European Co-operation in the Field of Scientific and Technical Research

COST 341

Habitat Fragmentation due to Transport Infrastructure

Belgian State of the Art Report (Draft June 2000)

European Commission
Directorate General Transport

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Chapter 1. Introduction

Fragmentation of natural habitats has been recognised as a significant factor which contributes towards the decline of biodiversity in Europe and has become a major concern for all those working in the nature conservation and management field. Previous research has established that linear transportation infrastructure (roads, railways and waterways in particular) can cause serious habitat fragmentation problems. In some parts of Europe, infrastructure development has been identified as *the* most significant contributor towards the overall fragmentation effect; other factors include intensive agriculture, industrialisation and urbanisation (which will not be considered in this publication). This report aims to provide an overview of the scale and significance of the fragmentation problem caused by transportation infrastructure in Belgium (Flanders), and to examine the strategies and measures that are currently being employed in an attempt to combat it.

Habitat Fragmentation: The Problem

Habitat fragmentation can be described as the splitting of natural habitats and ecosystems into smaller, more isolated patches. The process of fragmentation is driven by many different factors, but the direct loss or severance of natural habitat is the most evident. Other contributing factors include disturbance (in terms of noise and visual nuisance) and pollution (causing changes in local microclimate and hydrology), which act to reduce the suitability of adjacent areas for wildlife. The infrastructure itself contributes significantly towards habitat fragmentation by creating a barrier to animal movement. This may result in the isolation and extinction of vulnerable species. The steadily growing number of animal casualties associated with roads, railways and, to a lesser extent, waterways are a further clear indicator of the fragmentation effect. Fauna mortality, in particular, has served to raise the public perception of the problem, due to its inherent link to traffic safety. The construction of infrastructure can also lead to less obvious ‘secondary effects’ related to increased human activity (*i.e.* subsidiary development such as housing, industry, etc.). These areas fall outside the remit of this report, but it is important to recognise that they may intensify the fragmentation problem.

Development of Transportation infrastructure

For more than 2000 years, roads, railways and waterways have been built in Europe to provide an efficient means of transportation for labour, goods and information. Many historic roads have developed from paths used for local communication, constructed where topography permitted. As a result of its long history, infrastructure was embedded and integrated in the landscape. During the last century, however, technical innovations have liberated planners and engineers from the natural constraints of the terrain. This has meant that modern transportation infrastructure can be superimposed on almost any prevailing landscape pattern, resulting in greater disruption of ecological linkages and processes. Across Europe, the length of roads and railways planned for construction in the future is significant: *i.e.* more than 12,000 km and 11,000 km respectively in western Europe by 2010 (EEA, 2000; EEA, 1998). This is in addition to even higher levels of new construction in central and eastern Europe (CEC, 2001). With the increasing spatial demands of infrastructure facilities and the predicted continued growth in traffic flows, conflicts between infrastructure and the natural environment are inevitably set to increase in the future.

A Challenging Problem

The challenge across Europe is to adapt the existing and future transportation infrastructure to produce an ecologically sustainable transportation system. In practice, solutions must be found to the current fragmentation problems and a strategy for extending future infrastructure without intensifying fragmentation must be applied. The realisation amongst experts working in the transport and nature conservation fields in Europe of the scale of the problem and the need for co-operation in this field was the catalyst for the development of COST 341.

Background to COST 341

In 1997, the representatives of several European countries belonging to the Infra Eco Network Europe (IENE) group identified the need for co-operation and exchange of information in the field of habitat fragmentation caused by infrastructure at a European level (Teodorascu, 1997) The IENE members, recognising the need for support from the European Commission (EC), thus initiated COST 341: ‘Habitat fragmentation due to Transportation Infrastructure’, the aim of which was to assemble existing knowledge on the subject throughout Europe, review it critically and offer clear guidelines for those involved in future transport planning. COST 341 commenced in 1998 with a planned duration of between 4 and 5 years. The following countries and organisations have been official participants:

Austria (A)	Hungary (H)	Spain (E)
Belgium (B)	The Netherlands (NL)	Sweden (S)
Cyprus (CY)	Norway (N)	Switzerland (CH)
Czech Republic (CZ)	Portugal (P)	United Kingdom (UK)
Denmark (DK)	Republic of Ireland (IRL)	European Centre for Nature
France(F)	Romania (RO)	Conservation (ECNC)

Several countries and organisations outside the official membership have also contributed to COST 341. Recognition should be given to contributors from Estonia, Italy and the Worldwide Fund for Nature (WWF).

The goals of COST 341 were to:

- Review the current situation with regard to habitat fragmentation and de-fragmentation in Europe and publish the results in the form of a European Review;
- Publish a European Handbook which presents best practice guidelines, methodologies and measures for avoiding, mitigating against and compensating for the fragmentation effect;
- Create an online database containing information on relevant existing literature, projects and mitigation measures related to habitat fragmentation; and
- Publish a final report describing the entire project and the implementation of its results.

This European Review of 'Habitat Fragmentation due to Transportation Infrastructure' is therefore one of a package of COST 341 products. It is a synthesis of the information presented in individual National State-of-the-Art Reports produced by the participating countries. Most of the National Reports are also published separately in the originating country and can be downloaded from http://cost341.instnat.be/. The European Review is aimed primarily at infrastructure planners, designers, engineers and other professions involved in the construction and/or management of infrastructure. However, other target groups include: the technical and scientific research community, organisations involved in the fields of transportation and environmental protection; policy makers (at EC, national and local level); and members of the public.

The following text, the National State-of-the-Art Report for Belgium (Flanders), attempts to give an idea of the full scope and extent of the habitat fragmentation problem across Belgium (Flanders) and identify the range of solutions which are currently used to address it. Chapter 2 presents some basic ecological concepts that are integral to the understanding of the effects of fragmentation, the details of which are discussed in Chapter 3. Chapter 4 goes on to identify the main habitat types that are threatened by fragmentation, the causes of that fragmentation and the policy responses to it. This is followed by an overview of the scale and significance of the habitat fragmentation problem caused by transportation infrastructure, presented in Chapter 5. A description of how various planning instruments can be used to minimise habitat fragmentation is given in Chapter 6, whilst Chapter 7 examines the range of specific measures available for addressing the problem. It also gives recommendations with regard to the monitoring and maintenance of the measures in order to establish their levels of effectiveness. Chapter 8 deals with the safety and economic aspects associated with fragmentation (fauna collisions in particular) and Chapter 9 discusses the integrated and strategic approaches that should be applied in the planning of future infrastructure. Finally, Chapter 10 presents the general conclusions from the research and recommendations and principles for dealing with the problem in the future.

Chapter 2. Key Ecological Concepts

This chapter introduces some of the major ecological concepts that aid an understanding of the large-scale effects of infrastructure on wildlife: the concepts of landscape, scale and hierarchical organisation; the process of habitat fragmentation; the importance of habitat connectivity and corridors for animal movement; and metapopulation dynamics. There is a focus on landscape pattern and structure, particularly how these interact to determine the impact of infrastructure on wildlife. The chapter emphasises the importance of planning at a landscape scale and explains why the use of a broader, landscape ecological approach may shed new light on barrier and isolation effects.

Habitat fragmentation caused by transportation infrastructure is an issue of growing concern (Prillevitz, 1997). Possible effects of fragmentation on wildlife have been recognised and an impressive amount of empirical studies illustrate the widespread impact on species and ecosystems (see Chapter 3). The growing demand for information on efficient mitigation has, however, highlighted that the current understanding of the long-term, large-scale ecological consequences of infrastructure provision is insufficient (Treweek *et al.*, 1993; RVV, 1996; Seiler and Eriksson, 1997; Forman, 1998). It is apparent that impacts cannot be evaluated from a local perspective alone. Infrastructure planning must therefore involve a landscape wide, holistic approach that integrates technical, human and ecological requirements. Landscapes and habitats are two fundamental aspects that infrastructure planners must consider. This chapter clarifies the definitions of these, and other important terms and concepts relevant to habitat fragmentation.

2.1. LANDSCAPES AND HABITATS

The definition of the term *landscape* varies considerably between European countries and scientific domains. For the purposes of this document, it is defined as 'the total spatial entity of the geological, biological and human-made environment that we perceive and in which we live' (Naveh and Lieberman, 1994). Landscapes are composed of a *mosaic* of individual patches embedded in a matrix (Forman, 1995). The *matrix* comprises the wider ecosystem or dominating landuse type in the mosaic and usually determines the 'character' of the landscape, *e.g.* agricultural, rural, or forested. Landscape *patches* are discrete spatial units that differ from each other due to local factors such as soil, relief, or vegetation *e.g.* an area of forest surrounded by grassland, or a pond within a forest. Landscape patches may also be termed 'habitat'. In ecology, the term *habitat* is a species-specific concept of the environment in which a plant or animal finds all necessary resources for survival and reproduction (Whittaker *et al.*, 1973; Schaefer and Tischler, 1983). The size of a habitat is therefore entirely dependant upon the individual species' requirements: it can be anything from a pond, a meadow, a forest or even the entire landscape mosaic. The diversity of habitats within a landscape and the spatial arrangement of individual habitat patches together determine the biodiversity value of the landscape (Gaston, 1998). *Biodiversity* denotes the total variation among living organisms in their habitats, including the processes that link species and habitats.

2.2. LANDSCAPE CHANGE AND HABITAT FRAGMENTATION

Historically, human activities (driven by politics, economics, and cultural traditions) have altered landscape patterns, habitat quality and the ‘natural’ distribution of species (Stanners and Bourdeau, 1995; Jongman *et al.*, 1998). Across Europe, traditional small-scale landuse has been replaced by intensified methods that require large, homogeneous production units (Burel, 1992; Jedicke, 1994; Ihse, 1995; Skånes and Bunce, 1997). In modern rural landscapes, wildlife habitats have been reduced to small remnants scattered throughout the intensively used matrix. In addition, extensive natural areas, *e.g.* open marshland or contiguous forests, have been increasingly fragmented by infrastructure including roads, railways, waterways, drainage ditches, and power lines (*e.g.* Bernes and Grundsten, 1992; Kouki and Löfman, 1999; and Figure 2.1). As a result, species have come to depend on increasingly smaller patches of remnant semi-natural habitat and green corridors such as hedgerows, wooded field margins, infrastructure verges and small forest patches.

