completed, more than half of it will consist of large areas of connected nature areas (greater than 2,000 hectares in size); about 20per cent of the NEN will consist of patchworks of nature fragments and habitats. Both public and private actors will be involved in the local management of the NEN.

The development of the NEN is expected to be completed by 2018. Until recently progress was good, such that it was about halfway towards completion. However, the development of the NEN has been stalled during the recent years, especially where landscape works have been required to create or re-create wildlife habitats. One reason is being made with conservation management by private landowners. A few years ago the area target for subsidised conservation management by private landowners was raised considerably in order to improve the ecological conditions of the habitats within the NEN. But this resulted in reduced objectives for land acquisition.

Another problem has been the short supply of land. In this situation a clear planning regime and political and administrative commitment is essential if the national objectives for nature and the landscape are to be met.

1. Nature Balance 2006: National Ecological Network and Natura 2000. http://www.mnp.nl/en/publications/2006/NB2006NationalEcologicalNetworkAndNatura2000.html
2. Milieu en Natuur Planbireau. Summary. Nature Balance 2006 http://www.mnp.nl/bibliotheek/rapporten/500402003.pdf

Wildlife passages in the NL

Dutch ecosystems are highly fragmented into small habitat islands. One of the main reasons behind fragmentation is the country's dense road and railways network. Consequently, a number of ecological links, ranging from small wildlife tunnels under roads to large wildlife bridges, have been created to assist the movement of species within landscapes fragmented by transport.

The Netherlands has a national habitat connectivity plan that is consulted when planning for improvements to the transportation system, as well as individual projects. On existing highways, maintenance crews refer to the plan when implementing retrofit projects to enhance connections between habitats and protect species. The plan uses viability analyses at the population level and information about locations of elevated wildlife mortality from collisions (individual level). Because diminished population viability is in many cases exclusively a result of the presence of a road (i.e. 'a barrier'), both policymakers and managers give high priority to restoring habitat connectivity across highways. Wildlife passages are also one method to implement National Ecological Network (NEN) in the Netherland via road planning, i.e. wildlife passages can be considered as parts of artificial green corridors.

The most extensive wildlife passage measures are developed for badgers, which is the largest carnivore in the country. Many initiatives to save the badger result from cooperation between nongovernmental organizations (NGOs) and the Dutch environmental and transportation ministries. An extensive system of approximately 600 culverts is provided for connecting badger habitats, and highway maintenance funds are used for retrofits, which are based on a system-wide transportation plan for the entire country.

Properly wide and suitably constructed wildlife overpasses in the form of green or landscape bridges, and high estacades constitute an integral part of the protection of wild animals' populations, their habitats and migration corridors in the Netherlands. Surveys also show that almost all of the existing wildlife passages are used by more than one animal species.

References: Nature Balance 2006: Land use and environmental conditions. http://www.mnp.nl/en/publications/2006/NB2006LandUseAndEnvironmentalConditions.html

Slovakia

Legal framework for nature and landscape protection in Slovakia

Fragmentation of landscapes appears to be a growing issue in Slovakia, with pressure resulting from rapid economic development. The total area designated under Natura 2000 is relative large, however further efforts are needed to ensure that all relevant habitats are covered and that the designated sites form an ecologically coherent network. To reach these objectives several environmental obligations have been integrated into Slovakian legislation, including the Constitution.

One of the most significant legislative elements to ensure the establishment of an ecologically coherent network of protected areas is the Act on Nature and Landscape Protection (initially Act 287/1994, replaced by Act 543/2002 in 2003). This Act transposes the Habitats and Birds directives into national legislation. The Act also provides the basis for the establishment of the Territorial System of Ecological Stability (TSES), defined as 'an integrated [spatial] structure interconnected to other ecosystems, their components and elements, which ensure a diversity of life conditions and forms in the landscape'.

The TSES introduces bio-corridors as one of the landscape elements essential to biodiversity conservation. The concept of bio-corridors enables Slovakia to have a systematic approach for linking habitats that are currently isolated or threatened to become fragmented due to planned land-use (e.g. developing the transport and real estate sectors). As the concept forms a part of the national legislation, new opportunities are created for mitigating negative impacts caused by the fragmentation of landscapes.

