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European corridors: Strategies for corridor development for target species

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European corridors: Strategies for corridor development for target species

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Foreword

For many years the Dutch Government has been involved in the development of the National Ecological Network (NEN) of the Netherlands. The NEN was established as a policy in 1989, and since then much effort has been put into its implementation.

In the last 20 years much scientific research has been undertaken on metapopulation theory, connectivity and ecological networks. This research provides the scientific foundation for the ecological network approach. It has now been shown that ecological networks are essential to conserve biodiversity and to reverse the fragmentation process of landscapes and nature.

Ecological networks are also important for people and society because the ecological network concept appeals to the general public and policy-makers. It also provides a framework for stakeholder involvement, and supports the Ecosystem Approach, as endorsed under the Convention on Biological Diversity.
Within a coherent ecological network, corridors are a critical element for species migration and dispersal. For certain animal species, corridors at a European scale are necessary to increase their chances of survival, both now and in the future. Plants too move along corridors, specifically rivers and roads.

This brochure provides examples of corridor approaches for European target species, such as those protected under the Birds and Habitats' Directive or those that apppear in the Global or European Red Lists. The examples show that ecological networks are not merely a theoretical concept, but that they can also provide practical guidance for conservation measures. They build particularly on the information gathered over the years in landscape ecological research, especially on the effects of fragmentation.

Ecological networks are being developed at different scale levels in most EU member states - including those that recently joined. However the necessary coherence and connectivity between those national networks is often lacking. It is crucial that we look beyond our boundaries and co-operate across borders to connect different networks, through wildlife corridors.
Ecological networks are a priority theme for the Dutch government and its Ministry of Agriculture, Nature and Food Quality. I am convinced that this beautiful brochure on connectivity will be instrumental in stimulation cooperation across borders.

Giuseppe B. Raaphorst
Director of the Department for Nature
Ministry of Agriculture, Nature and Food Quality

Introduction: Ecological networks, why do we need them?

All organisms need a particular type of place to live in: this is the habitat of the species. For some species this habitat is very large, for others it is rather small, depending on their ecological characteristics and territory size. Western Europe is intensively used by man, with the result that habitats are 'fragmented' and sometimes lost. Figure 1 illustrates the process of fragmentation of natural areas. Extensive natural areas (upper scheme) are changed over time by human activity such as deforestation. The land surface is decreased, or broken up into small habitat patches (lower scheme).

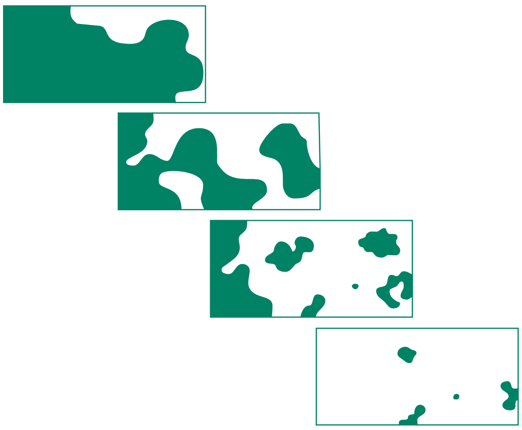


Figure 1
The process of fragmentation of natural areas

Due to the fragmentation of their habitat, many species in Western Europe have already disappeared or may disappear from several regions in the future. As natural areas are fragmented, only small populations of species can survive in the small and isolated habitat patches. Whether species survive or not, often depends on a fragile balance. For example a number of bad years, an epidemic disease or chance may result in the extinction of a species*.
However, good landscape connectivity will give species a better chance of survival in the long term. Moreover, the impact of climate change, which may result in species and habitats moving north in Europe, may be decreased if landscapes are well connected.

The connectivity of the landscape for a species depends on the mobility of a species and the type of the available habitat and its configuration in the landscape. In this respect corridors are very important for certain species. This brochure explains the characteristics of corridors and which types of corridor exist. The brochure then gives a number of practical examples of 'bridging landscapes' by means of the development of corridors.

Together with so-called 'core areas' corridors form essential components of ecological networks. An ecological network is a system of areas which are connected via ecological links or physical links. The ecological network usually consists of 'core areas' (protected or not), corridors, buffer zones and in some cases nature development or restoration areas.
A pivotal role in ensuring spatial cohesion of the network is therefore played by corridors.

Currently much effort is put into the development of ecological networks, e.g. by means of the construction of wildlife corridors and road crossings or underpasses. The following paragraph describes the political context for the development of ecological networks and corridors as part of these networks.

Notwithstanding the necessity of connecting fragmented areas, those areas which were always isolated as a result of physical-geographical barriers should normally not be connected, so as to preserve regional and genetical differences. Chance events however may lead to links between said isolated areas and should not be disturbed.

* *The concept behind this is found in the metapopulation theory, but will not be dealt with into detail in this brochure. The interested reader is referred to other authors that have dealt with this extensively* [1, 2, 3, 4, 5].

Ecological networks and international policies

The development of ecological networks and corridors is recognised as a positive policy for promoting nature conservation both at European and global levels.

The concept of ecological networks was officially recognised in Europe as an important approach for biodiversity conservation in the Pan-European Biological and Landscape Diversity Strategy (PEBLDS). The PEBLDS was endorsed in 1995 by 54 states in Europe and calls for the development of the Pan-European Ecological Network (PEEN). The PEEN presents a visionary approach for the conservation of biodiversity in Europe.
It promotes a Europe where nature is truly connected and where all European governments are actively engaged in establishing and maintaining a pan-European ecological network. The Habitat Directive of the European Union (1992) acknowledges in Article 10 the importance of landscape elements that enhance connectivity ('corridors'). Whilst building the EU ecological network Natura 2000, the Directive encourages member states to include those landscape elements in their land-use planning and development policies which they consider appropriate. Furthermore, other global and European policies such as the Bonn and Bern Convention oblige contracting parties to take effective measures in conservation and management of the listed species and habitats. Several of the species included in this brochure either occur on the lists of the international conventions or on EU-directives.

During the first years of the new millennium political attention for the development of ecological networks on a global level has increased considerably. At the World Summit on Sustainable Development in Johannesburg (2002) the importance of the development of regional and national ecological networks and corridors as a way to achieve sustainable development was confirmed in the Plan of Implementation.
Finally, during the Seventh Conference of Parties of the Convention on Biological Diversity (2004) ecological networks were incorporated in the work program on protected areas as a key conservation strategy.

Corridors in ecological networks

Corridors facilitate biological processes such as dispersal, migration or the regular movement of animals. As such, corridors strengthen the spatial cohesion of the network of habitat patches, which is crucial to the survival of many species.

Corridors should be tailor-made

It is important that the individual demands of species are taken into account during the development of corridors. Species differ in their requirements; therefore, corridors have to be tailor-made or species-specific in order to function effectively. However, corridors which are useful to an umbrella species may suit other species with similar requirements, which are typically less demanding than the umbrella species [6, 7].

The most important characteristics of a species that determine the type of corridor that a species requires are: the *dispersal capacity* of the species, the *habitat requirements* for its dispersal, its *dispersal mechanism* and its *dispersal strategy*.

Dispersal capacity: from local to global

The distance over which dispersal, migration and commuting movements occur vary greatly according to the species; birds migrate across continents, amphibians move a few kilometers and mice or carabid beetles may move only a few meters (fig. 2).
The scale of the corridor and the corresponding ecological network is therefore related to the movement capacity of the species. In general many of the small, immobile species require corridors on a local level. Medium sized species require corridors on a regional level. Large herbivores and carnivores need corridors on the continental scale, and many bird species have migration routes that extend over different continents. Therefore, connectivity for species has to be assessed at various scales. As a consequence networks also therefore need to be developed for different scale-levels.