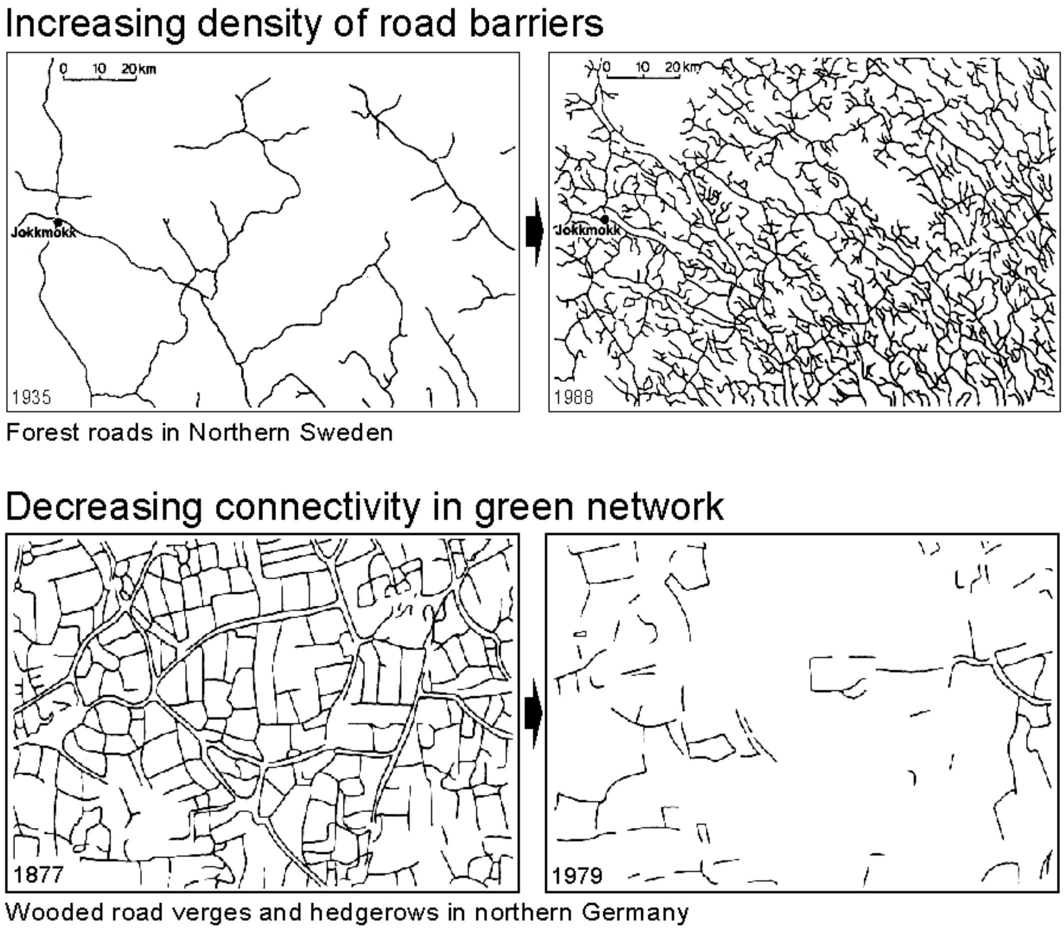

Figure 2.1 - Landscape change due to fragmentation and loss of connectivity. Top - Increase in forest road network in the Jokkmokk area in northern Sweden between 1935 and 1988 (after Bernes and Grundsten, 1992). Lower - Loss of vegetated corridors (tree rows, hedgerows, road verges) in the agricultural landscape of northern Germany between 1877 and 1979. (After Knauer, 1980)

Together, forestry, agriculture and urbanisation have significantly reduced landscape heterogeneity and the extent of 'natural' habitats (Richards, 1990; Jongman, 1995; and Figure 2.2). Globally, this loss of landscape heterogeneity and the fragmentation of large, previously undisturbed habitats has created a major threat to biodiversity (Burgess and Sharpe, 1981; Wilcox and Murphy, 1985; Gaston, 1998). To promote the sustainable use of landscapes, people must learn to think and plan at a larger scale, integrating the local considerations into a broader functional context (Forman, 1995; Angelstam, 1997).

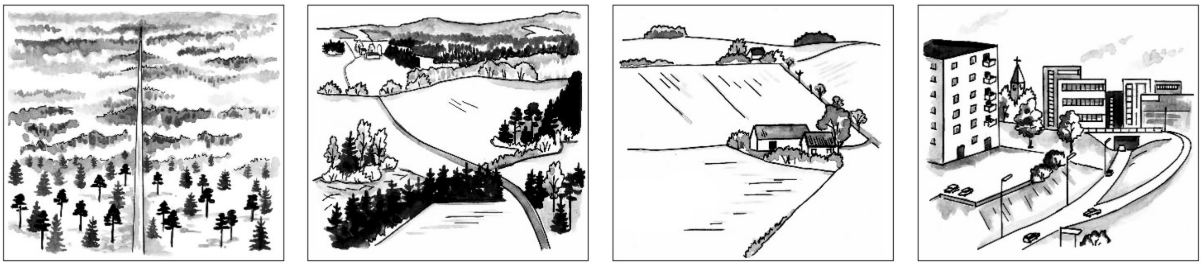

Figure 2.2 - Four types of landscapes that differ in the degree of human impact: A) A natural forested landscape containing a variety of natural ecosystems and habitats with little or no human influence; B) A mosaic, rural landscape where pastures, fields blend with forests that connect through hedgerows and strips of woody vegetation along small watercourses; C) A landscape dominated by agriculture and extensive land cultivation where remnants of the natural vegetation may be found in gardens and along infrastructure verges; 4) An urban landscape, strongly affected by infrastructure and built-up areas with little or no space for wildlife. (Drawings by Lars Jäderberg)

Habitat fragmentation is a process that splits contiguous habitat into smaller patches that become more and more isolated from each other. At the beginning of the fragmentation process, the loss of habitat is the driving force reducing species diversity in the landscape. Towards the end of the process, isolation effects become more important (Harris, 1984). Empirical studies indicate that the number of species drops significantly when more than 80% of the original habitat is lost and as habitat remnants become isolated (Andrén, 1994). The exact fragmentation thresholds depend on species' habitat requirements and mobility, and the mosaic pattern of habitats in the landscape. Where habitat remnants are connected through 'green' corridors or by small, suitable patches which serve as stepping stones (see Section 2.5), isolation effects may be minimised. The landscape may then support a higher diversity of species than would be expected from the overall area of remnant habitat. However, where roads or railways cause additional separation of habitats (see Chapter 3), critical thresholds of fragmentation may be reached much earlier (Figure 2.3). It is essential that infrastructure planning should therefore consider the existing degree of fragmentation in the landscape, species' characteristics and the ecological scale at which the fragmentation effect may be most severe (Seiler and Eriksson, 1997).

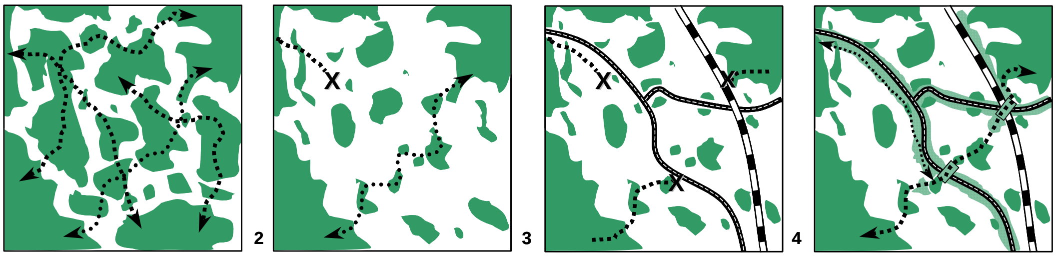

Figure 2.3 - (1) Fragmentation of an animals' habitat (shaded areas) reduces the ability of individuals to move across the landscape. (2) Some connectivity may be sustained through small habitat fragments or corridors. (3) Infrastructure imposes additional movement barriers and strengthens the isolation effect caused by habitat fragmentation. (4) Mitigation measures such as fauna passages and integrated road verge management can help to re-establish or even improve habitat connectivity in the landscape.

The consequences of habitat fragmentation to wildlife are complex, as species respond differently to the loss and isolation of their habitat. In general, species with limited mobility, large area requirements, or strong dependence on a certain type of habitat will be among the first to suffer the effects of habitat loss and isolation. These species generally respond to habitat fragmentation by modifying their individual behaviour patterns. Conversely, species that are abundant at a landscape scale, that utilise a variety of habitats and are more resilient to disturbance may not be affected so significantly. Although infrastructure may represent a significant barrier to their movement, local populations can be sustained so long as the habitat remnants remain sufficiently large. Isolation effects manifest themselves in this group of species through long-term demographic and genetic change within the population. Applying this knowledge in infrastructure planning is the key to preventing the ultimate consequence of habitat fragmentation - species extinction. In terms of defragmentation strategies, wide-roaming species will benefit most from improved habitat connectivity whilst for the smaller and less mobile species, more effort should be put into protecting and enlarging local existing habitats (Fahrig and Merriam, 1994).

2.3. Metapopulations, sinks and sources

Two ecological theories, regarding metapopulations (Levins, 1969) and sink and source population dynamics (Pulliam, 1988), contribute to the understanding of the complex processes of colonisation and extinction of populations in the landscape. These approaches help ecologists to predict the wider effects of habitat fragmentation and design effective strategies for the conservation of fragmented populations (Harris, 1984).

A *population* is a group of individuals of the same species that live in the same habitat, and breed with each other. When a habitat is fragmented, a system of local populations is formed. Where these are located close enough to permit successful migration of individuals, but are sufficiently isolated to allow independent local dynamics, the system is called a *metapopulation* (Hanski and Gilpin, 1991). The migration of individuals between the local *source* (where the number of births exceeds the number of deaths) and *sink* (with a negative birth to death ratio) populations has a stabilising effect on metapopulation dynamics (Pulliam, 1988). However, when the two populations are separated by new infrastructure barriers, sink populations will loose the essential input of individuals from their sources and consequently face a rapid decline and ultimately extinction (Watkinson and Sutherland, 1995; and Figure

2.4). Despite this theoretical knowledge, sink and source dynamics are extremely difficult to recognise and quantify from simple field observations.

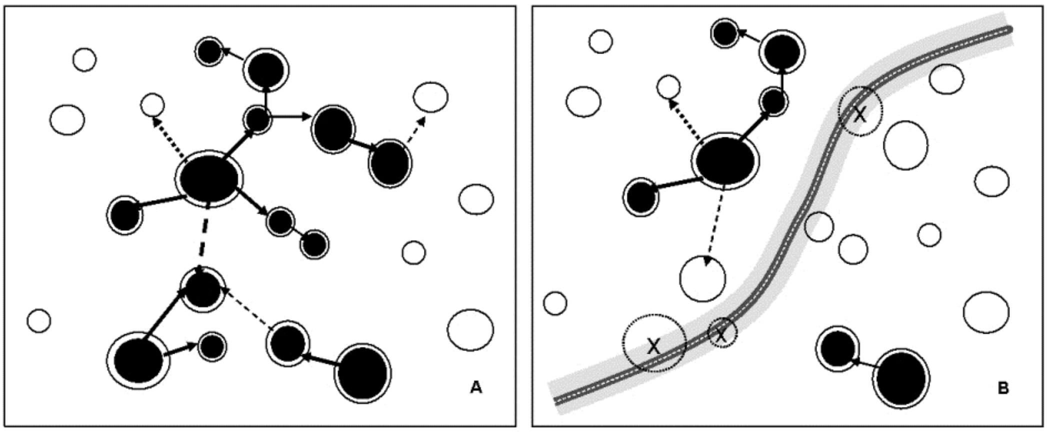

Figure 2.4 - Barrier effects on populations: (A) A metapopulation consists of a network of local populations that may vary in size and local dynamics, but are linked to each other through dispersal. Small local populations are more likely to go extinct than large populations, but the risks of this are minimised if they are well connected to surrounding populations from where they can be re-colonised; (B) Infrastructure construction causes a disturbance and loss of local populations within the network. In addition, infrastructure imposes a dispersal barrier that can prevent re-colonisation and isolate local populations from the rest of the metapopulation. If important source populations are cut off from the remaining sink populations, the entire metapopulation may be at risk of extinction.