Habitat fragmentation is also addressed in various Slovakian laws related to land-use and development. For example, whilst the Act on Nature and Landscape Protection and TSES offer a framework for providing different levels of protection for landscape elements, the Law on Spatial and Development Landscape (50/1976 with later amendments) supports the practical implementation of protected sites. This Act provides specific provisions for the protection of important landscape elements such as riverbank vegetation, forests, peat bog, rivers and cliffs.

The Slovakian framework for nature and landscape protection provides a number of legal tools for connecting isolated habitats and conserving important landscape features through spatial planning. For example, the implementation of bio-corridors helps to enable the movement of species between habitats, including Natura 2000 sites. If effectively implemented, Slovakian legislation can significantly help to reduce fragmentation and increase ecological connectivity in the country.

Landscape ecological planning approach (LANDEP) in Slovakia

Landscape ecological planning approach (LANDEP) is the main tool for land-use planning in Slovakia. The approach builds on environmental aspects of sustainable development and it aims at creating a landscape structure with balanced interrelations between landscape elements, socio-economic activities and ecological conditions of the area.

In practice, LANDEP approach is a combination of systemically arranged landscape-ecological methodologies. Landscape-ecological plans form an integral part of the approach and they are an obligatory part of spatial planning documentation at the regional level. The elaboration of the landscape-ecological plan is a complex process of mutual harmonisation of spatial requirements and other human activities with landscape-ecological conditions. LANDEP method has 5 steps: Landscape-Ecological (L-E) analysis, L-E synthesis, L-E interpretation, L-E evaluation and L-E proposals and measures. The finalised plan shows what the main land-use related threats to environment are, including aspects related to ecological connectivity. As an outcome, the landscape-ecological planning provides alternative proposals for the functional division of landscapes. These proposals reflect different degrees of suitability as regards maintaining the relationships among landscape components.

The LANDEP approach improves the integration of environmental and ecological considerations into the spatial planning processes. Consequently, the approach can positively contribute to rational and considerate utilization of natural resources and conservation of overall landscape quality and stability, including ecological connectivity.

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Spain

SITxell project for integrated land-use planning

In Spain, the use of non-building land forms an important element of territorial planning. It is also an essential starting point for formulating projects aimed at managing the open area systems in the country. In general, the current planning practises do not just aim at preserving individual non-building areas and area networks but rather proactively seek to manage the open areas in Spain in a more uniform and comprehensive manner.

Since 2003, the Technical Office for Territorial Planning and Analysis of the Barcelona Provincial Council has been carrying out a geographical information system (GIS) project (called SITxell) aimed at analysing the open areas of the Barcelona province. The purpose of the project is to plan the land-use on these areas and to identify the role they play in the overall natural areas system. The project is based on classical conceptual approaches for landscape planning (e.g. approaches introduced by Forman). In addition, a vast variety of geographical information regarding the attributes and values of the analysed open areas is taken into consideration. As an outcome, the project seeks to make specific proposals for the joint planning and management of the open areas in Barcelona province. The SITxell will also provide concrete data and criteria for the basis of local decision-making (e.g. analysis, diagnosis and systematisation of the ecological, landscape and socio-economic features of non building-land).

The SITxell provides a clear theoretical framework and practical tools that can be used to correct certain growth trends with potential negative impacts on the environment. It can also assist in managing conflicts between different land-uses and help at promoting management practice that ensure that the socio-economic development in open areas does not jeopardise the functioning of natural system. According to the current results, SITxell's proposes a) to strictly protect up to 70 per cent of existing open areas; b) restore some important habitats (e.g. river systems); c) improve forest, cattle and agriculture practices; and d) make transport infrastructure more permeable for species. In addition, SITxell also identifies a number of key areas to be protected in order to maintain ecological connectivity in the region.

The importance of the local government in defining territorial uses is gradually growing in Spain. SITxell provides the necessary territorial information for planning processes and it also provides general guidelines that help to improve connectivity between habitats.

The UK

Hedgerow Regulations in England and Wales

Hedgerows are characteristic and much valued features of many lowland landscapes in the United Kingdom. They also offer an important habitat for wildlife and can help to connect habitat patches for some species, although the evidence for this is currently equivocal[2]. Hedgerows may also provide some farming benefits, such as helping to prevent soil erosion and water run-off, providing shelter and controlling livestock, and protecting crops from wind damage. But despite these benefits many hedgerows have been lost in the UK largely as a result of agricultural intensification and associated preferences for large fields. The Hedgerow Regulations 1997, which apply to England Wales, were therefore developed to reduce the loss of important hedgerows and their associated biodiversity and landscape values.

