European corridors - example studies for the Pan-European Ecological Network

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Background document

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ABSTRACT

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The concept of corridors is assessed in relation to corridor requirements for different species groups. A typology is further developed, and apllied for representative species. A strategy for corridor development is presented for species with a (European) protection status. Those species are selected that are dependent on large scale (international) corridors.
Examples are given of practical solutions for habitat fragmentation for a selection of species. The species described are threatened in Europe, often, but not exclusively, due to fragmentation and loss of habitat. The species are protected under European and national legislation, and therefore they are relevant to the policies of European states. The result is a detailed analysis of required corridors, and other required measures for conservation of the species

Keywords: birds, corridors, dispersal strategy, ecological network, Europe, fish, invertebrates, landscape ecology, mammals, Natura2000, plants

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Contents

Appendices

Preface

This report presents the results of the project: 'European corridors and European target species'. As such this report is a product of different authors, colleagues involved. The editors have coordinated the project, compiled the contributions and did the editing and translation of some parts of the text.

The result may be considered as the 'State of the art', based on input from experts, research data, combined with spatial modelling to define best solutions for development of ecological corridors for species.

A brochure has been published on European corridors, 'European corridors: strategies for corridor development for target species', which is distributed in all European countries (Van der der Sluis, T., M. Bloemmen and I.M. Bouwma, 2004).
This technical report contains all background information of the brochure, as well as a description of the approach and choices made.

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We would like to thank in particular S. van Opstal (EC-LNV) for his advice and guidance on the work, Rob Wolters (ECNC) for his comments, Rienk Jan Bijlsma as programme leader, Bob Bunce for the editing of parts of the text (the Brochure), and all other people involved in some stages of the project.

"An animal inhabits its space, whether in a zoo or in the wild, in the same way chess pieces move about a chessboard-significantly. There is no more happenstance, no more "freedom", involved in the whereabouts of a lizard or a bear or a deer than in the location of a knight on a chessboard. Both speak of pattern and purpose. In the wild, animals stick to the same paths for the same pressing reasons, season after season."
(p. 26, Life of Pi, Yann Martel)

Summary

This report presents the role and function of corridors for different species groups. Corridors are essential for sustainable populations of plants and animals. A typology of corridors frequently used is a division into three types: linear corridors, stepping-stone corridor and landscape corridor. These principles have been worked out well for common species groups like birds and mammals, but some species were never properly assessed on their corridor requirements.

In this study we have assessed the requirements of terrestrial and aquatic invertebrates, and plant species. The concept of corridors was adjusted to those particular species groups. This has resulted in a different type of corridor which is in particular important for invertebrate species, the 'nodal corridor', or line corridor with nodes. In particular for less mobile, smaller organisms linear corridors with nodes where reproduction is possible are important, so that

In order to further develop the concept of the European ecological network, in this project readily available as well as more recent experiences were compiled with regard to the development of ecological networks for various species groups and in different regions of Europe.

Species were selected which are representative for the development of an ecological network in practice. It may be clear that it is impossible to cover all taxa and all relevant species in this study, so in different steps a selection was made: first species were selected which are protected under European, and often national legislation, and therefore they are relevant to the policies of European states. Those were selected of these species that have specific requirements for migration or dispersal, and are therefore dependent on corridors.

Out of these groups, a selection was made of representative species for which ecological descriptions or characterisations were prepared, analysing in brief the conservation aspects. Based on this description, target species were selected which may illustrate well the importance of corridors, for different ecosystems and different regions in Europe.

For the selected target species potential corridors were analysed based on dispersal characteristics and dispersal mechanisms. The resulting detailed analysis of required corridors, and other required measures for conservation of the species.demonstrate how fragmentation problems at a Pan European scale level could be resolved. As such this study provides some practical solutions for the development of ecological networks in Europe.

Examples for corridor development are presented for internationally important species, i.e. species with a (European) protection status, dependent on large scale (international) corridors. Practical solutions are given 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.
The examples have been prepared on the basis of current research and knowledge. These practical examples can be guiding in network development in different regions in Europe.

The solutions presented in this report 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, Brant 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 report and in the 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.

1 Introduction

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.

In unmodified ecosystems we can often observe a patchy distribution of habitat. Natural variation in soil, geology, topography will result in a diversity of natural habitats, on top of that we have natural dynamics, which will affect the landscape or vegetation type.

The variation in the landscape is in fact the scale of the landscape, and under natural conditions some fragmentation might occur due to the patchiness of the pattern.

In the present-day situation we are far off from this natural 'template'. Natural variation has decreased largely in Western Europe. Soils are disturbed, levelled; natural dynamics have almost disappeared, and have been replaced by man-induced management regimes. Changes in scale of operations, induced in part by European policy, have led to a homogenisation of habitat.

As a result, the patchy landscape has been replaced by a homogeneous landscape, with little variation over large distances. Western Europe is intensively used by man, with the result that natural 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).

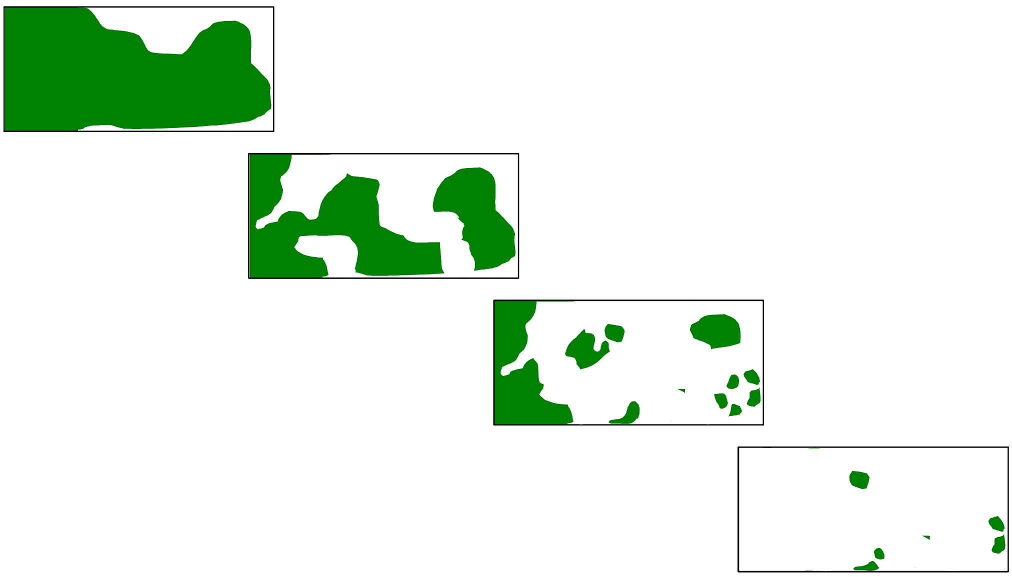


Figure 1: The process of fragmentation of natural areas

Due to the fragmentation of their habitat, many species in Western Europe have already disappeared or may disappear 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.

Three aspects complicate the identification of ecological corridors:
- There is no pan-European list available that indicates the target species for which the development of corridors in Europe is required. The available lists of target species for European policy (Natura, 2000: Birds Directive, Habitat Directive, Bern Convention, Bonn Convention, IUCN red list of threatened species) have a strong Western European focus.
- Migration and dispersal movement of target species differ much in regard of the spatial scale of the movement as well as the different dispersal vectors (wind, water, etc), which makes it difficult to develop a corridor typology that suits all targeted species.
- Due to the gradient of fragmentation of the European landscape and the occurrence of different species in this landscape, the bottlenecks for dispersal and migration of the different species are not located in the same place.

Connectivity of the landscape is species specific. The connectivity 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.

Some years back a report has been published on corridors of the Pan-European ecological network (Foppen *et al.*, 2000). This report presented an overview of principles of corridors, in particular at the European scale level. In addition, it gave few examples of different types of corridors, and an overview of protected mammals, birds, fish, amphibianss and reptiles that may benefit from the Pan-European corridors. At that time no attention could be paid to invertebrates and plant species.
It was felt that this was an omission, so in this study we have assessed the requirements of terrestrial and aquatic invertebrates, and plant species. Based on this the concepts of European corridors was adjusted to those particular species groups.

In order to further develop the concept of the European ecological network, in this project readily available[1] as well as more recent experiences were compiled with regard to the development of ecological networks for various species groups and in

[1] This project builds (forth) on the study of Foppen (2000) which was restricted to the species groups: birds, mammals, fish, amphibians and reptiles.

different regions of Europe (Klijn *et al.*, 2003, van der Grift & van der Sluis, 2003, van der Sluis *et al.*, 2001, 2003a, 2003b, 2003c, van Rooij *et al.*, 2003).

Based on the compiled data, a number of species were selected which are representative for the development of an ecological network in practice. It may be clear that it is impossible to cover all taxa and all relevant species in this study. For the selected target species potential corridors were analysed based on dispersal characteristics and dispersal mechanisms. The results of these analyses demonstrate how fragmentation problems at a Pan European scale level could be resolved. As such this study provides some practical solutions for the development of ecological networks in Europe.

1.1 General methodology

Foppen *et al.* (2000) described three corridor types for vertebrates (based on their function): migration corridor, commuting corridor and dispersal corridor. These corridors can have the following shapes: line corridor, stepping stone corridor and landscape corridor. In Foppen's typology the central question is WHY vertebrates move. For plants and invertebrates this question is less relevant because they often spread passively. More important for these species groups here is HOW they spread.
Therefore, plant and invertebrate experts have made, in this project, an overview of migration and dispersal mechanisms for plants and invertebrates (see par. **2.5**).

For the selection of the target species, a generic method was used. The generic method is a convergence process in 3 steps:
Step 1: compilation of pan-European species lists
Step 2: the preparation of ecological profiles for a selection of relevant species
Step 3: selection of species for spatial analysis

For each of these steps different, specific selection criteria were developed. This resulted in species lists, ecological profiles, and an analysis of relevant species.
For these relevant species characteristics such as the dispersal capacity, the use of corridors, knowledge gaps and compatibility with other forms of land use are discussed.
The analysis presents concrete solutions or measures required for species conservation.

1.1.1 Species selection for spatial analysis

For the selection of the target species, a generic selection method was used. Any exceptions made to the general selection criteria are clarified in paragraph **3.1**.

The generic method is a convergence process in 3 steps:
Step 1: compilation of a pan- European species lists
Step 2: selection of species for the preparation of ecological profiles
Step 3: selection of species for spatial analysis

For each of these steps different, specific selection criteria are applicable:

- Step 1 Compilation of a pan-European species lists

Several lists of endangered species are available. These lists have usually a strong Western European focus. In a preceding study a species list was prepared for mammals, birds, fish amphibians and reptiles (Appendix 1 in Foppen *et al.*, 2000). This list was extended in this study with the taxa vascular plants, aquatic- and terrestrial invertebrates that meet the following criteria:
- The basic principles of the study of Foppen (2000, p29) should be applicable to the selected species, that is, functional use of corridors (not random movements, and specific structure required), and movement ranges (in general exceeding 10 km).
- The species should be relevant at a European scale. This implies that the distribution area should either comprise various European countries or comparable areas throughout Europe,
- The species should be of political relevance. This implies that the species should have received a certain (protection) status or would required such a status, based on expert knowledge,
- the species must be endangered,
- the species must be vulnerable for fragmentation, for which dispersal corridors are a solution

Species that are better off with re-introduction instead of construction of corridors are excluded, as well as populations that never formed one single population due to geographical barriers.

- Step 2, Selection of species for the preparation of ecological profiles

From the pan-European species list, species are selected for which a so-called 'ecological profile' is compiled. The selection criteria are:
- The species is preferably an indicator species for a specific ecosystem or should be a so-called 'umbrella' species. In other words, the problem of the species should be representative for the problems faced by its entire ecosystem or species group.
- The species should be appealing, preferably non-controversial.

- Step 3, Selection of species for spatial analysis

A selection of species is made out of those ecoprofiles for which the ecological network and fragmentation problem is analysed. This selection is prepared on following criteria:

- Geographical information is required for key areas and corridor requirements of the species. The expected results should be illustrative for the necessity of corridors
- Practical solutions of bottlenecks for specific areas or regions can be expected.

1.1.2 Spatial analysis corridors

Where possible, the spatial analysis builds forth on existing analyses, European habitat maps, literature and projects. The spatial parameters used in the analyses are summarised in the ecoprofiles. There is a focus in the analyses on key locations and connections of the ecological network, because here most probably problems will occur for dispersal of the species. The analyses can be done with use of a spatial model (such as LARCH or METAPHOR), dependent on the relevance of such a model.

The spatial analysis may consist of the components which are discussed below:
- Maps of key areas and corridors for the various species groups: in order to generate these maps, important areas are selected based on European habitat maps, literature, expert judgement and available data from existing projects.
- General maps for some species groups, e.g. for bird migration corridors. These general maps are not per se based on (GIS) modelling.

Spatial (GIS) analysis for specific species from a species group: a spatial analysis is done in a GIS environment, making use of models such as e.g. Larch or Metaphor. These analyses are performed for species that are interesting representatives for the species group. The spatial analysis is based on existing expertise, studies and analyses (see e.g. Groot Bruinderink *et al.*, 2003, Klijn *et al.*, 2003). The parameters used for the GIS modelling are described in the relevant ecoprofiles.

Picture 1: Mountain ranges after form distinct corridors (Picture: Theo van der Sluis)

Picture 2: Rivers are imortant corridors for most species groups (Photo: Theo van der Sluis)

2 Ecological networks and corridors

2.1 Introduction

Species movement characteristics determine the distances over which dispersal can take place. For small vertebrates like mice it might be tens of meters, for large birds even hundreds of kilometres are possible. Adults of many species tend to have high site fidelity once they have chosen a breeding site. In general it is mainly juveniles that display large dispersal activity. Due to some innate dispersal 'urge' or pressed by density dependent effects a high rate of juveniles is leaving the site of birth. Particularly for ground-dwelling species like mammals and herpetofauna species it has been shown that during dispersal corridors are important features in the landscape (Bennett, 1999; Dawson, 1994; Vos *et al.*, 2002).

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.

Ecological networks are developed at different scale levels. At European level the Pan European Ecological Network (PEEN) is being developed. One of the aims of the PEEN is to improve the dispersal and migration of species of international importance.

2.2 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. Many European countries are attempting to realise ecological networks at a national or regional scale (Rientjes & Roumelioti, 2003).

The policy discussion on the need to establish an ecological network for Europe started in the beginning of the nineties as a result of the international conference 'Conserving Europe's Natural Heritage: Towards a European Ecological Network', held in Maastricht on 9-12 November 1993.

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.

To facilitate joint efforts and common approaches, the Council of the Pan-European Biological and Landscape Diversity Strategy established the Committee of Experts for the development of the Pan-European Ecological Network, which is served by a joint secretariat of the Council of Europe and European Centre for Nature Conservation. Annually representatives of the 54 states of the UN-ECE meet in a Committee of Experts to discuss a diverse range of issues related to the establishment of the Pan-European Ecological Network.

The Pan-European Ecological Network, as part of PEBLDS, is also considered to be a regional contribution by Europe to the Convention on Biological Diversity (1992). Furthermore many European countries are attempting to realise ecological networks at a national or regional scale (Jongman & Kristiansen, 2001, Rientjes & Roumelioti, 2003).

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. It is however not an obligatory aspect of the Directive (see Box 1 Article 10 Habitat Directive).

Box 1 Article 10 Habitat Directive

"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."

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 (see Box 2 Article 42 g from the Plan of implementation of the World Summit on Sustainable Development (26 August- 4 of September 2003).

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 report either occur on the lists of the international conventions or EU-directives.

Box 2 Article 42 g from the Plan of implementation of the World Summit on Sustainable Development (26 August- 4 of September 2003)

(42) Biodiversity, which plays a critical role in overall sustainable development and poverty eradication, is essential to our planet, human well-being and to the livelihood and cultural integrity of people. However, biodiversity is currently being lost at unprecedented rates due to human activities; this trend can only be reversed if the local people benefit from the conservation and sustainable use of biological diversity, in particular in countries of origin of genetic resources, in accordance with article 15 of the Convention on Biological Diversity. The Convention is the key instrument for the conservation and sustainable use of biological diversity and the fair and equitable sharing of benefits arising from use of genetic resources. A more efficient and coherent implementation of the three objectives of the Convention and the achievement by 2010 of a significant reduction in the current rate of loss of biological diversity will require the provision of new and additional financial and technical resources to developing countries, and includes actions at all levels to:

(g) To effectively conserve and sustainably use biodiversity, promote and support initiatives for hot spot areas and other areas essential for biodiversity and promote the development of national and regional ecological networks and corridors;

2.3 Concepts of ecological networks

The metapopulation theory states that in fragmented landscapes animal populations do not live in a continuous habitat but in a network of habitat patches, which are mutually connected by dispersal movements (Levins, 1970; Andrén, 1994; Hanski & Gilpin, 1997; Opdam, 2002). Whether an ecological network can sustain a persistent population or not, depends on:

- characteristics of a species: habitat preference, home range, dispersal capacity
- the amount, shape and area of habitat patches in a landscape
- Connectivity of the landscape, which defines how easily species can move to other habitat patches (spatial configuration of habitat patches).

In fragmented landscapes species can still maintain viable populations as long as local extinctions of small populations can be outbalanced by recolonisation. Populations in fragmented areas function as a metapopulation (Hanski, 1994; Bennett, 1999). Populations are distributed in habitat patches that are fragmented, but not totally isolated, called habitat networks. The key process for sustainability is dispersal (Opdam, 1990). Which habitat patches belong to a network for a particular species depends on the distance between the patches and the quality of the intervening landscapes (barriers, landscape resistance and presence of corridors).

As a result we see that natural habitats remain as islands in otherwise hostile environments, e.g. forests or moors might be isolated small patches in the large landscape. Wildlife populations dependent on larger areas may survive in fragmented situations, as long as remaining patches can function as a network, with possibilities for exchange, for dispersal, for commuting etc. Therefore, ecological network are of cardinal importance to maintain, support these populations.

Box 3: Concept of metapopulations and ecological networks

When natural habitat becomes fragmented as a result of landscape changes, small isolated patches are often too small to sustain viable populations. These small, local populations are always at risk from extinction, due to local 'disasters' or stochastic processes, e.g. fire, pollution, or storms. Occasionally breeding may also fail, with disastrous consequences for small populations of few individuals. So the small populations regularly become extinct. When these local populations are connected in an ecological network, the total area of habitat patches can offer possibilities for persistent populations of species.

Large populations with a very low probability of extinction, the so-called 'key populations', constitute the strong parts in a metapopulation occupying an ecological network (Verboom *et al.*, 2001). From these 'key patches' a net flow of individuals to other habitat patches in an ecological network takes place. In this way immigration occurs from key patches to local populations that became extinct. If there are many patches this process can increase overall sustainability. We consider this a metapopulation (Levins 1970, Andrén 1994). A metapopulation is sustainable if the chance of extinction is less than 5% in 100 years (Shaffer 1981, Verboom *et al.*, 2001).

Standards used to decide whether a metapopulation is sustainable or not are specific for each species. Small, short living species (for example: insects) are more vulnerable and require more individuals for a persistent population than larger, long living species (like the beaver). For less mobile species habitat patches should be situated closer together to form part of a coherent ecological network. On the other hand, the habitat area demands of e.g. insects are smaller.

An ecological network may consist of: core areas, buffer zones, corridors and, in some cases, restoration areas. In conservation in general the 'core areas' receive sufficient attention. Corridors, which may sometimes be equally important, are often neglected or assumed to be present.

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.

2.4 Concepts of corridors

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.

2.4.1 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 kilometres 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.