2.4. PLANT AND ANIMAL MOVEMENTS

The movement of organisms is a fundamental property of life. Plants ‘move’ passively via natural (*e.g.* wind, water, and animals) or human (*e.g.* vehicles) vectors that transport their pollen or seeds (Verkaar, 1988; Wace, 1977). Few studies have been carried out to investigate the effect of infrastructure on plant movements, but there is evidence that weeds and many exotic plant species spread along infrastructure verges into adjacent habitats (see Section 3.3). Animals are more directly affected by infrastructure barriers, but to understand the problem and evaluate the conflict between the barriers and animal movements, it is necessary to recognise differences in the type of movements and the scale at which these occur (Verkaar and Bekker, 1991). Animals move within and between foraging areas, home ranges, regions and even continents. These movements are necessary for the daily survival of individuals as well as for the long-term persistence of populations. Broadly, four categories of movements can be distinguished (Figure 2.5 and Table 2-1).

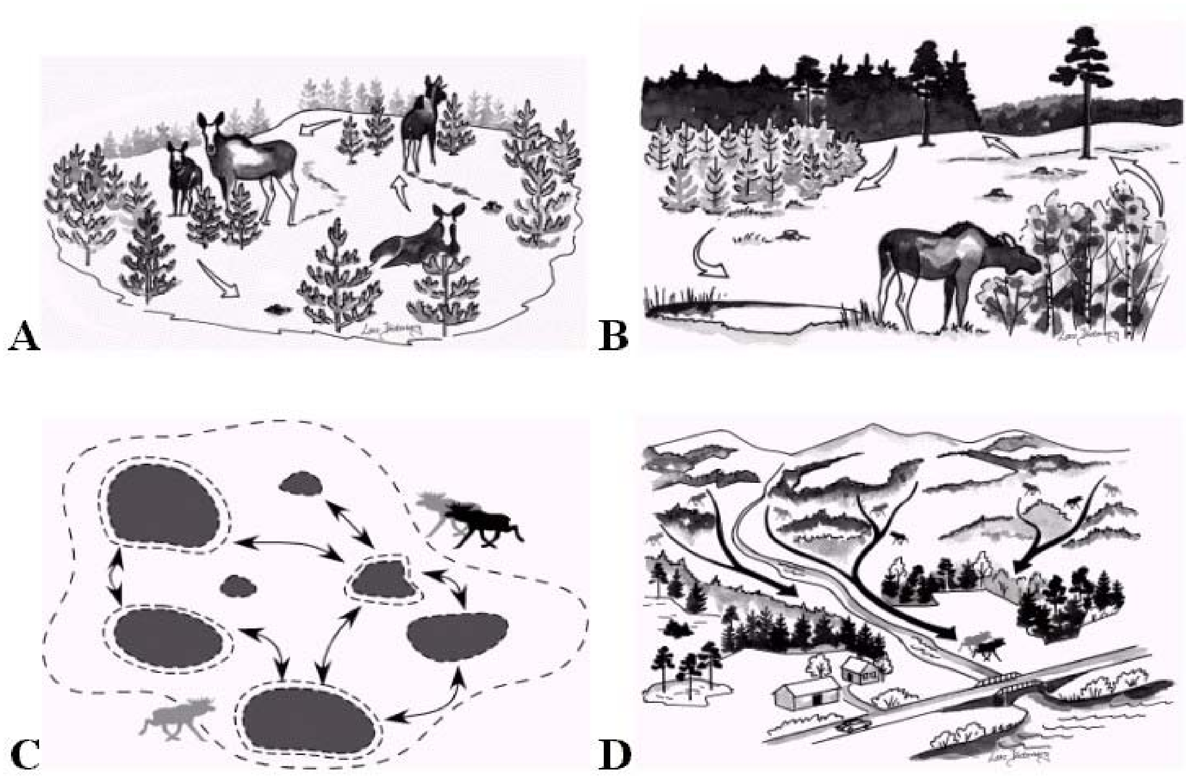

Figure 2.5 - Four basic types of animal movements: (A) Foraging movements of an individual within a forest stand; (B) diurnal or commuting movements between forest patches within the home range of an individual; (C) dispersal movements (emigration and immigration) between local populations; (D) migratory movements between seasonal habitats by local populations. These movement types refer to different spatial and temporal scales, but may occur simultaneously in the landscape. (Drawings by Lars Jäderberg)

Table 2-1 - Classification of Animal Movement Patterns.

Movement	Features
Foraging	Made in order to access food sources within a habitat patch (Figure 2.5 A); they are small-scaled, convoluted and rather diffuse.
Diurnal or commuting	Made regularly in the home range of an individual between different resources, *e.g.* between breeding site, foraging areas, water and shelter (Figure 2.5 B); they are generally straight (often along guiding structures such as forest edges, hedgerows or rivers) and directed towards a goal (*e.g.* Saunders and Hobbs, 1991; Baudry and Burel, 1997).
Dispersal	Made when individuals leave their birthplace or parental home range in order to establish their own territory. Occurs once, or a few times, during the lifetime of an individual and serves to sustain local populations within a metapopulation (Figure 2.5 C). Little is known about patterns of dispersal but structures and corridors used in diurnal movements are often utilised.
Migratory	Cyclic, long-distance movements between seasonal habitats, often conducted by groups of individuals or even entire local populations. Represents an adaptation to a seasonally changing environment and is essential to the survival of many species. Animals often migrate along traditional paths used by previous generations for hundreds of years that cannot easily be changed in response to a new barrier (Figure 2.5 D).

Where infrastructure dissects a foraging, commuting, dispersal or migration route, animals will have to cross the barrier and encounter a higher risk of mortality from traffic impact (Verkaar and Bekker, 1991). Most traffic accidents involving deer, for instance, occur during the hours around sunset and sunrise, when the animals are moving to and from their preferred feeding sites (Groot Bruinderink and Hazebroek, 1996). Migratory species are especially vulnerable to the barrier and mortality effects associated with infrastructure. Amphibians, for example, migrate as entire populations between breeding ponds and terrestrial habitats and consequently suffer extreme losses due to traffic mortality (Sjögren-Gulve, 1994; Fahrig *et al.*, 1995). The migration of larger ungulates, such as moose (*Alces alces*) in northern Scandinavia (Sweanor and Sandegren, 1989; Andersen, 1991) and red deer (*Cervus elaphus*) in the Alps (Ruhle and Looser, 1991) also causes particular problems in relation to traffic safety.

Animal movements are an important consideration in wildlife management and conservation. Knowledge about the type and the extent of animal movement may help to increase traffic safety, reduce road mortality and/or find adequate places for mitigation measures such as fences and fauna passages (Putman, 1997; Finder *et al.*, 1999; Pfister, 1993; Keller and Pfister, 1997). Empirical data on animal movement is still limited and more field research is required in order to understand where, and how, artificial or semi-natural structures can be used to lead animals safely across infrastructure barriers.

2.5. Connectivity, corridors and ecological networks

Habitat connectivity denotes the functional connection between habitat patches. It is a vital, species-specific property of landscapes, which enables the movement of an animal within a landscape mosaic (Baudry and Merriam, 1988; Taylor *et al.*, 1993). Connectivity is achieved when the distances between neighbouring habitat patches are short enough to allow individuals to cross easily on a daily basis. In fragmented landscapes, connectivity can be maintained through: i) a close spatial arrangement of small habitat patches serving as stepping-stones; ii) corridors that link habitats like a network and; iii) artificial measures such as fauna passages over roads and railways (Figure 2.6).

Hedgerows and field margins, wooded ditches, rivers, road verges and power-lines are all ‘ecological corridors’ (Merriam, 1991). These support and direct movements of wildlife, but may also serve as a refuge to organisms that are not able to survive in the surrounding landscape (see Section 3.3.2). Most of the empirical data on the use of ecological corridors by wildlife refers to insects, birds and small mammals (*e.g.* Bennett, 1990; Merriam, 1991; Fry, 1995; Baudry and Burel, 1997) (see also Chapter 5). Little is known yet about the use of these rather small-scale structures by larger mammals (Hobbs, 1992).

Figure 2.6 - Hedgerows and woody road verges ('Knicks') in northern Germany provide the only bush and tree vegetation available in the landscape. Together they create a network of green corridors on which many species in that area depend for shelter and food. Naturally, these corridors also have a strong impact on the movement of species that shy away from the open fields and pastures. (Photo by Andreas Seiler)

The re-creation of ecological corridors is envisioned as the most effective strategy against habitat fragmentation in Europe. Recently, the concept of an ecological infrastructure - promoting the movement of wildlife in an otherwise hostile environment (Van Selm, 1988), has become adopted as a conservation tool by landscape architects (Dramstad *et al.*, 1996), and road planners (Saunders and Hobbs, 1991; Seiler and Eriksson, 1997; Jongman, 1999). Strategic ecological networks, such as the NATURA 2000 network or the Pan-European Ecological Network (Bennett and Wolters, 1996; Bennett, 1999; Opstal, 1999) attempt to apply the concept on a European scale by seeking to link areas designated for nature conservation (Jongman, 1994). Considering these 'networks' in the planning of infrastructure may help to highlight critical bottlenecks in habitat connectivity and identify where special mitigation measures may be required in the future.

2.6. Scale and hierarchy

The concepts of scale and hierarchy are essential to the understanding of ecological pattern and processes in the landscape (Urban *et al.*, 1987; Golley, 1989; Wiens, 1989). *Scale* defines the spatial and temporal dimensions of an object or an event within a landscape; every species, process or pattern owns its specific scale (Figure 2.7). For the purposes of environmental impact assessment (EIA), the scale at which ecological studies are undertaken is a fundamental consideration which determines the type of mitigation solutions that are designed. If an EIA is limited to an individual habitat, the wider (and potentially more serious) impacts at the landscape scale will be overlooked. Conversely, if too large a scale is selected for study, small sites that together comprise important components of the ecological infrastructure in the landscape may be ignored.

