CHAPTER 4

ECOLOGICAL NETWORKS, FROM CONCEPT TO IMPLEMENTATION

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Abstract. The conceptual and theoretical core of landscape ecology links natural sciences with related human sciences and human activity with landscape pattern, process and change and its impacts. Generating ecological networks means modeling species and landscape patterns. The concept of ecological networks is especially applicable in highly fragmented landscapes where species behave as metapopulations. Analysis of habitat availability is an important precondition for planning ecological networks. However, also the communication with the stakeholders is crucial when ecological networks have to be realized. As ecological network planning means biodiversity management outside protected nature reserves and parks, it also means confrontation between interests and finding ways for cooperation between all users of the wider landscape.

1. INTRODUCTION

Landscape ecology integrates ecology and geography and in this way it deals with spatial variation in landscapes at a variety of scales. It includes the biophysical and societal causes and consequences of landscape heterogeneity. Above all, it is broadly interdisciplinary. This is surely the case in planning ecological networks.

The planning of ecological networks includes not only the ecological modelling, but also the societal debate on implementation and societal benefits and costs. The conceptual and theoretical core of landscape ecology links therefore natural sciences with related human sciences such as the spatial pattern or structure of landscapes and its relationship with processes in the landscape, the relationship of human activity with landscape pattern, process and change and its impacts.

Large parts of the European landscapes, but also parts of the African, Japanese, Indonesian, Chinese and Andean landscapes have been in traditional agricultural use for centuries. The history of these landscapes is different from natural landscapes. In

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agricultural landscapes the intensity of disturbances is greater; the decisions made by man are the main influence on land use patterns. In the nineteenth century markets often were of local or regional importance. Farmers did sell their products in the region that could be reached with the transport available (Hubert, 1991). In regions such as northern Portugal special regulations existed and still exist to maintain the balance between farmers. At present we live in a world with a world market. Our meat comes from Argentina, cloths from China and cars from Europe or Japan. That also has changed the way we deal with our landscapes and the space that is left for animals.

Land use changes are of all times. Under the influence of changes in food demand, caused by demographic events, the cultivated area of Europe has shown considerable fluctuations (Rabbinge et al., 1996). Periods of expansion and periods of contraction of cultivated area occurred all over the world and during all ages. The idea that we are facing a new period of contraction in Europe is therefore not exceptional and to some extent supported by the characteristics of the present situation of increasing technology and stable or even decreasing population. We see that the world market makes the expansion occur in other parts of the world such as China and Latin America.

We see two trends in the landscape occurring, homogenisation and fragmentation (Jongman, 2002) where homogenisation means that land is becoming more homogeneous, field become larger and forests become larger. Fragmentation means that the land is ever more dissected by infrastructure and urban constructions. The important question that follows from this is how to mitigate its negative effects for biodiversity.

In the last decades landscape ecological principles have become part of biodiversity conservation. Site based nature conservation can only be successful if the conservation sites are huge as it is in Russia. Even then larger carnivores are threatened. Species have especially difficulties to survive in fragmented landscapes. This made nature conservation change from site protection towards conservation of ecological networks including the wider landscape based on principles from population dynamics (McArthur and Wilson, 1967; Opdam, 1991). Nowadays nature reserves and national parks are considered as units within which the biological diversity of species only can be maintained on the long run if they are connected with other larger units (Jongman, 1995).

Development of ecological networks is a process that integrates landscape ecological science and societal processes in the phase of problem statement, modelling and planning. It also integrates disciplines, as it has to deal with ecological, institutional and socio-economic aspects. These interactions are always ongoing and makes the process challenging.

2. ECOLOGICAL NETWORKS: NATURE IN THE WIDER COUNTRYSIDE

If nature cannot survive in land especially set apart and we have to accept, that birds, mammals, insects and plants move through the countryside, then we also have to accept that they need space. In a planned and intensively used land as we have in many parts of the world this means that nature has to be one of the backbones of spatial planning: it makes spatial planning the director of environmental conservation. It means concretely that beside official site protection through national parks and nature reserves multifunctional zones should be developed and maintained: ecological corridors, greenways or landscape linkages that have aesthetic functions, contribute to an attractive living environment, have an educational function, a recreational function and last but not least an ecological function (Jongman, 2004)

Ecological networks are the result of science based nature conservation, of nature conservation planning. Its basis is founded in biogeography, population dynamics, landscape ecology and land use science. The planning process contains ecological elements, but requires also political, land use planning and awareness components. Without the incorporation of these aspects ecological networks cannot survive as a concept and cannot be realised. This means that they should be based on scientifically based models, on tested scenarios and in participative planning procedures.