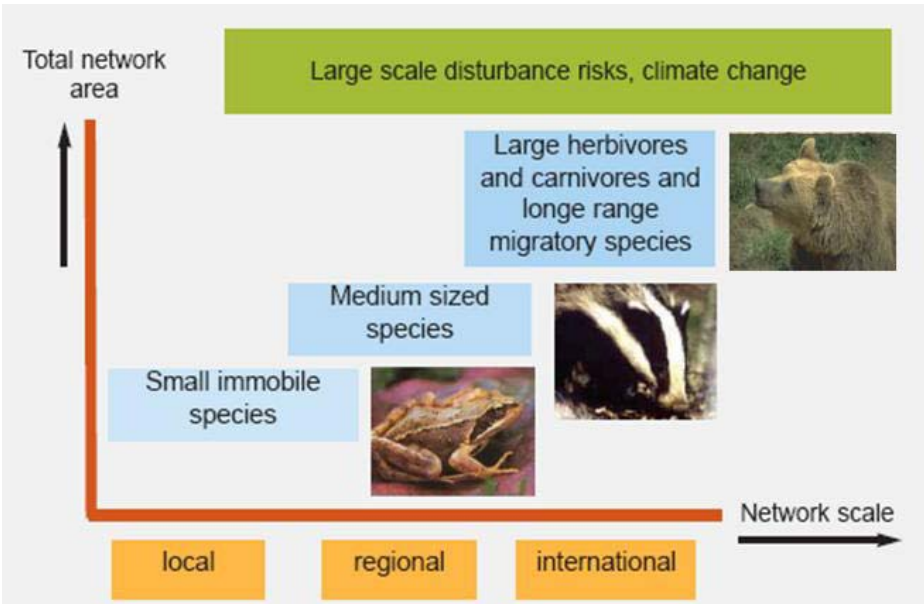


Figure 2: Different species require different scales for the ecological network (derived from Bouwma et al., 2003)

2.4.2 Functions of Corridors

Corridors can be classified into three classes according to the functions that they fulfil (Foppen *et al.*, 2000, Bennett, 1999):

(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 kilometres) for vertebrates, or to tens of kilometres for wider ranging species. Good examples of species using commuting corridors are badgers and bats (Broekhuizen, 1986, Limpens & Kapteijn, 1991).

(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) (Platteeuw, in press).

(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.
Dispersal corridors can aim at various processes related to the functioning of the (meta) population. Three types have been distinguished:

    (a) One-step dispersal corridor
    A one-step dispersal corridor links two habitat patches with each other and has a length that is less than the maximum dispersal distance of the species. This means that the species can reach the new habitat patch within one step.

    (b) Reproduction corridor.
    In many situations it is not enough to have a corridor allowing individuals to disperse in one step between two habitat patches. Distances presumably are too large to cross by an individual disperser. A corridor of new (small) habitat patches is necessary which are suitable for reproduction of the species. This will allow for a sufficient dispersal flux between the two main habitat areas. A special case is when the dispersal capacity of a species is so limited that continuous reproduction habitat is needed to link populations. Examples are invertebrates and plants. In general these types of corridor

need relatively large areas of suitable habitat in order to allow for reproduction. In some cases it might be a better strategy to invest in new habitat by enlarging the existing patches (see also Bennett, 1999 and Vos *et al.*, 2002). However, existing natural reproduction corridors with large dimensions could be very valuable to preserve, e.g. mountain chains and river floodplains.

(c) Range expansion corridor
The use of range expansion corridors is mostly related to the topic of climate change (Bennett, 1999, Spellerberg, 1992). In an evolutionary sense, range expansion corridors must have been important structures for instance for plants to spread across mountain chains, warm river valleys etc, following climate change after the ice age (see Van Opstal, 1999 for an example). It is however doubtful whether these structures will also function in relation to the expected future climate changes (global warming). The general feeling is that the expected climate changes are so fast as compared to the changes that occurred historically, that vulnerable species, mostly plants, will not be able to respond quickly enough by changing their distribution (Bennett, 1999).

2.5 Dispersal mechanisms of species

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.

Box 4: Survival strategy of species: R- & K-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.

Which habitats may be important for those species with the K-strategy? In particular in the climax stadia, e.g. in

1 primary forests
2 old shrubland communities (maquis, Buxus)
3 bogs
4 sea/lakes/river/brooks
5 rocky habitats, nutrient-poor and dry soils in extreme climates

In particular for these species with a very narrow 'niche', with limited tolerance for abiotic and biotic factors, the so-called stenotope species, European corridors may be very important.

2.5.1 Mammals

The dispersal mechanism of birds was partly discussed in Foppen *et al.* (2000). The group of mammals varies very much, they are aquatic (e.g. dolphins), flying (e.g. bats); they differ very much in range and size (dormouse up to elk) and are therefore all very different.

In general the mammal group depends either on linear corridors and corridors which consist of stepping stones. These corridors are sometimes required for foraging, more often for dispersal though. In particular for larger mammals and mammals with particular habitat requirements like bats, lack of corridors is a major bottleneck.

2.5.2 Birds

The dispersal mechanism of birds was partly discussed in Foppen *et al.* (2000). The majority of European bird species are migratory. The concept of more or less isolated or fragmented populations, for which corridors are required to survive in the long term, is therefore not applicable for migratory birds. Birds solve this by migration, since during migration it is usually one population, which mixes. Migration corridors are required though, with stepping stones, where birds can fatten up again (Platteeuw, in press).
Non-migratory birds may do need dispersal corridors.

2.5.3 Invertebrates

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.
For species moving by air Pan-European corridors do not seem very important (although preferential corridors may exist, e.g. on mountain passes). For the other dispersal mechanisms, Pan-European corridors may be important.

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, corridors in general 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, the emerged adults fly upstream to lay their eggs.

On the other hand are movements of invertebrates that are independent from updraft and wind, partly because these species stay in their boundary layer, partly because these species are very good flyers that can use landmarks, lee sides from wind, and have tactics to fly against the wind (e.g. some butterflies and hover flies). Therefore (Pan-European) corridors can be important for these species.

Aquatic invertebrates are dependent on dispersal and migration to maintain sustainable populations. Especially in running waters, these processes play a dominant role. Ephemeral water bodies have probably triggered dispersal phenomena in the evolutionary past. The life cycles of especially aquatic insects show that dispersal and migration are essential elements for survival. The river Rhine shows that recolonisation is only possible from its own discharge area and, moreover, that introduction from other discharge areas (Ponto-Caspian species) is extraordinary successful if natural predators and parasites are absent (see box 5).

Box 5: Reasons and stimuli for dispersal

Dispersal has many varieties, within lower taxa (families and genera), and even within species.
Within higher and lower taxa the habitat determines (as template for the survival strategy) the dispersal capacity of a species. The average dispersal capacity can differ between families and between higher taxa, but, depending on the habitat, the dispersal capacity of subsequent species diverges and differs variably from the average.
The dispersal capacity and willingness to dispers is often a flexible characteristic. Several species of carabid beetles, grasshoppers and other species groups have wingless as well as winged adults. With Field grasshoppers (*Chorthippus brunneus*) to grow wings is decided in the 1st and 2nd juvenile shedding stage. If species density in these stadia is (locally) high, long-winged adults will develop. Such wing dimorphism always occurs also with winged grasshopper species. Long-winged cone-head (*Conocephalus discolor*) dispersers have 20% longer wings than non-dispersing adults. Research on the Milkweed bug (*Oncopeltus fasciatus*) has shown that the willingness to disperse is directed by a certain hormone level. This level can rise twice in a lifetime above a threshold that stimulates dispersal, firstly after leaving the pupal case, and secondly, from stress signals at high population densities. The first phase, after emergence, takes only a few days. In some insect species groups the tissue of the flying muscles of females will be broken down and reformed into eggs. Thus, a female can fly, or lay eggs, not both (socalled oögenesis-flight syndrome, Johnson 1960).
Spiders that disperse via web threads usually will disperse in the 2nd, 3rd, 4th or 5th shedding stage. Dispersal activity is higher within dense populations, especially when preys are scarce (van Wingerden 1977, 1980, Legel & van Wingerden 1980).

Johnson (1969) distinguishes three types of strategies for migrating/dispersing insects:

- Emigration without return (i.e. dispersal). Adults, living only one season, emerge in the reproduction habitat, disperse, and lay eggs and die (see dispersal corridor, par. 2.4.2).
- Emigration and return by the same individuals within one season. The adults migrate from the reproduction habitats towards nutrient-rich habitats, and return later in the season to lay eggs in the old habitats or in different places (migration corridor, par. 2.4.2).

- Emigration to hibernation- or summer habitats and return by the same individuals after a diapause (migration corridor).

There are theoretical models suggesting that organisms have to disperse, even in stable conditions, when the chance for survival is low in the reproduction habitat (Peckarsky *et al.*, 2000). They showed that short-living Baetis females after emerging in an environment that still is dried out have two alternatives: flying to other localities with water or dying. Flying, even over short distances, seems to be an important mechanism of dispersal with several local populations as result (see box 6).

Box 6: Invertebrate dispersal

It may take decades until invertebrates or other animals and plants with restricted dispersal power have (re-)colonised habitats through corridors managed as core habitat, or through nodal habitats. What time-span is acceptable? Is it sensible to invest energy in such corridors? Yes it is! Although the species requirements are high, and the investments become effective only after a long time, the K species in question need protection, otherwise they cannot cope with the ongoing deterioration and fragmentation of its habitat, resulting in extinction. Fortunately, some K species are able to disperse rather well. For such, - next to be identified – species, such nodal corridors may be significant. Examples are:
Wood ant (*Formica rubra*) flying queens may bridge 2 km just after emergence and mating. Lay-out and management of pine or deciduous wood lots at every two kilometres may provide (re-)colonisation of a neighbouring habitat area. These queens orient themselves to high vertical tree- or hedgerows and forest edge, and, in addition, will benefit from the decrease in windspeed leeward of these elements. Therefore, providing such nodal corridors with hedge- or tree-rows may enhance chances of re-colonisation a next node.
From the consultation of invertebrate specialists it appeared that many groups utilise wind shelter of tree lines and hedgerows during controlled flight. Examples are the earlier mentioned Wood ant queens, Robber flies and butterflies. In addition, many other non-flying species appeared to walk or hop along such line elements, such as carabid beetles (Jepson 1994), the Dark bush cricket *Pholidoptera griseoaptera* (Diekötter et al. in press). Moreover, rough verges and banks covered by perennial grass, tall herbs and shrubs may be utilised similarly by Robber flies, butterflies, provided that these elements are managed (mown, cut) extensively, and on a small scale (with three year intervals or longer). Therefore, the earlier mentioned habitat nodes may be interconnected by those tree, shrubby and roughness line-elements in order to form appropriate corridors between neighbouring but separated habitat patches.

Dragonflies (Odonata) are well-known migratory species, but Caddis flies (Trichoptera), Stoneflies (Plecoptera), Ephemeroptera and Megaloptera are poorer colonizers. In contrary, certain species of water bugs (Hemiptera), flies and mosquito's (Diptera) and beetles (Coleoptera) are excellent colonizers, possessing invader qualities. Species from these orders are often the first to colonize new or temporary habitats.

The primary goal of the adult phase of the typical aquatic insects' life cycle is mating and deposition of eggs in habitats that are successful for the development of larvae. Adult insects fly upstream to lay eggs. The young larvae move downstream by overpopulation or catastrophic drift and populate downstream habitats. When they are successful, they pupate and the emerged adults fly upstream to lay their eggs. Distances between the two habitats may vary between some tens of meters to (sometimes) tens of kilometres. An interesting feature is the necessity for mating.

The females have to mate before they can oviposit. In many species, mating takes place in swarms at special places, for example bushes or trees along the shore. Changes in riparian vegetation may inhibit mating and so the success of populations of aquatic insects.

Long distance dispersal
Long distance dispersal is a common feature in benthic invertebrates and this has always been considered as a passive, but necessary phenomenon enabling some individuals to reach the right habitats for colonization. The important role of physical transportation processes in regulating the number of colonizers in a new area is emphasized since long. It is known as the recruitment limitation of supply-side ecology. Abundances may vary as a function of the time needed to reach new areas (settlement-rate). Colonization is considered more important for the population structure than internal processes like predation and competition (Palmer *et al.*, 1996).

Hill & Fox (2003) have demonstrated that about 20% of the British butterflies benefit from the warmer climate. These are good flyers and generalists. The other 80% are decreasing by loss of habitat by factors not caused by climate change or because northern species loose their cool habitats, especially in fens. It is not unlikely that the same counts for aquatic invertebrates. Optimism about the results of global warming is not justified.

Inland dispersal
Inland dispersal has been for long an under-exposed item, but it must be considered as necessary for the colonization of new habitats and as participation of aquatic insects in terrestrial food-webs (Kovats *et al.*, 1996). Also recolonisation of formerly degraded rivers is dependent on dispersal by rest populations in the catchments or from inland dispersal. An example is the recolonisation by certain species in the river Rhine. There are well-documented evidences of Hydropsyche contubernalis and Epheron virgo recolonising the river Rhine after the Sandoz fire that exterminated all life in the main stream. Gradual recovery of former habitats has been registered, where downstream recolonisation took place with tens or hundreds of kilometres each year. Generally speaking, restoration of streams is seldom followed by a rapid recovery of the original ecosystem. Reason for this is that egg-bearing females have to reach the restored habitat from far-away catchments and this may take many years or even tens of years.

There are different factors influencing inland dispersal: abiotic factors such as temperature, wind, clouds and air moisture are directly responsible for departure, timing and duration of the flights. Properties of the habitat like permanence, sustainability, frequency and strength of disturbances may influence the dispersal behaviour in the long term. Large rivers must be considered as permanent habitats with predictable discharge patterns, here the substrate shall be disturbed less than in small rivers in case of high discharges. Species of large rivers are adapted to the specific conditions and show restricted dispersal behaviour. Moreover, large rivers are far apart and dispersing adults with a short lifetime are totally dependent of strong winds to reach other (large) catchments. Inland dispersal by adults from large rivers and lakes is not spatially directed.

A migration or dispersal flight is ended if the animal is triggered to lay eggs, to search for food or if the colonized habitat is suitable. Migration behaviour has developed in species that live in habitats temporarily unsuitable for reproduction or in habitats that totally disappear.

There are four categories of dispersal and migration by non-flying aquatic invertebrates or non-flying stages of insects:

- Drift or downstream movement. As has already been stipulated, downstream movements of insect larvae form an essential part of the life cycle. Downstream movement or drift may occur actively or passively.
- Upstream movement is always active. The animals have to overcome the forces of the current. They move through stretches with low current under the banks or sometimes overland.
- Local or sideway movement seems trivial in the framework of this study, but it turns out to be of major importance for the survival of most running water species.
- Arial movement is used to leave the aquatic environment by clinging to birds or flying insects.

Drift in water is a well-studied phenomenon (Brittain & Eikeland, 1988: Waters, 1972: Hynes, 1970: Pechlaner, 1986). There are different forms of drift:

- Catastrophic drift is related to discharge conditions, in which the substrate is physically disturbed and animals are transported by the current (Minckley, 1964). Catastrophic drift is caused by extreme spates, but other causes may be the drainage of effluents or toxic substances, warm water from cooling systems or desiccation. It is obvious that catastrophic drift shall occur more in the changed ecosystems of the agricultural or industrial landscape and shall be more disastrous than in natural systems.
- Behavioural drift (Waters, 1965) is demonstrated during daily activities like feeding, mating and moving around (mainly during the night (Brusven, 1970: Statzner, 1979)) and actively seeking the water column (active drift) e.g. to escape predators.
- Distributional drift to colonize new habitats in the same system. This is seen especially in hatched young animals (Nishimura, 1967: Ulffstrand *et al.*, 1974). This form of drift may cover short distances (Brittain & Eikeland, 1988) or larger stretches up to several kilometres. Distributional drift also takes place at night, probably to avoid predation by visual hunters like fish (Allan, 1984).
- Constant drift or background drift comprises low numbers of individuals that accidentally loose their grip and come into the current.

Upstream movement takes place in many species, but seldom compensates for drift (except in the case of flying insects). Most macro invertebrates are positively rheotactic and move under the banks in rows upstream. Hughes (1969) describes the relation between drift and upstream movement as two steps back (drift) to one step forward (upstream movement). Some animals leave the water to go upstream. It is known of the River Crayfish (Müller-Motzfeld *et al.*, 1986) and several species of stonefly with wingless females, which creep upstream overland to deposit their eggs in the stream (Hynes, 1970).

Aerial distribution by 'hosts' like water birds and flying water insects is used by Crustaceans, Bivalvia, Ostracoda, Gastropods, Hirudinea and water mites. This form of distribution is undirected, but as most of these hosts live in the same environment, there is a good chance that the 'hitch-hikers' arrive in suitable habitats.

2.5.4 Plant species

Plants use predominantly passive dispersal. Hereby occurrence of corridors is not of direct importance. Apart from passive dispersal, some plant species can (only over a short distance) disperse actively by shooting off ripe seeds. For long distance dispersal many plant species have developed morphological adaptation of their seeds that makes transport (and thus dispersal) by external factors (the vector) possible. Seeds may have developed hook- or prickle formed structures (for transport by animal furs), or meaty fruits (for consumption and being excremented somewhere else), or bubble shaped structures (transport by water), or hair- or feather formed structures (for transport by wind).
A limiting condition for the use of corridors in above-mentioned cases is the presence of suitable habitat, since only then a species can survive. Another limiting condition is that the corridor must be suitable for the transporting vector. Apart from these limiting conditions there are other factors that can influence the dispersal of species, e.g. germination factors.
The following long distance dispersal vectors can be distinguished (IRIS database):

1. water
2. wind
3. mammals, externally
4. mammals, internally
5. birds, externally
6. birds, internally
7. traffic.

Within the Netherlands a study was made on the potential of long distance dispersal vectors within plant communities (Ozinga, Bekker, Schaminée & Van Groenendael, 2004, in prep). Attention was given to gradients of soil humidity, the availability of nutrients and of light. Around 900 higher plant species were being studied.

The potential of dispersal by water (1) is strongly related to the availability of water. Seed dispersal by water can play an important role in the species composition within wet plant communities. Also from species living in average humid habitat, 20-40% of the species can be transported by water: the role of flooding is relevant.
Potential for dispersal by wind (2) increases with diminishing nutrition availability and increasing openness of the vegetation. Studies show that wind dispersal is not

very effective: the main part of the seeds comes down relatively close to the mother plant. Just a few seeds are transported further. Increase of dispersal via large mammals (3, 4) takes place along a daylight gradient (an increase of large grazers in open areas). Potential for transport by birds (5, 6) is optimal within closed vegetations (forests, shrubs).

Table 1: Characteristics vectors for plant species

	water	wind	mammals, externally	mammals, internally	birds, externally	birds, internally	traffic
Water availability							
High (wet)	xxx						
Medium	x						
Low (dry)							
Nutrient availability							
Poor		xxx					
Medium		x					
Rich							
Daylight availability							
Low (dark)					xxx	xxx	
Medium		x	x	x	x	x	
High (light)		xxx	xxx	xxx			

For dispersal of plant species, linear shaped habitats are effective, but also here dispersal takes places over just a short distance, e.g. brook valley vegetation or along forest edges.
Movement of flocks of sheep can stimulate plant dispersal. In particular transhumance and shepherding may count for plant dispersal over longer distance. Also identical management measures on farm land may facilitate spread of characteristic species, in particular annuals and typical plant communities (with e.g. Lilium bulbiferum or Lathyrus tuberosus) of arable fields.
To study the importance of corridors for higher plant species the dispersal factors were put into a matrix, together with simplified EUNIS-habitats. For habitat combinations is globally indicated whether corridors can play a role as well.

Table 2: Habitats & vectors (- = not relevant, +/- = some relevance, + relevant, ++ very relevant)

	water	wind	mammals, externally	mammals, internally	birds, externally	birds, internally	traffic
Stable systems							
coast/dunes	++	++	-	-	+	+	-
surface water and banks	++	++	+	-	++	-	-
mires, bogs and fens	+	+	-	+	++	+	-
grasslands	+/-	++	++	++	-	+	+
heathland, scrub and tundra*	+/-	+	+	+	+	+	+
forests*	+/-	-	+	+	-	++	-
Unstable systems							
ruderal habitats	-	+	-	-	-	-	++

* Very dependent on moisture content and nutrient availability

2.6 Functions of corridors for species groups

We see that the functions of corridors for species differ, as well as the mechanisms. Per species group different mechanisms apply (Table 3). Data on mammals and birds can be found in Foppen *et al.*, 2001.

Table 3: Functions of corridors and mechanisms for movements for different species groups

Function: Mechanism	Dispersal	Commuting	Migration
active transport, by air	birds terrestr. invertebrates dragonflies butterflies	birds	birds
passive, by air	terrestr. invertebrates plants		
active, by water	aquatic invertebrates fish		fish
passive, by water	aquatic invertebrates plants		aquatic invertebrates
active, over land	mammals amphibians	mammals	mammals amphibians
passive, over land	plants		

2.7 Corridor typology

Corridors should be described and analysed based on the requirements of the relevant species, and at the relevant scale the species. What may be functioning as a corridor for one species might be a barrier habitat for another. A corridor for Hedgehog may be habitat for a Stag beetle. This makes it difficult to define in general what a good corridor looks like and how it will function on the ecosystem level. However, there is a growing need for guidelines and standards for corridors to be used on various landscape planning and policy levels. In order to know when, for what and how corridors can be designed it is important to have a clear perception of what kind of purposes corridors can have for the conservation of wildlife (Foppen, 2000).