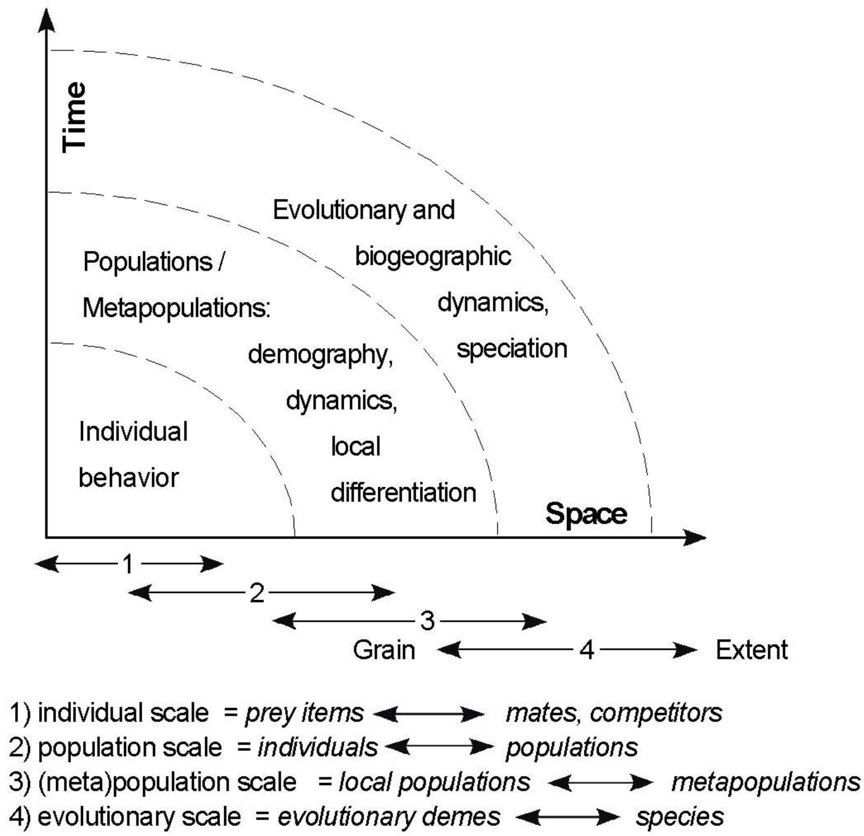

Figure 2.7 - Domains of scale in space and time. Enlarging the scale shifts the focus towards higher organisational levels that reveal new processes and dynamics. Nb. large spatial scales refer to small scales in map dimension. (Combined from Wiens, 1989 and Haila, 1990)

Closely related to scale is the *hierarchical structuring of nature* in which any system at a given scale is composed of a number of sub-systems at smaller scales (O'Neill *et al.*, 1986). For example, a metapopulation is comprised of local populations, which in turn are made up of many individuals (Figure 2.8).

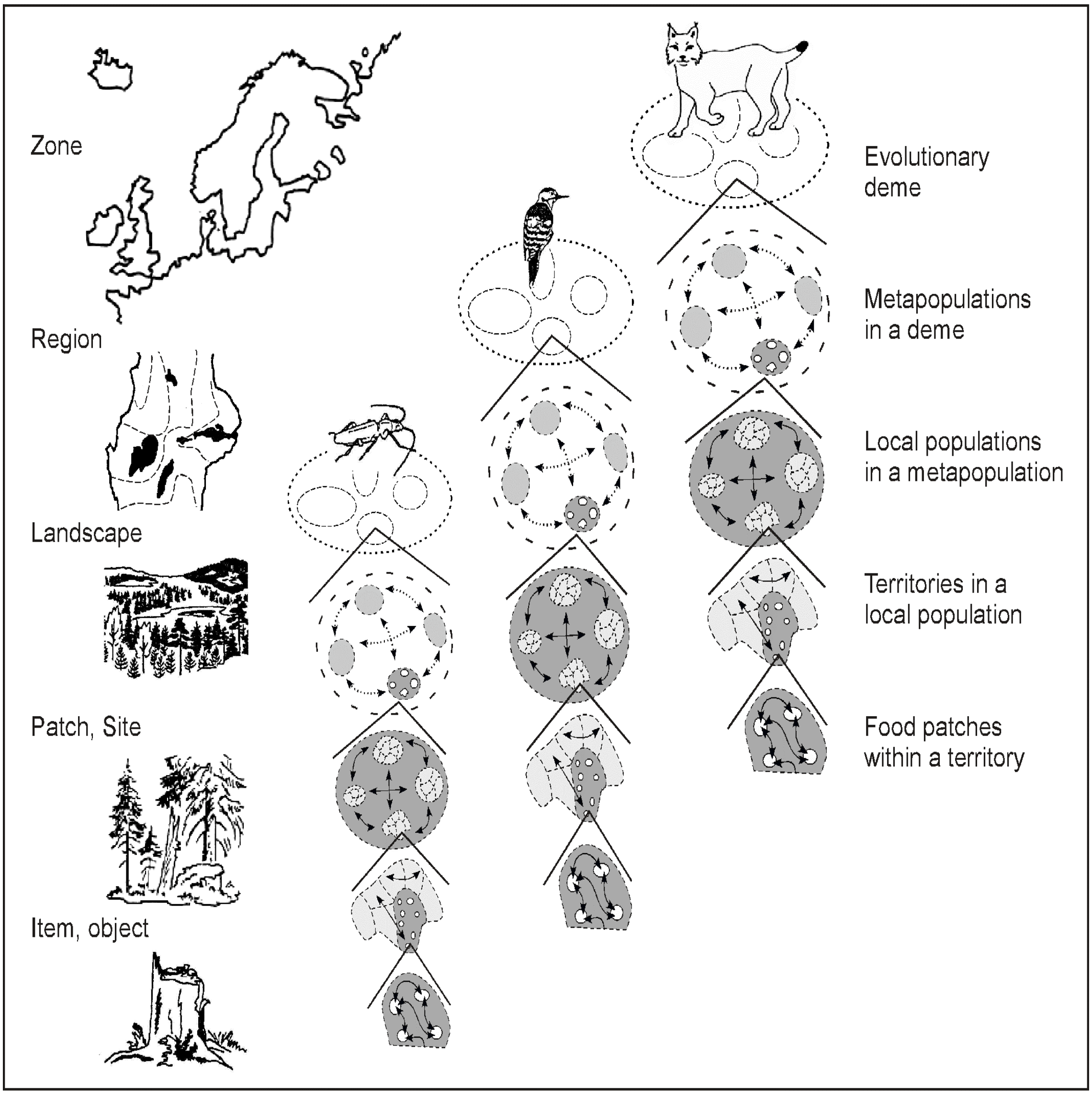

Figure 2.8 - Hierarchical layering in ecology. Food patches are nested in individuals' territories, which make up the habitat of a local population. In turn, these local populations make up metapopulations that together comprise the evolutionary deme of a species. At each hierarchical level (*i.e.* site, landscape, region, zone), the spatial entities are linked trough the movement of individuals. (Redrawn after Angelstam, 1992)

In order to predict the effects of habitat fragmentation in relation to ecological properties at a given level (*e.g.* for a population), both of the adjacent levels in the hierarchical system (*i.e.* individual and metapopulation) must be considered (Senft *et al.*, 1987; Bissonette, 1997). In terms of the application of this principle to infrastructure planning, a theoretical example is outlined below.

Imagine a new railway that is to be built through a forest. On a topographical map, the forest may comprise a rather homogeneous green area. From a biological point of view, however, the forest is home to numerous local populations of animals, such as beetles that live on old growth trees (see Figure 2.8), and it forms the territory of an individual lynx. A new railway through this landscape will affect the beetle primarily at the population level due to the destruction of their habitat and increased separation of local populations. Disturbance and barrier effects of the new infrastructure may drive some of the local populations to extinction, but the metapopulation may still persist. For the lynx, the railway matters mostly at the individual level. Traffic increases mortality risk and the railway barrier may dissect the lynx's home range into smaller, unviable fragments. The lynx is a relatively rare species, in which the loss of one single individual can be significant to the population in a region.

Depending on the vulnerability of a species at regional scale, the effects on individuals or the population(s) have to be evaluated on a case-by-case basis and mitigation strategies designed accordingly. If studied solely from a local perspective, the importance of barrier and fragmentation effects are likely to be underestimated, because consequences to the populations will first become apparent at a larger spatial scale.

2.7. SUMMARY

This chapter has introduced some specific ecological concepts that are relevant to the better understanding of landscape pattern and process in infrastructure planning. For further reading on the presented topics, see Forman (1995), Bissonette (1997), Farina (1998), Sutherland (1998), or Jedicke (1994). The most important principles can be summarised as follows:

- *The effects of infrastructure on nature cannot be evaluated solely from a local perspective; infrastructure planning must focus on the landscape scale.*
- *Habitat connectivity across the landscape is essential for ensuring the survival of wildlife populations. Connectivity can be provided by ecological 'green' corridors, 'stepping stones', or technical mitigation measures e.g. constructing a bridge between severed habitats.*
- *The impact of habitat fragmentation on wildlife is dependent on individual species and landscape characteristics. Where the impact is below a critical threshold, populations can be sustained, but beyond this threshold, seemingly small changes in the environment may cause unexpected and irreversible effects (e.g. the extinction of local populations). The larger the spatial scale concerned, the longer the time-lag until effects may be detectable.*
- *Infrastructure planning needs to integrate both regional and local-scale issues. A hierarchical approach can help to identify the most important problems and their solutions at each planning level. People should 'think globally, plan regionally but act locally' (sensu Forman, 1995).*

There is still a long way to go before ecological tools are fully developed and implemented in road planning, but since the problems and their solutions are universal, joint research and combined international efforts are required. Only through interdisciplinary work (between planners, civil engineers and ecologists) can effective tools for assessing, preventing and mitigating against the ecological effects of infrastructure, be developed and applied.

Landscape and wildlife ecology together provide a body of theories and methodologies for the assessment of ecological impacts such as habitat fragmentation. Empirical studies are, however, scarce and more research is needed to investigate the critical thresholds beyond which populations cannot be sustained. The construction and daily use of transportation infrastructure can result in wide ranging ecological impacts that need to be identified and addressed. The specific nature of these impacts is discussed in more detail in Chapter 3.

Chapter 3. Effects of Infrastructure on Nature

This chapter presents an overview of the major ecological impacts of infrastructure, with a particular focus on those effects that impact upon wildlife and their habitats. The focus of this chapter is on the primary effects of transportation infrastructure on nature and wildlife, as these are usually the most relevant to the transport sector. Secondary effects following the construction of new roads or railways, *e.g.* consequent industrial development, or changes in human settlement and landuse patterns, are dealt with in more depth in Chapter 5 (Section 5.5). For more discussion and data on secondary effects see Section 5.5.

The physical presence of roads and railways in the landscape creates new habitat edges, alters hydrological dynamics, and disrupts natural processes and habitats. Maintenance and operational activities contaminate the surrounding environment with a variety of chemical pollutants and noise. In addition, infrastructure and traffic impose movement barriers to most terrestrial animals and cause the death of millions of individual animals per year. The various biotic and abiotic impacts operate in a synergetic way locally as well as at a broader scale. Transportation infrastructure causes not only the loss and isolation of wildlife habitat, but leads to a fragmentation of the landscape in a literal sense.