3. THE MODELLING OF ECOLOGICAL NETWORKS

Natural species can migrate over long distances and they also move through the landscape in search of food, shelter and new breeding sites. They travel at different scale levels constructing their own pathways and their own network. Migrating species are especially vulnerable. They cannot be identified as being present at every moment and they often compete with human land use. In Europe many species are adapted to the cultural landscapes of Europe as accessible and non-hostile land with food and shelter. The role of ecological networks will be to maintain and where needed to restore these functions of the landscape.

An ecological network should be geared towards an ecosystem (forest, marshland, moors) or species. A strategic choice of target species benefits many more species than an arbitrary sole species in the network design. There are focal species that have broad-scale effects on the ecosystem level (Simberloff, 1998; Dale et al., 2000): turnstone species (top predators, like wolf, brown bear, otter) ecological engineers (beaver, red deer) and umbrella species (red deer).

The concept that can be used for assessments in man-dominated landscape in general and for designing ecological networks is the metapopulation concept (Levins, 1970; Opdam, 1988; Hanski and Gilpin, 1997). A metapopulation is a set of populations in a habitat network connected by inter-patch dispersal. A habitat network is a set of habitat patches close enough to have a reasonable level of inter-patch dispersal. Habitat is a species-specific term for the set of conditions a species needs to feed, survive and reproduce.

Several approaches are available with their advantages and drawbacks: (1) an empirical approach (census based) (2) a fully mechanistic approach (PVA model based), (3) a statistical approach (landscape index-based) and (4) a spatial standard based approach that is a mixture of the first three (Verboom and Pouwels, 2004).

In highly fragmented landscapes, the occurrence of a species at a certain moment in time does not necessarily mean that the species is part of a sustainable population. The reason is that metapopulation dynamics, such as local extinctions and recolonization processes are taking place constantly and reduce the value of single observations. In conservation planning for metapopulations of more than one and mostly many species, it would for example not be a sound strategy to conserve all the patches where a species is found at a certain moment in time and neglect others patches. Moreover, what we see as distribution patterns of species is the result of historical developments in land use and populations can be in a process of adapting to the present day landscape. Probably, the populations are lagging behind the landscape changes (Tilman et al., 1994). Therefore ecological networks cannot be based entirely upon species distribution data but have to be based on a more general long-term strategy.

Another method of assessment is using spatially realistic Population Viability Analysis (PVA) to determine the management perspectives for certain species, usually key species, indicator species, or endangered species of specific interest (Lande, 1988; Lankester et al., 1991; Lindenmayer and Possingham, 1994, 1995). As opposed to the distribution data based approach dynamic population processes are taken into account. However, it is time consuming to unravel the life history of species to point out the relevant parameters and find the right values for them. Moreover, such models can hardly be calibrated and/or validated because of their stochastic nature, their long time horizon, and chance fluctuations in real metapopulations and in real landscapes. Because it is so time consuming, such a PVA can be performed for only one or at the most a small number of species (Verboom and Pouwels, 2004).

An approach that that combines the advantages of the above methods without their major drawbacks is based upon Ecologically Scaled Landscape Indices (ESLI, Vos et al., 2001), Landscape Cohesion Assessment (Opdam et al., 2003) and the key patch approach (Verboom et al., 2001). Ecologically scaled landscape indices (ESLI's) take landscape characteristics into account as encountered by the species in the landscapes and it is estimated in carrying capacities. These ESLI's have a greater power for predicting sustainability of populations than distribution statistics and landscape statistics alone (Vos et al., 2001). At the Alterra institute this approach is elaborated under the name LARCH.