Figure 2
Different species require ecological networks at different scales (adjusted after Bouwma et al. 2003 [8])

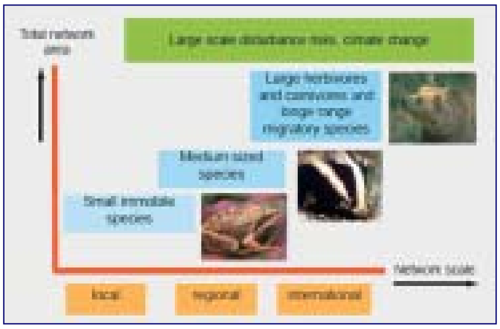


Figure 2

Dispersal mechanisms

There are two main dispersal mechanisms: species can move actively (walking, flying or swimming) or passively (spread of plant seeds by animals). In the latter case the animals may act as the ‘transporting vectors’. For species that disperse passively, the presence of corridors is often more important for the transporting vectors than for the species itself. In general birds, mammals, amphibians and reptiles move around actively. Invertebrates move around both actively and passively (see box 1), plants disperse at a larger scale level predominantly passively.

For many invertebrate species the dispersal capacity and willingness to disperse is often a flexible characteristic. Several species of carabid beetles, grasshoppers and other species groups have both wingless and winged adults. If species density is locally high during their development, long-winged adults will develop.

The dispersal mechanisms of invertebrates are: 1. by air, 2. within/on water or within rivers or streams, 3. terrestrial (walking, jumping) and 4. through a vector species.

Box 1
Movements of invertebrates

Some insects disperse actively; individuals will fly away, make webs or crawl to a high point. Subsequently many insects are transported passively by means of vertical air movements (thermal, turbulence) or by wind. For invertebrates that disperse passively by air, in general corridors will not be very important. For species that disperse through water, or disperse actively or attached to a vector, corridors at various scale levels are important.
In a typical river system the adult of aquatic insects fly upstream to lay eggs. The young larvae then move downstream by overpopulation or catastrophic drift and populate downstream habitats. When they have dispersed successfully, they pupate and the cycle starts all over again.

Dispersal strategy

Over time species have developed different strategies for dispersal. Some species are adapted to the spatial dynamics of habitats that occur only temporarily. These species are called R-species and are usually mobile, more opportunistic species. Species adapted to habitats that do change minimally over time are more specialised in maintaining their niche in a given habitat than in dispersal. These species are called K- species. In contrast with R-species, K-species generally depend on corridors, because their particular habitat is sometimes destroyed or severely affected by fragmentation processes.

Functions of corridors

Corridors can be classified into three classes according to the functions that they fulfill. [9, 10]

(1) *Commuting corridors* are used for regular movements from resting/breeding sites to foraging areas. A commuting corridor links elements that have a different function within the home range of a species. It supports daily movements between these elements and acts beneficially because it reduces predation risk, offers guidance and facilitates movement through the landscape. Normally these movements are restricted to short distances (up to a few kilometers) for vertebrates, or to tens of kilometers for wider ranging species. Good examples of species using commuting corridors are badgers and bats [11, 12].

(2) *Migration corridors* are used for annual migratory movements from one resource area to another (e.g. from breeding to wintering ground).The biological process of migration is a principal activity for many species groups. The most well known are bird and fish migrations. In their journey from one resource area to another some species will benefit from the use of corridors. This can be in the shape of a continuous linear pathway (e.g. riparian fish species). More often the pathway will consist of a set of areas used during migration as ‘stopover’ places (e.g. marshes for waterfowl and waders) [13].

(3) *Dispersal corridors* are used for a one-way movement of an individual (usually a juvenile) or population from either its site of birth (for juveniles) or its former breeding area to a new breeding area. Dispersal is an essential process leading to the immigration of individuals into other populations or to (re)colonisation of suitable habitat patches. In order to differentiate between individuals and populations, dispersal corridors may be sub-divided into three types; one step dispersal corridors, reproduction corridors and range expansion corridors [9].

A typology of corridors

In addition to the classification according functionality, corridors can be classified into three to four classes according to the shape that they have: *line, stepping stone* and *landscape corridors.* Invertebrates use what may be regarded as a fourth 'sub-type': line corridors with nodes as shown in Figure 3.

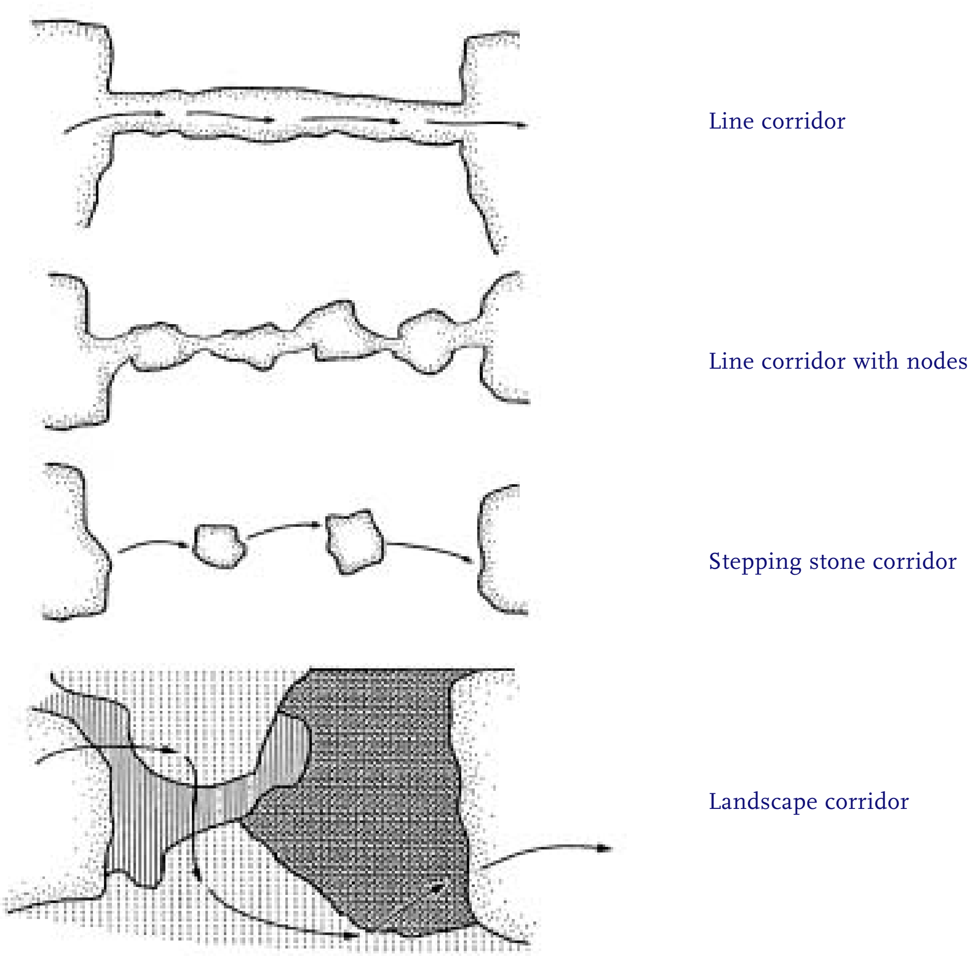
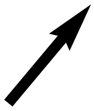
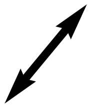
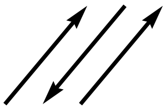
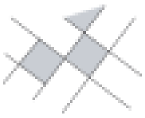


Figure 3
Corridor types (adjusted after Bennett 2002 [10])

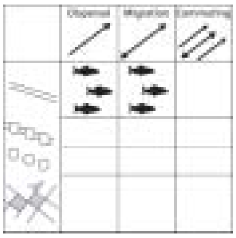
Corridors may be important to connect core areas, but also internal fragmentation of core areas is sometimes problematic, as is illustrated by the border fence of Bialowieza which separates the Polish and the Belarus parts of this last major remnant of the natural European lowland forest.