Corridors can be classified into three to four classes according to the shape that they have: line, stepping stone or landscape corridors.

These three corridor types do assume a good dispersal capacity of the species. Within a generation or life phase large distances of tens of kilometres may be covered. For species with a limited dispersal capacity, corridors have limited importance, unless
a) They are managed as a reproduction area, and
b) They are effective within an acceptable time-span.

Therefore, in addition to the above mentioned three types of corridor, we propose a fourth type of corridor, in particular suitable for invertebrates: the nodal corridor, which are used in particular by invertebrates (Figure 3).

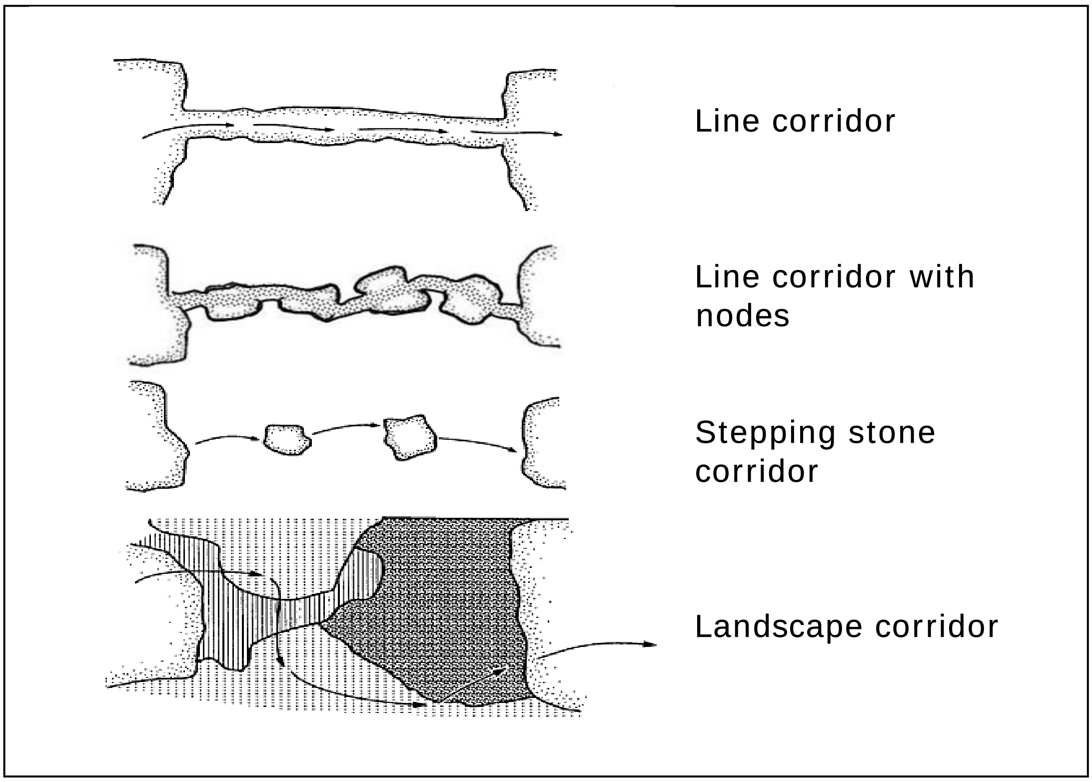


Figure 3: Corridor types (adjusted after Bennett, 1999)

- A line corridor is a continuous linearly shaped linkage between two habitat patches/areas. For some species it means that the corridors will only function when there is no physical interruption (obvious in e.g. fish in a stream or river); for other species, physical gaps in the corridor can be bridged (e.g. birds crossing 50 meter gaps in a hedgerow).
- Line corridor with attached nodes (Nodal corridor) is a type of corridor with large areas for reproduction of species (a node). The spacing of nodes should meet the capacity of the species. This results in a corridor with nodes, or a 'rope with knots' a species builds up populations in these nodes and in the succession of generations disperses from node to node. The spacing of nodes should meet the capacity of the species to fly or walk within its lifetime between the nodes, in order to have a chance to disperse within a generation to an adjoining node.
- A stepping stone corridor contains habitat in discrete locations situated in between source and target area. The areas do not need to be linear, every shape is possible. The landscape in the matrix, surrounding the stepping stones is usually very inhospitable for a species. Examples are blocks of forest habitat in an agricultural landscape that serve as stepping stones for a forest animal moving from one area to another.
- Landscape corridors consist of a mosaic of patches with different qualities, each with different functions for a species, for example a mosaic of foraging, hiding and sleeping places. In general, the mosaic has a very low resistance for species. There are no absolute barriers and individuals use most parts of the corridor.

The line corridor with nodes is identical to the stepping stone corridor, except for the fact that not the same individuals continue to hop from patch to patch, but subsequent generations may hop from habitat patch to habitat patch, finally reaching the habitat area with higher survival chances.
The most extreme form of a nodal corridor is when the whole corridor meets the habitat requirements of a particular species. This so-called reproduction corridor (2.2.3) should be designed, as well as managed, as core habitat. Such an extreme form of corridor may be necessary for species with very weak dispersal power, such as mites that eat dead fungi (Siepel, 1994), earthworms (10 m per year), snails and other soil dwelling animals. For such organisms it will take too much time (hundreds of years) before they may colonise a separated neighbouring habitat. In these cases re-introduction has better prospective. E.g. fungi-eating mites were re-introduced in the nature development area 'Goudplevier' by spreading cut sods from grass dominated heath (Berris & Gorter, 1991)

Based on this typology it is possible to give an indication of the relationship between dispersal mechanism and corridor type (Table 4). This forms of course a generalisation, there are exceptions due to the large variety in dispersal mechanisms, e.g. as result of the intricate relationships with host species or vector species.

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.

Table 4: Relationship between dispersal mechanisms and corridor shape

mechanism/shape	**linear corridor**	**'linear corridor with attached nodes'**	**stepping stone**	**landscape mosaic**
active transport, by air		terr. invertebrates butterflies dragonflies	dragonflies butterflies birds	butterflies birds
passive transport, by air			plants terr. invertebrates	plants terr. invertebrates
active transport, by water	fish aq. invertebrates			
passive transport, by water, floating	aq. invertebrates plants		plants	
active transport, over land	mammals amphibians	mammals amphibians	mammals amphibians	mammals amphibians
passive transport, over land	plants		plants	plants

Picture 3: Atlantic salmon (Photo G. van Ryckevorsel)

Picture 4: Stag beetle (Photo ALTERRA)

3 Results spatial analyses

3.1 Approach species selection

In paragraph 1.1.1 the general procedure was described for the selection of relevant European target species. In this paragraph the selection is refined for each species group. This is required because the starting point is different for different groups. E.g. groups like invertebrates are less studied are not well presented in the Habitats Directive or Bern Convention, and no commonly accepted Red Lists are available.

3.1.1 Mammals

Selection of European species
General species lists do exist, i.e. from Siepel *et al.* (2000) and Foppen *et al.* (2000). Siepel compared the species in the European Red List, Bern Convention (Annex 2) and Habitats Directive (Annex 2 and 4). In addition to the criteria mentioned in paragraph 1.1.1, the following criteria were applied:

- Only those species from the list which may be limited in their current distribution as a result of fragmentation were selected
- Marine species as well as flying species were excluded

Selection of ecoprofiles
Based on the 'The Atlas of European Mammals' (Mitchell-Jones *et al.*, 1999) those species were selected with a fragmented distribution area. Some underestimation may be inherent to this method, since distribution maps may be incomplete or inaccurate. Exotic species were excluded. Species with a naturally fragmented distribution area, due to geographical factors were not taken into consideration. In principle the following species are of interest for the selection of ecoprofiles:

- Canis lupus (Wolf)
- Felis silvestris (Wild cat) - Lynx lynx (Eurasian lynx)
- Mustela eversmannii (Steppe polecat) - Mustela lutreola (European mink) - Lutra lutra (Otter)
- Ursus arctos (Brown bear)
- Bison bonasus (European bison)
- Cervus elaphus (Red deer)
- Spermophilis citellus (European ground squirrel)
- Castor fiber (European beaver)

A selection was made out of this list on the basis of the ecosystems and the following ecoprofiles were prepared:

Table 5: species for which ecoprofiles have been prepared

Species	Ecosystem	Region	scale
Wolf	forests, grasslands	Southern Europe	Continent
Otter	wetlands	Netherlands/Germany	Region
Eurasian lynx	forests	Western Europe	Continent
Europ. ground squirrel	steppe	South-eastern Europe	Region
Brown bear	forests	Central Italy	local

The otter also represents a species like the Beaver

Selection for analyses of species
Two species are analysed, the Eurasian lynx and the Brown bear. The Eurasian lynx is a true European species, with a good potential for recolonisation of former habitats. Besides, the species receives much attention already and is of interest for the general public.
The Brown bear is quite similarly meeting public interest and interest of politicians and governments in general.
For the European ground squirrel it was concluded that detailed maps would be required of parts of Eastern Europe, and particular ecological data is lacking on existence of sub-species. Modelling of the otter is also rather complex, since it is a versatile species which needs particular combinations of habitat, and a good water quality. At this stage, modelling of these species does therefore not seem feasible.

3.1.2 Birds

Selection of European species
The general species list from Foppen *et al.* (2000) was used as a basis.

Selection of ecoprofiles
Species from the list were selected based on:
- Ecosystem requirements
- Eurasian species, without (major) migration to Africa

This resulted in the following species:
White-fronted goose
Lesser white-fronted goose
Brent goose
Bewick's swan
Eurasian crane
White stork
White-tailed eagle
Osprey
Little bustard
Eurasian spoonbill
Sandwich tern
Most birds are migratory species, with a partly exception of the Little bustard, which was selected because it is vulnerable to fragmentation. Furthermore, those species

were selected for which agricultural intensification due to the European agricultural policy may have effects. In addition, a selection was made out of this list on the basis of the ecosystems.
The following ecoprofiles were prepared:

Table 6: species for which ecoprofiles have been prepared

Species	Ecosystem	Region	scale
White-fronted goose	floodplains, tundra	Northern Europe	Continent
Brent goose	coastal plains	Northern Europe	Continent
Eurasian crane	peat bogs	North-west Europe	Continent
Little bustard	steppe	South-eastern Europe	region

Selection for analyses of species
Two species were analysed, the Brent goose and Eurasian crane. This analysis was done on the basis of available knowledge and (field) data.

The Brent goose is selected because it is the only species of the four who not only breeds in natural habitats but also still winters in largely natural habitats. Heavy pressure on the wintering habitats may however cause more feeding on agricultural grasslands. The other species have already lost much natural wintering habitat, and mainly occur on cultural fields.

The choice for the Eurasian crane is made because of its transition from disappearing old cultural lands like oak fields towards the more recent corn fields.

3.1.3 Invertebrates

Selection of European species
For invertebrates no complete and consistent lists are available for all of Europe, or they are too long, non existent, or the information on dispersal capacity and habitat is not clear. A European Red list only exist for spiders, isopods, butterflies, beetles, ants, grasshoppers, bush crickets, one Mantid, and land snails. So not for bugs, hoverflies, lacewings, bees, etc. Moreover those lists differ very much in the number of species per taxonomic group. Therefore we have to make do with existing lists, local lists, or specific groups which were well assessed. The selection in this report is therefore partly incomplete still and is based on knowledge and expert judgement of the authors.

The general species list of threatened and vulnerable invertebrates was used from Bal *et al.* (2001). The list of threatened butterfly species (Van Swaay & Warren, 1999) was used to select the species with dispersal and fragmentation problems (Appendix 1). For grasshoppers also the IUCN red list as well as the Dutch Red list for grasshopper was consulted. In addition, also the Bern Convention and Habitats Directive were checked for presence of relevant invertebrates.
The Dutch Red List of aquatic invertebrates may be misleading, due to the different nature of aquatic habitats. Species rare in the Netherlands may be very common elsewhere, vice versa.

The principle of movement ranges exceeding 10 km. does not always apply; also species with a dispersal distance of less than 10 km. were included, provided they are representative for the fragmentation problem on a European scale level.

- Only those species from the list which may be limited in their current distribution as a result of fragmentation were selected
- Marine species as well as flying species were excluded.

For terrestrial invertebrates the following criteria were selected:
- Species which may be limited in their current distribution as a result of fragmentation (K-species, or R-species using rare temporarily available habitat)
- species dispersing through water, on land (walking, hopping) and by foresis
- flying species (having control on direction and speed)
- species which may be favoured by European corridors.
- species movements influenced by men
- migrating species
- commuting species.

For the relative good dispersing species among the K-strategists, pan-European corridors may contribute to survival. They live in long-existing habitats such as
Old climax forest (note: different vegetation types exist),
Old shrub communities (maquis, Buxus), (note: different vegetation types exist)
Fens and bogs,
Large as well as long-existing waters,
Old-stage stony and sandy soils which are nutrient poor or/and under the influence of extreme climatic conditions.

Selection of ecoprofiles
Aquatic invertebrates from the European list were selected based on:
- Presence in the river Rhine, since this is one of the best examples of a dynamic habitat, with corridors for fish and invertebrates
- Availability of information about the movements of organisms through this corridor.

Six species have been selected on the basis of their different dispersion strategies (Tabel 7).

Table 7: aquatic invertebrate species for which ecoprofiles have been prepared

Species	Ecosystem	Region	scale
Hydropsyche contubernalis (caddis fly)	river	Rhine region	regional
Hydropsyche bulgaromanorum (caddis fly)	river		
Chelicorophium curvispinum (amphipod)	river		
Epheron virgo (mayfly)	river		
Gomphus flavipes (dragonfly)	river		
Corbicula fluminea (Asian clam)	river		
Palaemon longirostris (prawn)			

Hydropsyche contubernalis, a caddis fly, is not a Red List species, but may be treated as an umbrella species for other caddis flies from the Dutch Red List (Bal *et al.*, 2001). *Hydropsyche bulgaromanorum* has recently been found in the river Rhine and its history is comparable with that of *H. contubernalis*.
Epheron virgo, a may fly, is not a Red List species, but may be treated as an umbrella species for other mayflies from the Dutch Red List (Bal *et al.*, 2001). *Gomphus flavipes,* (Yellow-legged dragonfly) is a Red List species, and also included in the Bern Convention and Habitat Directive

For Terrestrial invertebrates K-strategists of old woodland are selected, since there is very little old natural woodland. Most forests are production forests, being exploited for wood-industry, leaving little dead wood. Some of the wood eating insects have very long life-cycles, typical for K-strategists (e.g. larval stage of Lucanus cervus takes 5 – 8 years). Therefore the dispersal range is probably small. So, remains of old natural woodland should be connected by corridors containing dead wood deliberately.
Also K-strategists under bush-crickets are of interest, large insects, in many species without wings. Long optional life cycles, e.g. eggs are in diapause during 2 – 8 years. Ephippiger species are wingless, and are moving rather slowly. Fragmentation problems have arisen in the Netherlands, where it – some 50 – 100 years ago – yet commonly occurred along railways. Very rare is Gampsocleis glabra in Western Europe, and moreover scattered over the whole of Middle and Southern Europe.

For terrestrial vertebrates the following ecoprofiles were prepared:

Table 8: terrestrial invertebrate species for which ecoprofiles have been prepared

Species	Ecosystem	Region	scale
Apollo	Dry grassland, cliffs	Central + North Europe	Continent
Dusky large blue	Humid grassland	Central Europe	Continent
Large copper	Grassland	Central Europe	Çontinent
Stag beetle	Mature forest	Central Europe	Continent
Heath bush cricket	Heather	Central Europe	Continent

Selection for analyses of species
Four invertebrate species were analysed, the Yellow-legged dragonfly, Large copper, Stag beetle and Heath bush cricket.

3.1.4 Fish

Selection of European species
The general species lists from Foppen *et al.* (2000) were used as a basis.

Selection of ecoprofiles
No selection criteria were prepared, but from the list species were selected by the Project team based on:
- Migration behaviour
- Availability of data

This resulted in the following species (Table 9).

Table 9: Fish species for which ecoporfiles have been prepared

Species	Ecosystem	Region	scale
Atlantic salmon	River & sea	North-west Europe	Continent
Sea lamprey	River & sea	North-west Europe	Continent
Barbel	River	North-west Europe	Continent
Sturgeon	River & sea	North & Eastern Europe	region

The choice for Salmon, Sea Lamprey, Barbel and Sturgeon was made because of their migration behaviour. The species migrate between the Sea and spawning areas upstream, except for the Barbel, which migrates within the river itself
They occur in different habitat types, marine habitat, brackish and fresh water spawning grounds.
Due to the barriers the species have declined rapidly, and thanks to the defragmentation and improvement of water quality it has been possible to improve the situation for these species.

3.1.5 Plant species

Selection of European species

- Based on the list of European vascular plant species with 14.885 records, which has been developed for the project Target Species, a matrix has been prepared (Table).
- From this list sub species, genera and species of the Macaronesiën region were excluded
- From the list those species were selected which are included in one or more of the following policy documents: Bern Convention, annex II, IV or V of the Habitats Directive, and the IUCN-2000 Red List[2]. In total 535 vascular plants have been selected.

To apprehend the importance of corridors for vascular plants the important distribution vectors were estimated in relation to the simplified EUNIS-habitats. For different combinations has been indicated whether corridors may play a role for its dispersal (Table 10).

The IRIS database was linked with the list of 535 priority species, to obtain an indication of the potential long-distance vectors and corridors which may contribute to the protection of the species.

Also specific corridors and migration of wildlife or livestock was assessed (e.g. transhumance in Scandinavia and Southern Europe) and seed dispersal by animal vectors, e.g. old forest plants and red deer or wild boar, or waterfowl and aquatic species, e.g. pondweed (Potamogeton) and Bewick's swan.

[2] A limitation to the IUCN-2000 Red List is that some species are taxonomically not well defined, and sub-species and varieties have been excluded, so the list is incomplete for vascular plants.

Table 9: Simplified Eunis habitats and long distance dispersal vectors (- = not relevant, +/- = some relevance, + relevant, ++ very relevant)

Vector	**Representative species**
wind	Botrychium matricarifolium, Lycopodium annotinum, Spiranthes aestivalis, Liparis loeselli
water	Myosotis scorpioides, Salvinia natans, Trapa natans, Luronium natans, Liparis loeslli, Apium repens
fur	Bromus interruptus, Agrimonia pilosa, Cynoglossum sphacioticum, Apium repens
dung	Bromus interruptus, Luzula arctica, Poa laxa, Agrostis gracililaxa
birds	Ilex perado, Daphne ssp., Frangula azorica, Ribes sardoum, Sorbus ssp

Species were assessed typical for dynamic ecosystem processes, e.g. rivers where habitat loss, or levee raising and strengthening with basalt rock result in decline of species (e.g. IJssel River and Black poplar *Populus nigra*. However, those species are usually not priority species for nature protection.
Selection criteria ecoprofiles:

- One of the criteria of Foppen et al (2000) is that species have a dispersal distance exceeds 10 km. For plant species also species with less dispersal capacity are selected, provided that they are representative for fragmentation at a European scale level.
- Species are selected based on the vector species.
- Dutch example species are selected, since information about fragmentation and the importance of corridors is less available and accessible for species of other regions.

Table 11: Plant species numbers in the priority lists for nature conservation

Database 14.885 species	Bern	Habitat, Annex II	Habitat, Annex IV	Habitat, Annex V	IUCN-2000
Bern	402				
Hab. Dir. Annex II	210	279			
Hab. Dir. Annex IV	41	-	48		
Hab. Dir. Annex V	0	-	-	15	
IUCN-2000	6	5	0	0	48

Simplified Eunis-habitats	water	wind	mammals, external	mammals, internal	birds, external	birds, internal	traffic
Stable ecosystems							
coast/dunes	++	++	-	-	+	+	-
water and shore	++	++	+	-	++	-	-
rich fen, poor fen, mire	+	+	-	+	++	+	-
grasslands	+/-	++	++	++	-	+	+
heathers, shrub lands and tundra*	+/-	+	+	+	+	+	+
forests*	+/-	-	+	+	-	++	-
instable ecosystems							
ruderal habitats	-	+	-	-	-	-	++

* Much dependent on moisture and nutrient availability

The following species were selected to prepare ecoprofiles:
- Floating water plantain, *Luronium natans*
- Fen orchid, *Liparis loeselli*
- Creeping marshwort, *Apium repens*

3.2 Ecological profiles target species

The landscape is assessed on the basis of a set of so-called 'ecological profiles'. An ecological profile contains information on species ecology, habitat requirements and spatial characteristics of a species. Based on the preliminary species selection, ecological profiles were prepared (Table). Based on the conservation issues, spatial ecology and available literature, used to describe the ecoprofiles, it is possible to assess the potential for a spatial analysis of this species, and whether this may result in interesting example for corridor development.