In this approach the area or ecosystem is assessed on presence of habitat for the selected target species. Based on the quality and quantity of habitat it is defined what potential populations are, and if these populations can be considered viable. A population is considered sustainable or persistent if the chances of extinction are less than 5 % in 100 years (Shaffer, 1987).

In a the Italian part of the Life-Econet project for Emilia Romagna three ecosystem types were selected, which cover most important natural habitat types in the study area: woodland, wetland, and grassland (Bolck et al., 2004). To assess whether these ecosystem types might function for specific wildlife species, species were selected, which can be considered representative for these ecosystems. The selected species operate at a scale that is appropriate for this landscape, with different dispersal ranges and some also sensitive for barriers. For these species was assessed whether the ecosystem still functions as an ecological network.

It has been verified with the help of the LARCH model what at present the connectivity and fragmentation is in the provinces of Bologna and Modena. The result of the analysis shows that the provinces have a serious fragmentation problem. Obviously, the area remaining with natural habitat (only 5%) is too small for many species present. The natural areas can only partly function as a network: many species suffer from fragmentation. In the scenarios for future development shapes of the new corridors have been included as planned in the scenario (strips of land with edges, trees, grass and little pond; a "generic" project in order to test the possible connectivity of the scenario. One of the main conclusions is that habitat requirements for most selected species are high.

Table 1. Selected species for analysis with LARCH for Emilia Romagna(It); species sensitive for barriers are shaded.

Dispersal capacity Habitat type	Barrier sensitivity	small range (0-10 km)	large range (10-50 km)
Woodland	Sensitive	-	European polecat (Putorius putorius)
	Not sensitive	Red-backed shrike (*Lanius collurio*)	Turtledove (*Streptopelia turtur*)
Wetlands/ marshland	Sensitive	Italian crested newt (*Triturus carniflex*)	-
	Not sensitive	Banded demoiselle (*Calopteryx splendens*)	Bittern (*Botaurus stellaris*)
Grassland	Sensitive	-	-
	Not sensitive	Stonechat (*Saxicola torquata*)	Yellow wagtail (*Motacilla flava*) Quail (*Coturnix coturnix*)

To be effective in conservation planning this ecological knowledge and modelling results must be translated into technical solutions and policy. Design and management of linkages for conservation can be viewed in a biological way, a socio-political way and as a design problem (Bennet, 1999).

Analysis of benefits to flora and fauna is an important first step and an essential basis for evaluating design and management of the landscape and of ecological networks. Within an ecological network ecological corridors are species specific and they can have a variety of functions. Knowledge of the ecological structure and processes in the landscape, combined with the behaviour and ecology of species is of utmost importance in the design of ecological networks and corridors. In all cases the landscape has to be adapted to its ecological function using forests, hedgerows, streams and small forests for guidance and shelter. The design, the related functions and ecosystem services as translated in benefits and costs are key issues in the further process of implementation of the ecological network.

Doing so, means, that calculations should be made of the area of different habitats that is needed for maintaining viable populations of species. These are different for different species in different environments. In the polar areas species need more space than in the tropics because of food availability. Grassland bird species need different areas and population sizes than carnivores and also require different landscape structures.

When having stated how much and what type of habitat should be available for different species, then it is still not clear for most of us, what the preferred landscape will be. To understand and communicate these ideas, one needs landscape models. This is a way to summarise and make visible what focal species and habitat requirements mean. In the Netherlands the province of Gelderland summarised the multitude of possible focal species in seven landscape models named a focal species and focusing on linkage of specific habitats (Bolck et al., 2004). The focal species are expected to be a proxy for a group of species and more animal and plant species are expected to make use of this kind of landscape structures. In Gelderland the landscape models consist of a planned zone of 250-500 meter wide with a continuous corridor or steppingstones. For walking species with a high dispersal capacity a corridor for movement and foraging might be sufficient in most cases an on the scale of regional planning.

Table 2. Overview of the landscape models for ecological corridors developed by the province of Gelderland and based on habitat requirements and landscape structure (Bolck et al., 2004).

