Establishment of a National ecological network to conserve biodiversity Pros and cons of ecological corridor

Ecological corridors are a fundamental element in the National ecological network approved by the Grenelle environmental agreement in order to reduce ecosystem damage caused by fragmentation of the natural habitat zones of species. How can their effectiveness be evaluated? This article sums up current knowledge on their pros and cons.

Fragmentation and destruction of habitats due to human activities are considered one of the main causes of biodiversity loss. The reduction in the size of habitat fragments and their increasing isolation decrease, over the long term, the viability of the species populations, due to the reduction or even the halt of population exchanges when discontinuities are created.

To compensate the negative effects of natural-habitat fragmentation, conservation biologists advised increasing connectivity [1] between habitats to maintain and, if possible, improve the viability of target-species populations (Bennett, 2003). Connectivity between habitat patches throughout a landscape has become a major issue for biodiversity conservation. One of the frequently selected options to re-establish connectivity is the creation of corridors [2] between the disconnected habitats. In addition, the value of corridors was underscored recently in light of the ecological consequences of climate change which will inexorably cause geographic shifts in bioclimatic conditions and thus force many species to migrate to maintain favourable life-cycle conditions.

The role of corridors has thus become a topic of active scientific debate and research for over ten years (Beier et Noss, 1998; Bennett, 2003). However, caution is still advised concerning the generalisation of corridors in operational terms because our understanding of the mechanisms behind the role of corridors in the functioning of ecological systems is still incomplete. Further scientific work and recent literature reviews were required to demonstrate an overall positive effect of connectivity on species dispersal (Beier et Noss, 1998; Bennett, 2003; Gilbert-Norton, 2010).

In terms of public decision-making, the assumed positive role of corridors has influenced national and international political agreements for a number of years. The Earth summit on sustainable development in 2002 and the Convention on biological diversity called for conservation efforts in ecological networks and corridors to limit the decline of biodiversity. In the EU, the Member states adopted in 1996 a Pan-European strategy to protect biological and landscape diversity, in which one of the main goals is to create a Pan-European ecological network. In France, pilot projects for ecological networks were launched years ago in certain regions and departments, including Nord Pas-de-Calais, Franche-Comté, Alsace and Isère. Following the Grenelle environmental meetings in 2007, the Ecology ministry designated the improvement in the ecological network as a priority for the National biodiversity strategy and set up an operational committee to determine the practical conditions for the network on the national scale. The wording of commitment no. 73 in the Grenelle agreement, concerning a National ecological network interconnecting the entire country, was "France commits to creating a National ecological network to restore the flows of wild fauna and flora species between zones of high ecological value…."

In this article, we will provide a scientific point of view on ecological corridors and highlight the need to ensure the strong involvement of scientists in setting up the national ecological network and in assessing its effects on species and on biodiversity.

1. All the elements in a landscape that facilitate or limit movements of the individuals of a species determine the "functional connectivity of the landscape". It is necessary to distinguish between "functional or biological connectivity", which depends on the ecological requirements of the species in question, and "structural or spatial connectivity", which simply qualifies the physical links between the elements of a landscape.

2. Generally speaking, the term corridor designates any functional link between ecosystems or between the habitats of a species (or group of interdependent species) that enables its dispersal and migration.

❶ **The National ecological network aims to maintain a good circulation of species and to guarantee the return of ecosystem goods and services.**

The key ecological concepts underlying ecological networks and corridors

The beneficial role attributed to corridors is due in large part to the application of the theory of island biogeography. This ground-breaking theory is based on the study of habitat islands that are favourable to a given community in an unfavourable environment, using actual islands as a model. The number of species on an island results from a dynamic balance between the colonisation and extinction rates. The closer the island is to the mainland, the greater the probability of colonisation by new species because the travel distance is shorter. In this case, the extinction rate of the species on the island is low because individuals from the mainland can reinforce declining populations (rescue effect). In addition, the larger the island, the lower the extinction rate and the more individuals the island can intercept during their dispersal.

There are numerous limits to this theory, i.e. it assumes the situation is in equilibrium, the types of local communities are ignored and the environment is perceived as a uniformly unfavourable context with islands of favourable habitat.

More recently, the theory of metapopulations (Hanski, 1999) presented biological populations not as isolated elements, but as part of a set of subpopulations, more or less isolated geographically, but interconnected by individuals that contribute to maintaining a flow of genes between the various subpopulations of a given species. The exchanges depend on the ability of species to disperse, but also on the landscape structure which is more or less favourable to the movement of individuals.