Table 12: Ecological profiles prepared for this study

taxon	selected species	analysed
Mammals	Eurasian otter	
	European beaver	
	Lynx, Eurasian lynx	yes
	Wolf	
	Brown bear	yes
	European ground squirrel	
Birds	Brent goose	yes
	Eurasian crane	yes
	White-fronted goose	
	Little bustard	
Terrestrial invertebrates	Apollo	
	Stag beetle	yes
	Heath Bushcricket	yes
	Dusky large blue	
	Large copper	yes
Aquatic invertebrates	Hydropsyche contubernalis (caddis fly)	
	Chelicorophium curvispinum (amphipod)	
	Ephoron virgo	
	Asian clam	
	Palaemon longirostris (prawn)	
	Yellow-legged dragonfly	yes
Fish	Sea lamprey	yes
	Barbel	
	Sturgeon	
	Atlantic Salmon	yes
Plant species	Floating water plantain	
	Fen orchid	
	Creeping marshwort	

The ecological profiles were not included in this report but are available with the authors.

3.3 Mammals

3.3.1 Lynx, *Lynx lynx*

Ecology and protection

Lynx where formerly widely distributed throughout Europe. As human populations expanded, suitable habitat was destroyed by deforestation and agriculture, while persecution by hunters and intensification of traffic further reduced the species range. The current European distribution is clearly associated with large continuous forest regions. Home-range size within these regions varies depending on 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. Open habitat is unsuitable due to the lack of cover for hunting and lack of possibility to create dens.

The international legal and conservation status is embedded in the Bern Convention Annex III, EU Habitats & Species Directive Annex II & IV and CITES Annex II. EC 338/97, Annex A.

Problem

Relatively small populations of the Lynx easily go extinct as a result of environmental stochasticity, such as prey availability, poaching or traffic collisions. Current distribution of the Eurasian Lynx over Central and Western Europe follows a rather scattered pattern. Important core areas are: East Poland, the Carpathian region, the Alps and Jura. The Czech Sumava and German Bavarian Forest harbour recently established populations. In some western areas they were reintroduced very recently (Schadt *et al.*, 2002).

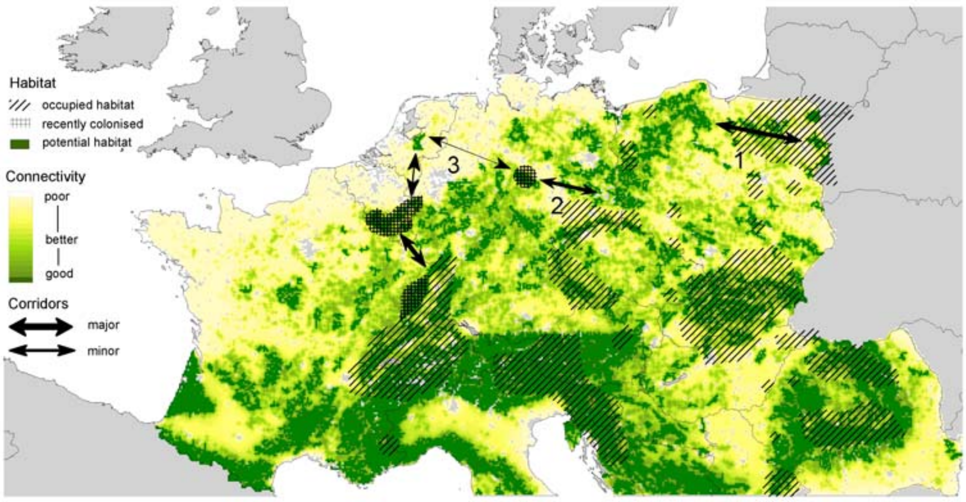


Figure 4: Connectivity of the European landscape for the Eurasian lynx, as defined with METAPHOR, and potential corridors

Analysis
With the LARCH model potential habitats and the connectivity of the landscape was evaluated for the Lynx. The analysis shows that the distribution of potential habitat is patchy and that much potential habitat is not well-connected with currently occupied areas (Figure 4). Especially the peripheral recently colonised areas differ in connectivity with occupied areas. Spontaneous recolonisation of potential habitat may be facilitated by incorporating it into an ecological network. To strengthen the European lynx population it would be wise, from an ecological point of view, to invest first in these peripheral groups where small populations face the threat of extinction.

Solutions
Development of an ecological network for these large mammals would certainly increase chances of spontaneous colonisation of these areas. Recent Lynx observations in northern Belgium, the southern parts of the Netherlands and from the Dutch Veluwe area indicate the potential for colonisation of small isolated areas. Incorporating smaller, in potential suitable areas for the lynx into an ecological network of suitable habitat could facilitate spontaneous colonisation of these potential habitats. Most relevant may be three important ecological corridors:

- Between North-eastern and North-western Poland (1, in Figure 4),
- From western Poland, south of Berlin, towards the Harz area and (2)
- Between South-eastern Belgium and the French-Swiss Vosges and Jura area (3).

Species benefiting
Development of an ecological network for Lynx will benefit a large range of mammals like Red deer, Roe deer, Wolf, Brown bear, Badger, Wild cat and Pine marten. Also other forest inhabiting smaller mammals, birds and insects could benefit depending on the scale and construction of a corridor.

3.3.2 Brown bear, *Ursus arctos*

Ecology and Protection status
Brown bears occurred once throughout Europe, but they disappeared from most areas as human populations expanded, deforestation and agriculture destroyed suitable habitat, and hunters heavily persecuted the species.
Today the total number of brown bears in Western Europe is about 14,000 (excluding Russia) (http://www.large-carnivores-lcie.org/bear01.htm). The species is included in the Bern Convention and Habitats directive.

The populations of Western Europe have suffered most from the severe persecution. A handful of populations remain, less than 100 animals, some almost extinct (Pyrenees in France, central Austria, Tessin in Italy) or are vulnerable but fairly stable (Spain, Italy, and Greece). Estimates for the Abruzzo population in Italy vary from 40 to 80 individuals (Swenson *et al.*, 2000, Posillicco *et al.*, 2004). The number of bears in Umbria is limited to a few individuals, mainly inhabiting the south-eastern part of the region. For that reason Action Plans were developed, to improve the situation of the species. As a result of conservation measures populations seem to make a slow comeback, as was shown in Italy and Austria.

In Fennoscandia and Central Europe (Romania and bordering countries) the populations are not endangered, and in some areas still hunted.

Problem
Fragmentation is one of the main problems in Southern and Western Europe, in combination with habitat loss and pressure from agriculture. The combination of habitat fragmentation and habitat loss has resulted in small remaining populations. Once the population comes under a critical threshold of total area, populations might go extinct, as was shown in Tessin and the Pyrenees.

Bears as well as wolves were persecuted for ages, since they were considered a pest for agriculture, due to livestock losses, in particular in the mountain regions with pastoral livestock systems. However, good herding practices reduce livestock kills, as was shown in Italy.

Analysis
The Brown bear occupies a variety of habitats, but European populations are restricted mainly to mountain woodlands. The main habitat requirement for Ursus arctos is some area with dense cover in which it can shelter by day.

The preferred habitat of the Brown bears in Abruzzo consists of mixed deciduous forest primarily composed of Quercus cerris and Ostrya carpinifolia, monospecific beech forests and high Apennine grassland (Zunino, 1990).

In Greece bear habitat is formed by large remote mountainous forests characterized by mixed coniferous and hardwood vegetation with openings and rich undergrowth of fruit bushes and grass, rugged topography and rocky parts. Landscapes with agro-pastoral features are also part of brown bear habitat.

One of the populations where the number of animals is fairly stable with potential to improve is Abruzzo. Valleys and infrastructure separate the (large) national parks. The distribution area contracted due to persecution and fragmentation (Figure 5). But still occasionally observations are done outside the core area of National Park Abruzzo. Dispersal does occur, probably mainly by male bears, since females tend to be slower in dispersal.

If stable or viable 'satellite populations' would be established outside the park (1) the population can grow, (2) populations are spread over more areas. As a result the risk of extinction decreases (Van der Sluis *et al.*, 2003a).

With the METAPHOR model it was assessed what the impact would be on overall population viability when existing national parks would be connected. These results showed that the viability of the population would improve.

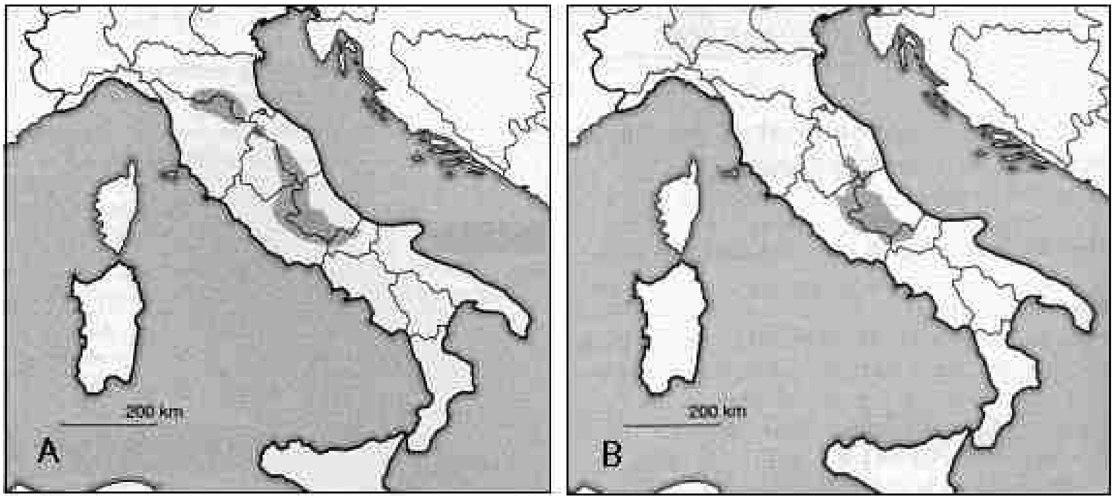


Figure 5: Distribution of the Brown bear in the Appennines. A: 18-19th Century; B: actual distribution (after Boscagli, 1999). Obtained from: http://www.corpoforestale.it/weborsolife/attivita/progettocattura.htm.

Solutions
Large tracts of land are already protected within the national parks of Region Abruzzo: Sirente Velino, Majella, Gran Sasso and areas in Marche. The overall connectivity between the national parks is limited at the moment, and habitat in between these parks is not very suitable for the Brown bear, which might require more cover from the vegetation (2003a). Figure 6 shows the connectivity of the landscape.

Requirements for the corridor would be:
- Create a corridor from Parco d'Abruzzo to Sirente-Velino (near Cocullo/Carrito), planting of open mountain ridge with indigenous vegetation
- Create a corridor from the Sirente-Velino and Monti della Laga regional park (near Navelli/Barsciano). This requires an Ursoduct as well as planting a forest strip of one kilometre width (Van der Grift & van der Sluis, 2003)
- Create a corridor from Parco d'Abruzzo to Majella national park, by planting in the valley a forest strip of one kilometre width

Species benefiting
The project would of course benefit more species. Not only the obvious mammal species such as Roe deer, Wolf, Badger, Wild cat, Lynx, Pine marten but also smaller mammals like Red squirrel, Common shrew, Pygmy shrew, Bank vole, Wood mouse and Dormouse. Forest birds would benefit, like Chiffchaff, blackcap, amphibian and reptile species like Green lizard, common toad

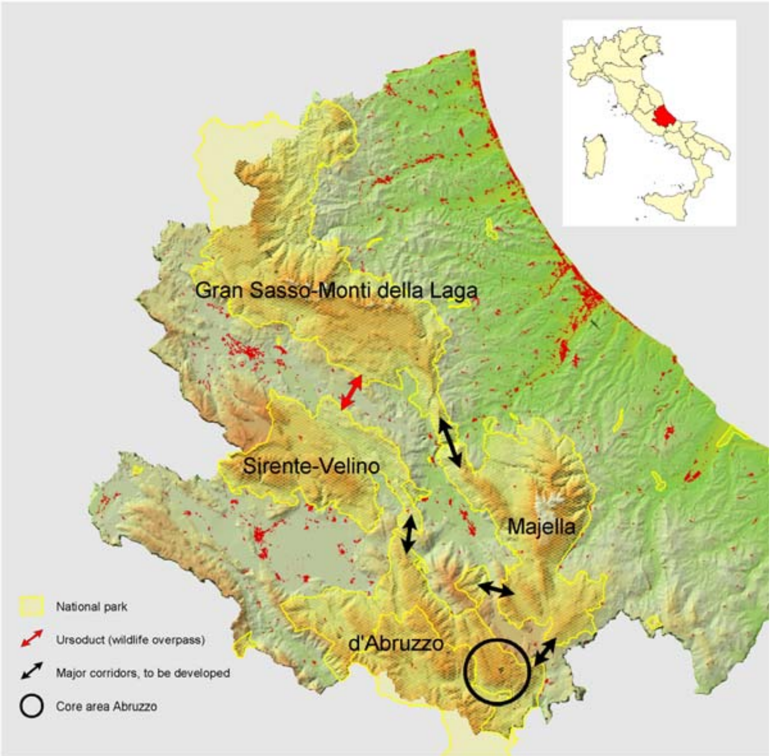


Figure 6: Solutions to defragment Bear habitat in Abruzzo (Van der Sluis et al., 2003a)

Existing initiatives and projects

Two projects were done recently towards the conservation of the Brown bear: a Life Nature Project directed at conservation activities towards the brown bear and the Life-Econet project (http://www.corpoforestale.it/wai/serviziattivita/Progetti_Ricerche/progetti/orsolife/). The latter is aimed at the development of ecological networks and general improvement of the landscape connectivity (http://www.lifeeconet.com/study_areas2.htm). One of the outcomes of the latter study was the beneficial effect of the development of a corridor connecting Abruzzo with Sirente Velino and Gran Sasso.

Such an undertaking could be done in conjunction with existing plans to reconstruct the road connecting L'Aquila with Sulmona and Castel di Sangro.

3.4 Birds

3.4.1 Brent Goose, *Branta bernicla bernicla*

Ecology and Protection status

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. These areas are typically threatened by habitat loss due to encroachment by man. More recently grasslands and arable lands (with amongst others winter wheat) are also used as winter and spring staging areas, which leads to conflicts with agricultural interests.

The population of the Black-bellied Brent Goose has undergone large fluctuations in the last century. Before the 1930s wintering Brent geese were numerous, presumably around 100.000 birds, on the extensive eelgrass beds at the coasts of Western Europe. In the 1930s Brent Goose numbers declined towards 20.000 birds with the sudden die-off of these eelgrass beds. In the 1970s, after full protection from hunting in Western Europe, population numbers increased up to 300.000 birds, with large fluctuations depending upon their breeding success. Recently, however, the population decreased again to around 150.000 birds.

The Brent goose is included in Annex 3 of the Bern Convention. Special attention is required 'as a result of its dependence on coastal habitat which is under severe pressure and which frequently results into conflict with human interests' (AEWA).
An International Flyway Management Plan for the Brent Goose has been drawn in 1997, to consolidate the population recovery until the 1990's and to eliminate conflicts with agriculture on the wintering and spring staging areas.

Problem
Low breeding success, habitat loss and conflicts with agriculture are the main problems for the Brent Goose. No cause is known yet for the low breeding success. Habitat loss in winter and spring staging areas has resulted in more geese feeding on grasslands and arable lands and hence in more conflicts with the farming community.

Analysis
The most important winter and spring staging areas as well as stopover sites have been discovered using satellite telemetry and colour-ringing resighting schemes.
Brent geese breed in a 2-month short summer 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 (Figure 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 Brent Geese will try to breed. With insufficient fat reserves Brent Geese are known to skip breeding completely for that season.

Figure 7: Migration routes for Brent goose, with major stepping stones

Solutions
It is most urgent that stop-over sites along the migration corridors receive protection especially for the Wadden Sea and the White Sea, because of their importance as fattening and refuel areas and hence their major implications for increasing breeding success.
To decrease tension with farmers, it should be stimulated that agreements are made with farmers, and that they are compensated for allowing the geese to winter on their lands.

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 Wigeon (Anas penelope), Barnacle Goose (Branta leucopsis) and Greenland White-fronted Goose (Anser albifrons flavirostris). The White Sea, the main stopover site during migration, is also important for Bewick's Swan (Cygnus bewickii). In the breeding areas Herring Gulls (Larus argentatus) colonies are often used. Brent Geese also nest in association with Snowy Owl (Nyctea scandica) and Rough-legged Buzzard (Buteo lagopus).

Existing initiatives and projects
In a Dutch experiment agricultural areas were designated as winter and spring staging areas for geese. The farmers obtained compensation for creating proper conditions for the geese and their attitudes were generally positive.
Within the next 2 years larger areas of agricultural and natural lands will be delineated as 'safe haven' for geese. Outside these areas disturbance is allowed to chase the geese towards the delineated areas. In this way the agricultural damage will decline while the geese population numbers should remain viable.

3.4.2 Eurasian Crane, *Grus grus*

Ecology and Protection status

The Eurasian Crane is a migratory species with a distribution throughout Europe, Asia and northern Africa. Their breeding areas are in northeastern Europe and northern Asia. Their wintering areas extend from southern Europe, North Africa, the Middle-East, India and China. These breeding and wintering areas are connected via several migration routes (see Figure 8). The two main European migration routes are the west and eastern European flyway (Figure 8), 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 and is probably stable to increasing, yet with local declines.

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 Eurasian Crane is classified as at 'Lower Risk' (least concern) under the revised IUCN Red List Categories. Breeding populations in European Russia and central Siberia are classified 'vulnerable',.

Problem

Wetland loss and degradation and in addition intensification of agriculture, form main threats to Eurasian Crane populations. 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 an increase of human disturbance.

As a result the breeding populations in western and southern Europe and northeastern China decrease. Another important consequence of the loss of habitat is the concentration of the West European crane population in increasingly larger flocks at feeding and roosting sites. This causes more risks for the cranes as less and less alternatives are available when e.g. a local draught reduces the feeding capacity of a stop over site, or the spread of diseases within a sub-population. Also conflicts may arise, farmers have reported incidents of crop damage at stop over sites along migration routes and in the wintering areas in eastern France, northern Spain and India.

Analysis
Practical starting points for conservation are protection and restoration of habitat in the breeding areas as well as in the stop-over sites along the flyway as well as the wintering areas (Figure 8). For the Eurasian Crane this comes mainly down to conservation of wetlands and extensively used agricultural areas.

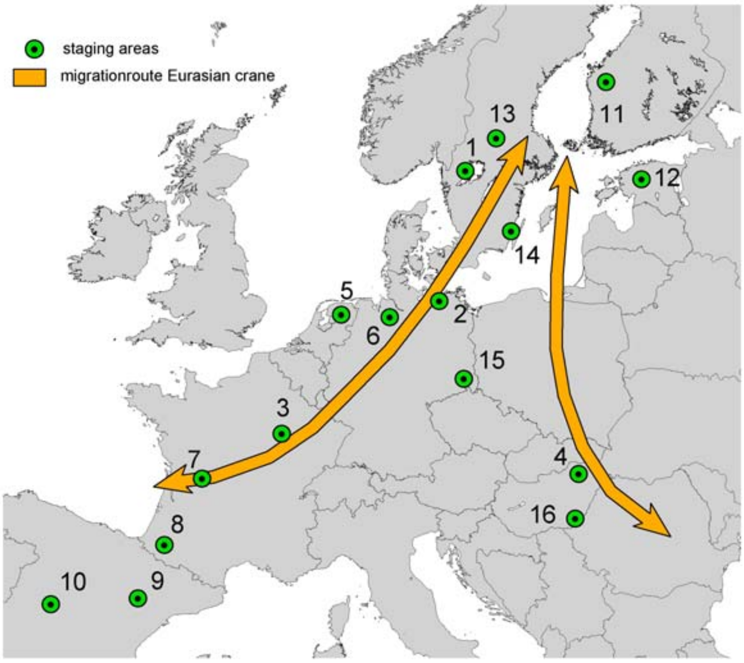


Figure 8: Migration routes for Eurasian crane, with major stepping stones

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 (Figure 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 benefitting
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.