The functions and forms of corridors can be used to develop a corridor typology. Table 1 shows the possible combinations of functions and forms of corridors [14]. Often a corridor might have several functions for a species, e.g. it might serve both for commuting or dispersal objectives.

Table 1
Shape and functions of corridors for different species

Shape \ Function	**Dispersal**	**Migration**	**Commuting**
			
linear corridor 	Atlantic salmon Sea lamprey	Atlantic salmon Sea lamprey	
linear corridor with attached nodes 	Stag beetle Large copper Yellow-Legged-Dragonfly		Large copper
stepping stones 	Lynx Yellow-Legged-Dragonfly	Brent goose Eurasian crane Yellow-Legged-Dragonfly	
landscape mosaic 	Brown bear Large copper	Brown bear	Brown bear

The examples of corridor development presented in this brochure can be used as practical approaches for the improvement of landscape connectivity and as such indirectly for the increase of biodiversity in fragmented landscapes. The species for which examples of corridor development are presented in this brochure are put in the relevant place of table 1.
Every example is described according to the species' general ecology and conservation status, the connectivity problem is analyzed, possible solutions are presented, and an indication is given of the species or species' groups that may benefit from the proposed measures.



Atlantic salmon *(Salmo salar)*

Ecology

The Atlantic salmon has a North-Atlantic distribution that ranges from Portugal to the Arctic Circle. It includes rivers in Spain, France, the UK, Ireland, Norway, Sweden and Finland. Outside of Europe the main areas for Atlantic salmon are Iceland, Greenland, Eastern Canadian provinces and the North-east of the USA.

Salmon are raised in spawning areas located in the upstream tributaries of large rivers. The species migrates after some years to the sea, to return in three months again to its spawning area for its reproduction and death. For its migration the species requires rivers without barriers. The spawning will only take place in areas with clean water with high oxygen levels and moderate currents. Fish that take part in the migration have lived for at least one winter at sea. Almost 100 % of the adults will return, only few fish get lost on their way and may colonise new rivers [15].

Conservation status

The Atlantic salmon is listed in appendices II and V of the EU Habitats Directive and on appendix III of the Bern Convention (which does not apply to salmons in sea water). Indirectly the species receives protection via the EU Water Framework Directive, which aims for the improvement of the water quality. The species is not listed on the IUCN Red-list.

Problem

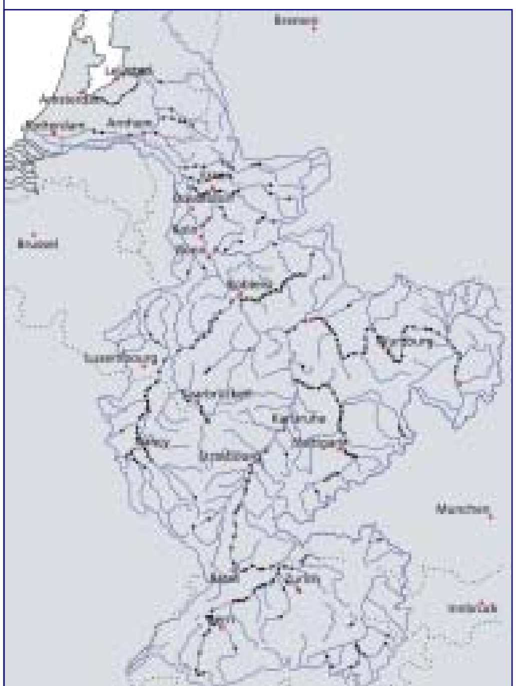
In the early 1960s the Atlantic salmon was threatened by extinction in North-west European countries, due to water pollution and effects of pesticides applied in intensive agriculture. Over the last decades water quality has improved and the salmon now occurs throughout the entire basin of the river Rhine. However, civil engineering structures such as dams, weirs and culverts form an obstacle for migration to the upstream located spawning areas (Map 1) and changes in river morphology have resulted in the gradual degradation of juvenile and spawning habitat. Also the marine environment of the Atlantic salmon is threatened because of changes in sea surface temperatures, industrial fishing and an increase of sea lice associated with fish farming. A small problem is related to salmon that have escaped from fish farms and that are genetically different. These fish may cause hybridisation and natural competition with native Salmon.

Solutions

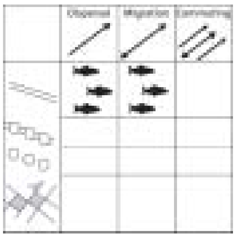
Many initiatives illustrate that a combination of measurements is required to restore the land-scape connectivity for the Atlantic salmon. These measurements comprise the improvement of water quality, the bypassing of obstructions such as dams, weirs and culverts (e.g. by fish passes in the Netherlands), the restoration of spawning areas by restoration of the morphology of rivers and streams (Belgium and Germany), and in some cases young fish have been reintroduced in tributaries of big rivers (the Meuse/ Ardennes and Rhine/Sieg and Ahr). **The corridor required for migration and dispersal is of the 'linear type'.** A coordinated approach is required though, the connectivity may be a major problem, but for Salmon to reach its spawning areas a chain of measures is required.

Species benefiting

The Atlantic salmon is an indicator of rivers that meet high water quality standards. If the rivers are improved then not only the Atlantic salmon will benefit, but also other species such as Sea lamprey, Sturgeon, Barbel, Trout, Allis shad, Twaite shad and European bullhead.



Map 1
Major barriers for fish species such as Salmon and Sea lamprey in the river Rhine (adjusted after Schulte-Wülwer-Leidig, [16])



Sea lamprey *(Petromyzon marinus)*

Ecology

The Sea lamprey is one of the most primitive vertebrates. Although the species is not a fish, it is often considered as such. The Sea lamprey parasitises fish species which will actually not be seriously affected by it. The Sea lamprey lives in the sea and migrates to spawning areas in the middle- and upper reaches of large rivers. These areas are characterised by shallowness, ripples, a strong current (1-2 m/s) and a sun-lit rocky substrate. Thousands of eggs are deposited in a shallow burrow that is covered with sand. The larvae hatch and are carried by the stream to suitable muddy banks. They stay there for some years, feeding on algae and vegetative material. After five to eight years the larvae metamorphose into the parasitic fish species. They swim downstream and live for another 3 years at sea, before returning to the spawning area to repeat the same cycle [17, 18].

Conservation status

The Sea lamprey is listed in the EU Habitats Directive (appendix II) and in appendix III of the Bern Convention. In many European countries the species also occurs on the national Red-list of fishes, but it is not listed as an IUCN Red-list species.

Problem

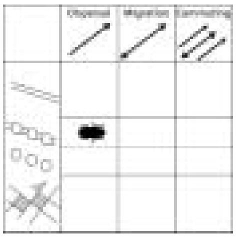
In the past many polluting effluents were discharged into rivers and indirectly into the sea which affected the population of the Sea lampreys. Nowadays pollution and eutrophication have a major impact on the species by destroying both spawning gravels and nursery muds. Furthermore river management practices such as canalisation, dredging and water regulation, as well as water extraction and land drainage have negative effects on Sea lamprey populations as they destabilize spawning gravels and nursery silts. Physical barriers such as weirs and dams may also affect all these factors and result in major detrimental effects on the success of spawning of Sea lampreys. Finally the population of Sea lampreys may be endangered by (over)exploitation of fishery.