A metapopulation is therefore a system that persists due to a dynamic balance between local extinctions and immigration of new populations to sites that have become unoccupied (Hanski, 1998). Interruptions in the flow of genes between populations weaken the gene pools of each population, thus making individuals in isolated populations more vulnerable. In addition, an interruption in the flow of individuals may cause certain populations to become extinct when numbers drop and cannot be compensated by external arrivals.

It follows logically from the above that the best means to maintain population viabilities is to encourage migratory flows between habitats. This theory was rapidly linked to the concept of connectivity and served to support the idea of corridors. However, in spite of some convincing results, there is to date no proof that this theory is generally applicable nor that corridors in fact facilitate flows. This lack of proof is largely due to the complexity of the measurements required to validate or invalidate the theory.

Landscape ecology, which came into its own particularly during the 1990s, studies the relations between spatial mosaics of habitats and the functioning of ecological systems, population dynamics and biodiversity in general. The discipline has been the starting point for a great amount of work that has shown the importance of maintaining landscape structures providing connections between natural habitats and correct ecological functioning of the landscape. In landscape ecology, the notion of corridors plays a central role with two other related concepts, patches and the matrix. These are the three primary elements in landscape ecological analysis. However, the "patch-corridor-matrix" model is now losing ground to the "landscape mosaic" model where all landscape elements interact with the living organisms and the landscape is no longer seen in a binary manner (habitat and non-habitat).

Definition, types and ecological roles of corridors

According to the concepts and terminology of landscape ecology, a corridor is a linear landscape element linking habitats (the patches) and that encourages flows between habitats within a generally unfavourable environment (the matrix) (Beier et Noss, 1998). The corridors are very important for the species whose vital habitat is larger than the average patch size or for those whose survival depends on daily or seasonal movements between habitats ("ecological" corridors). On a different temporal scale, the corridors serve for species dispersal and genetic exchanges between populations ("biological" corridors).

In more general terms, corridors can play numerous roles (see figure ❶), that of habitat (permanent or temporary), conduit for species dissemination, filter, barrier, source (individuals exit the corridor) or sink (organisms enter the corridor, but do not survive). Among landscape elements serving as corridors are riparian vegetation, hedge networks, forest edges, grassy strips, roads and other linear infrastructures created by humans. Corridors can have different shapes, i.e. linear, with nodes, with disconnected nodes (stepping stones) or a landscape mosaic (see figure ❷). A corridor can always play a number of roles simultaneously, but for different species. For example, a wooded corridor may be a dispersal conduit for forest species, but a filter for meadow species.

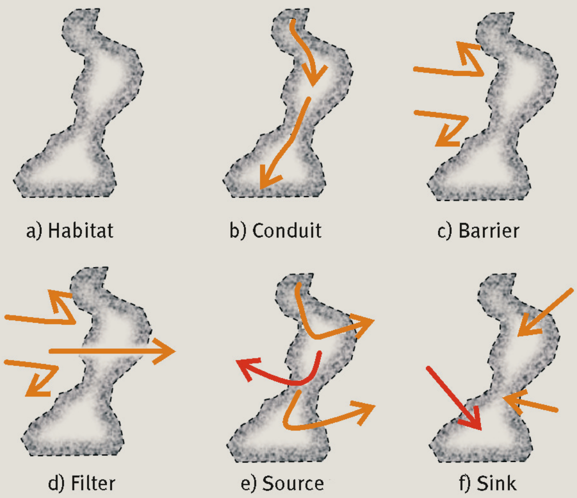
However, the use of corridors as a conservation tool remains fairly controversial because numerous studies have failed to validate the theoretical hypotheses (Beier et Noss, 1998). Their functioning is in fact more complex than the simplified "patch-corridor-matrix" structure. The matrix may be more or less permeable to individuals and its quality may be crucial in increasing or reducing connectivity within a landscape. For example, some species may travel more quickly in relatively unfavourable habitats than in more favourable habitats and as a result the immigration rate between patches may not increase in the presence of corridors. But on the other hand, there is often a risk of higher mortality in the less favourable habitats.