An increasing body of evidence relating to the direct and indirect ecological effects of transportation infrastructure on nature includes the comprehensive reviews of van der Zande *et al.* (1980); Ellenberg *et al.* (1981); Andrews (1990); Bennett (1991); Reck and Kaule (1993); Forman (1995); Spellerberg (1998); Forman and Alexander (1998); and Trombulak and Frissell (2000). Impressive, empirical data has also been presented in the proceedings of various symposia (*e.g.* Bernard *et al.*, 1987; Canters *et al.*, 1997; Pierre-LePense and Carsignol, 1999; Evink *et al.*, 1996, 1998 and 1999; and Huijser *et al.*, 1999). Bibliographies on the topic have been compiled by Jalkotzky *et al.* (1997), Clevenger (1998), Glitzner *et al.* (1999), and Holzang *et al.* (2000). Readers are encourages to consult these complementary sources for further information on the topics discussed in brief below.

3.1. PRIMARY ECOLOGICAL EFFECTS

Most empirical data on the effects of infrastructure on wildlife refers to primary effects measured at a local scale. Primary ecological effects are caused by the physical presence of the infrastructure link and its traffic. Five major categories of primary effects can be distinguished (Figure 3.1; see also: van der Zande *et al.* (1980); Bennett (1991); Forman (1995)):

- *Habitat loss* is an inevitable consequence of infrastructure construction. Besides the physical occupation of land, disturbance and barrier effects in the wider environment further decrease the amount of habitat that is suitable or available for wildlife.
- *Disturbance/Edge effects* result from pollution of the physical, chemical and biological environment as a result of infrastructure construction and operation. Toxins and noise affect a much wider zone than that which is physically occupied.

- *Mortality* levels associated with traffic are steadily rising (millions of individuals are killed on infrastructure each year in Europe), but for most common species this, traffic mortality it is not considered as a severe threat to population survival. Collisions between vehicles and wildlife are also an important traffic safety issue, and attract wider public interest for this reason.
- *Barrier* effects are experienced by most terrestrial animals. Infrastructure restricts the animals' range, makes habitats inaccessible and can lead to isolation of the population.
- *Corridor* habitats along infrastructure can be seen as either positive (in already heavily transformed low diversity landscapes) or negative (in natural well conserved landscapes where the invasion of non native, sometimes pest species, can be facilitated).

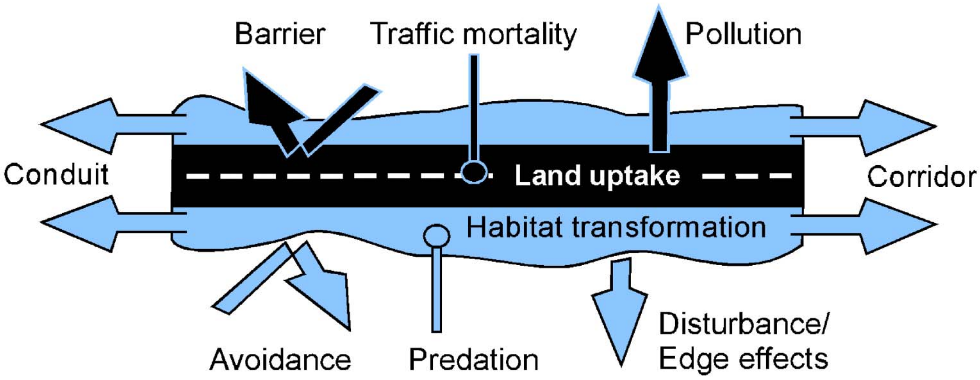

Figure 3.1 - Schematic representation of the five primary ecological effects of infrastructure which together lead to the fragmentation of habitat. (Modified from van der Zande *et al.*, 1980)

The impact of these primary effects on populations and the wider ecosystem varies according to the type of infrastructure, landscape, and habitat concerned. Individual elements of infrastructure always form part of a larger infrastructure network, where synonymous effects with other infrastructure links, or with natural barriers and corridors in the landscape, may magnify the significance of the primary effects. The overall fragmentation impact on the landscape due to the combined infrastructure network may thus not be predictable from data on individual roads and railways. When evaluating primary (ecological) effects of a planned infrastructure project it is essential to consider both the local and landscape scales, and fundamentally, the cumulative impact of the link when it becomes part of the surrounding infrastructure network.

3.2. HABITAT LOSS

3.2.1. Land take

Motorways may consume more than 10 hectares (ha) of land per kilometre of road and as a large part of that surface is metalled/sealed it is consequently lost as a natural habitat for plants and animals. Provincial and local roads occupy less area per kilometre, but collectively they comprise at least 95% of the total road network and hence their cumulative effect in the landscape can be considerably greater. If all the associated features, such as verges, embankments, slope cuttings, parking places, and service stations etc. are included, the total area designated for transport is likely to be several times larger than simply the paved surface of the road (Figure 3.2). In most European countries, the allocation of space for new infrastructure is a significant problem for landuse planning. It is not surprising therefore that landtake is a fundamental consideration in Environmental Impact Assessment (EIA) studies and forms a baseline for designing mitigation and compensation measures in modern infrastructure projects (OECD, 1994, see also Section 5.4.1).

The physical occupation of land due to infrastructure is most significant at the local scale; at broader scales it becomes a minor issue compared to other types of landuse. Even in rather densely populated countries such as The Netherlands, Belgium or Germany, the total area occupied by infrastructure is generally estimated to be less than 5-7% (Jedicke, 1994). In Sweden, where transportation infrastructure is sparser, roads and railways are estimated to cover about 1.5% of the total land surface whilst urban areas comprise 3% (Seiler and Eriksson, 1997; Sweden Statistics, 1999).

Figure 3.2 - Slope cuttings along a road in Spain. (Photo by Martí Pey/Minuartia Estudis Ambientals)

3.3. DISTURBANCE

The total area used for roads and railways is, however, not a reliable measure of the loss of natural habitat. The disturbance influence on surrounding wildlife, vegetation, hydrology, and landscape spreads much wider than the area that is physically occupied and contributes far more to the overall loss and degradation of habitat than the road body itself. In addition, infrastructure barriers can isolate otherwise suitable habitats and make them inaccessible for wildlife. The scale and extent of the spread of disturbances is influenced by many factors including: road and traffic characteristics, landscape topography and hydrology, wind patterns and vegetation type and cover. In addition, the consequent impact on wildlife and ecosystems also depends on the sensitivity of the different species concerned. To understand the pattern, more has to be learned about the different agents of disturbance.

Many attempts have been made to assess the overall width of the disturbance zone around infrastructure developments (Figure 3.3). Depending on which impacts have been measured, the estimations range from some tens of metres (Mader, 1987a) to several hundred metres (Reichelt, 1979; Reijnen *et al.*, 1995; Forman and Deblinger, 2000) and even kilometres (Reck and Kaule, 1993; Forman *et al.*, 1997). Thus, despite its limited physical extent, transportation infrastructure is indeed one of the more important actors in the landscape and its total influence on landuse and habitat function has probably been widely underestimated. Forman (2000) estimated that transportation infrastructure in the USA directly affects an area that is about 19 times larger than the 1% of the USA land surface that is physically occupied.

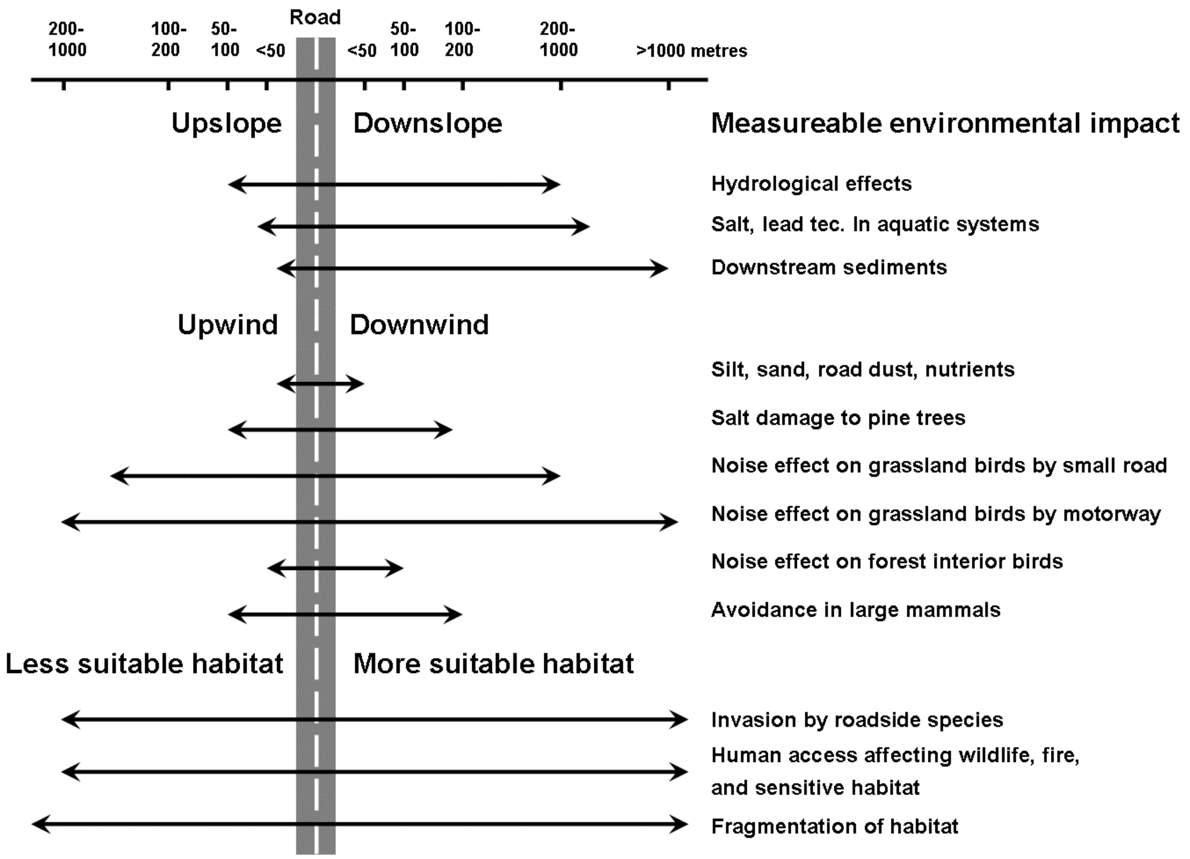

Figure 3.3 - Disturbance effects spreading from a road into the surrounding landscape. The distance over which disturbances affect nature depends on topography, wind direction, vegetation and the type of disturbance. The width of the affected zone is likely to be larger than some hundred meters on average. (Redrawn after Forman *et al.*, 1997)

3.3.1. Physical disturbance

The construction of infrastructure affects the physical environment due to the need to clear, level, fill, and cut natural material. Construction work changes soil density, landscape relief, surface- and groundwater flows, and microclimate, and thus alters land cover, vegetation and habitat composition. Wetlands and riparian habitats are especially sensitive to changes in hydrology *e.g.* those caused by embankments (Findlay and Bourdages, 2000) and cuttings which may drain aquifers and increase the risk of soil erosion and extensive earthslides that have the potential to pollute watercourses with sediments (*e.g.* Forman *et al.*, 1997; Trombulak and Frissell, 2000). The canalisation of surface water into ditches can also significantly change water run-off and debris flows, and thereby modify disturbance regimes in riparian networks (Jones *et al.*, 2000).