Solutions

These are similar to those for the Atlantic salmon (Map 1). Thus the habitat connectivity for the Sea lamprey can be increased with the removal of barriers and weirs in major streams and rivers. The map shows the large number of barriers and dams in the river Rhine. **The required corridor for dispersal and migration is of the 'linear type'**, connecting a reproduction area with two main habitats. Furthermore the availability of sufficient suitable spawning areas in the upper reaches of large rivers and the improvement of the water quality in upper and middle reaches of streams benefit the development of the larvae. Therefore, the restoration of the natural river morphology, with its associated natural dynamics, will be beneficial for the Sea lamprey.

Species benefiting

Species such as Atlantic salmon, Sturgeon, Barbel, Trout, Allis shad, Twaite shad and European bullhead will benefit from the proposed measures.



Stag beetle *(Lucanus cervus)*

Ecology

The Stag beetle is one of the largest insect species in Europe. The larval development in dead wood takes five till eight years. Although females are able to fly and need to do so in order to search for stumps for mating and laying eggs, they tend to stay in the neighbourhood of the stump they emerged from. Chances for colonisation of new habitats are therefore limited.
The Stag beetle is common only in Northern and Central Spain and Northern Italy and is rather stable. In South-eastern England its populations are surviving well in three core areas. Distribution patterns have been shrinking since 1900 in the remaining countries, leaving only small isolated populations.

Conservation status

The Stag beetle is listed in appendix III of the Bern convention and in appendix II of the EU Habitats Directive. In many European countries the European Stag beetle also occurs on the national Red-lists, but it does not occur on the IUCN Red-list since the species is not endangered on a global scale.

Problem

The main risks for the Stag beetle is its vulnerability -due to its long life cycle which requires large stumps in an undisturbed environment- and the relatively small dispersal range of the females. It appears that the main condition for survival and gradual dispersal forms a rather dense network of undisturbed patches with old large stumps of deciduous trees and sap trees for adult feeding as well.
At the landscape level the beetle is affected by the disappearance and fragmentation of old deciduous forests, leading to smaller and more isolated habitat patches. As a result, the distribution of the beetle is scattered (Map 2).
At the local level, forestry activities also minimize the remaining suitable habitat because they consist of the removal and disturbance of large pieces of dead wood from the forests and the cutting of deciduous trees for forest regeneration purposes. Consequently only small stumps are left behind which are too small for proper larval development of the beetle. In addition the use of herbicides and insecticides threatens the beetle.

The decline and fragmentation of habitat of the Stag beetle also affects other saproxylic (wood-boring) insects; Map 3 shows the distribution of forests containing habitats of 200 endangered species of woodboring invertebrates compiled by the Invertebrate Consultants' Group of the CDSN-committee[19]. Countries for which such habitats are presented are: Norway, Sweden, Finland, Denmark, Germany, Switzerland, England and Belgium. For France data was only partly available and no forests were considered appropriate for listing in Ireland and the Netherlands.

Some forests are of respectable size, but others are as little as 40 ha. The greater part lies within mountainous parts of the continent. The distribution pattern shown on the map clearly demonstrates that forests being important for saproxylics are either isolated relicts in unforested regions or – although embedded in large woodland regions – isolated from similar forests.

Solutions

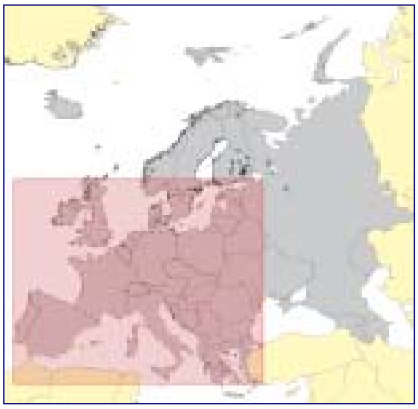
To create more breeding possibilities for the Stag beetle old and moribund deciduous trees as well as large stumps of these trees are required. At the local level connectivity can be enhanced by the introduction of natural and artificial breeding facilities, such as dead wood pyramids, loggeries and large wooden boxes filled with wood chips and sawdust. The location of these breeding habitats should be based on the core areas already present. The **corridors connecting the breeding places should be of the 'nodal type'** with nodes every 2 km.

At the landscape level connectivity can be enhanced with the maintenance of ancient woods, conservation of forest remnants, hedgerows and old deciduous trees. The exchange of individuals between isolated patches of old deciduous woodland can be facilitated with plant schemes for deciduous trees in the vicinity of forest remnants, single trees, open areas and coniferous woodland. These corridors should be constructed away from roads, as Stag beetles are very vulnerable to traffic.

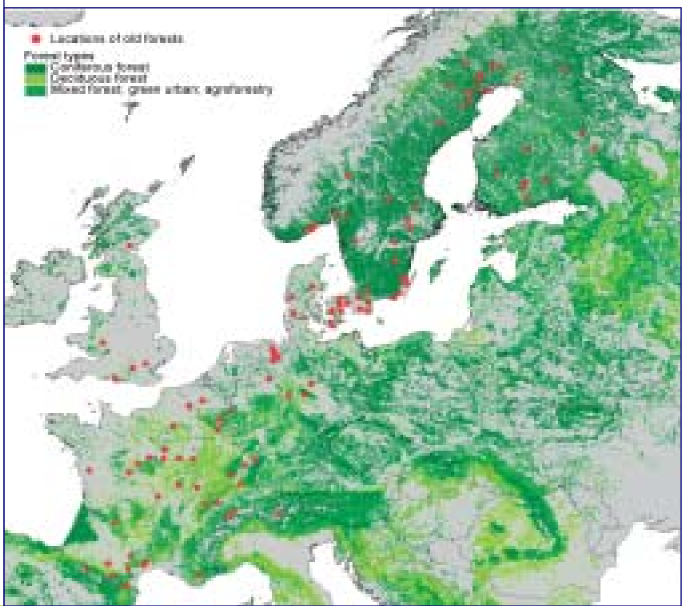
Species benefiting

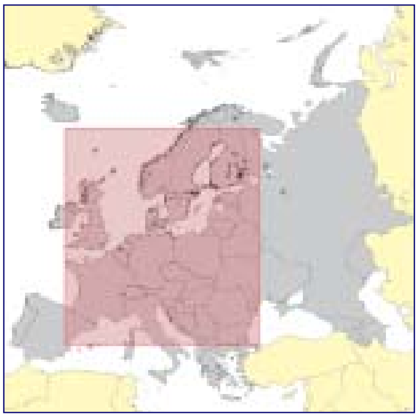
The Stag beetle is exemplary for the strongly declining group of large wood boring (saproxylic) beetles, such as the black tinder fungus beetle. If ancient woods are maintained then ancient woodland indicator plants will also benefit.

Photo: Alterra

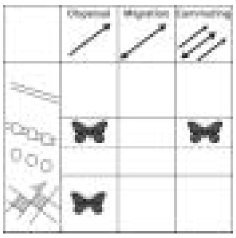


Map 2
Distribution of Stag beetle in Europe





Map 3
Western and Northern European forests indentified as being of potential international importance by their fauna of saproxylic (wood-eating) invertebrates. Based on results of the Saproxylic Invertebrates Project (Speight 1989 [19]).



Large copper *(Lycaena dispar batava)*

Ecology

The Large copper usually occurs in natural marsh vegetation along water courses, rivers and marshes, but may also be found in unimproved, semi-natural grasslands (Figure 6). The male defends his territory, whilst the female wanders over large wetlands looking for a male or -after mating- for a plant to deposit eggs. The females are quite mobile and can colonise relatively quickly suitable habitats up to a distance of ten km. This means that the butterfly functions very well in mosaics of habitat patches.

The Large copper has declinded significantly in Western Europe, whereas Eastern European populations are mostly stable (Map 4). At the northern limit of its range in Estonia and more recently in Finland, the butterfly is expanding, probably caused by global warming in the last decades.