Those promoting corridors argue that they act as conduits, thus facilitating travel by individuals between patches, enabling the flow of genes, reducing fluctuations in population levels and the risks of inbreeding depression, i.e. they decrease the risk of population extinction (see table ❶). A recently published meta-analysis[3] (Gilbert-Norton *et al.*, 2010) shows that a corridor increases individual movements between patches by 50% on average, compared to patches not connected by a corridor. But it also showed that not all taxonomic groups are helped. For example, movements of birds were less favoured than that of invertebrates, nonavian vertebrates and plants. We have summarised the effects of corridors and the roles played for various taxonomic groups (plants, arthropods, birds and micromammals) and indicated the best corridor type and width to fulfil their function (see table ❷).

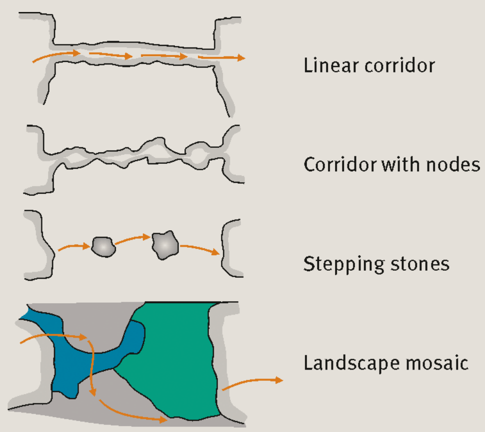
Conversely, corridors may also have negative effects for biodiversity (see table ❶). They may result in loss of alleles in a set of connected patches, increase the risk of predation due to the edges and increase propagation of diseases and invasion by alien species, notably along rivers and roads. They may also act as sinks for certain species. Simulations on the population dynamics of forest ground beetles (Coleoptera, Carabidae) showed that when a forest is significantly fragmented, the presence of hedges (corridors) played an unfavourable role because individuals living in forest patches travelled along the hedges and pass more frequently in the agricultural matrix, where their survival rate is low (Pichancourt *et al.*, 2006). Hedges thus act as drains that draw species to unfavourable habitats.

However, few studies have proven negative effects on the part of corridors built or preserved for conservation purposes (Beier et Noss, 1998). Problems are rather limited to alien or invasive species and artificial corridors such as roads and railroads which are, in general, not the type of corridor that designers wish to create. In addition, it is necessary to contrast the gains and losses in terms of

❶ The six possible ecological roles of corridors.



❷ The different structures of a corridor (according to Bennett, 2003).



3. The results of this meta-analysis were based on 78 experiments drawn 35 scientific studies published between 1988 and 2008, and dealing with amphibians (1 species), birds (7), fish (2), invertebrates (29), mammals (22) and plants (17).

conservation. For example, invasive species have excellent dispersal capabilities and it is not certain that corridors significantly increase their success rate in colonising new habitats. Flag species, on the other hand, often have poor colonisation capabilities and would be the most likely to benefit from corridors. Finally, careful positioning and suitable management of the habitats serving as corridors should compensate any negative effects.

Limits to knowledge and methodological difficulties

Current limits to scientific knowledge mean that implementation of the National ecological network will encounter three difficulties.

- the difficulty to generalise the results obtained for one species or landscape;;
- the cost in time and effort for experiments and monitoring on the landscape scale to demonstrate the functional role of corridors;
- the limits to our practical knowledge on where to install corridors, their shape, structure, width and composition, and on which species or taxa to monitor or encourage.

Concerning generalisation of the obtained results, it is not sufficient to study model species that are highly mobile and thus react rapidly to experiments. It is vital to show that a corridor is effectively used by species sensitive to fragmentation, that do not tolerate habitats highly impacted by human activities and whose population dynamics are limited by their dispersal capacity.

It will continue to be difficult to "demonstrate" the correct functioning of an ecological corridor because numerous criteria must be fulfilled:

- confirm that the species is present in the corridor and moves from one end to the other;
- compare the respective frequencies of movements *via* and outside the corridor;
- prove that movement via the corridor improves the population persistence in the connected patches;
- demonstrate gene flows between populations.

Few studies address the last two criteria because that would require longer population monitoring and analysis of gene flows between patches. Establishment of large study sites requires considerable human and financial resources and also raises a number of methodological problems (Beier et Noss, 1998). In fact, the size of current experimental corridors rarely corresponds to real landscapes in which species disperse (small surfaces, corridors less than 25 metres in width and fairly short, ~ 150 metres). Finally, methods are complex because, in order to limit bias, it is necessary to find landscapes having similar composition and spatial configuration of habitat fragments, but with fragments connected by a corridor in one case and fragments not connected in the other. These difficulties make models and scenarios all the more useful.