3.5 Terrestial invertebrates

3.5.1 Large Copper, *Lycaena dispar*

Ecology and Protection status

The species occurs usually in natural marsh vegetation along water courses, rivers and marshes, but also in unimproved, semi-natural grasslands (Figure 9). In the north-western part of its range Lycaena dispar batava occurs in low densities in large nature reserves. Here the species depends on certain succession stages in the transformation from open water to forest. In the rest of Europe the Large Copper usually has two generations and occurs in higher densities. The male defends his territory, while the female wanders over large wetlands looking for a male or (after mating) for the foodplant to deposit eggs.The females are quite mobile and can colonize relatively fast suitable habitat up to a distance of 10 km. This means that the butterfly can function very well in a mosaic of habitat patches.

The Large Copper has decreased considerably in Western Europe, whereas Eastern European populations are mostly stable (Figure 9). In the northern edge of its range the butterfly is expanding its range in Estonia and more recently Finland. This is most probably caused by global warming in the last decades.

The Large Copper is listed on annex II of the Bern Convention and on annex II and IV of the Habitats Directive. In many countries (e.g. The Netherlands) the butterfly is also protected by national law.

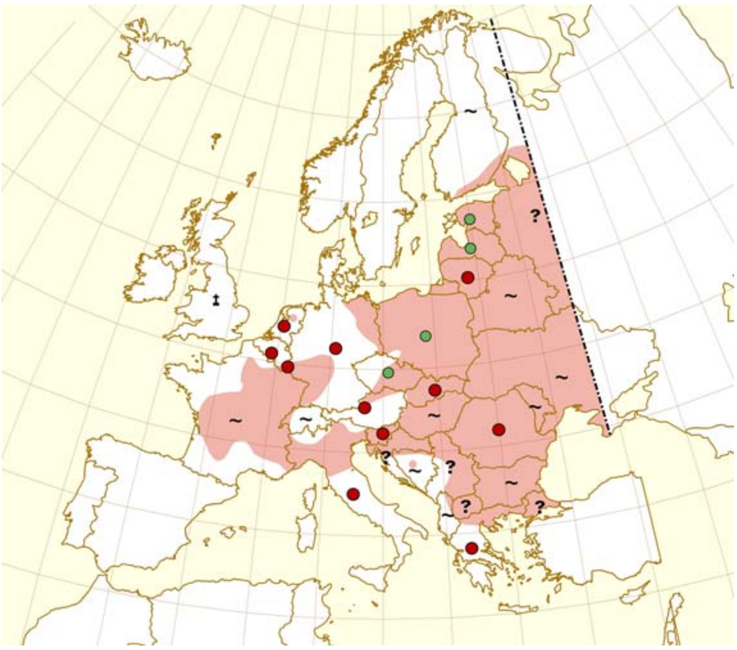


Figure 9: distribution map Large Copper (adjusted after Kudrna, 2002)

Problem
As a consequence of the intensification of agriculture in Northwestern Europe large marshes and natural, humid grasslands have been drained, reduced in size and form no longer connected habitat for the Large Copper. In Eastern Germany and Poland, large viable populations still exist, but changes in agriculture as a consequence of their accession to the European Union can be expected.

Analysis
An analysis was done with the landscape ecological model LARCH to identify suitable habitat for the species (on the basis of the CORINE habitat classification). This was compared with the actual distribution pattern of the Large copper. In the northern part of Central Europe (Figure 10) large core populations are available in the Pripyat flood-plain in Belarus (1) and the Kaliningrad area in Russia (2). Poland itself has a strong core population in the Biebrza river valley (3). Further west in the extensive Polish agricultural landscape (4) populations are smaller, but still well connected. Eastern Germany also maintains good populations (5), but in Northwestern Germany (6) the wetlands are too small, scattered and isolated (figure 4). Although the population ecology differs slightly for this species, the model also predicts reasonably well the potential distribution of Lycaena dispar batava in The Netherlands (7). In reality this subspecies is restricted to Northwest Overijssel and Southern Friesland (8).

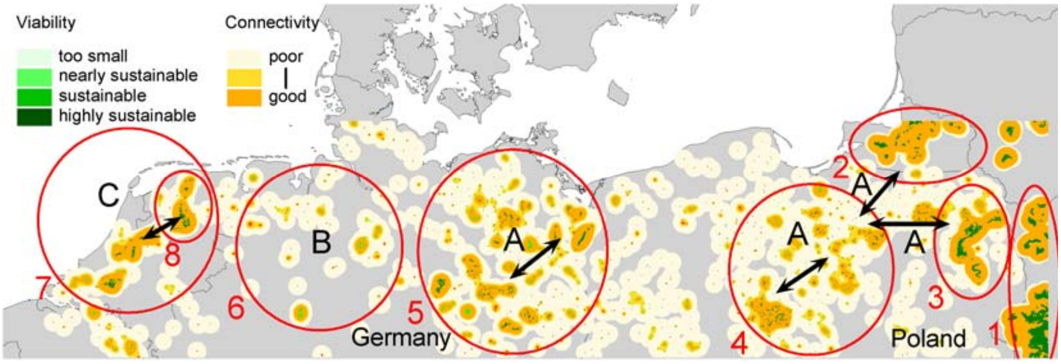


Figure 10: possible corridorrs connecting existing core areas of Large copper

Solutions
The solutions are illustrated in Figure 10.

A. The accession of Poland to the European Union will cause agriculture to intensify. This will 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 (3) and Kaliningrad (2). More or less the same applies to Eastern Germany.
B. In the northwestern part of Germany wetlands are small and isolated. This means that the Dutch race Lycaena dispar batavus is isolated from populations in Eastern Germany. Only a large scale creation of wetlands could be a solution to this problem.
C. In The Netherlands large and apparently suitable areas are still available. Especially in the area Oostvaardersplassen / Vechtplassen / Nieuwkoopse Plassen habitat seems to be available. This area could be connected to the main

area (8). This core area of the Large Copper in The Netherlands could be extended for long term survival of the species.

This means, in summary, that corridors for connecting different networks are required, as well as corridors which link smaller local populations within a network. Landscape connectivity at network scale and population scale, whereby the landscape matrix is very important.

Species benefiting
Lycaena dispar 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 for this butterfly.

3.5.2 Stag Beetle, *Lucanus cervus*

Ecology and Protection status
The European Stag Beetle is one of the largest insect species in Europe. The larval development in dead wood takes 5 till 8 years. The species is threatened in many European countries and therefore protected. Although females are very able to fly, (and do so in 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 small.

Only in Northern and Central Spain, and Northern Italy the Stag Beetle is common and 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. Rare and vulnerable is its status in Germany, the Netherlands, Belgium, Sweden, Lithuania, England and Wales. Very rare, nearly extinct is the species in Latvia and Denmark.
Although the European Stag Beetle is a red-list species in many countries, it is not endangered world wide, and it is therefore not at the IUCN red-list.

The main risks for the Stag beetle are 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 minimise 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; Figure 14 shows the distribution of forests containing habitats of 200 endangered species of woodboring invertebrates compiled by the Invertebrate Consultants' Group of the CDSN-committee (Speight, 1989). 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 patttern 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.

Analysis

Although deciduous forests are remaining in many countries, the distribution of the Stag Beetle is scarce and scattered (see maps). This is due to the ongoing disappearance and fragmentation of old deciduous forests, leading tot smaller and more isolated appropriate habitat patches, as well as to their inappropriate management and exploitation (see above): clearcut practices and stumps are removed or grinded. So, rather dense networks of old voluminous stumps of deciduous trees, which are required for survival and dispersal, are becoming less dense and fragmented as well.

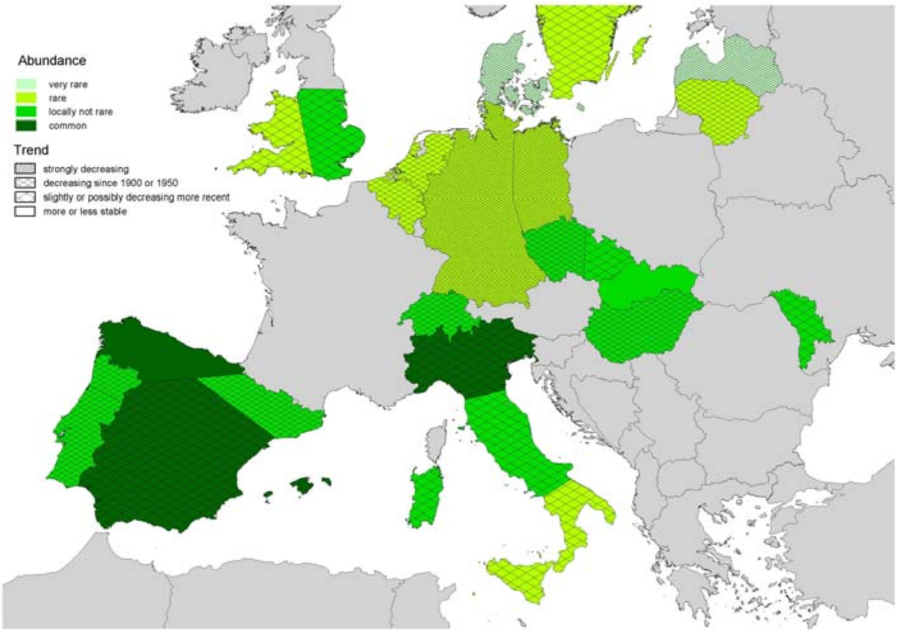


Figure 11: Distribution of Stag beetle in Europe

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 loggeries and large wooden boxes filled with wood chips and sawdust (Figure 13) and dead wood pyramids (Figure 12). 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.

Figure 13: Box with sawdust, as breeding place for Saproxylic insects (picture: M. Fremlin)

Figure 12: wood pyramid as breeding place for Saproxylic insects (picture: M. Fremlin)

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 European Stag Beetle is exemplary for the strongly declining group of large wood boring (saproxylic) beetles.

Because of its large size and typical shape, the species is very apt for information and teaching. The Stag Beetle is exemplary for large wood boring (saproxylic) beetles. This group is declining very strongly, much stronger than many other insect groups. All declining species need stable forest conditions, old living trees with dead parts, dead standing or fallen trees, large stumps, stubs and trunks. They all are endangered by too intensive forest management, sanitary cuttings, removal of dead wood, and fragmentation of old forests.

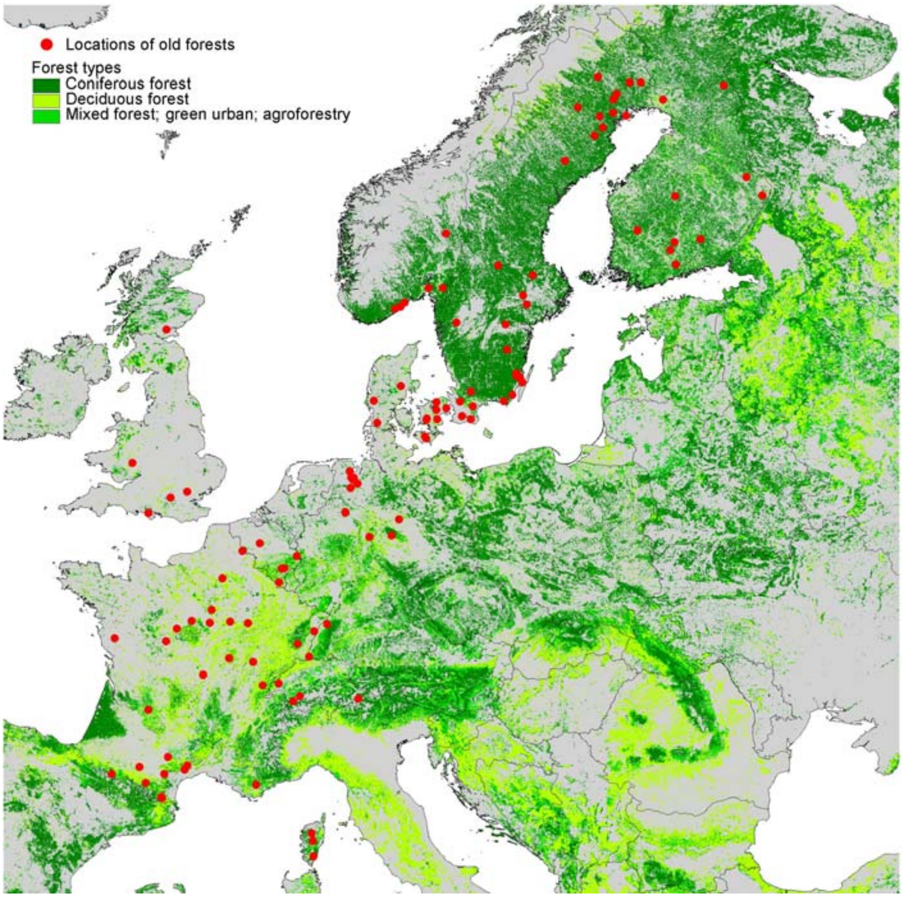


Figure 14: Western and Northern European forests identified as being of potential international importance by their fauna of saproxylic (wood-eating) invertebrates. Based on results of the Saproxylic Invertebrates project (Speight, 1989)

3.5.3 Heath Bush-cricket, *Gampsocleis glabra*

Ecology and Protection status

The heath bush cricket Gampsocleis glabra is a large xero-thermic insect species. Individuals are winged and long-legged, and have a body length of appr 2.5 cm, augmented with a 2 cm long ovipositor in females.

The North-Western biotopes in which G.glabra is found are: large, dry heath, on a sandy soil mixed with little loam Between heather plants and grass tufts soil is mostly bare, with very few moss or litter. Due to military use (shooting) and/or frequent management of burning vegetation is rather homogeneous over large areas, and many spots and broad strips of bare sand (which is the egg deposition habitat) are present, and their is hardly no litter layer (Clausnitzer, 1994). Such areas are the last ones where the species survives in the Netherlands (Veluwe, Oldenbroekse heide) and Germany (Lüneburger Heide), and may therefore be considered as optimal habitat. In the Causses of France it is found in open grassland, with 40-50 cm high grasses on a stony chalk soil, partially ploughed agriculturally in earlier times. Also here little soil is covered by mosses and lichens, and litter- and humus layer are nearly absent. In Hungary the species lives a.o. in drifting dunes, too, often in the vicinity of water.

Analysis
In the Netherlands Gampsocleis glabra occurs only at Oldenbroek Heath, in the North-East of the Veluwe area. In the 20th century it was found at minimally 15 different locations, all restricted to a pleistocene sand area (Veluwe). There was one ancient patch in Belgium (extinct now), and apart of Lüneburger Heath three other patches in Germany (the one near Mainz is extinct now). There are 12 scattered areas in Middle and Eastern Europe, and in addition a large area in the Balkan. Moreover there are 3 large and 4 smaller areas in France and Spain (Kleukers *et al.*, 1997).

Vital is the occurrence of a mosaic of vegetated and bare patches – preferably without moss and litter - on a dry coarse soil apparently for two reasons related to egg development (a) and bush cricket physiology (b):

a. Bare ground absorbs radiation very well. Consequently bare ground surface and upper soil temperatures rise rapidly in the morning as well as after cloudy weather and rain, and reach high maximal values very soon, especially if the soil consists of coarse material or is stony. This promotes proper egg development and emergence, so that larval development will be complete not too late in the season, facilitating completion of the seasonal cycle before winter. Especially if a species has a high Q10, physiological processes (eating, growth, development and egg production) accelerate strongly with rising temperature. Although this is not investigated for G. glabra, related species appeared to have high Q10, and relatively high lower thresholds for development (Wingerden *et al.*, 1991, Wingerden *et al.*, 1993).
b. If vegetation is open and soil is not covered by moss and litter bush crickets may absorb warmth from up and below simultaneously. Vegetation structure, however, has to be present yet, for shelter against extreme weather conditions, such as rain, wind, low temperature and intense sun radiation.

Such sparsely vegetated areas have become rare since the aerial deposition of Nitrogen has started round from 1950 onwards. Since, heather has been replaced by grasses growing in dense tufts, and bare sand has been covered by moss and litter layers. Consequently maximum soil surface temperatures have decreased. This prevents the warming up of the cold blooded insect from up and down simultaneously. Such conditions may only be restored or created by sod cutting, or burning.

Solutions
The European distribution map from 1900 onwards shows that there is some correlation with the CORINE-habitats: continental moors and heathlands, sparsely vegetated land and burnt areas. It does not occur near the Atlantic coast. In France, the Netherlands, and Germany, recent distribution is much more scarce and scattered as compared to earlier distribution (see map). Recent occurrences in the Netherlands, Germany and Northern and Middle France are so distant from each

other, that enlargement of habitats or the construction of internal corridors to empty and nearby former patches would be more realistic as well as prospective than corridors-in-between. Especially in the cluster of occurrences in South-eastern France such an approach of enlargement and interconnection of present and former habitat patches may be advantageous for species persistence. Corridors have to be of the type of heath-, grass-, or low and open scrubland, with nodes of habitats attached to it every few kilometers. The habitats should consist of 2 – 3 ha patches of open heath or grass vegetation on bare coarse-grained soil. This habitat type may be developed and managed as well by sod-cutting and burning in winter. The recent fire-outbreaks in the South of France may provide new chances for G. glabra.

Also in Hungary distribution is more scattered than before. Here are nice opportunities for real border crossing corridors, in co-operation with Austria (Neusiedler See-gebiet), Slovakia and Romania.

Gampsocleis glabra is a good example for large insect species (declining faster than smaller species) of warm and dry open vegetation, which is declining due to agriculture and aerial deposition of Nitrogen. Such insect species belong to the preys of by eye searching predators, such as declining insectivorous birds.

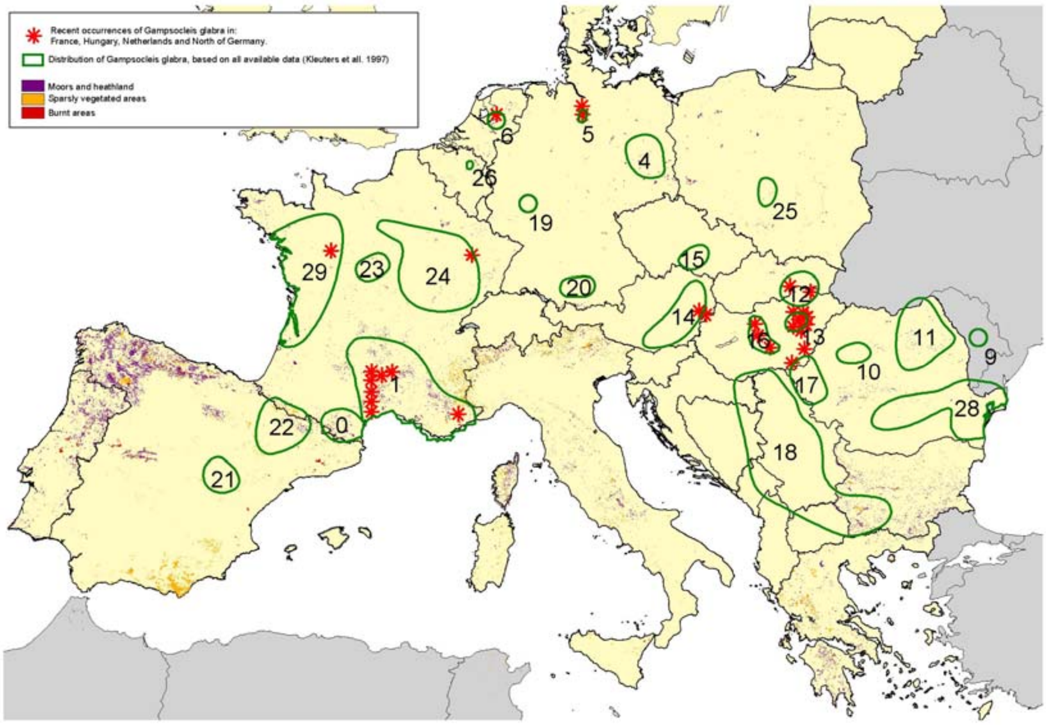


Figure 15 Distribution area of the Heath Bush-cricket, with the selected habitat map

Species benefitting
other thermo-xerophilous (warmth and dry preferring) species, that, as a result of atmospheric N-deposition, soil eutrophication and consequent changes in vegetationstructure and microclimate – have become rare in large parts of Europe, such as from the groups of grasshoppers, bushcrickets, butterflies, lizards, snakes

3.6 Aquatic invertebrates

3.6.1 Yellow-legged Dragonfly, *Gomphus flavipes*

Ecology and Protection status
G. flavipes is found in lower courses of a few large rivers in Western Europe, but is more common in Eastern Europe. The most southern places are in Greece, the most northern in Estonia. In the first decades of the 20th century it was more common in Western Europe, but in the second half of the century it was 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 (Figure 15).