Conservation status

The Large copper is listed on appendix II of the Bern Convention and on appendix II and IV of the EU Habitats Directive. The butterfly is listed as 'at Lower Risk, Nearly threatened species' on the IUCN Red-list.

Problem

The biggest threat to the Large copper is the fragmentation of its habitat, which are the large marshes and natural, humid grasslands. Intensification of agriculture in North-western Europe has resulted in drainage and reduction in size of these habitats. In Eastern Germany and Poland, large viable populations still exist, but unfavourable changes in agricultural practice could take place following the accession of these countries to the European Union.

By means of a LARCH* analysis potential habitat of the Large copper was identified and compared with the actual distribution pattern of the species (Map 5). In many areas (1, 2, 3) large core populations exist whereas in other regions populations are smaller, but still well connected (4, 5). In areas such as North-western Germany (6) however the wetlands are too small, scattered and isolated. Although the ecology differs slightly for this species, the model also predicts reasonably well the potential distribution of the Large copper in the Netherlands (7). In reality this subspecies is restricted to the Dutch regions of North-west Overijssel and Southern Friesland (8).

Solutions

To increase the connectivity for the Large copper two types of corridors are required.
Firstly corridors connecting different networks and secondly corridors which link smaller local populations within a particular network.

** LARCH (Landscape Analysis and Rules for Configuration of Habitat) is a landscape ecological model to assess the landscape and viability of populations.*

The **landscape matrix** is very important for the development of such network corridors, but also **linear corridors with attached nodes** are needed to link the smaller local populations. The solutions are illustrated in Map 5.

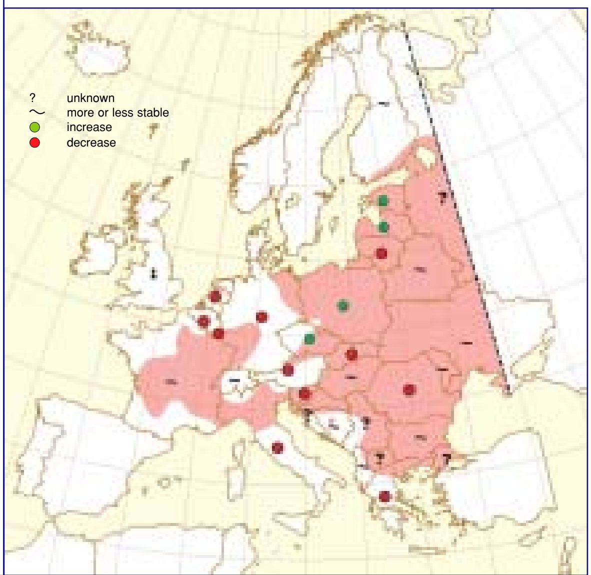
The capitals in Map 5 show the different areas discussed:
The accession of the new member states to the European Union (A) could cause agricultural intensification in these countries. This may lead to the fragmentation of the wetlands in Central Poland. It is important that existing wetlands with Lycaena dispar populations are maintained and the area is connected to the Biebrza valley (3) and Kaliningrad (2). Intensification may also be expected in Eastern Germany.
In the North-western part of Germany (B) wetlands are small and isolated. This means that the Large copper population occurring in the Netherlands is isolated from populations in Eastern Germany. Only a large scale creation of wetlands could be a solution to this problem.
In the Netherlands relatively large and apparently suitable habitats are still available, especially in the region that consists of the Oostvaardersplassen / Vechtplassen / Nieuwkoopse Plassen (C). This region could be connected to the core area in North-West Overijssel (8). This core area of the Large copper in The Netherlands could thus be extended for long term survival of the species.

Species benefiting

The Large copper is an umbrella species for many other wetland insects. But also other species of large wetlands, such as the Otter and many birds will profit from action taken to favour this butterfly.

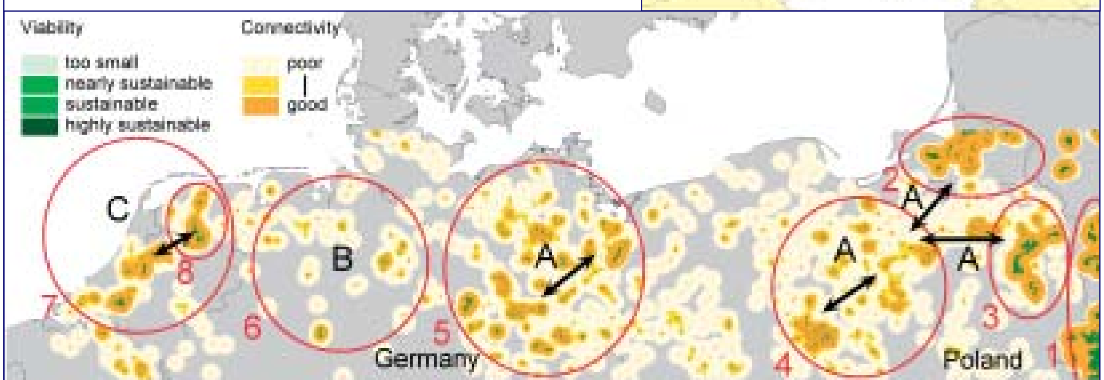
Figure 6

Typical brook valley habitat in Central Europe.



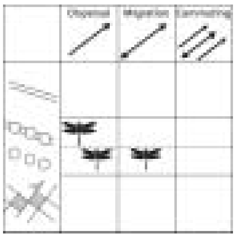
Map 4

Distribution of Large copper in Europe (adjusted after Kudrna, 2002 [20]).



Map 5

Ecological core areas and possible corridors to improve the network viability of the Large copper (based on an analysis by Alterra & Vlinderstichting).



Yellow-legged Dragonfly *(Gomphus flavipes)*

Ecology

The Yellow-legged dragonfly is found in the lower sections of a few large rivers in Western Europe, and is more common in Eastern Europe. The preferred habitat is formed by shallow braided river stretches with low current velocity. Shallow, sandy slopes between groins where current velocity is low are sub-optimal. The larvae live in sand or between fine particulate matter on the river bottom. They prefer warmer places[21]. The development from egg to adult lasts generally three years so that habitat conditions can not change too much over such a period.

In the first decades of the 20th century the species was rather common in Western Europe, but it has now become restricted to a few populations along the Loire and the Allier and a few rivers in Eastern Germany (Elbe and Spree). Currently recolonisation takes place from Central and Eastern Europe (Map 6). The species expands rapidly in the Netherlands after the first discovery in the river Waal. Within a few years, most of the large rivers and some smaller ones have been recolonised and the number of records is larger than in the beginning of the 20th century.

Conservation status

The Yellow-legged dragonfly is included in the European Red-list, the EU Habitats Directive (appendix IV) and the Bern Convention (appendix II). In addition it is listed as an endangered species on the IUCN Red-list.

Problem

The Yellow-legged Dragonfly was extinct from the river Rhine and most other large Western European rivers for almost 100 years. The reasons for this decline are probably water pollution, as well as a loss of habitat by canalisation of rivers and streams and changed management of the water edges. Nowadays the species has reappeared in several rivers in Western Europe such as the Elbe[22], the Lower Rhine[23], the Waal, the Grensmaas, the IJssel and the national park the Biesbosch.

It is a critical species in relation to the life conditions of larvae as well as adults and it is not possible that these conditions have suddenly become more favorable than a hundred years ago. Possibly, therefore, climate change has triggered the sudden expansion, as the larvae show preference for warmer sites. Furthermore, the adults that can fly over large distances may also be sensitive to higher temperatures.