Concerning practical installation conditions, we invite readers to consult the document drafted by the Fédération des parcs naturels régionaux de France (Quiblier, 2007), which proposes guidelines to set priorities and determine the target species.

❶ Advantages and disadvantages of ecological corridors

Potential advantages	Potential disadvantages
Increased immigration, which could: • increase or maintain species richness and diversity; • increase the population sizes of particular species; • decrease probability of extinction; • permit species re-establishment; • prevent inbreeding depression / maintain genetic diversity.	Increased immigration, which could: • facilitate the spread of diseases, pests, invasive and alien species; • decrease the level of genetic variation between populations due to outbreeding depression.
Increased foraging area for wide-ranging species	Facilitate spread of fire and other contagious catastrophes
Provide escape cover for movement between patches	Increase exposure to hunters, poachers and predators
Increase accessibility to a mix of habitats	May not function for species not specifically studied
Provide alternative refuge from large disturbances	Cost and possible conflicts with other conservation efforts for threatened species (increase size of habitat patches, improve matrix quality, species translocation)

❷ Effect and function of corridors of different organisms

Groups	Effect	Functions	Type	Width	Remarks
Plants	+ + =	Habitats relais	Dense or open, depending on the species	› 10-20 m	Complex effects depending on vectors and diaspores.
Arthropods	+ + –	Habitat, conduit, sink	Herbaceous (Orthoptera), open ligneous vegetation (butterflies), wooded (forest ground beetles)	› 20-90 m	Notable effect on less mobile species and for highly fragmented habitats. Complex corridors are favourable.
Birds	+ =	Secondary habitat, conduit	Stepping stones		The effects of corridors for birds are variable and not well documented. The stepping-stone structure (patches fairly close to each other forming relays) would appear to be a good option.
Micromammals	++ = –	Conduit, secondary habitat	Dense to semi-open	‹ 10 m	Excessively wide corridors would seem to cause transversal movements that hinder the conduit function. Excessively narrow corridors create risks of high predation. Studies show high presence of predators in corridors (mustelids, cats, foxes, etc.).

Effect : + positive, = neutral, – négative.

Implementation in the National ecological network

We suggest readers first consult the article by Amsallem *et al.* (2010) in this issue (page 34-39) and the two guides published by the operational committee for the National ecological network (COMOP TVB, 2010a et b). The first guide presents the major issues and strategic decisions taken in formulating the national ecological network, the second is more for technicians working for the State services and the regions on drafting the future regional ecological-continuity plans (SRCE).

We highlight here three important points that are not addressed (or very little) in these documents. Given, first of all, the speed with which the National ecological network will be set up and, secondly, the lack of precise scientific knowledge required to provide the persons in charge with practical recommendations, it will be necessary to avoid ecological corridors resulting more from strong political and real-estate pressures than relevant ecological criteria.

First of all, we favour the creation of a close partnership between the scientific community, managers of nature zones and the regional committees in charge of setting up the National ecological network.

Secondly, we wish to insist on the importance of establishing evaluation systems to determine the effectiveness of corridors over the short, mid and long terms, and generally to gain new knowledge on their roles. These evaluation systems must include:

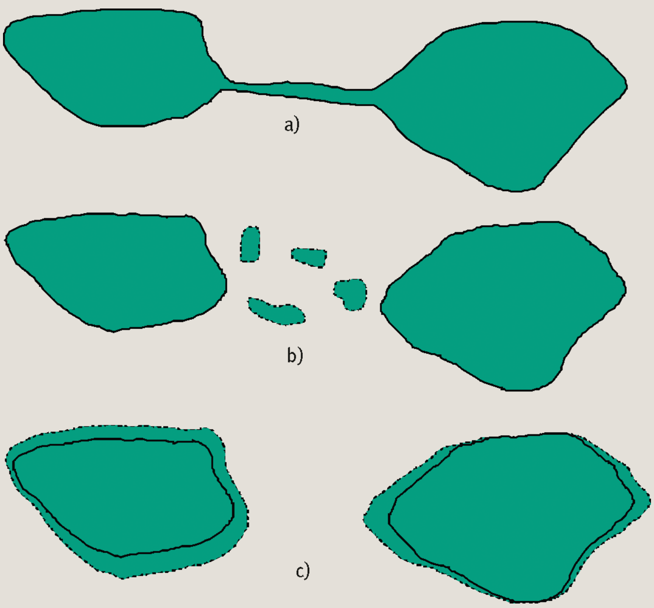
- a comparison between a control and managed landscapes, i.e. between landscapes with connected and non-connected patches;
- an initial biodiversity "status report" on a limited number of target species selected for their high sensitivity to habitat fragmentation;
- a biodiversity monitoring protocol over the short to mid-term, on populations of target species (flows of individuals, monitoring of demographic parameters, gene flows).