Landscape model	Focal species/ habitat	Characteristics of the landscape zone
Badger (*Meles meles*)	Small mammals	Wooded banks, small forests (8%), 500 m wide
Crested newt (*Triturus cristatus*)	amphibians	Corridor and stepping stones, 250 m wide
Lizard	Reptiles, butterflies	Corridor and stepping stones (1 and 10 ha) with oligotrophic grassland or heathland, 250 m wide
Copper (*Lycaena phleas*)	butterflies	Stepping stones (0,5 and 4 ha) oligotrophic grassland or heathland, 250 m wide
White Admiral (*Limenites camilla*)	butterflies	Stepping stones, well structured landscape, humid forest, 250 m wide
Reed warbler (*Acrocephalus schoenobaenus*)	Reed birds	Stepping stones (2,5 and 25 ha), reed marsh
Ide (*Leuciscus idus*)	Brooks, streams	Natural banks, spawning places

For the crested newt (*Triturus cristatus*) the landscape can be modelled as an ecological corridor with steppingstones embedded in the landscape. Ponds and other wet landscape elements are essential and also will be favouring other amphibians like the green frog (*Rana arvalis*), tree frog (*Hyla arborea*), common spadefoot (*Pelobates fuscus*) and the grass snake (*Natrix natrix*).

Such a small-scale landscape should consist of a coherent network of linear elements. Additionally at least five small ponds of about 500 m^2 are found in every kilometre length of the network. The core of the corridor consists of elements 1 ha with natural vegetation of shrub, humid oligotrophic grassland, deciduous wood, wooded banks, drains, ditches, brooks and banks. Depending on their location and function they will have a minimum width (10-15 m), are not more than 100 m apart and mitigating measures have been taken to cross barriers (tunnels, drainpipes). The landscape should contain a sufficient number of ponds with well-developed water and bank vegetation and open spaces; terrestrial habitat consists of shrub, hedges or wooded banks with sufficient dead wood and holes as hiding places.

4. PLANNING AND IMPLEMENTATION OF ECOLOGICAL NETWORKS

The land required to maintain or establish linkages may be in private ownership, public (government) ownership, or it may comprise multiple parcels with a diverse range of owners including private individuals, companies, government agencies or authorities and community or conservation groups. Ideally, a long-term arrangement with the responsible land managers is required to ensure that there is an ongoing commitment to the objective of the linkage (Bennett, 1999).

Summarising it can be stated that design principles have to be given to assure a successful realisation and functioning:

- Minimal width, the wider the corridor the better it will serve multifunctionality; sizes have been given for different situations from 15 metres to 200 and even 600 or 1000 meters wide, varying for urban and rural situations and terrestrial and riverine corridors;
- Well established connectivity for species and man, depending on the longitudinal design of the corridor and the barriers in it;
- Differences in use should be taken into account; man is using trails during the day, badgers move during the beginning of the night and dawn, amphibians migrate in the early spring and linkages should be adapted to these habits;
- Habitat diversity within the ecological corridor; a greater variety makes it more attractive for different species as well as for man;
- Accessibility from the surrounding land makes the ecological corridor multifunctional;

Ecological networks can be designed at the national, regional and local level. For implementation in the field the local level is the most appropriate; for regional planning and coordination with other land uses such as agriculture, road planning and urbanisation mostly the regional level is essential as at that level land use-planning decisions are taken. The national and international levels are more important for the spatial coherency within a country and between countries. At this level also the major policy decisions are taken, although, at least in Europe and in the USA, states in the federation and autonomous regions might have an important role in national decision making for biodiversity planning (Jongman et al., 2004).

The different levels of decision making and the involvement of several authorities and NGO's in implementing ecological networks means, that the institutional and socio-economic aspects of ecological networks are as much important as are the pure ecological aspects. In Italy the Province of Bologna made agreements with the municipalities involved to co-finance ecological corridor projects (Bolck et al., 2004). In the Netherlands NGO's provinces, municipalities and water boards cooperate in the implementation of ecological corridors. To boost the implementation of ecological corridors the Dutch province of Gelderland started the project Green Connections. Realisation of ecological corridors requires an integrated approach because of the interaction with other land use claims such as agriculture water management, infrastructure housing and recreation. The province has asked water boards – for the water based corridors - and municipalities – for the terrestrial corridors - to play a co-ordinating role in the implementation process.