Preferred habitat is formed by shallow braided river stretches with low current velocity. Sub-optimal habitats are shallow, sandy slopes between groins. Because of the groins, current velocity is low (Rijn, Elbe, Weser). Larvae live in sand or between fine particulate matter on the river bottom. They prefer warmer places (Bos & Wasscher, 1997). The development from egg to adult lasts generally three years (2-4). This means that habitat conditions may not change too much over longer periods. Adults stay in the vicinity of the river, but in other places they disappear inland. It is unknown how far and to where.
The species is a protected species, included in the European red list, in the Habitats Directive and the annexes of the Bern Convention.

Problem
The Yellow-legged Dragonfly was extinct from the river Rhine and most other western European rivers for almost 100 years. Reasons for the decline are probably pollution and loss of habitat by canalization and a changed management of the shores. In the nineties of the last century the species reappeared in Germany (Elbe: Bruemmer *et al.*, 1994). In the river Rhine expansion took place from 1995 and in 2000 it was found up to the northern Oberrhein (Schöll, 2002). In The Netherlands, the first living larva was found at Nijmegen and larval skins were found at several places alongside the river Waal. Individuals were observed from Nijmegen till the Biesbosch and along the Nederrijn. In 2000 it was found along the Grensmaas in Limburg and in Belgium (first observation). In 2001 G. flavipes has been found along the river IJssel.
Reasons were probably the water pollution and canalization of rivers and streams. Also the changed management of the shores of large European rivers may have attributed.
Currently recolonisation is taking place from central and Eastern Europe takes place.

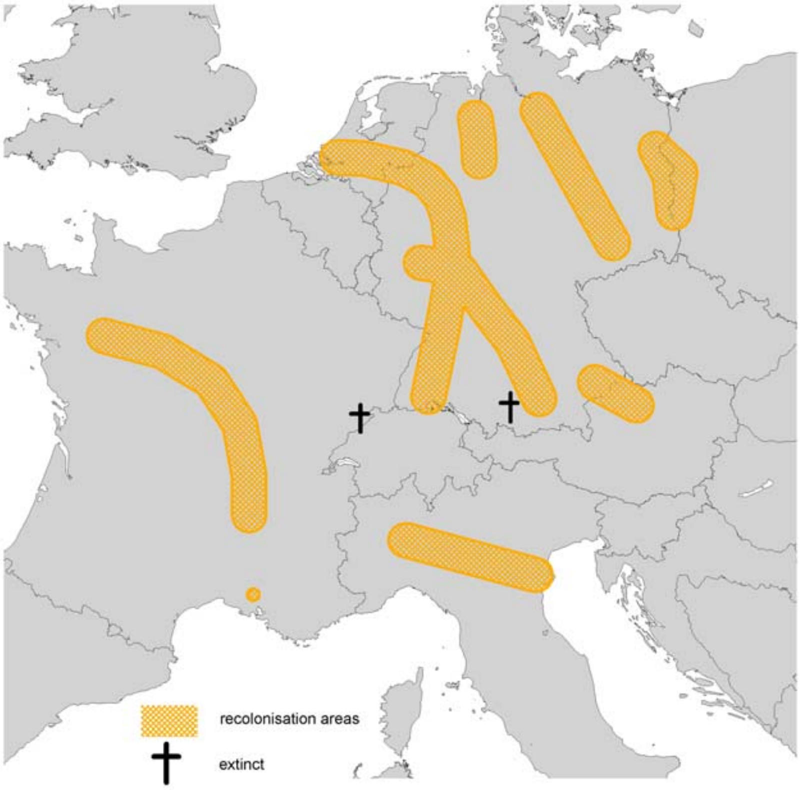


Figure 156: Distribution area of the Yellow-legged dragonfly (Crombaghs & Habraken, 2002)

Solutions
To enhance the life conditions one should:

- improve the water quality
  Obviously the water quality has improved considerably, because the species has returned in the rivers Rhine and Meuse. A higher temperature may have contributed as well.
- create larval habitats
  The present observations in the canalised river Rhine indicate an adaptation to habitats between groins. More natural habitats can be created in nature development programs.
- create adult habitats
  Nature development programs should also improve the adult habitat. At present ruderal vegetation is used as a substitute for sunny, sandy shores with patches of floodplain vegetation. Two possible solutions are the improvement of water quality and the creation of larval and adult habitats. Larval habitats are currently associated with habitats between the groins of a canalized river such as e.g. the river Rhine. More natural habitats can be created in nature development programs. Adult habitats could be improved by nature development in which ruderal vegetation is currently used as a substitute for 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 Odonata and eight species of Trichoptera (van den Hoek & Verdonschot, 2001). Certainly more species from other groups such as molluscs, oligochaetes, beetles and chironomids should follow.

3.7 Fish

3.7.1 Atlantic Salmon, *Salmo salar*

Ecology and protection status
The Atlantic salmon is a large fish species, well known for its homing ability, agility, strength and persistence in overcoming obstacles to reach spawning grounds upstream. And the taste of this fish is marvellous.
The species is born in spawning areas located in the upstream tributaries of large rivers, the species migrates after some years to the sea, to return to its spawning area for its reproduction and die.

The spawning takes place in areas with clean water with high oxygen levels and moderate velocity levels. Fish that take part in the migration are usually larger than 60 cm and 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. During the migration (back to the spawning areas) of two to three months, the fish hardly eat. By the end of December they reach the spawning areas, they mate, and the majority will die. Only 5 % may migrate to the sea, to return next winter again (Maitland, 2003; Greenhalgh, 1999).

The Atlantic salmon is listed in annexes II and V of the European Union's Habitat Directive as a species of European importance.

The species has a North Atlantic distribution. The current distribution ranges from Portugal to the polar circle. It includes rivers in Spain, France, the UK, Ireland, Norway, Sweden, Finland. Outside of Europe the main areas for Atlantic salmon are Iceland, Greenland, Eastern Canadian provinces and the Northeast USA. Antropogenic effects have restricted current distribution, particularly man-made barriers and deterioration of water quality.

Problem
The Atlantic salmon has declined mainly due to morphological and hydrological changes of the environment, water pollution, and the fragmentation of habitat.
In the early 60s the Atlantic salmon was at the brink of extinction in Northwest European countries, due to water pollution and effects of pesticides. Over the years the situation has improved much though, so far that in most rivers the water quality is good enough again.

The Salmon occurs throughout the entire basin of the river Rhine, but civil engineering structures such as dams, weirs and culverts, form an obstacle for migration (Figure 16). Due to barriers the Atlantic salmon can not reach the upstream located spawning areas anymore.
Also changes in river morphology have resulted in loss of important breeding areas.

Salmon stocks are currently thought to be under threat in both the freshwater and marine phases. In freshwater the gradual degradation of juvenile and spawning habitat is giving cause for concern. Land use, in particular intensive agriculture, is thought to have the greatest effect.
The relationships between changes in the marine environment, marine survival rates and salmon populations are not always clearly understood. Several potential reasons have been put forward:

- Changes in sea surface temperatures with reduced areas of suitable habitat and hence increased intra-specific competition.
- Fish farming, resulting in localised increases in sea lice
- Industrial fishing can affect marine-phase salmon both indirectly via over-explotation of their food source (sand, eel fishery), or directly inadvertently netted as by-catch.

For the freshwater phase adequate habitat diversity of the type provided by the typical riffle/pool sequence is important for both juvenile and adult salmon. The pools provide the deeper holding areas required by adults, the riffles provide the fry and parr habitats, and suitable spawning sites are provided at the point where pool shallows become a riffle and water velocity increases.

In natural situations, pool/riffle sequences typically repeat at intervals of five to nine channel widths. However, many rivers channels have been extensively modified for land drainage and flood defence, and the characteristics pool/riffle sequence with its attendant habitat diversity has often been lost. River sections modified in this way might there fore be considered for restoration to a more natural habitat, thus enhancing production of juvenile salmon.

Analysis
As we see in Figure 16 (based on Schulte-Wülwer-Leidig, 1994) a large number of dams and weirs is present, obstructing migration for Salmonids.
To conserve the Atlantic Salmon for Europe factors such as barriers, change in rivers and water quality and the loss of spawning areas and habitats be solved. Also the problems related to escaped Salmon from fish farms that are genetically different, forms a threat due to hybridisation and competition, as well as intensive fisheries at sea.
Furthermore, restoration of the morphology rivers, streams and spawning areas is required.

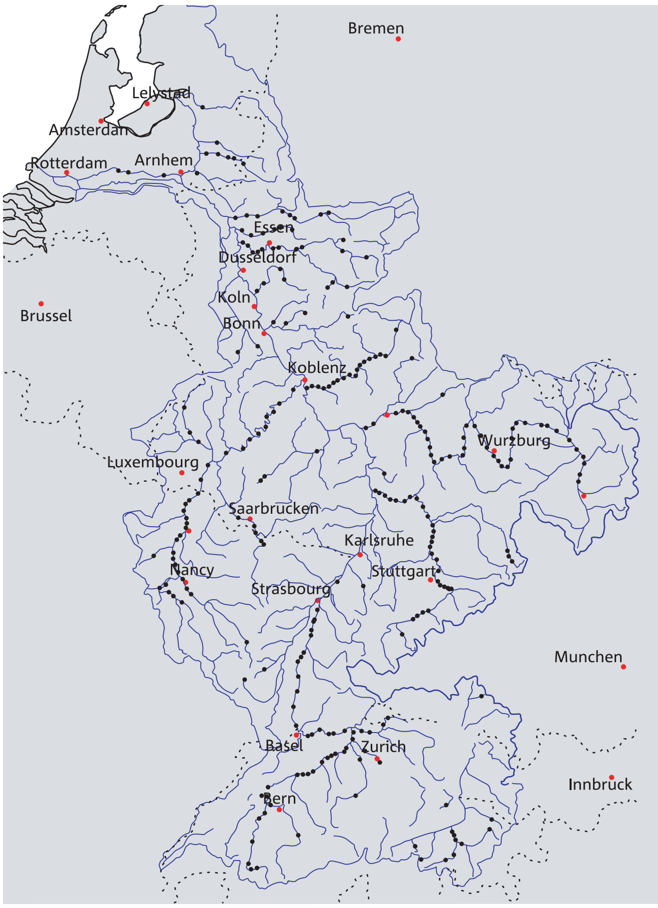


Figure 16: Major barriers for fish species such as Salmon and Sea lamprey in the river Rhine (adjusted after Schulte-Wülwer-Leidig (1994)

Solutions
For Salmon it is important to remove barriers like dams, weirs and culverts (Figure 16).
The water quality has been improved, and further improvement is still important for some tributaries since the Salmon is a highly demanding species. Improvement of the water quality is also one of the aims of the Water Framework Directive.
Some important improvements were realised: the water quality has improved, and many dams and weirs were made passable for fish, e.g. in the Netherlands, where many fish passages were made. In Belgium and Germany spawning areas are being restored. Reintroduction of young fish, in tributaries of the Meuse (Ardennes) and Rhine (Sieg and Ahr) may contribute to a recovery of the Salmon population.
Together these measures may realise that Salmon can reach the reproduction areas, but also that the quality of habitat is restored so that Salmon can end its life cycle again.

General importance
Species such as Sea lamprey, Sturgeon, Barbel, Trout, Allis shad, Twaite shad and European bullhead will benefit from the proposed measures.

3.7.2 Sea lamprey, *Petromyzon marinus*

Ecology and protection status

The three known Lampreys in Europe, River-, Brook- and Sea lamprey are the most primitive of all living vertebrates. They are no true fish, but as such is often referred to them. The Sea lamprey is by far the largest of the three lamprey species and can reach a length of 100 cm and a weight till up to 2.5 kg.
The Sea lamprey is listed in the Habitats Directive (annexes II and V), annex III of the Bern Convention and in many European country it is also on the Red list of fishes.

Like most other Lampreys, the Sea lamprey parasites other fish species. Those other species usually will survive. The Sea Lamprey is migrating: they are a marine species, but migrate along freshwater rivers for spawning. These spawning areas are in the middle- and upper reaches of large rivers. These are shallow areas, ripples, with a strong current (1-2 m/s) and a sun-lit rocky substrate. Migration takes place from February till June. Thousands of eggs are deposited in a shallow burrow that is covered with sand.

The larvae hatch and are taken by the stream to suitable muddy banks. They stay there for some years, feeding on algae and vegetarian material. After 5-8 years they metamorphose into the parasitic fish species. They swim downstream and live for another three years at see, before returning to the spawning area to repeat the same cycle.

Problem

Threats for Sea lampreys are pollution, river management and development, development of barriers (Figure 16), predators and possibly introduced species.
In the past many polluting effluents were discharged into rivers and indirectly into the sea. Due to the pollution most rivers lost their populations of Sea lamprey. In addition to direct toxic effects pollution can have a major impact on Sea lamprey by smothering both spawning gravels and nursery silts.

River management, water extraction and land drainage can have negative effects on Sea lamprey populations. Variable levels of water during the wrong time of the season can lead to unstable habitats, spawning gravels and nursery silts may be flooded and disturbed at the wrong time and left dry at others. Another negative side effect may be caused by fisheries. The distribution of larvae is affected most by the location of spawning sites, stream flow, water temperature, streambed pollution and downstream migration. Physical barriers in streams may affect all these factors, which results in major detrimental effect on the distribution of spawning Sea lampreys.

Mortality rates in Sea lamprey population are probably rather low and consistent throughout the larval period. Apart from the effect of fluctuating physical factors, especially during the embryonic period, it is known that the larvae are eaten by eel, stickleback and other fish as well as birds such as herons. Losses may be particularly high during dispersal from the nest to the silt beds, and a high mortality probably occurs at metamorphosis. There are a number of records of birds and mammals attacking adult Sea lampreys, especially at spawning time.

Analysis
Similar to the Atlantic Salmon (Figure 16), this species is dependent on removal of barriers in major streams and rivers.

Solutions
Weirs and dams form impassable barriers. But also pollution, eutrophication, exploitation, canalisation and destruction of suitable spawning areas and habitat (e.g. by dredging and water regulation) result in a considerable loss of suitable habitat for the Sea lamprey.

Recovery measures for this species are removing barriers and weirs, so that the Sea lamprey can reach from the sea its spawning areas again. Improvement of the water quality in upper and middle reaches of streams is important for the larvae. Also the availability of sufficient suitable spawning and (growing?) habitat in the upper reaches of large rivers.

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

3.8 Plant Species

The concept of corridors is in general very useful for conservation of the fauna. Although it remains sometimes difficult to develop practical solutions for corridor development based on the theory, it is clear that animals can disperse actively via corridors, which is essential for their long term survival.

For plants it is a problem that they rarely disperse actively, and at least not over larger distances. This results in a 'random' distribution of plants, in which other factors are very important. Plants remain fully dependent on the site conditions, as well as the abiotic situation. Finally, for longer dispersal distances the morphological characteristics of seeds and transporting vectors (such as wind, water, mammals, and birds) are important, and complicate the application of the corridor-theory.

The large number of plant species, the limited information about species dispersal capacity in relation to corridors makes it very difficult to do a spatial analysis for plants.

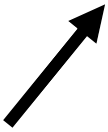
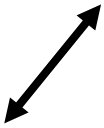
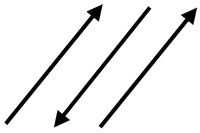
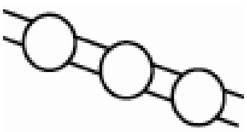
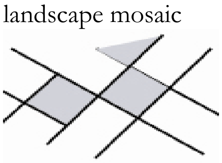
In particular literature seems to be lacking of plant species dispersal via migration corridors, for that reason we did not proceed further with this study for plants.

3.9 Integration of results for different taxa

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. Often a corridor might have several functions for a species, i.e. it might serve both for commuting or dispersal objectives.

Table 10 shows the required shape and fucntion of corridors of those species for which examples of corridor development are presented in this report.

Table 10: Shape and functions of corridors for different species

Shape \ Function	Dispersal 	Migration 	Commuting 
linear corridor 	Otter Beaver Atlantic salmon Sea lamprey Mayfly Barbel Caddisfly Chelicorophium curvispinum Asian clam	Otter Atlantic salmon Sea lamprey Sturgeon Palaemon longirostris	Beaver
linear corridor with attached nodes 	Otter Beaver Stag beetle Large copper Yellow-Legged Dragonfly		Large copper
stepping stones 	Otter Beaver Lynx Wolf Yellow-Legged Dragonfly Heath bushcricket Dusky large blue Little bustard	Brent goose White-fronted goose Eurasian crane Yellow-Legged Dragonfly	
landscape mosaic 	Otter Beaver Brown bear Lynx Wolf Large copper Apollo European ground squirrel	Brown bear European ground squirrel	Brown bear Little bustard

Undisturbed and unmanaged rivers are major corridors the Vistula River, Pland (Picture R. Reijnen)

4 Conclusions

4.1 General conclusions

In this report 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 report 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 has 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 report 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, Brant 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 report 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.

4.2 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 'grassroots 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, which 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 used to be only harmful for nature, may now be used for improving natural conditions. A good example is the upgrading of roads which includes construction of fauna' passages which actually decrease the impact of the already existing road (e.g. the example in this report 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.