Finally, the National ecological network does not consist simply of improving connectivity between habitats. The advantages of new corridors must be compared with those of three other options:

- creating a habitat dispersed throughout the matrix (stepping stones);
- increasing the size of patches, i.e. compensating habitat losses;
- introducing individuals in isolated patches where populations are becoming extinct (see figure ❸).

It is necessary to clearly distinguish between the "corridor" and "patch size" effects because the presence of the corridor also increases the habitat size and thus the population. A number of studies on the effects of fragmentation show that the total quantity of habitats in a landscape is more important than the spatial configuration. What is more, theoretical research based on population-dynamics models taking into account the spatial structure of the patches has shown that an enlarged, non-connected patch produces better results when the patch is big and cut off from the source. This result, which contradicts the expected positive effect of a corridor, indicates that corridors are not always the best method for conservation of fragmented populations.

❸ Other options for conserving biodiversity within the National ecological network.



a) Create a corridor with high habitat quality.

b) Improve matrix quality by creating habitat patches of lesser quality between large patches. Another option not shown here is a consistent improvement in habitat quality throughout the matrix.

c) Increase the size of patches by an amount equivalent to that of the corridor, which in theory is a means to increase the population size and reduce the edge effect.

Conclusion

Research on the role of ecological corridors is recent and though the most recent reviews indicate a generally positive role consistent with ecological theories, they have not yet provided absolute proof on a positive role of connectivity elements in the landscape that is sufficient to compensate the negative effects of habitat fragmentation on biodiversity. The effectiveness of corridors depends on many criteria, i.e. dispersal conditions and species behaviour, corridor characteristics and type of surrounding matrix. However, maintaining and restoring connectivity do not constitute an artificial modification of the landscape, but rather a return to an earlier state in which environments were less degraded and fragmented. The precautionary principle would incite us first to maintain existing corridors. In addition, in light of the ample proof of the detrimental effects of habitat loss on the isolation of populations and communities, compensation of fragmentation is a logical step (Bennett, 2003).

In spite of all the above, it is important to bear in mind that connectivity is not the only solution to fragmentation and degradation of natural habitats. Biodiversity preservation must also be analysed in terms of the quantity and quality of natural habitats, through a reduction in anthropogenic pressures on natural environments, increases in the size of protected zones and improvements in matrix quality. In short, it is necessary to undertake a general, ecological restoration of environments.

The creation of the National ecological network must address biodiversity-conservation issues on the national scale and it is necessary to map the core areas, buffer zones and corridors to be conserved, restored or created. Given that decision-aid tools in this field are still in their very first stages of development, we wish to insist on the points presented below.

- It is better to invest in conserving existing natural corridors than to create new corridors in environments without plant cover. Correlatively, it is not certain that recreating ecological connections in extremely fragmented landscapes will have significant effects.
- Corridor projects must be designed to enable subsequent assessment of their effectiveness.
- Corridor projects must be compared to other conservation options. ■

Authors

Laurent Bergès
Cemagref, centre de Nogent-sur-Vernisson,
UR EFNO, Écosystèmes forestiers,
Domaine des Barres, 45290 Nogent-sur-Vernisson
laurent.berges@cemagref.fr

Philip Roche
Cemagref, centre d'Aix-en-Provence,
UR EMAX, Écosystèmes méditerranéens et risques,
3275 Route de Cézanne, CS 40061,
13182 Aix-en-Provence Cedex 05
philip.roche@cemagref.fr

Catherine Avon
Cemagref, centre de Nogent-sur-Vernisson,
UR EFNO, Écosystèmes forestiers,
Domaine des Barres, 45290 Nogent-sur-Vernisson
catherine.avon@cemagref.fr

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▶ You can consult the bibliography on www.set-revue.fr