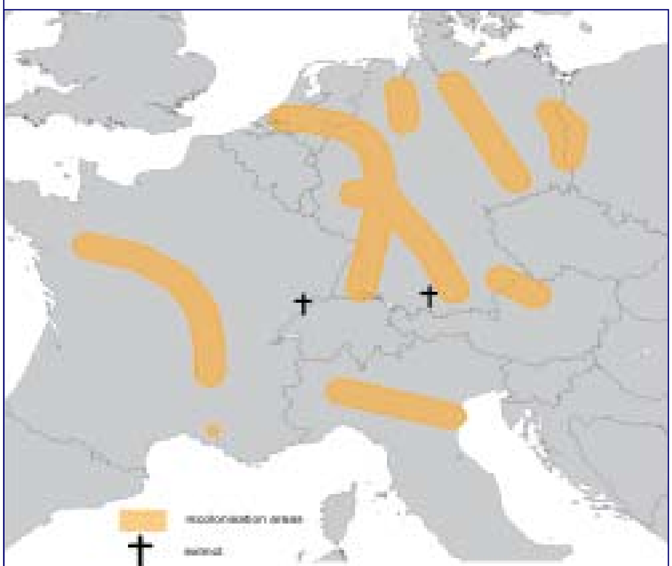
Solutions

Present observations of the Yellow-legged dragonfly in the rivers Rhine and Meuse suggest that the habitat connectivity for the species may be enhanced by the improvement of water quality and the creation of larval and adult habitats in nature development programs. Corridors are therefore of the **linear type with nodes** (larvae) as well as **stepping stones** (adults).

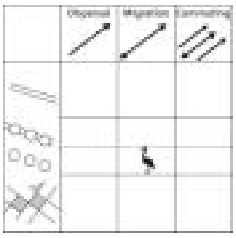
Larval habitats may be developed, although in the canalised river Rhine the species appears to be adapted to artificial habitats between groins. The adult habitat could be improved by using vegetation of disturbed habitats as a substitute for the optimal habitat of sunny, sandy shores with patches of floodplain vegetation.

Species benefiting

If climate change is the main factor responsible for the reappearance of Yellow-legged dragonfly in the large rivers, more macro invertebrates can be expected to follow the same pattern. Among these are ten species of other dragonflies & damselflies and eight species of caddisflies [24]. Certainly more species from other groups such as clams, mussels & snails, earthworms, beetles and midges should follow.



Map 6
Distribution area of Yellow-legged dragonfly (Crombaghs & Habraken, 2002 [25])



Brent goose *(Branta bernicla bernicla)*

Ecology

Brent geese traditionally occur on semi-natural coastal habitats such as lowland tundra, salt marshes, mudflats and eelgrass beds along the Russian and Western European coasts.

Brent geese breed in a short summer of two months on the Taimyr Peninsula in Northern Siberia. The winter and spring staging areas are found along the coasts of Denmark, Germany, the Netherlands, Belgium, France and the UK (Map 7). Brent geese concentrate in the Wadden Sea area to fatten up before the migration to the breeding area starts at the end of May. The Russian White Sea area harbours important stopover sites to refuel before continuing to the breeding areas. These last two areas, Wadden Sea and White Sea, are of great importance: only with a proper weight upon arrival in the breeding areas can the Brent geese breed. With insufficient fat reserves Brent geese are known to skip breeding completely for that season. The population of the Black-bellied Brent goose has undergone large fluctuations in the last century, which is associated with the availability of eelgrass and hunting practices. The current flock is estimated to consist of 150,000 birds.

Conservation status

The Brent goose is included in appendix III of the Bern Convention and in the Birds Directive (annex II). An International Flyway Management Plan for the Brent goose has been drawn in 1997 and special attention for the bird is required by the African Eurasian migratory Waterbird Agreement.

Problem

Low breeding success, habitat loss and conflicts with agriculture are the main problems for the Brent goose. No cause is yet known for the low breeding success.
The semi-natural coastal habitats used as winter and spring staging areas are typically used by man, which leads to habitat loss for the Brent goose. As a result more geese have recently started to feed on grasslands and arable crops, e.g. winter wheat, which leads to further conflicts with the farming community.

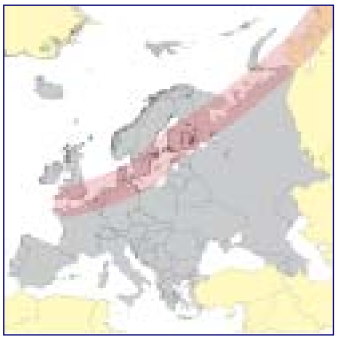
Solutions

It is most urgent that stop-over sites **(stepping stones)** along migration corridors of the Brent goose receive effective protection (Map 7). This applies especially to the Wadden Sea and the White Sea because of their importance as fattening and refuel areas and their major implications to the increase of the breeding success.
To decrease potentials conflicts of interest between farmers and goose conservation, it should be stimulated that management agreements are concluded, so that farmers get compensated for allowing the geese to feed on their lands.

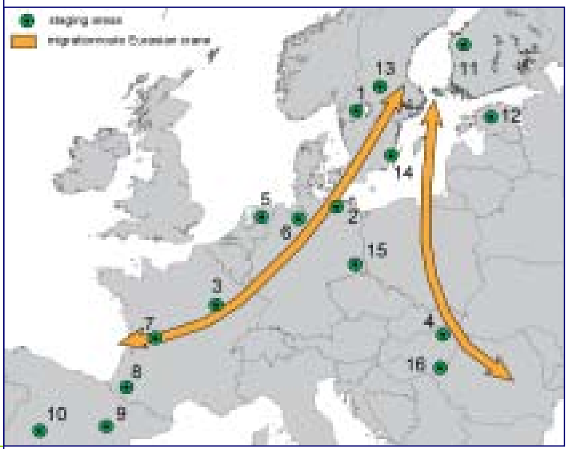
Brent goose (Branta bernicla bernicla)

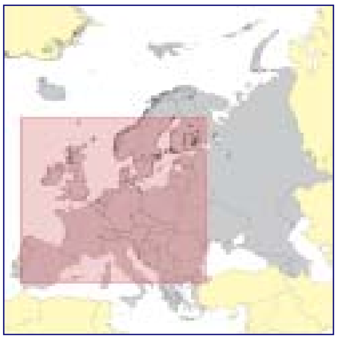
Species benefiting

Area protection (in wintering, migration and breeding sites) and compensation agreements (mainly in wintering sites) would also benefit species regularly sharing the same area as the Brent goose. In the winter and spring staging areas the Brent goose is regularly associated with Widgeon, Barnacle Goose and Greenland White-fronted Goose. The White Sea, the main stopover site during migration, is also important for Bewick's swan. In the breeding areas Herring Gulls colonies are often used. Brent geese also nest in association with Snowy owl and Rough-legged buzzard.

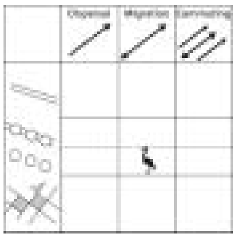


Map 7
Migration routes for Brent goose, with major stepping stones





Map 8
Migration routes of Eurasian crane, with major stop over sites



Eurasian crane *(Grus grus)*

Ecology

The Eurasian crane is a migratory species, with a distribution throughout Europe, Asia and Northern Africa. The breeding habitat of the Eurasian crane consists primarily of moorlands, bogs, swampy clearings in dense forests and even steppe areas are used if associated with water. Foraging areas include extensive agricultural areas such as grain fields and Holm oak areas in Spain. The breeding and wintering areas are connected via several migration routes (Map 8). The two main European migration routes are the West and Eastern European flyway, with important stop-over sites as Lake Hornborga, 12,000 birds (1), the Bock-Rügen area, 40,000 birds (2), Lac du Der-Chantecoq, 50,000 birds (3) and Hortobagy National Park, 65,000 birds (4). The global population numbers to c. 220,000 – 250,000 birds is probably stable to increasing, yet with local declines.