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Picture: Artificial canals in an intensively used agricultural area of the Po Plains, Emilia-Ropmagna (Picture Theo van der Sluis)

Appendix 1 European invertebrate species list

Source: Bal, D., Beije, H.M., Fellinger, M., Haveman, R., van Opstal, A.J.F.M., van Zadelhoff, F.J. (2001). Handboek Natuurdoeltypen. Tweede, geheel herziene editie. Expertisecentrum LNV, Wageningen.
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Spiders

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Grote gerande oeverspin	Dolomedes plantarius	VU		I

Kreeftachtigen

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Rivierkreeft	Astacus astacus	VU		I

Ants

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Behaarde rode bosmier	Formica rufa	LR(nt)		I
Glanzende gastmier	Formicoxenus nitidulus	VU		I
Kale rode bosmier	Formica polyctena	LR(nt)		I
Woekermier	Anergates atratulus	VU		I
Zwartrugbosmier	Formica pratensis	LR(nt)		I

Kevers

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Gestreepte waterroofkever	Graphoderus bilineatus	VU	HR2/4	I
Vliegend hert	Lucanus cervus		HR2	I

Nachtvlinders

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Hulstblad	Phyllodesma ilicifolia	VU		I
Spaanse vlag	Euplagia quadripunctaria		HR2	I

Butterflies

Based on Van Swaay & Warren (1999)

Anthocharis damone
Archon apollinaris
Archon apollinus
Boloria frigga
Boloria thore
Boloria titania
Coenonympha hero
Coenonympha oedippus
Coenonympha tullia
Colias chrysotheme
Colias hecla
Colias myrmidone
Colias nastes
Erebia christi
Erebia embla
Erebia epistygne
Erebia medusa
Erebia sudetica
Euchloe simplonia
Euphydryas aurinia
Euphydryas intermedia
Euphydryas maturna
Euphydryas orientalis
Glaucopsyche alexis
Gonepteryx maderensis
Hipparchia azorina
Hipparchia maderensis
Hipparchia miguelensis
Hipparchia occidentalis
Leptidea morsei
Lopinga achine
Lycaena helle
Lycaena ottomanus
Maculinea alcon
Maculinea arion
Maculinea nausithous
Maculinea rebeli
Maculinea teleius
Melanargia titea
Melitaea aetherie
Melitaea aurelia
Melitaea britomartis
Muschampia proteides
Neolycaena rhymnus
Nymphalis vaualbum
Nymphalis xanthomelas
Parnassius apollo
Parnassius phoebus
Pieris cheiranthi
Pieris wollastoni
Plebeius hesperica
Plebeius trappi
Polyommatus caeruleus
Polyommatus dama
Polyommatus damone
Polyommatus eroides
Polyommatus humedasae
Polyommatus poseidon
Pseudochazara euxina
Pseudophilotes bavius
Pseudophilotes vicrama
Pyrgus centaureae
Pyrgus cirsii
Scolitantides orion
Spialia osthelderi
Thymelicus acteon
Tomares ballus
Tomares callimachus
Tomares nogelii
Triphysa phryne
Zerynthia caucasica

Kokerjuffers

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Adicella filicornis	GE	Z
Agapetus ochripes	GE	Z
Agrypnia obsoleta	KW	tz
Allogamus auricollis	GE	Z
Anabolia brevipennis	KW	tZ
Annitella obscurata	GE	Z
Apatania fimbriata	GE	Z
Athripsodes albifrons	EB	TZ
Brachycentrus subnubilus	EB	TZ
Ceraclea alboguttata	EB	TZ
Ceraclea dissimilis	KW	Tz
Ceraclea nigronervosa	BE	TZ
Drusus annulatus	GE	Z
Drusus trifidus	GE	Z
Ernodes articularis	KW	tZ
Glossosoma conformis	GE	Z
Goera pilosa	KW	tz
Grammotaulius nigropunctatus	EB	TZ
Grammotaulius nitidus	EB	TZ
Grammotaulius submaculatus	GE	Z
Hagenella clathrata	KW	tZ
Halesus tessellatus	BE	TZ
Holocentropus insignis	VN	TZ
Hydatophylax infumatus	GE	Z
Hydropsyche dinarica	GE	Z
Hydropsyche fulvipes	GE	Z
Hydropsyche instabilis	KW	tz
Hydropsyche modesta	GE	Z
Hydropsyche pellucidula	KW	tz
Hydroptila cornuta	VN	TZ
Hydroptila dampfi	VN	TZ
Hydroptila pulchricornis	GE	Z
Hydroptila sparsa	BE	TZ
Hydroptila tineoides	EB	TZ
Ithytrichia lamellaris	VN	TZ
Lasiocephala basalis	KW	tZ
Lepidostoma hirtum	BE	TZ
Leptocerus interruptus	KW	tZ
Leptocerus tineiformis	KW	tz
Limnephilus auricula	KW	tz
Limnephilus binotatus	KW	tz
Limnephilus bipunctatus	GE	Z
Limnephilus centralis	KW	tz
Limnephilus elegans	EB	TZ
Limnephilus fuscicornis	EB	TZ
Limnephilus griseus	EB	TZ
Limnephilus ignavus	KW	tZ
Limnephilus incisus	EB	TZ
Limnephilus luridus	KW	tZ
Limnephilus marmoratus	KW	tz
Limnephilus nigriceps	BE	Tz
Limnephilus stigma	BE	Tz
Limnephilus vittatus	KW	tz
Lithax obscurus	GE	Z
Lype phaeopa	KW	tz

	Melampophylax mucoreus		GE	Z
	Micrasemodes minimus		VN	TZ
	Molanna albicans		GE	Z
	Neureclepsis bimaculata		KW	tz
	Notidobia ciliaris		KW	tz
	Odontocerum albicorne		EB	TZ
	Oecetis notata		EB	TZ
	Oligoplectrum maculatum		VN	TZ
	Oligostomis reticulata		EB	TZ
	Oxyethira falcata		GE	Z
	Parachiona picicornis		GE	Z
	Polycentropus flavomaculatus		KW	tZ
	Potamophylax luctuosus		GE	Z
	Psychomyia pusilla		GE	Z
	Ptilocolepus granulatus		GE	Z
	Rhadicoleptus alpestris		GE	Z
	Sericostoma flavicorne		VN	TZ
	Setodes argentipunctellus		GE	Z
	Setodes punctatus		EB	TZ
	Setodes viridis		VN	TZ
	Silo piceus		VN	TZ
	Stenophylax permistus		BE	Tz
	Tinodes pallidulus		GE	Z
	Tinodes unicolor		GE	Z
	Triaenodes reuteri		EB	TZ
	Triaenodes simulans		BE	TZ
	Trichostegia minor		KW	tz
	Wormaldia occipitalis		GE	Z
	Wormaldia subnigra		GE	Z

Grasshoppers and krekels

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Blauwvleugelsprinkhaan	Oedipoda caerulescens		KW	Tz
Bosdoorntje	Tetrix bipunctata		VN	TZ
Boskrekel	Nemobius sylvestris	i	TNB	iz
Bramensprinkhaan	Pholidoptera griseoaptera	i	TNB	iz
Duinsabelsprinkhaan	Platycleis albopunctata	i	TNB	iz
Europese treksprinkhaan	Locusta migratoria ssp. migratoria		VN	TZ
Gouden sprinkhaan	Chrysochraon dispar		KW	tz
Klappersprinkhaan	Psophus stridulus		VN	TZ
Kleine wrattenbijter	Gampsocleis glabra		EB	TZ
Locomotiefje	Chorthippus apricarius		GE	Z
Moerassprinkhaan	Stethophyma grossum		KW	tz
Rosse sprinkhaan	Gomphocerippus rufus		GE	Z
Sikkelsprinkhaan	Phaneroptera falcata		GE	Z
Steppesprinkhaan	Chorthippus vagans		GE	Z
Veenmol	Gryllotalpa gryllotalpa	i	KW	itz
Veldkrekel	Gryllus campestris		BE	Tz
Weidesprinkhaan	Chorthippus dorsatus		GE	Z
Wrattenbijter	Decticus verrucivorus		EB	TZ
Zadelsprinkhaan	Ephippiger ephippiger ssp. vitium		BE	Tz
Zoemertje	Stenobothrus lineatus		KW	Tz
Zompsprinkhaan	Chorthippus montanus		KW	tz

Steenvliegen

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

	Amphinemura standfussi				KW	tz
	Amphinemura sulcicollis				KW	tz
	Euleuctra geniculata				VN	TZ
	Isogenus nubecula				VN	TZ
	Isoperla grammatica				VN	TZ
	Isoptena serricornis				VN	TZ
	Leuctra fusca				VN	TZ
	Leuctra nigra				EB	TZ
	Marthamea selysii				VN	TZ
	Nemoura avicularis				KW	tZ
	Nemoura cambrica				KW	tz
	Nemoura dubitans				BE	tZ
	Nemoura marginata				KW	tZ
	Nemurella pictetii				KW	tz
	Perlodes microcephala				KW	tZ
	Protonemura meyeri				GE	Z
	Protonemura nitida				VN	TZ
	Taeniopteryx nebulosa				VN	TZ
	Xanthoperla apicalis				VN	TZ

Dragonflies

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

Bandheidelibel	Sympetrum pedemontanum				GE	Z
Beekoeverlibel	Orthetrum coerulescens ssp. coerulescens			i	KW	itz
Beekrombout	Gomphus vulgatissimus			i	BE	iTz
Bosbeekjuffer	Calopteryx virgo ssp. virgo				BE	Tz
Bruine korenbout	Libellula fulva			i	KW	itz
Bruine winterjuffer	Sympecma fusca				BE	Tz
Donkere waterjuffer	Coenagrion armatum				VN[4]	TZ
Dwergjuffer	Nehalennia speciosa				VN	TZ
Gaffellibel	Ophiogomphus cecilia		HR2/4		EB	ITZ
Gevlekte glanslibel	Somatochlora flavomaculata				EB	TZ
Gevlekte witsnuitlibel	Leucorrhinia pectoralis		HR2/4		BE	ITz
Gewone bronlibel	Cordulegaster boltonii ssp. boltonii				BE	TZ
Glassnijder	Brachytron pratense			i	KW	itz
Groene glazenmaker	Aeshna viridis	LR(nt)	HR4		BE	ITz
Hoogveenglanslibel	Somatochlora arctica				BE	TZ
Kempense heidelibel	Sympetrum depressiusculum				GE	Z
Koraaljuffer	Ceriagrion tenellum ssp. tenellum			i	TNB	iz
Mercuurwaterjuffer	Coenagrion mercuriale ssp. mercuriale				VN	TZ
Noordse glazenmaker	Aeshna subarctica ssp. elisabethae				BE	TZ
Noordse winterjuffer	Sympecma annulata ssp. braueri		HR4		EB	ITZ
Oostelijke witsnuitlibel	Leucorrhinia albifrons		HR4		EB	ITZ
Plasrombout	Gomphus pulchellus			i	TNB	iz
Rivierrombout	Gomphus flavipes ssp. flavipes				VN[5]	TZ
Sierlijke witsnuitlibel	Leucorrhinia caudalis				VN	TZ
Speerwaterjuffer	Coenagrion hastulatum				EB	TZ

[4] In 1999 teruggevonden.
[5] Sinds 1996 weer gevestigd langs de grote rivieren.

Tengere pantserjuffer	Lestes virens ssp. vestalis	KW	tz
Venwitsnuitlibel	Leucorrhinia dubia ssp. dubia	KW	tz
Vroege glazenmaker	Aeshna isosceles ssp. isosceles	KW	Tz
Zuidelijke oeverlibel	Orthetrum brunneum	GE	Z

Haften

Populatieomvang van sleutel- en lokale populatie: 500 respectievelijk 50 RE.

	Ametropus fragilis	VN	TZ
	Baetis buceratus	GE	Z
	Baetis digitatus	GE	Z
	Baetis lutheri	GE	Z
	Baetis muticus	GE	Z
	Baetis niger	GE	Z
	Baetis tracheatus	GE	Z
	Brachycercus harrisella	GE	Z
	Caenis lactea	GE	Z
	Caenis rivulorum	GE	Z
	Centroptilum pennulatum	GE	Z
	Choroterpes picteti	VN	TZ
	Ecdyonurus affinis	VN	TZ
	Ecdyonurus dispar	VN	TZ
	Ecdyonurus insignis	GE	Z
	Ecdyonurus lateralis	KW	tz
	Ecdyonurus torrentis	GE	Z
	Ecdyonurus venosus	GE	Z
	Ephemera glaucops	EB	TZ
	Ephemera vulgata	KW	tz
	Habroleptoides modesta	VN	TZ
	Habrophlebia lauta	VN	TZ
	Heptagenia coerulans	VN	TZ
	Heptagenia flava	KW	tZ
	Heptagenia fuscogrisea	EB	TZ
	Heptagenia longicauda	EB	TZ
	Heptagenia sulphurea	BE	Tz
	Isonychia ignota	VN	TZ
	Leptophlebia marginata	KW	tz
	Metreletus balcanicus	GE	Z
	Oligoneuriella rhenana	VN	TZ
	Palingenia longicauda	VN	TZ
	Paraleptophlebia cincta	GE	Z
	Paraleptophlebia submarginata	KW	tz
	Potamanthus luteus	VN	TZ
	Siphlonurus aestivalis	VN	TZ

Appendix 2 European plant species list

Species name	Bern Convention	Habitat Directive Annex 2	Habitat Directive Annex 4	Habitat Directive Annex 5	endemic (acc. Flora Europea	IUCN 2000
Abies cephalonica Loudon						LR/nt
Abies nebrodensis (Lojac.) Mattei	x	x			x	CR
Achillea glaberrima Klokov	x				x	
Achillea thracica Velen.	x				x	
Adonis cyllenea Boiss, Heldr. & Orph.	x				x	
Adonis distorta Ten.	x	x			x	
Agrimonia pilosa Ledeb.		x				
Agrostis gracililaxa Franco	x				x	
Aldrovanda vesiculosa L.	x	x				
Alisma wahlenbergii (Holmberg) Juz.	x	x			x	
Allium grosii Font Quer	x	x			x	
Allium regelianum A. Becker	x				x	
Alyssum borzaeanum E.I. Ny r dy	x					
Alyssum pyrenaicum Lapeyr.	x	x			x	
Ammi trifoliatum (H.C. Watson) Trelease	x	x			x	
Anarrhinum longipedicellatum R. Fernandes				x	x	
Anchusa crispa Viv.	x	x			x	
Androcymbium europaeum (Lange) K. Richter	x		x		x	
Androcymbium rechingeri Greuter	x	x				
Androsace cylindrica DC.	x		x		x	
Androsace mathildae Levier	x	x			x	
Androsace pyrenaica Lam.	x	x			x	
Andryala levitomentosa (E.I. Ny r dy) P.D. Sell	x				x	
Anemone uralensis Fischer ex DC.	x				x	
Angelica heterocarpa Lloyd	x	x			x	
Angelica palustris (Besser) Hoffm.	x	x				
Anthemis glaberrima (Rech. fil.) W. Greuter	x	x			x	
Anthemis trotzkiana Claus ex Bunge	x					
Antirrhinum charidemi Lange	x	x			x	
Antirrhinum lopesianum Rothm.			x			
Apium repens (Jacq.) Lag.	x	x				
Aquilegia alpina L.			x		x	
Aquilegia bertolonii Schott	x	x			x	
Aquilegia kitaibelii Schott	x	x				
Arabis sadina (Samp.) Coutinho		x				
Arceuthobium azoricum Wiens & F.G. Hawksworth		x				
Arctagrostis latifolia (R. Br.) Griseb.		x				
Arctophila fulva (Trin.) N.J. Andersson		x				
Arenaria humifusa Wahlenb.		x				
Arenaria nevadensis Boiss. & Reuter	x	x			x	
Arenaria provincialis Chater & Halliday	x	x			x	
Armeria berlengensis Daveau		x			x	
Armeria littoralis Willd.		x			x	
Armeria pseudarmeria (Murray) Mansfeld	x	x			x	
Armeria rouyana Daveau	x	x			x	

Species name	Bern Convention	Habitat Directive Annex 2	Habitat Directive Annex 4	Habitat Directive Annex 5	endemic (acc. Flora Europea	IUCN 2000
Armeria soleirolii (Duby) Godron	x	x			x	
Armeria velutina Welw. ex Boiss. & Reuter	x	x			x	
Armoracia macrocarpa (Waldst. & Kit.)	x				x	
Arnica montana L.				x	x	
Artemisia eriantha Ten.				x	x	
Artemisia genipi Weber				x	x	
Artemisia granatensis Boiss.	x	x			x	
Artemisia insipida Vill.	x				x	
Artemisia laciniata Willd.	x	x				
Artemisia oelandica (Besser) Komarov		x			x	
Artemisia pancicii (Janka) Ronniger	x	x				
Asphodelus bento-rainhae P. Silva	x	x			x	
Asplenium azoricum Lovis, Rasbach & Reichstein	x					
Asplenium hemionitis L.	x		x			
Asplenium jahandiezii (Litard.) Rouy	x	x			x	
Aster pyrenaeus Desf. ex DC.	x	x			x	
Aster sibiricus L.	x					
Astragalus algarbiensis Cosson ex Bunge	x	x			x	
Astragalus centralpinus Br.-Bl.	x	x			x	
Astragalus maritimus Moris	x	x				
Astragalus peterfii J v.	x				x	
Astragalus physocalyx Fischer	x				x	
Astragalus pseudopurpureus Gusuleac	x					
Astragalus setosulus Gontsch.	x				x	
Astragalus tanaiticus C. Koch	x				x	
Astragalus tremolsianus Pau	x	x			x	
Astragalus verrucosus Moris	x	x				
Astragalus wolgensis Bunge	x					
Athamanta cortiana Ferrarini	x	x			x	
Atropa baetica Willk.	x	x				
Aurinia uechtritziana (Bornm.) Cullen & T. Dudley	x					
Avenula hackelii (Henriq.) J. Holub	x	x			x	
Azorina vidalii (H.C. Watson) Feer	x	x				
Bassia saxicola (Guss.) A. J. Scott	x	x				
Bellevalia hackelii Freyn			x		x	
Bellis azorica Hochst.	x				x	
Beta adanensis PamukÎ. ex Aellen	x					
Betula oycoviensis Besser						VU
Betula pendula Roth						EN
Biscutella neustriaca Bonnet	x	x			x	
Biscutella vincentina (Samp.) Rothm. ex Guinea		x			x	
Boleum asperum (Pers.) Desv.	x	x			x	
Borderea chouardii (Gaussen) Heslot	x	x			x	
Botrychium matricariifolium (Retz.) Braun ex Koch	x					
Botrychium multifidum (S.G. Gmelin) Rupr.	x					
Botrychium simplex E. Hitchc.	x	x				
Brassica glabrescens Poldini	x	x				
Brassica insularis Moris	x	x			x	
Brassica macrocarpa Guss.	x	x			x	

Species name	**Bern Convention**	**Habitat Directive Annex 2**	**Habitat Directive Annex 4**	**Habitat Directive Annex 5**	**endemic (acc. Flora Europea**	**IUCN 2000**
Brassica oleracea L.	x				x	
Braya linearis Rouy		x				
Braya purpurascens (R. Br.) Bunge	x					
Bromus bromoideus (Lej.) Cr''pin	x					
Bromus grossus Desf. ex DC.	x	x			x	
Bromus interruptus (Hackel) Druce	x				x	
Bromus moesiacus Velen.	x				x	
Bupleurum capillare Boiss. & Heldr.	x	x				
Bupleurum dianthifolium Guss.	x					
Calamagrostis chalybaea (Laest.) Fries		x				
Caldesia parnassifolia (L.) Parl.	x	x				
Calypso bulbosa (L.) Oakes		x				
Campanula gelida Kovanda	x					
Campanula lanata Friv.	x				x	
Campanula morettiana Reichenb.	x		x		x	
Campanula romanica Savul.	x				x	
Campanula sabatia De Not.	x	x			x	
Carduus myriacanthus Salzm. ex DC.	x	x				
Carex acuta L.		x				
Carex holostoma Drejer		x				
Carex secalina Willd. ex Wahlenb.	x					
Carlina diae (Rech. fil.) Meusel & K''stner	x				x	
Carlina onopordifolia Besser ex Szafer, Kulcz. & Pawl.	x					
Centaurea balearica Rodr.	x	x			x	
Centaurea corymbosa Pourret	x	x			x	
Centaurea fraylensis Schultz Bip. ex Nyman		x			x	
Centaurea hermannii F. Hermann	x					
Centaurea horrida Badaro	x	x			x	
Centaurea jankae Brandza	x				x	
Centaurea kalambakensis Freyn & Sint.	x	x			x	
Centaurea kartschiana Scop.	x	x			x	
Centaurea lactiflora Hal csy	x	x			x	
Centaurea niederi Heldr.	x	x			x	
Centaurea peucedanifolia Boiss. & Orph.	x	x			x	
Centaurea pontica Prodan & E.I. Ny r dy	x				x	
Centaurea rothmalerana (J. ArSnes) Dost l		x			x	
Centaurium rigualii Esteve	x	x			x	
Centranthus trinervis (Viv.) B''guinot	x				x	
Cephalanthera cucullata Boiss. & Heldr.	x	x				
Cerastium alsinifolium Tausch	x				x	
Cerastium azoricum Hochst. ex Seub.	x					
Chaerophyllum azoricum Trelease	x	x				
Cinna latifolia (Trev.) Griseb.		x				
Cistus palhinhae Ingram		x			x	
Cochlearia polonica A. Fr''hlich	x				x	
Coincya rupestris Porta & Rigo ex Rouy	x	x				
Colchicum arenarium Waldst. & Kit.	x				x	
Colchicum corsicum Baker	x		x		x	
Colchicum cousturieri Greuter	x		x			