The clearance of a road corridor changes microclimatic conditions: it increases light intensity, reduces air humidity, and creates a greater daily variation in air temperature. These changes are naturally strongest where the road passes through forested habitats *e.g.* Mader (1987a) observed changes in forest microclimate up to 30 metres from the edge of a forest road. Artificial edges produced by road construction are usually sharp and can be compared to the new edges created by clear cutting in forests (Jedicke, 1994). The opening of the forest canopy will adversely affect the occurrence of forest interior species such as lichens or mosses, but can favour species adapted to open and edge habitats (*e.g.* Ellenberg *et al.*, 1981; Jedicke, 1994).

3.3.2. Chemical disturbance

Chemical pollutants such as road dust, salt, heavy metals, fertiliser nutrients, and toxins are agents which contribute towards the disturbance effect caused by transportation infrastructure. Most of these pollutants accumulate in close proximity to the infrastructure but, in some cases, direct effects on vegetation and fauna can be observed at distances over several hundreds of metres away (*e.g.* Evers, 1976; Santelmann and Gorham, 1988; Bergkvist *et al.*, 1989; Hamilton and Harrison, 1991; Reck and Kaule, 1993; Forbes, 1995; Angold, 1997).

Dust, mobilised from the infrastructure, is transported and deposited along verges and in nearby vegetation; epiphytic lichens and mosses in wetlands and arctic ecosystems are especially sensitive to this kind of pollution (*e.g.* Auerbach *et al.*, 1997). De-icing and other salts (*e.g.* $NaCl$, $CaCl_2$, KCl, $MgCl_2$) can cause extensive damage to vegetation (especially in boreal and alpine regions (Blomqvist, 1998) and to coniferous forests), contaminate drinking water supplies and reduce the pH-level in soil (which in turn increases the mobility of heavy metals) (Bauske and Goetz, 1993; Reck and Kaule, 1993). Heavy metals and trace metals *e.g.* Pb, Zn, Cu, Cr, Cd, Al (derived from petrol, de-icing salts, and dust) can accumulate in plant and animal tissues and can affect their reproduction and survival rates (Scanlon, 1987 and 1991). Traffic exhaust emissions contain toxins such as polycyclic aromatic hydrocarbons, dioxins, ozone, nitrogen, carbon dioxide, and many fertilising chemicals. Changes in plant growth and plant species diversity have been observed and directly attributed to traffic emissions in lakes (Gjessing *et al.*, 1984) and in heathland at a distance of over 200 metres away from the road (Angold, 1997).

3.3.3. Traffic noise

Although disturbance effects associated with noise are more difficult to measure and less well understood than those related to chemicals, it is considered to be one of the major factors polluting natural environments in Europe (Vangent and Rietveld, 1993; Lines *et al.*, 1994). Areas free from noise disturbance caused by traffic, industry or agriculture have become rare at a European scale and tranquillity is perceived as an increasingly valuable resource (Shaw, 1996). Although noise seldom has an immediate physiological effect on humans, long exposure to noise can induce psychological stress and eventually lead to physiological disorder (*e.g.* Stansfeld *et al.*, 1993; Lines *et al.*, 1994; Job, 1996; Babisch *et al.*, 1999). Whether wildlife is similarly stressed by noise is questionable (see Andrews, 1990), however, timid species might interpret traffic noise as an indicator of the presence of humans and consequently avoid noisy areas. For instance, wild reindeer (*Rangifer tarandus*) avoid habitats near roads or utilise these areas less frequently than would be expected from their occurrence in the adjacent habitat (Klein, 1971). Traffic noise avoidance is also well documented for elk, caribou and brown bear (Rost and Bailey, 1979; Curatolo and Murphy, 1986). However, whether this avoidance is related to the amplitude or frequency of traffic noise is not known.

Birds seem to be especially sensitive to traffic noise, as it directly interferes with their vocal communication and consequently their territorial behaviour and mating success (Reijnen and Foppen, 1994). Various studies have documented reduced densities of birds breeding near trafficked roads (*e.g.* Veen, 1973; Räty, 1979; van der Zande *et al.*, 1980; Ellenberg *et al.*, 1981; Illner, 1992; Reijnen and Foppen, 1994). Extensive studies on willow warblers (*Phylloscopus trochilus*) in The Netherlands showed the birds suffered lower reproductivity, lower average survival, and higher emigration rates close to trafficked roads (Foppen and Reijnen, 1994). Box 3.1 details some of the major studies that have contributed towards knowledge in this field.

It has been shown that environmental factors such as the structure of verge vegetation, the type of adjacent habitat, and the relief of the landscape will influence both noise spread and species density, and thus alter the amplitude of the noise impact (*e.g.* Reijnen *et al.*, 1997; Kuitunen *et al.*, 1998; Meunier *et al.*, 1999). If verges provide essential breeding habitats that are rare or missing in the surrounding landscape, species density along infrastructure may not necessarily be reduced, even though disturbance effects may reduce the environmental quality of these habitats (Laursen, 1981; Warner, 1992; Meunier *et al.*, 1999). Although strategic research regarding the disturbance thresholds of species in relation to infrastructure construction and operation is lacking, the species with the following attributes are considered to be most vulnerable to disturbance and development impacts (Hill *et al.*, 1997):

- large species;
- long-lived species;
- species with relatively low reproductive rates;
- habitat specialists;
- species living in open (e.g. wetland) rather than closed (e.g. forest) habitats;
- rare species;
- species using traditional sites; and
- species whose populations are concentrated in a few key areas (UK-SoA, 5.4.3).

3.3.4. Visual and other disturbance

The effects of traffic also include visual disturbance *e.g.* from artificial lighting or vehicle movement but these impacts do not generally receive as much attention as traffic noise or toxins. Artificial lighting has a conflicting effect on different species of fauna and flora: it can act as a valuable deterrent to deer and a readily accessible insect food supply to bats, but at the same time it can disrupt growth regulation in plants (Campbell, 1990; Spellerberg, 1998), breeding and behaviour patterns in birds (Lofts and Merton, 1968; Hill, 1992), bats (Rydell, 1992), nocturnal frogs (Buchanan, 1993), and moth populations (Frank, 1990; Svensson and Rydell, 1998). A study on the influence of road lights on a black-tailed godwit (*Limosa limosa*) population in The Netherlands, for example, indicated that the breeding density of this species was significantly reduced in a zone of 200 to 250 metres around the lights (De Molenaar *et al.*, 2000).

Certain types of road lights, such as white (mercury vapour) street lamps are especially attractive to insects, and therefore also to aerial-hawking bat species such as pipistrelles (*Pipistrellus pipistrellus*) (Rydell, 1992; Blake *et al.*, 1994). This increases the exposure of bats to traffic and may entail increased mortality due to collisions with vehicles. Furthermore, lit roads can constitute linear landscape elements, which bats may use to navigate in open areas (UK-SoA).

Box 3.1 - Studies on the effect of traffic noise on breeding birds

Between 1984 and 1991, the Institute for Forest and Nature Research in The Netherlands has carried out extensive studies of the effect of motorways and roads with traffic intensities between 5,000 and 60,000 vehicles a day on populations of breeding birds (Reijnen *et al.*, 1992; Reijnen, 1995). Two types of landscape, forest (Reijnen *et al.*, 1995a) and open grassland (Reijnen *et al.*, 1996) were compared. For 33 of the 45 forest species and 7 of 12 open grassland species, a road traffic effect was established and bird densities declined where the traffic noise exceeded 50 decibels (dbA). Birds in woodland reacted at noise levels of only 40 dbA. It was concluded that road traffic has an effect on the total density of all species and that there are clear indications that traffic noise is the main disturbing factor responsible for reduced densities of breeding birds near roads.

Based on the observed relationship between noise burden and bird densities, Reijnen, Veenbaas and Foppen (1995) proposed a simple model predicting the distance over which breeding bird populations might be affected by traffic noise (Figure 3.4). According to this model, roads with a traffic volume of 10,000 vehicles per day and a traffic speed of 120 km/h, passing through an area with 70% woodland, would significantly affect bird densities at distances between 40 and 1,500 m. When the model is applied to the entire area of The Netherlands, it suggests that at least 17% of bird habitats are affected by traffic noise (Reijnen *et al.*, 1995b).

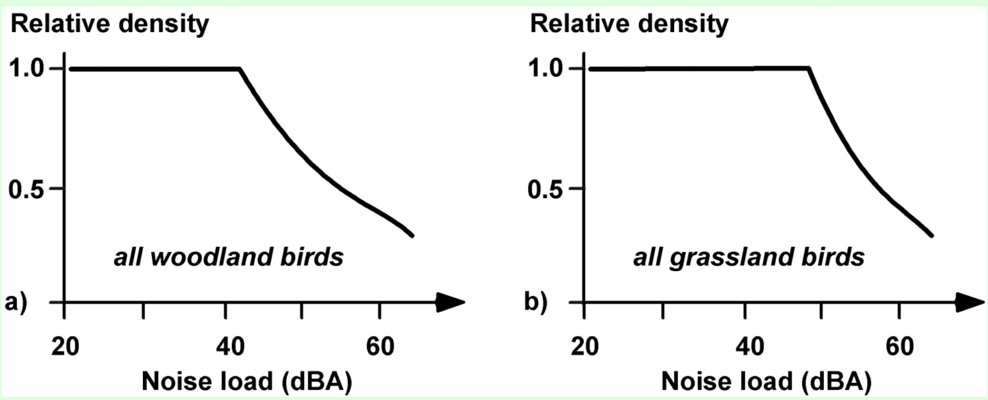

Figure 3.4 - Schematic representation of the impact of traffic noise on breeding bird populations in The Netherlands. When the noise load exceeds a threshold of between 40 and 50 dBA, bird densities may drop significantly. The sensitivity to noise and thus the threshold is different between species and between forest and open habitats. (From

Reijnen, Veenbaas and Foppen, 1995)

Helldin and Seiler (2001) tested the predictions of Reijnen *et al.* (1995a) model for Swedish landscapes and found that the expected reduction in breeding bird densities could not be verified. On the contrary, some species even tended to increase in densities towards the road. It was concluded that the Dutch model might not be directly applicable in other countries and that habitat changes as a consequence of road construction under some circumstances could override the negative effects of traffic noise on the surroundings (S-SoA, 5.4.3).

Species are negatively affected due to the artificial lighting upsetting their natural biological systems which are reliant on day length, and disturbing their spatial orientation and diurnal activity patterns. It is therefore possible that mitigation measures will also have conflicting effects on different species. From the studies that have been carried out, the following basic principles for reducing the impact of road lighting are suggested:

- Avoid lighting on roads crossing natural areas; and
- Use methods of lighting which are less alluring, especially for insects.