The regulations aim to protect important hedgerows in the countryside by controlling their removal through a system of notification. The system applies to countryside hedgerows which are at least 20 metres long, or which meet a hedgerow at either end. Garden hedges are not affected.
Under the Hedgerow Regulations:

- it is a criminal offence deliberately to remove most countryside hedgerows without permission;
- if you remove a hedgerow without permission (whether it is important or not) you may face an unlimited fine.

Any landowner who wishes to remove a hedgerow, if it is not exempt as above must serve a Hedgerow Removal Notice in writing to their local planning authority. The authority then has 42 days to determine whether or not to issue a Retention Notice. It will therefore asses the importance of the hedgerow using criteria set out in the regulations. In general permission will not be given for the removal of hedges that are defined by the regulations as being 'important', which includes hedges that are over thirty years old and of high historic or wildlife value.

Although the regulations are rather complex and have been subject to some criticism, it has been acknowledged that the legal protection of hedgerows has helped to further reduce rates of hedgerow loss.

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Agri-environment schemes to protect biodiversity in England

Many habitats in the UK have become highly fragmented, especially in lowland areas, primarily as a result of urbanization, infrastructure and agriculture. Agri-environment measures have provided an important mechanism for biodiversity conservation throughout the EU. They have been used in the UK as the principal means of supporting conservation measures on farmland and most other semi-natural habitats other than closed-canopy forest. Within England two agri-environment schemes have significantly helped to maintain and improve habitat connectivity benefits: the Environmentally Sensitive Areas (ESA) scheme and the Countryside Stewardship Scheme (CSS).

The Environmentally Sensitive Areas Scheme was introduced in 1987 to offer incentives to encourage farmers to adopt agricultural practices which would safeguard and enhance parts of the country of particularly high landscape, wildlife or historic value. Its aim is to establish a balance between agriculture and conservation. Environmentally Sensitive Areas (ESAs) are particular parts of the countryside where the landscape, wildlife and historic interest are of national importance. There are 22 ESAs in England covering over 1.1 million hectares. Each ESA has a range of tiers which prescribe different management practices[1].

The ESA scheme is voluntary. Farmers with eligible land in ESAs were offered a ten-year agreement that provides an annual payment in return for following a prescribed set of farming practices designed to conserve and enhance the landscape, historic and wildlife value of the land under agreement. These might include, for example, planting new hedges or restoring ponds or traditional farm buildings[2].
ESA resulting environmental benefits have included: improved numbers of wading birds in lowland wet grassland; protection and improvement of species rich grassland on the chalkdowns and in hay meadows; landscape improvements from better management of features such as hedges and dry stone walls and from conversion of arable to grassland; protection of historic features, such as ancient field systems.

Countryside Stewardship Scheme (CSS) was initially launched as a pilot scheme in 1991 and aimed to provide incentives to landowners, farmers and other land managers to take specific measures to conserve enhance or re-create important landscape types and to provide for public enjoyment of them. CSS aims are to: sustain the beauty and diversity of the landscape, improve and extend wildlife habitats, conserve archaeological sites and historic features, restore neglected land or features, create new habitats and landscapes; and improve opportunities for countryside enjoyment. It operated throughout England outside Environmentally Sensitive Areas[3].

CSS offered also ten-year agreements to landowners under which annual revenue payments were provided for following prescribed management practices, with supplements for additional work over and above annual management. The scheme also offered capital payments for a wide range of one-off works[3].

ESA and CSS schemes have been largely successful in maintaining biodiversity, landscape and historic interest values within agreement land. ESAs and CSS have helped to maintain and enhance habitat connectivity included the following: hedgerow planting/restoration, ditch management/restoration, pond and habitat creation/restoration, water level management, grass strip/margin creation in arable fields, uncropped margin creation in arable field, reduced fertilizer /pesticide inputs in arable fields and margins, maintenance of winter stubbles, maintenance of summer fallows. Although the impacts of the schemes on ecological connectivity have not been studied quantitatively, they have undoubtedly played a significant role in improving connectivity between fragmented habitats.
The schemes have recently been reviewed and replaced by a new Environmental Stewardship Scheme which has similar objectives.

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