Conservation status

The Eurasian crane is classified under the revised IUCN Red List Categories 'as at Lower Risk, least concern'. Breeding populations in European Russia and central Siberia are classified 'Vulnerable'. The bird does not occur on the Bern Convention but is included in the EU Birds Directive appendices.

Problem

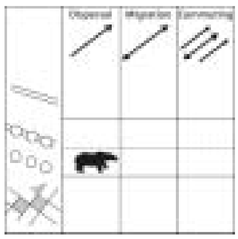
The Eurasian crane populations are currently threatened by wetland loss or degradation and intensification of agriculture. These processes affect the breeding and wintering areas of the birds as well as the stop-over sites on their migration routes. Other threats include hunting and the increase of human disturbance. An important consequence of the loss of habitat is the concentration of the European crane population in increasingly larger flocks at feeding and roosting sites. This causes more risks for the birds as less and less alternatives are available when e.g. a local drought reduces the feeding capacity of a stop over site. Also conflicts with farmers may arise as crops may be damaged at stop over sites along migration routes as well as in the wintering areas.

Solutions

The practical starting points for conservation of the Eurasian crane comprise the protection and restoration of potential habitat in the breeding areas, the stop-over sites along the flight paths and the wintering areas which all function as migration **stepping stones** (Map 8). Examples of projects in Fochteloerveen, Netherlands (5), Elbe, East Germany, (6), and Hortobagy, Hungary, (4) illustrate that this mainly comes down to conservation of wetlands and extensively used agricultural areas.

Species benefiting

The European Crane serves as an umbrella species for other wetland species in its whole distribution area. The main species to benefit are therefore White-tailed eagle, geese, ducks and swans.



Eurasian lynx *(Lynx lynx)*

Ecology

The Eurasian lynx used to occur throughout Europe, but currently the European distribution is associated with a rather scattered pattern of large continuous forest regions. Important core areas are: East Poland, the Carpathians, the Alps and the Jura Mountains.

The Czech Sumava and German Bavarian Forest hold recently established populations. In some Western European regions the species has been reintroduced very recently.

The home-range size within these regions varies according to the season, prey-density, sex and age. Dense populations are mainly found where prey availability of roe deer and chamois is high. Human activity and intensive land use is tolerated as long as there is enough cover.

Conservation status

The Eurasian lynx is protected under the Bern Convention (appendix III), EU Habitats Directive (appendix II and IV, for some Eastern European countries annex V), CITES (Appendix II) and IUCN Red list (Near Threatened status).

Problem

With the LARCH model* the potential habitat and the connectivity of the landscape were evaluated for the Eurasian lynx. The analysis shows that the potential habitat has a patchy distribution; the suitable habitat is being destroyed by deforestation and agriculture.

Some potential suitable habitat is badly connected with core areas. The recently colonised peripheral areas are especially badly connected with already occupied areas. The latter is problematic for the species, because relatively small populations of the Eurasian lynx may easily become extinct as a result of environmental stochasticity (random fluctuations), such as prey availability, poaching (nowadays), hunting (in the past) or road kills.

Solutions

To strengthen the European lynx population it would be advisable to improve the connectivity of the landscape, the peripheral areas where small populations face the threat of extinction.

Recent Lynx observations in Northern Belgium, the southern parts of the Netherlands and the Dutch Veluwe indicate the potential for colonisation of small isolated areas.

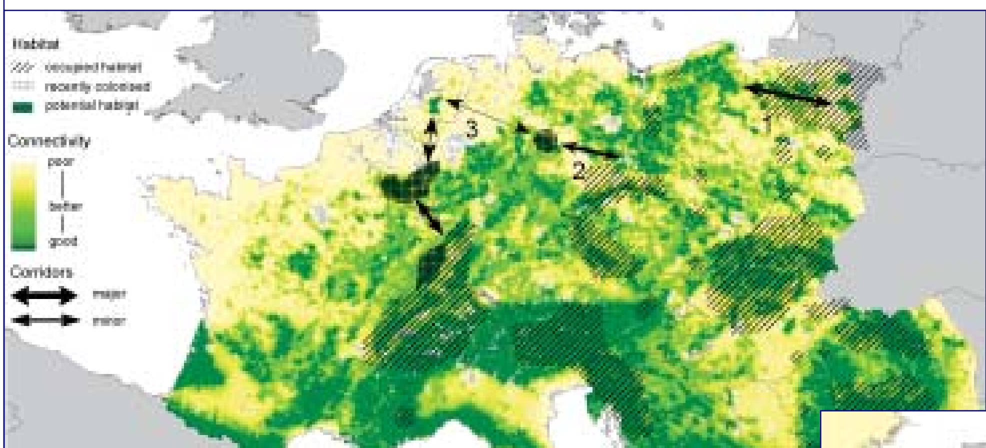
Spontaneous recolonisation of potential habitat (forest) may be facilitated by incorporating **corridors with stepping stones** into the ecological network for the Lynx.

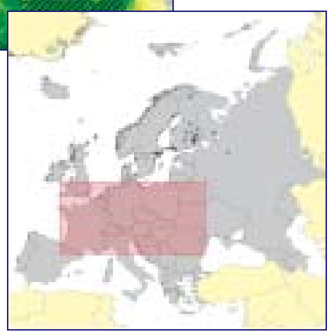
The most effective corridors are indicated on Map 9 and comprise the area between North-eastern and North-western Poland (1), the area from Western Poland, the south of Berlin, towards the Harz area (2) and the area between South-eastern Belgium and the French-Swiss Vosges and Jura area (3).

* LARCH (Landscape Analysis and Rules for Configuration of Habitat) is a landscape ecological model to assess species' habitat and viability of populations.

Species benefiting

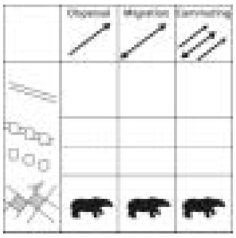
The development of an ecological network for the Lynx will benefit a large range of mammals such as Red deer, Roe deer, Wolf, Brown bear, Badger, Wild cat and Pine marten. Also other smaller mammals, birds and insects that live in forests could benefit from the corridors depending on the shape the corridor.





Map 9

Connectivity of the European landscape for the Eurasian lynx, and potential corridors



Brown bear *(Ursus arctos)*

Ecology

Brown bears once lived in many places in Europe. Bears require cover and protection, feeding and hibernating areas. The most suitable habitats therefore consist of landscape mosaics and densely forested areas. European populations are mainly restricted to mountain woodlands with agro-pastoral features. It is assumed that male bears disperse faster than females.

The bears are distributed over a few populations consisting of less than 100 animals. Some are almost extinct (Pyrenees in France, Central Austria, and Tessin in Italy); others are vulnerable but fairly stable (Spain, Italy, and Greece) whereas in Fennoscandia and Central Europe (Romania and bordering countries) the populations are not endangered, but in some areas still hunted.

Conservation status

The Brown bear is protected under the Bern Convention (appendix II) and EU Habitats Directive (appendix II and IV), but is not listed on the IUCN Red-list.

Problem

In the past the populations of Brown bears in Europe have suffered most from severe persecution by hunters who considered the species responsible for the loss of livestock. Nowadays in Southern and Western Europe populations of the species have further declined as deforestation and agriculture have increasingly fragmented and destroyed suitable habitats. The combination of habitat fragmentation and habitat loss has resulted in small, isolated populations which might become extinct if the surface of the habitat becomes too small. Map 10 illustrates the connectivity of the landscape for the Brown bear for the Abruzzo national park.