The movement of vehicles (probably in combination with noise) can also alter behaviour and induce stress reactions in wildlife. Madsen (1985), for instance, observed that geese foraging near roads in Denmark were more sensitive to human disturbance than when feeding elsewhere. Reijnen *et al.* (1995a) did not observe any effect of the visibility of moving cars on breeding birds, however, Kastdalen (*pers. comm.*) reported that moose (*Alces alces*) approaching a fauna passage under a motorway in Norway ran off as large trucks passed overhead. Heavy trucks and, more especially, high-speed trains produce intensive, but discontinous noise, vibration and visual disturbance which has the effect of frightening many mammals and birds. It is documented that many larger mammals avoid habitats in the vicinity of trafficked roads and railways (*e.g.* Klein, 1971; Rost and Bailey, 1979; Newmark *et al.*, 1996), but this avoidance results from many different interacting factors, amongst which noise and visual disturbance from vehicles comprise a small part.

3.3.5. Conclusions

Artificial lighting, traffic noise, chemical pollutants, microclimatic and hydrological changes, vibration and movement are just a few sources of disturbance that alter the habitats adjacent to infrastructure. In many situations, such disturbances are probably of marginal importance to wildlife, and many animals habituate quickly to constant disturbance (as long as they do not experience immediate danger). This does not imply, however, that disturbance should not be considered during the EIA process. On the contrary, because measures to mitigate against these types of disturbance are usually simple and inexpensive to install, they can easily be considered and integrated during the planning and design process. Many of the studies cited above were not specifically designed to directly investigate the disturbance effect of infrastructure, nor to inform the development of tools for impact evaluation or mitigation. However, to assess the width and intensity of the road-effect zone, research is needed that specifically addresses the issue of the spread of disturbance and the effect thresholds for individual species. Until there is a better understanding of such issues, the precautionary principle should be applied in all cases to prevent unnecessary negative effects.

3.4. CORRIDOR FUNCTION

Planted areas adjacent to infrastructure are highly disturbed environments, often hostile to many wildlife species, yet they can still provide attractive resources such as shelter, food or nesting sites, and facilitate the spread of species. In heavily exploited landscapes, infrastructure verges can provide valuable refuges for species that otherwise could not survive. Verges, varying in width from a few metres up to several tens of metres, are multipurpose areas, having to fulfil technical requirements such as providing free sight for drivers thus promoting road safety, and screening the road from the surrounding landscape. Typically, traffic safety requires that the vegetation adjacent to roads is kept open and grassy but farther away from the road, verges are often planted with trees and shrubs for aesthetic reasons, or to buffer the spread of salt and noise (Figure 3.5). Balancing technical and biological interests in the design and management of verges is a serious challenge to civil engineering and ecology. It offers a great opportunity for the transport sector to increase and protect biodiversity at large scale (Mader, 1987b; Van Bohemen *et al.*, 1991; Jedicke, 1994).

Figure 3.5 - Verges can vary considerably between different landscapes and countries. Left: A motorway in southern Sweden consisting only of an open ditch. Toxins and salt from the road surface can easily spread onto the adjacent agricultural field. Right: A highway in Germany. Densely planted shrubs and trees along roads provide potential nesting sites for birds and screen the road and its traffic from the surrounding landscape. (Photos by A. Seiler)

3.4.1. Verges as habitat for wildlife

Numerous inventories indicate the great potential of verges to support a diverse range of plant and animal species (*e.g.* Hansen and Jensen, 1972; Mader *et al.*, 1983; Van der Sluijs and Van Bohemen, 1991; Sjölund *et al.*, 1999). Way (1977) reported that verges in Great Britain supported 40 of the 200 native bird species, 20 of 50 mammalian, all 6 reptilian species, 5 of 6 amphibian, and 25 of the 60 butterfly species occurring in the country. In areas, where much of the native vegetation has been destroyed due to agriculture, forestry or urban development, verges can serve as a last resort for wildlife (Loney and Hobbs, 1991). Many plant and animal species in Europe that are associated with traditional (and now rare) grassland and pasture habitats, may find a refuge in the grassy verges along motorways and railways (Sayer and

Schaefer, 1989; Melman and Verkaar, 1991; Ihse, 1995; Auestad *et al.*, 1999). Shrubs and trees can provide valuable nesting sites for birds and small mammals (Adams and Geis, 1973; Laursen, 1981; Havlin, 1987; Meunier *et al.*, 1999) and also offer food and shelter for larger species (Klein, 1971; Rost and Bailey, 1979).

Other elements of the infrastructure itself can also provide attractive, yet sometimes hazardous, habitat for wildlife. For instance, stone walls and drainage pipes under motorways in Catalonia, Northeast Spain, are often populated by lizards and common wall geckos (*Tarentola mauritanica*) (Rosell and Rivas, 1999). Cavities in the rocky embankments of railways may be used as shelter and breeding sites by lizards (Reck and Kaule, 1993) and bats may find secure resting sites underneath bridges (Keeley and Tuttle, 1999). However, caution needs to be given to the inherent hazards associated with these structures. In the UK, for example, drainage pipes are recognised as representing a significant mortality risk to reptiles (Tony Sangwine, *pers comm.*). Careful design, management and maintenance of these structures is required in order to minimise the potentially negative impacts on the wildlife utilizing them. The first objective should be to identify which engineering elements may be of benefit to which species, and the second to determine how this benefit can be maximised without compromising the primary function of the structure.

Many wildlife species can benefit from verges if they provide valuable resources that are rare or missing in the surrounding landscape. However, it is unlikely that these human-made habitats will develop the ecological value of comparable natural habitat types found some distance from the infrastructure. The composition of species found in transportation infrastructure verges is generally skewed towards a higher proportion of generalists and pioneers that can cope with high levels of disturbance (Hansen and Jensen, 1972; Adams and Geis, 1973; Niering and Goodwin, 1974; Douglass, 1977; Mader *et al.*, 1983; Blair, 1996). It is not surprising that species, which regularly visit road corridors to forage or nest, feature frequently in traffic mortality statistics (see Section 3.5). In this respect, infrastructure corridors may act as an ecological trap, outwardly offering favourable habitat conditions but with the hidden high risk of mortality. When designing and managing verges, it is therefore advisable to consider the risk of creating an ecological trap that may kill more species than it sustains.

3.4.2. Verges as movement corridors for wildlife

As well as providing a habitat for wildlife, verges may also serve as a conduit for species movement (active or passive) like ‘natural’ corridors in the landscape (see Section 2.4). In The Netherlands, bank voles (*Clethrinomys glareolus*) have colonised the Zuid-Beveland peninsula after moving along wooded verges of railways and motorways (Bekker and Mostert, 1998). Getz *et al.* (1978) documented that meadow voles (*Microtus pennsylvanicus*) dispersed over about 100 km in six years along grassy verges in Illinois, USA. Kolb (1984) and Trewhella and Harris (1990) observed that the movement of foxes (*Vulpes vulpes*) into the Edinburgh area of the UK was strongly influenced by the presence and direction of railway lines. Badgers living in the city of Trondheim, Norway, are known to use riverbanks and road verges to move within the city (Bevanger, *pers. comm.*). The actual surface of the infrastructure (mainly small roads with little traffic) may also be used as pathways by larger mammals. Vehicle and human movement along the infrastructure may also serve as a vector for plants, seeds or small, less mobile animals (Schmidt, 1989; Bennett, 1991). For instance, Wace (1977) found seeds of 259 plant species in the sludge of a car-washer in Canberra, Australia, some of which derived from habitats more than 100 km away. This accidental transport of seeds may offer an explanation for the high proportion of exotic and weed species found along verges (Mader *et al.*, 1983; Tyser and Worley, 1992; Ernst, 1998) that are considered a severe threat to native flora (Usher, 1988; Spellerberg, 1998).

It is clear that infrastructure verges can facilitate animal movement and enable the spread of plants and other sessile species. It may therefore seem feasible to integrate infrastructure corridors into the existing (natural) ecological network (Figure 2.6). However, several important characteristics distinguish verges from ‘natural’ corridors and may hamper a successful linkage between technical and ecological infrastructure (Mader 1978b; Mader *et al.*, 1990). Habitat conditions (particularly microclimatic and hydrological) vary considerably within verges and infrastructure networks have intersections where animals face a higher risk of traffic mortality than if they had travelled along another natural corridor in the landscape (Madsen *et al.*, 1998; Huijser *et al.*, 1998; 1999).

Also, the predation pressure within verges may be increased compared to the surrounding habitat, because carnivores are attracted to traffic casualties as a food source.

Thus, the overall corridor effect is ambiguous. Verges may provide valuable habitats for wildlife, but primarily for less demanding, generalist species that are tolerant of disturbance and pollution and are resilient to the increased mortality risk associated with the traffic. Verges can support wildlife movements, but also serve as a source of ‘unwanted’ or alien species spreading into the surrounding habitats. The overall corridor function of infrastructure verges will most likely be influenced by the ecological contrast between the vegetation/structure in the corridor and the surrounding habitat (Figure 3.6). To better understand this complexity and give practical advice to road planners, more empirical studies are needed.

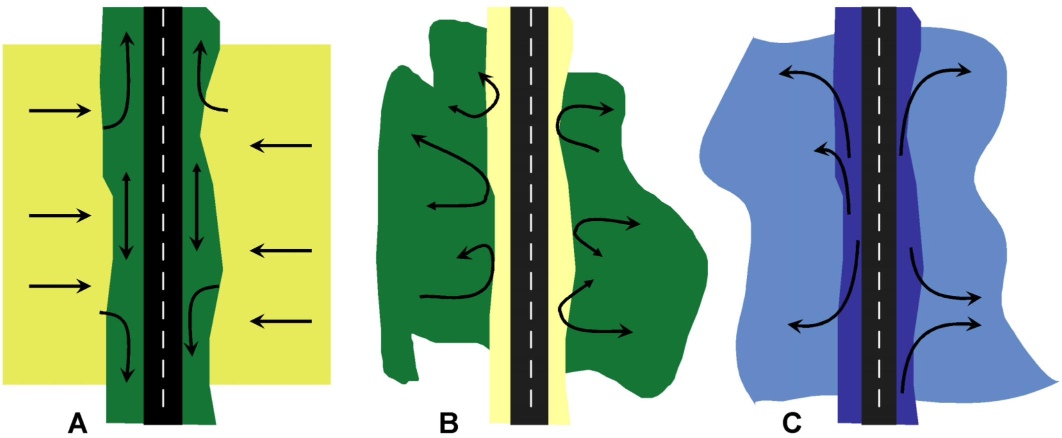

Figure 3.6 - The corridor function differs with respect to the surrounding landscape: A) Open, agricultural landscapes: richly vegetated verges can provide a valuable habitat for wildlife and facilitate movement. B) Forested landscapes: open and grassy verges introduce new edges and can increase the barrier effect on forest interior species. C)

Verges may also serve as sources of species spreading into new habitats or re-colonising vacant areas. (Modified from Mader, 1987b)

3.5. Fauna casualties

3.5.1. The phenomenon

Road mortality is probably the most widely acknowledged effect of traffic on animals, as carcasses are a common sight along trafficked roads (Figure 3.7). The number of casualties appears to be constantly growing as traffic increases and infrastructure expands (Stoner 1925; Trombulak and Frissell, 2000). Forman and Alexander (1998) concluded that 'sometime during the last three decades, roads with vehicles probably overtook hunting as the leading direct human cause of vertebrate mortality on land'. The scale of the problem is illustrated by the numbers of known road kills (see Section 5.3 and Table 5.7).