The plans for the further development of ecological networks in Europe are ambitious. The 5th Ministerial Conference "Environment of Europe" concluded that *"by 2008, all core areas of the Pan-European Ecological Network will be adequately conserved and the Pan European Ecological Network will give guidance to all major national, regional and international land use and planning policies as well as to the operations of relevant economic and financial sectors*". It is obvious that these targets cannot be met without the active cooperation of relevant land use sectors such as agriculture and forestry, and local and regional planning authorities. The Pan-European Ecological Network will expand beyond the "traditional" domain of nature conservation of protected areas. It will include vast stretches of land over which nature conservation authorities and NGOs have no "jurisdiction". The targets can only be realized in partnerships between the conservation sector (government and NGO) and the various stakeholders involved (ECNC, 2004).

Partnerships are built on mutual interests. The interests of the conservation sector are believed to be clear: conserving biodiversity. Who are the other partners (stakeholders) and what are their interests? It is argued that the integrity of an ecological network as landscape mosaic and perceived as part of an integrated regional or national plan can only be sustained with active support of the "various stakeholders". Generating active stakeholder support for ecological networks has taken many forms.

In the case of the "Life ECOnet" project in Cheshire, United Kingdom the approach to gain support, involved five equally important and co-dependent elements:

Technical development of a landscape database in GIS and the application of landscape ecology principles;

- Assessing and influencing land use policy and instruments;
- Demonstrating integrated land use management;

- Engaging stakeholders;
- Dissemination.

Two important principles were embedded in these elements. The approach, and the resulting ecological network, must allow integration of environmental issues with socio-economic functions of the landscape and the acceptance of the landowners and consumers of the landscape. Secondly, the approach must provide an identifiable product on which the varied skills, knowledge and attitudes of stakeholders can focus (James, undated). It is clear that in this approach the ecological modelling is only the first step. The four following steps involve the integration of ecological knowledge into society and policy decisions.

In the case of Estonia the approach to gain support took the form of meetings and public campaigns with emphasis placed on (Sepp and Kaasik, 2002):

- Multifunctional nature of ecological networks (e.g. increased environmental health conditions, recreational opportunities);
- Conservation of "flagship species" to highlight the importance of biodiversity conservation; and
- The accommodation of semi-natural habitats or other "use areas" that allow traditional farming practices in the networks.

In many cases in the USA, like the Yellowstone – to – Yukon ecological network, the initiative did not come from government (Yellowstone to Yukon Conservation Initiative, 2006). As most Northern American Greenway plans Y2Y is very much a grassroots initiative enjoying support from a large variety of NGOs and other civil society organisations (360 in total) with the objective to ensure that the eco-region continues to support natural and human communities. In a number of states in the USA (Florida, Georgia, Massachusetts, Rhode Island) the state has embraced these plans into Statewide Greenway Plans based on the integration of biodiversity and civil interest issues (Florida Greenway Commission, 1994). Comparable grassroots-based plans are developed in Portugal around the cities of Lisbon, Porto and Coimbra (Machado et al., 1997). Here the initiative has been a combination of universities and NGO's. The support from the authorities - and therefore its realisation – is still a difficult process.

What these cases have in common is that they focus not only on the conservation of biodiversity but also accommodate the exploitation and consumption of natural resources (Ahern, 2004). Serious efforts are made both to buffer sites of high conservation value from potentially damaging forms of land use and to find ways of reconciling the exploitation of natural resources with biodiversity conservation (Bennett and Wit, 2001).

The eastern section of the Netherlands National Ecological Network (EHS) provides a case to illustrate the possible benefits of an ecological network. In this case the ecological network has multifunctional objectives. Conservation and restoration of nature and biodiversity are priorities but they are not the only objectives of the EHS. Such as large claim for space in the densely populated Netherlands can only be justified if it also provides a solution for other problems and needs:

- Realised environmental objectives through the production of clean water, water management, sustainable use of natural resources (such as timber) and the absorption of CO_2;
- The protection of important rural, cultural-historical, archaeological and geological values, fulfilling – under conditions – important recreational functions, sustainable agriculture and fisheries, transport over water (under conditions);
- An attractive environment for living and business locations by maintaining high-priced qualities such as green space and tranquillity;
- Provide space for people to relax and experience nature.