Solutions

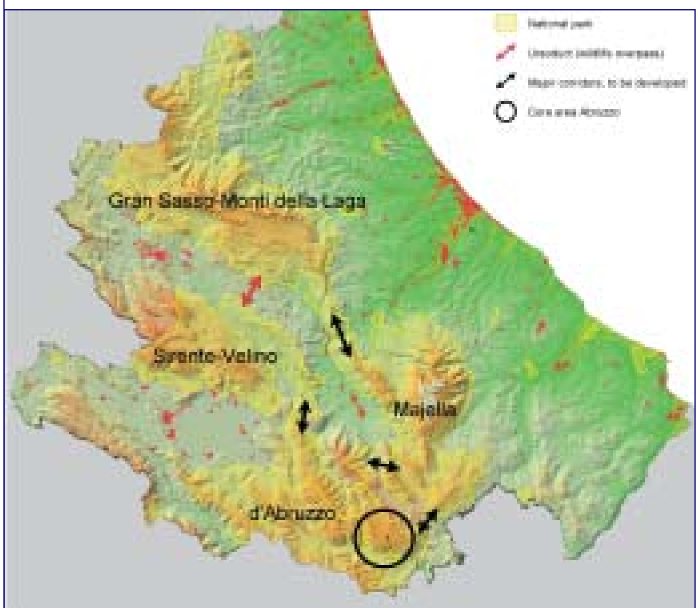
The Brown bear can be protected by good herding practices which reduce livestock kills and make the hunting of bears unnecessary. In addition the risk of extinction of isolated populations would decrease if stable or viable satellite populations could be established outside core areas allowing the population to grow and spread out over more areas. Occasional observations outside the core area of the Abruzzo Park demonstrate that dispersal is indeed possible, despite the fragmentation by road infrastructure and lack of vegetation[26, 27]. With the METAPHOR model* it was shown that the overall viability of the population would improve if the national parks would be connected with the development of corridors.

Corridors required are of the **landscape type**, which offer cover and protection, and over longer distances also foraging possibilities. The corridors should be planted with indigenous vegetation, which provides cover to migrating bears. An 'Ursoduct' would be required to bridge an open plain with road between the National parks of Sirente-Velino and Monti della Laga National park [26, 28].

* *SmallSteps, a movement model, provides an estimate of the connectivity of habitat patches for the Brown bear. The model takes into account the properties (resistance) of the landscape in-between the patches (landscape matrix). Calculated connectivity is used in METAPHOR, a population dynamic simulation model, to estimate metapopulation viability*

Species benefiting

Conservation measurements for the Brown bear will benefit mammal species such as Roe deer, Wolf, Badger, Wild cat, Lynx and Pine marten but also smaller mammals such as Red squirrel, Common shrew, Pygmy shrew, Bank vole, Wood mouse and Dormouse. In addition forest birds such as Chiffchaff and blackcap will benefit.



Map 10
Corridors for the Brown bear, connecting National parks in Abruzzo (based on Van der Sluis et al. 2003 [26])

Conclusions

In this brochure a number of examples were given of practical solutions for specific problems in the field of habitat fragmentation. The problem for all species described is that they are threatened in Europe, often, but not exclusively, due to fragmentation and loss of habitat.
All species presented are protected under European, and often national legislation, and therefore they are relevant to the policies of European states.

The examples of corridors presented in this brochure can also be used for the development of strategies for the conservation of the specific ecosystem in which the given species lives. For example measures taken for the Atlantic salmon based on the corridor requirements for that species may benefit any other species that have similar requirements of clean and dynamic rivers (e.g. Sea lamprey, Sturgeon or Trout). As such the measurements for this group of species can form an improvement in the entire ecosystem.

The cases presented have in common that at one stage the species were more widespread then at present. The landscape has changed, habitats were lost, and land use has altered the potential habitat available to the species.
These changes in habitat can be related to the 'landscape configuration', and to the 'ecological network'.

The solutions presented in this brochure are related to habitat restoration (Salmon, Sea lamprey, Yellow-legged dragonfly), development of corridors (Brown bear, Lynx) creation of stepping stones along corridors (Stag beetle, Brent goose, Eurasian crane), creation of cohesive landscapes (landscape mosaics; e.g. Large copper, Brown bear). These measures are all dependent on the process of spatial planning, and the application of these measure are therefore dependent on decisions of politicians and policy-makers, regional and national planners, river authorities, and farmers.
For the development of the ecological network of species all these different stakeholders are important, and must be involved in the preparation and planning process.

Corridors are essential parts of ecological networks. The planning or development of corridors requires:

- knowledge of the requirements of species;
- cooperation, between regions and across national borders;
- a long term vision for conservation measures that must be integrated in a spatial planning and landscape context.

The practical solutions presented in this brochure refer to individual cases, but could be applied elsewhere. They may be of use for species action plans or for the acquisition of funding for conservation projects.
The solutions may be useful for the implementation of action oriented European programs and Strategies, such as PEBLDS and the EC Biodiversity Strategy, and for the allocation of European funding sources, such as the EU Life regulation, The Rural pillar of the Common Agricultural Policy and EU Structural funds.

Considerations

Integration of corridors into other land use policies

Safeguarding, management and development of corridors requires the involvement of various land use sectors, therefore, this aspect needs to be integrated in national policies of all other land use sectors. This also applies to the development of relevant EU policies, such as the Transport policies (Trans-European Infrastructure Network TEN), the Common Agricultural Policy CAP, and Regional Policies. The ecological connectivity requirements of species occurring in Europe should receive much more priority in these EU policies, also in the light of the impact of climate change in Europe on habitats and species.

Define the goal of corridors clearly

Corridors can have many functions and purposes. Therefore in the practice of planning one needs to define the ambition with respect to the development of corridors and the related beneficial effect on ecosystems. Important questions will have to be answered, such as: does one pursue a low ambition level for less demanding species, or does one want to facilitate populations of top predators such as the Brown bear or the Atlantic salmon? Although both options are feasible, a high ambition level requires more investment and perseverance, from planners and politicians alike. Above all, it requires support and interest from local people and communities who should support conservation at the 'grass-roots level'.

Special attention needed for species of semi-natural grasslands

The current widespread polarisation in land use (intensification as opposed to abandonment) will have major impact on the landscape, and therefore on the ecological network of species. In particular species of semi-natural grasslands - or species that use corridors of this type- may be at a disadvantage due to these changes. For these species the development or consolidation of corridors is likely to become of crucial importance in the future.

Make use of opportunities offered by new developments

The planner or policy maker can use potential 'threats' as new opportunities for rural development and urban planning. Possible land use developments that were harmful for nature, may now be used for improving natural conditions. A good example is the upgrading of roads -which includes the construction of fauna passages- which actually decrease the impact of the already existing road (e.g. the example in this brochure of the Brown bear in Abruzzo). The benefits of the proposed measurements for conservation agencies are clearcut; However, they may also be used by transport or economic policy departments in order to create local support.

For more information on the development of the Pan-European Ecological Network please consult the following:

Documents

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Foppen, R.P.B., I.M. Bouwma, J.T.R. Kalkhoven, J. Dirksen & S. van Opstal, (2000)
Corridors of the Pan-European Ecological Network: concepts and examples for terrestrial and freshwater vertebrates. Alterra and ECNC. ECNC Technical Report, ECNC, Tilburg.

Janssen, J.A.M. & J.H.J. Schaminée, S.M.J. Brasseur, F.G.W.A. Ottburg, A.H.P. Stumpel & A.H. Hoffmann (2004). Europese Natuur in Nederland. Soorten van de Habitatrichtlijn. KNNV, Utrecht, 112 pp.

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Klijn, J.A., A.J.F.M. van Opstal, & I.M. Bouwma (2003).
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The Netherlands/Budapest, Hungary.

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The architecture of the Pan-European Ecological Network: suggestions for concept and criteria. IKC-report 37, Wageningen, the Netherlands.

Websites

Alterra: http://www.alterra.wur.nl/uk/

ECNC: http://www.ecnc.org