Species name	Bern Convention	Habitat Directive Annex 2	Habitat Directive Annex 4	Habitat Directive Annex 5	endemic (acc. Flora Europea	IUCN 2000
Colchicum davidovii Stefanov	x					
Colchicum fominii Bordzil.	x					
Colchicum micranthum Boiss.	x					
Coleanthus subtilis (Tratt.) Seidl	x	x				
Comperia comperiana (Steven) Ascherson & Graebner	x					
Convolvulus argyrothamnus Greuter	x	x				
Coronopus navasii Pau	x	x				
Cotoneaster granatensis Boiss.					x	LR/cd
Crambe koktebelica (Junge) N. Busch	x					
Crambe tataria Sebe½k	x					
Crepis crocifolia Boiss. & Heldr.	x	x			x	
Crepis purpurea (Willd.) Bieb.	x					
Crocus etruscus Parl.	x		x		x	
Crocus robertianus C.D. Brickell	x				x	
Culcita macrocarpa C. Presl	x	x				
Cupressus sempervirens L.						LR/nt
Cyclamen coum Miller	x					
Cymodocea nodosa (Ucria) Ascherson	x					
Cynoglossum sphacioticum Boiss. & Heldr.		x			x	
Cypripedium calceolus L.	x	x				
Cytisus aeolicus Guss. ex Lindley	x	x			x	
Daboecia azorica Tutin & E.F. Warburg	x				x	
Daphne arbuscula Celak.	x					
Daphne petraea Leybold	x	x			x	
Daphne rodriguezii Texidor	x	x			x	
Dendranthema zawadskii (Herbich) Tzvelev	x					
Dianthus hypanicus Andrz.	x				x	
Dianthus laricifolius Boiss. & Reuter		x			x	
Dianthus nitidus Waldst. & Kit.	x				x	
Dianthus rupicola Biv.	x	x				
Dianthus serotinus Waldst. & Kit.	x				x	
Dianthus urumoffii Stoj. & Acht.	x				x	
Diplazium sibiricum (Turcz. ex G. Kunze) Kurata		x				
Diplotaxis ibicensis (Pau) G½mez-Campo	x	x				
Diplotaxis siettiana Maire	x	x				
Diplotaxis vicentina (Coutinho) Rothm.		x				
Draba cinerea Adams		x				
Draba dorneri Heuffel	x					
Draba glabella Pursh		x				
Dracocephalum austriacum L.	x	x				
Dracocephalum ruyschiana L.	x					
Dryopteris corleyi Fraser-Jenkins	x	x				
Dryopteris fragrans (L.) Schott		x				
Echium candicans L. fil.		x				
Eleocharis carniolica Koch	x	x				
Erica scoparia L.						LR/cd
Erigeron frigidus Boiss. ex DC.	x	x			x	
Erodium astragaloides Boiss. & Reuter	x	x			x	
Erodium chrysanthum L''H''r. ex DC.	x				x	

Species name	Bern Convention	Habitat Directive Annex 2	Habitat Directive Annex 4	Habitat Directive Annex 5	endemic (acc. Flora Europea	IUCN 2000
Erodium rupicola Boiss.	x	x			x	
Erucastrum palustre (Pirona) Vis.	x	x			x	
Eryngium alpinum L.	x	x			x	
Eryngium viviparum Gay	x	x			x	
Erysimum hungaricum Zapal.	x					
Euphorbia nevadensis Boiss. & Reuter	x		x		x	
Euphorbia stygiana H.C. Watson	x	x			x	
Euphorbia transtagana Boiss.		x			x	
Euphrasia azorica H.C. Watson	x	x			x	
Euphrasia grandiflora Hochst.	x	x			x	
Euphrasia marchesettii Wettst.	x	x			x	
Euphrasia mendoncae Samp.				x		
Ferula orientalis L.	x					
Ferula sadleriana Ledeb.	x					
Festuca brigantina (Markgr.-Dannenb.) Markgr.-Dannenb.		x			x	
Festuca elegans Boiss.		x				
Festuca henriquesii Hackel		x			x	
Frangula azorica Grubov	x	x				LR/nt
Fritillaria conica Boiss.	x		x		x	
Fritillaria drenovskii Degen & Stoj.	x		x		x	
Fritillaria epirotica Turrill ex Rix	x				x	
Fritillaria euboeica Rix	x				x	
Fritillaria graeca Boiss. & Spruner	x				x	
Fritillaria gussichiae (Degen & D"rfler) Rix	x		x		x	
Fritillaria obliqua Ker-Gawler	x		x		x	
Fritillaria orientalis Adams	x					
Fritillaria rhodocanakis Orph. ex Baker	x		x		x	
Fritillaria tuntasia Heldr. ex Hal csy	x				x	
Galanthus nivalis L.				x	x	
Galium cracoviense Ehrend.	x				x	
Galium litorale Guss.	x	x			x	
Galium moldavicum (Dobrescu) Franco	x				x	
Galium rhodopeum Velen.	x				x	
Galium viridiflorum Boiss. & Reuter	x	x			x	
Gaudinia hispanica Stace & Tutin	x	x			x	
Genista dorycnifolia Font Quer	x	x			x	
Genista holopetala (Fleischm. ex Koch) Bald.	x	x			x	
Genista tinctoria L.	x					
Gentiana ligustica R. de Vilmorin & Chopinet	x	x			x	
Gentiana lutea L.				x	x	
Gentianella anglica (Pugsley) E.F. Warburg	x	x			x	
Geum bulgaricum Pancic	x				x	
Globularia stygia Orph. ex Boiss.	x	x			x	
Gypsophila papillosa Porta	x	x			x	
Haberlea rhodopensis Friv.	x				x	
Halimium verticillatum (Brot.) Sennen		x			x	
Hedysarum razoumowianum Helm & Fischer ex DC.	x					
Helianthemum caput-felis Boiss.	x	x				

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Helichrysum sibthorpii Rouy	x		x		x	
Herniaria algarvica Chaudhri	x	x				
Herniaria maritima Link	x	x			x	
Hippuris tetraphylla L. fil.		x				
Hyacinthoides vicentina (Hoffmanns & Link)		x				
Hymenostemma pseudanthemis (G. Kunze) Willk.	x	x			x	
Hypericum aciferum (W. Greuter) N.K.B. Robson	x	x			x	
Ilex perado Aiton						LR/nt
Iris boissieri Henriq.			x		x	
Iris lusitanica Ker-Gawler				x		
Iris marsica I. Ricci & Colasante	x				x	
Isoetes azorica Durieu ex Milde	x	x			x	
Isoetes boryana Durieu	x	x			x	
Isoetes malinverniana Cesati & De Not.	x	x			x	
Jankaea heldreichii (Boiss.) Boiss.	x		x		x	
Jasione lusitanica A. DC.	x	x			x	
Jonopsidium acaule (Desf.) Reichenb.		x				
Jonopsidium savianum (Caruel) Ball ex Arcangeli		x				
Juncus valvatus Link		x				
Juniperus brevifolia (Seub.) Antoine	x				x	EN
Jurinea cyanoides (L.) Reichenb.	x	x				
Jurinea fontqueri Cuatrec.	x	x			x	
Kosteletzkya pentacarpos (L.) Ledeb.	x	x				
Lactuca watsoniana Trelease	x	x			x	
Lamyropsis cynaroides (Lam.) Dittrich	x					
Lamyropsis microcephala (Moris)		x			x	
Larix decidua Miller						VU
Laserpitium longiradium Boiss.	x	x			x	
Laurus azorica (Seub.) Franco						LR/nt
Leontodon boryi Boiss. ex DC.	x	x			x	
Leontodon duboisii Sennen ex Widder	x				x	
Leontodon microcephalus (Boiss. ex DC.) Boiss.	x	x			x	
Leontodon siculus (Guss.) Finch & P.D. Sell	x	x			x	
Leucojum nicaeense Ardoino	x	x			x	
Leuzea centauroides (L.) J. Holub		x			x	
Leuzea longifolia Hoffmanns. & Link		x			x	
Leuzea rhaponticoides Graells				x	x	
Ligularia sibirica (L.) Cass.	x	x				
Lilium jankae A. Kerner	x					
Lilium rhodopaeum Delip.	x				x	
Linaria algarviana Chav.	x	x			x	
Linaria ficalhoana Rouy	x	x			x	
Linaria flava (Poiret) Desf.	x	x				
Linaria hellenica Turrill	x	x			x	
Linaria loeselii Schweigger	x				x	
Linaria ricardoi Coutinho	x	x			x	
Linaria tonzigii Lona		x			x	
Lindernia procumbens (Krocker) Philcox	x		x			
Linum dolomiticum Borb s	x					

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Linum maritimum L.		x				
Liparis loeselii (L.) L.C.M. Richard	x	x				
Lithodora nitida (Ern) R. Fernandes	x	x			x	
Lotus azoricus P.W. Ball	x	x			x	
Luronium natans (L.) Rafin.	x	x			x	
Luzula arctica Blytt		x				
Lycopodium annotinum L.				x		
Lycopodium clavatum L.				x		
Lysimachia minoricensis Rodr.	x					
Lythrum flexuosum Lag.	x	x			x	
Lythrum thesioides Bieb.	x					
Mandragora autumnalis Bertol.			x			
Mandragora officinarum L.	x					
Marsilea azorica Launert & Paiva	x	x				
Marsilea batardae Launert	x	x				
Marsilea quadrifolia L.	x	x				
Marsilea strigosa Willd.	x	x				
Melanoselinum decipiens (Schrader & Wendl.)		x				
Microcnemum coralloides (Loscos & Pardo) Buen	x					
Micromeria taygetea P.H. Davis	x	x			x	
Moehringia hypanica Grinj & Klokov	x					
Moehringia jankae Griseb. ex Janka	x				x	
Moehringia lateriflora (L.) Fenzl		x				
Moehringia tejedensis Huter, Porta & Rigo	x		x			
Moehringia tommasinii Marchesetti	x	x			x	
Murbeckiella sousae Rothm.	x		x		x	
Muscari gussonei (Parl.) Tod.	x	x			x	
Myosotis azorica H.C. Watson	x	x			x	
Myosotis lusitanica Schuster		x				
Myosotis maritima Hochst.	x	x				
Myosotis rehsteineri Wartm.	x	x				
Myosotis scorpioides L.	x					
Najas flexilis (Willd.) Rostk. & W.L.E. Schmidt	x	x				
Najas tenuissima (A. Braun) Magnus	x	x			x	
Narcissus asturiensis (Jordan) Pugsley		x			x	
Narcissus bulbocodium L.				x		
Narcissus calcicola MendonÎa		x			x	
Narcissus cyclamineus DC.		x			x	
Narcissus fernandesii G. Pedro		x				
Narcissus humilis (Cav.) Traub		x				
Narcissus longispathus Pugsley	x		x		x	
Narcissus scaberulus Henriq.	x	x			x	
Narcissus triandrus L.	x		x		x	
Narcissus viridiflorus Schousboe	x	x			x	
Naufraga balearica Constance & Cannon	x	x			x	
Nepeta dirphya (Boiss.) Heldr. ex Hal csy	x	x			x	
Nepeta sphaciotica P.H. Davis		x				
Odontites granatensis Boiss.	x	x			x	
Oenanthe conioides Lange	x	x				

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Olea europaea L.						LR/nt
Omphalodes kuzinskyanae Willk.	x	x				
Omphalodes littoralis Lehm.	x	x			x	
Ononis maweana Ball	x	x				
Onosma polyphylla Ledeb.	x					
Onosma propontica Aznav.	x					
Onosma tornensis J v.	x				x	
Ophioglossum polyphyllum A. Braun	x	x				
Ophrys argolica Fleischm.	x		x		x	
Ophrys lunulata Parl.	x	x			x	
Orchis punctulata Steven ex Lindley	x					
Origanum dictamnus L.	x	x			x	
Origanum scabrum Boiss. & Heldr.	x				x	
Ornithogalum reverchonii Lange	x		x			
Paeonia cambessedesii (Willk.) Willk.	x	x			x	
Paeonia parnassica Tzanoudakis	x	x				
Paeonia tenuifolia L.	x					
Papaver laestadianum (Nordh.) Nordh.		x			x	
Papaver lapponicum (Tolm.) Nordh.	x					
Papaver radicatum Rottb.		x			x	
Pedicularis sudetica Willd.	x					
Persea indica (L.) Sprengel						LR/cd
Petagnia saniculifolia Guss.	x	x			x	
Petrocoptis grandiflora Rothm.	x	x			x	
Petrocoptis pardoi Pau	x	x			x	
Petrocoptis pseudoviscosa Fern ndez Casas	x	x				
Phoenix theophrasti Greuter	x	x			x	LR/nt
Physoplexis comosa (L.) Schur	x		x		x	
Picconia azorica (Tutin) Knobl.	x	x			x	EN
Picea omorika (Pancic) Purkyne					x	VU
Picris willkommii (Schultz Bip.) Nyman	x		x		x	
Pilularia minuta Durieu ex A. Braun	x					
Pinguicula nevadensis (H. Lindb.) Casper	x	x			x	
Pinus nigra Arnold						VU
Pinus peuce Griseb.					x	LR/nt
Poa granitica Br.-Bl.	x				x	
Poa laxa Haenke	x				x	
Polemonium boreale Adams	x					
Polygonum foliosum H. Lindb.		x				
Posidonia oceanica (L.) Delile	x					
Potentilla delphinensis Gren. & Godron	x	x			x	
Potentilla emilii-popii E.I. Ny r dy	x					
Potentilla silesiaca Uechtr.	x					
Primula apennina Widmer	x	x			x	
Primula deorum Velen.	x				x	
Primula egaliksensis Wormsk.	x					
Primula frondosa Janka	x				x	
Primula glaucescens Moretti	x		x		x	
Primula nutans Georgi		x				

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Primula palinuri Petagna	x	x			x	
Primula scandinavica Bruun		x			x	
Primula spectabilis Tratt.	x		x		x	
Prunus lusitanica L.						EN
Prunus ramburii Boiss.					x	VU
Pseudarrhenatherum pallens (Link) J. Holub		x			x	
Puccinellia phryganodes (Trin.) Scribner & Merr.		x				
Pulsatilla patens (L.) Miller	x	x				
Quercus cerrioides Willk. & Costa						LR/cd
Quercus ilex L.						LR/nt
Quercus petraea (Mattuschka) Liebl.						LR/cd
Ramonda serbica Pancic	x		x		x	
Ranunculus fontanus C. Presl	x					
Ranunculus lapponicus L.		x				
Ranunculus weyleri MarSs	x	x			x	
Reseda decursiva ForskÅl	x	x				
Rhazya orientalis (Decne) A. DC.	x					
Rheum rhaponticum L.	x				x	
Ribes sardoum U. Martelli	x	x			x	
Rosmarinus eriocalix Jordan & Fourr.	x		x			
Rouya polygama (Desf.) Coincy	x	x				
Rumex azoricus Rech. fil.	x	x			x	
Rumex rupestris Le Gall	x	x				
Rupicapnos africana (Lam.) Pomel	x					
Ruscus aculeatus L.				x		
Salicornia veneta Pignatti & Lausi	x	x				
Salix salviifolia Brot.		x				
Salix tarraconensis Pau					x	CR
Salvinia natans (L.) All.	x					
Sanicula azorica Guthnick ex Seub.	x	x			x	
Santolina elegans Boiss. ex DC.	x		x		x	
Saxifraga berica (B"guinot) D.A. Webb	x				x	
Saxifraga cintrana Kuzinsky ex Willk.	x		x		x	
Saxifraga florulenta Moretti	x	x			x	
Saxifraga hirculus L.	x	x				
Saxifraga osloensis Knaben		x			x	
Saxifraga presolanensis Engler	x		x		x	
Saxifraga tombeanensis Boiss. ex Engler	x	x			x	
Saxifraga valdensis DC.	x		x		x	
Saxifraga vayredana Luizet	x		x		x	
Scabiosa nitens Roemer & Schultes	x	x			x	
Schivereckia podolica (Besser) Andrz.	x				x	
Scilla beirana Samp.			x		x	
Scilla odorata Link	x		x		x	
Scrophularia sublyrata Brot.				x	x	
Senecio elodes Boiss. ex DC.	x	x			x	
Senecio nevadensis Boiss. & Reuter	x	x			x	
Serratula tanaitica Smirnov	x					
Seseli intricatum Boiss.	x	x			x	

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Sibthorpia peregrina L.		x				
Sideritis javalambrensis Pau	x	x			x	
Sideritis serrata Cav. ex Lag.	x	x				
Silene cretacea Fischer ex Sprengel	x				x	
Silene discolor Sm.	x					
Silene haussknechtii Heldr. ex Hausskn.	x					
Silene hicesiae Brullo & Signorello		x				
Silene hifacensis Rouy ex Willk.	x	x			x	
Silene holzmannii Heldr. ex Boiss.	x	x			x	
Silene longicilia (Brot.) Otth		x				
Silene mariana Pau	x	x				
Silene orphanidis Boiss.	x	x			x	
Silene rothmaleri P. Silva	x	x				
Silene sangaria Coode & Cullen	x					
Silene velutina Pourret ex Loisel.	x	x			x	
Sisymbrium cavanillesianum	x					
Sisymbrium confertum Steven ex Turcz.	x					
Sisymbrium supinum L.	x	x				
Smilax canariensis Brouss. ex Willd.	x					
Soldanella villosa Darracq	x	x				
Solenanthus albanicus (Degen & Bald.)	x					
Sorbus anglica Hedl.						VU
Sorbus arranensis Hedl.						VU
Sorbus austriaca (G. Beck) Hedl.						LR/cd
Sorbus badensis D?ll						VU
Sorbus bristoliensis Wilmott						EN
Sorbus decipiens (Bechst.) Irmisch						CR
Sorbus eminens E.F. Warburg						VU
Sorbus franconica Bornm. ex D?ll						VU
Sorbus heilingensis D?ll						VU
Sorbus lancastriensis E.F. Warburg						LR/nt
Sorbus leptophylla E.F. Warburg						CR
Sorbus leyana Wilmott						CR
Sorbus multicrenata Bornm. ex D?ll						EN
Sorbus parumlobata Irmisch ex D?ll						CR
Sorbus pseudofennica E.F. Warburg						VU
Sorbus pseudothuringiaca D?ll						VU
Sorbus subcordata Bornm. ex D?ll						VU
Sorbus subcuneata Wilmott						VU
Sorbus teodorii Liljefors		x				
Sorbus velebitica K rp ti						DD
Sorbus vexans E.F. Warburg						VU
Sorbus wilmottiana E.F. Warburg						CR
Spergularia azorica (Kindb.) Lebel		x			x	
Spiranthes aestivalis (Poiret) L.C.M. Richard	x		x			
Steveniella satyrioides (Steven) Schlechter	x					
Stipa austroitalica Martinovsky	x	x				
Stipa bavarica Martinovsky & H. Scholz	x	x			x	
Stipa danubialis Dihoru & Roman	x				x	

Species name	Bern Convention	Habitat Directive Annex 2	Habitat Directive Annex 4	Habitat Directive Annex 5	endemic (acc. Flora Europea	IUCN 2000
Stipa styriaca Martinovsky	x	x			x	
Stipa syreistchikovii Smirnov	x					
Symphytum cycladense Pawl.	x	x				
Syringa josikaea Jacq. fil. ex Reichenb.	x				x	
Tetraclinis articulata (Vahl) Masters						LR/nt
Teucrium charidemi Sandwith	x		x		x	
Teucrium lamifolium D''Urv.	x					
Teucrium turredanum Losa & Rivas Goday	x	x			x	
Thesium ebracteatum Hayne	x	x				
Thlaspi jankae A. Kerner	x				x	
Thorella verticillatinundata (Thore) Briq.	x	x			x	
Thymelaea broterana Coutinho	x		x		x	
Thymus aznavourii Velen.	x				x	
Thymus camphoratus Hoffmanns. & Link	x	x			x	
Thymus capitatus (L.) Hoffmanns. & Link			x			
Thymus carnosus Boiss.	x	x			x	
Thymus cephalotos L.	x	x				
Trachelium asperuloides Boiss. & Orph.	x					
Trapa natans L.	x					
Trichomanes speciosum Willd.	x	x				
Trifolium saxatile All.	x	x			x	
Trisetum subalpestre (Hartman) Neuman	x	x				
Tuberaria major (Willk.) P. Silva & Rozeira	x	x			x	
Tulipa goulimyi Sealy & Turrill	x				x	
Tulipa hungarica Borb s	x					
Tulipa praecox Ten.	x					
Typha minima Funck	x					
Typha shuttleworthii Koch & Sonder	x					
Ulex densus Welw. ex Webb				x	x	
Vaccinium arctostaphylos L.	x					
Verbascum cylleneum (Boiss. & Heldr.) O. Kuntze	x					
Verbascum haussknechtii Heldr. ex Hausskn.	x					
Verbascum litigiosum Samp.		x			x	
Verbascum purpureum (Janka) Huber-Morath	x				x	
Veronica euxina Turrill	x					
Veronica micrantha Hoffmanns. & Link		x			x	
Veronica turrilliana Stoj. & Stefanov	x				x	
Vicia bifoliolata Rodr.	x	x			x	
Vicia dennesiana H.C. Watson	x	x				
Vincetoxicum pannonicum (Borhidi) J. Holub	x				x	
Viola athois W. Becker	x		x		x	
Viola cazorlensis Gand.	x		x		x	
Viola cryana Gillot	x					
Viola delphinantha Boiss.	x		x		x	
Viola hispida Lam.	x	x			x	
Viola jaubertiana MarSs & Vigineix	x	x			x	
Wagenitzia lancifolia (Sieber ex Sprengel) Dost l	x		x		x	
Woodwardia radicans (L.) Sm.	x	x				
Zelkova abelicea (Lam.) Boiss.	x	x				VU
Zostera marina L.	x					