Meeting the requirements of nature while at the same time taking into account local stakeholders' wishes creates public support and willingness of third parties to invest in the areas. The public is prepared to pay taxes and entry fees; farmers (sometimes against payment of conservation subsidies) are willing to consider adapted land management options; owners of country estates and small businesses are interested in investment in nature (Ministry of ANF, 2004).

Examples of tangible benefits in the Dutch province of Gelderland are:

- Investments in nature-based tourism and recreation generate employment and incomes;
- Nature as catalyst for investment prompt estate agents, water utilities and sand extraction companies to expand the acreage of land under conservation management hereby adding to the value of the ecological network while boosting their production and profit;
- The enhanced value of nature allows the introduction of innovative and self-sustaining payment mechanisms for farmers to maintain environmentally valuable landscapes (from growing maize to growing nature);
- The nature landscape provides clean drinking water and increasingly allows temporary storage of excess river water that may otherwise threaten low-lying population centres.

Formulating it in extremes and in line with the recent thinking of "nature has to pay for itself" a multifunctional ecological network may become an opportunity for rural development rather than a (short-term) cost to society. Appropriate planning and control would ensure a rural development that is sustainable and as such contributing to the natural resources the development depends upon, truly a win-win scenario.

Having defined an ecological network as a landscape mosaic with both biodiversity conservation as well as sustainable utilisation objectives it will be clear that this cannot be easily planned when the aim is to optimise the balance between the objectives. However, planning of ecological networks cannot be done without including all relevant stakeholders.

An adequate institutional context is needed. The landscape or regional scale involves long-term processes, operate across an array of administrative units and embrace a large number and wide range of stakeholders depending heavily on the (harmonised) institutional setting that should be conducive for stakeholder involvement (e.g. respected rule of law, robust zoning arrangements, effective enforcement procedures, financial security for corporate stakeholders, clearly defined public and private ownership patterns (Bennett, 2004; Somma, 2004). It may even be that new multi-stakeholder organizations, platforms or networks are required to ensure the delivery of results that were previously the domain of narrow-focussed (typically environmental) agencies (Miller, 1996).

The foundation of a multi-stakeholder process towards the planning and development of an "ecology and development network" requires a shared vision amongst the stakeholders. This vision specifically needs to foster stakeholder participation and convincing of the joint interests. This is especially challenging given the complex social and economic implications of working at a large geographical scale. This also means that far from the ecological models flexibility is needed in setting goals as this is important to make use of positive action in a region or community to join forces in common interest cases.

Planners and managers of an "ecology and development network" need a range of social, environmental and economic information at local, regional and national scale (Rientjes, 2000). Information about the importance of ecosystem goods and services is among others required to mobilise public support for the network and to empower local stakeholders to participate meaningfully in the decisions that affect their lives. Integrating socio-economic information with environmental information would provide new perspectives on sustainable use of biodiversity of the network. However, most information remains sector specific and lacks an analytical and holistic perspective. Bringing this information together in a learning environment is vital because the success of the network will depend upon the stakeholders being fully informed on how the project will affect them.

A broad-based initiative such as an ecological network brings along process management challenges. Developing a comprehensive proposal that can meet all strategic objectives, collecting and collating data, bringing together all stakeholders and ensuring their commitment, attracting funding, and ensuring effective implementation requires substantial investment in the management process, and the adoption of an integrative and adaptive approach. Lessons drawn show that process management does not have to be the prerogative of government (Bennett, 2004).

The ecological network provides environmental goods and services that have a direct use value such as timber and game, recreation and human habitat and indirect use values (watershed protection, climate regulation, erosion control, maintenance of biodiversity). The possible uses have different meanings for different stakeholders and in order to facilitate decision-making about the importance of an ecosystem it is vital to engage in valuation of these goods and services to allow trade-offs (Lette and Rozemeijer, 2005).

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