Figure 3.7 - Wildlife casualties – a common view along roads and railways. (Photos by H. De Vries and C. Rosell)

The quantity of road kills is such that collisions between vehicles and wildlife comprise a growing problem not only for species conservation and game management, but also for traffic safety, and the private and public economy (Harris and Gallagher, 1989; Hartwig, 1993; Romin and Bissonette, 1996; Putman, 1997). In most countries, traffic safety is the driving force behind mitigation efforts against fauna casualties (see Chapter 8) and although human fatalities are a relatively rare outcome in wildlife-vehicle collisions, the number of injured people and the total economic costs, including damage to vehicles, can be substantial. Police records in Europe (excluding Russia) suggest more than half a million ungulate-vehicle collisions per year, causing a minimum of 300 human fatalities, 30,000 injuries, and a material damage of more than 1 billion Euro (Groot Bruinderink and Hazebroek, 1996). From an animal welfare point of view, there is also concern about road casualties: many animals that are hit by vehicles are not immediately killed, but die later from injuries or shock. Hunters complain about the increasing work to hunt down injured game (Swedish Hunters Association, *pers. comm.*) and train drivers in northern Sweden complain about the unpleasant experience of colliding with groups of reindeer and moose (Åhren and Larsson, 1999).

3.5.2. Ecological significance of wildlife-traffic collisions

Evaluating the ecological importance of road mortality for a species involves considering the species' population size and recruitment rate. Large numbers of casualties of one species may not necessarily imply a threat to the survival of that species, but rather indicate that it is abundant and widespread. For many common wildlife species, such as rodents, rabbits, foxes, sparrows, or blackbirds, traffic mortality is generally considered insignificant, accounting only for a small portion (less than 5%) of the total mortality (Haugen, 1944; Bergmann, 1974; Schmidley and Wilkins, 1977; Bennett, 1991; Rodts *et al.*, 1998; see also Table 5.7). Even for red deer (*Cervus elaphus*) , roe deer (*Capreolus capreolus*) or wild boar (*Sus scrofa*), traffic mortality generally accounts for less than 5% of the annual spring populations in Europe (Groot Bruinderink and Hazebroek, 1996). In contrast to natural predation, traffic mortality is non-compensatory, and the kill rate is independent of density. This implies that traffic will kill a constant proportion of a population and therefore affect rare species most significantly. In general, species that occur in small isolated populations, and those which require large extensive areas for their home ranges, or exert long migratory movements, are especially sensitive to road mortality. Indeed, for many endangered or rare species around the world, traffic is considered as one of the most important sources of mortality (Harris and Gallagher, 1989).

3.5.3. Factors that influence the occurrence of wildlife-traffic collisions

There are various factors that determine the risk of animal-vehicle collisions (Figure 3.8). The numbers of collisions generally increase with traffic intensity and animal activity and density. Temporal variations in traffic kills can be linked to biological factors which determine the species' activity *e.g.* the daily rhythm of foraging and resting, seasons for mating and breeding, dispersal of young, or seasonal migration between winter and summer habitats (Van Gelder, 1973; Bergmann, 1974; Göransson *et al.*, 1978; Aaris-Sorensen, 1995; Groot Bruinderink and Hazebroek, 1996). Changes in temperature, rainfall or snow cover can also influence the occurrence and timing of accidents (Jaren *et al.*, 1991; Belant, 1995; Gundersen and Andreassen, 1998).

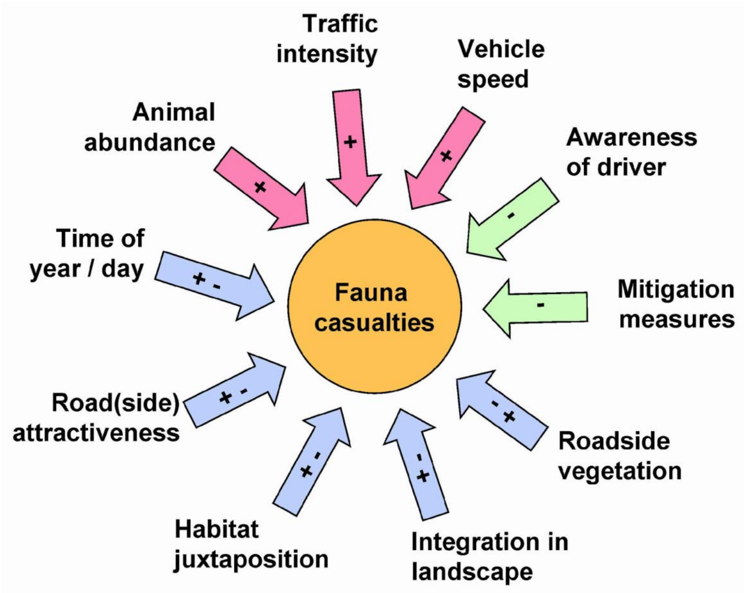

Figure 3.8 - Factors influencing the number of wildlife traffic accidents.

Roadkills seem to increase with traffic intensity to an optimum point, after which they level off. It seems that very high traffic volumes, noise and vehicle movements have the effect of deterring many animals, hence mortality rates do not increase further with higher traffic flows (Oxley *et al.*, 1974; Berthoud, 1987; Van der Zee *et al.*, 1992; Clarke *et al.*, 1998; see Figure 3.10). The occurrence of mitigation measures such as fences or passages and the programme of verge management clearly affects the local risk of accidents. The clearance of infrastructure verges of deciduous vegetation, for instance, has proven to reduce the number of moose (*Alces alces*) casualties in Scandinavia by between 20% and 50% (Lavsund and Sandegren, 1991; Jaren *et al.*, 1991). On the other hand, where verges provide attractive resources to wildlife, the risk of vehicle-animal collisions is likely to be increased (Feldhamer *et al.*, 1986; Steiof, 1996; Groot Bruinderink and Hazebroek, 1996).

Spatial pattern in road kills clearly depends on animal population density and biology, habitat distribution and landscape structure, but also on road and traffic characteristics (Puglisi *et al.*, 1974'; Ashley and Robinson, 1996, Finder *et al.*, 1999). In species with limited mobility and specific habitat requirements, such as many amphibians, it can be relatively simple to identify potential conflict areas. Most amphibian casualties occur during a short period in spring, when the animals migrate to and from their breeding ponds and are concentrated where roads dissect the migration routes (van Gelder, 1973). Roads that pass close to breeding ponds, wetlands and the animals' foraging habitats, are likely to cause a much greater kill rate than roads outside the species' migratory range *i.e.* about 1 km (see Vos and Chardon, 1998; Ashley and Robinson, 1996).

Other species, especially larger mammals, depend less on specific habitat types and utilise the landscape at a broader scale, which makes it more difficult to locate possible collision 'hotspots' (Madsen *et al.*, 1998). However, where favourable habitat patches coincide with infrastructure, or where roads intersect other linear structures in the landscape (*e.g.* hedgerows, watercourses, and other (minor) roads and railways), the risk of collisions is usually increased (Puglisi *et al.*, 1974; Feldhamer *et al.*, 1986; Kofler and Schulz, 1987;

Putman, 1997; Gundersen *et al.*, 1998; Lode, 2000). For example, collisions with white-tailed deer (*Odocoileus virginianus*) in Illinois are associated with intersections between roads and riparian corridors, and public recreational land (Finder *et al.*, 1999). Traffic casualties amongst otters (*Lutra lutra*) are most likely to occur where roads cross over watercourses (Philcox *et al.*, 1999). Road-killed hedgehogs (*Erinaceus europaeus*) in The Netherlands are often found where roads intersect with railways (Huijser *et al.*, 1998). Also foxes and roe deer (*Capreolus capreolus*) in Denmark are more often found near intersections than elsewhere along roads (Madsen *et al.*, 1998).

The different factors influencing wildlife-traffic accidents must be fully understood before any local need for mitigation can be evaluated, and effective measures designed and constructed (Romin and Bissonette, 1996; Putman, 1997). GIS-based analysis of traffic kills and wildlife movements, in relation to roads and landscape features, may provide the necessary insight to enable predictive models for impact assessment and the localisation of mitigation measures to be developed and applied (Gundersen *et al.*, 1998; Finder *et al.*, 1999; see also Section 6.4).

3.6. BARRIER EFFECT

3.6.1. The components of the barrier effect

Of all the primary effects of infrastructure, the barrier effect contributes most to the overall fragmentation of habitat (Reck and Kaule, 1993; Forman and Alexander, 1998). Infrastructure barriers disrupt natural processes including plant dispersal and animal movements (Forman *et al.*, 1997). The barrier effect on wildlife results from a combination of disturbance and avoidance effects (*e.g.* traffic noise, vehicle movement, pollution, and human activity), physical hindrances, and traffic mortality that all reduce the number of movements across the infrastructure (Figure 3.9). The infrastructure surface, gutter, ditches, fences, and embankments may all present physical barriers that animals cannot pass. The clearance of the infrastructure corridor and the open verge character creates habitat conditions that are unsuitable or hostile to many smaller species (see Section 3.3.1). Most infrastructure barriers do not completely block animal movements, but reduce the number of crossings significantly (Merriam *et al.*, 1989). The fundamental question is thus: how many successful crossings are needed to maintain habitat connectivity?

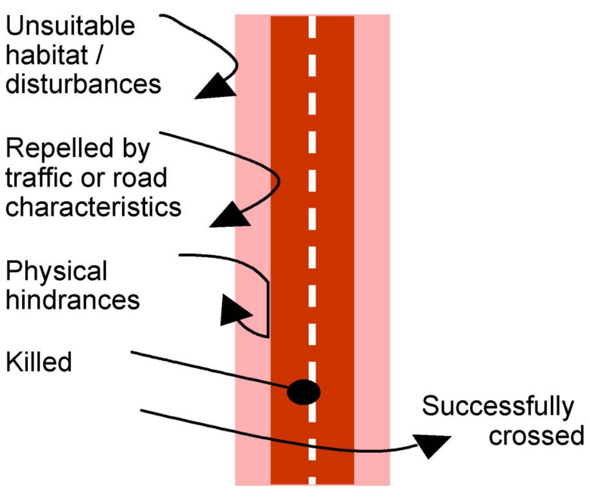

Figure 3.9 - The barrier effect of a road or railway results from a combination of disturbance/deterrent effects, mortality and physical hindrances. Depending on the species, the number of successful crossings is but a fraction of the number of attempted movements. Some species may not experience any physical or behavioural barrier, whereas others may not try to even approach the road corridor. To effectively mitigate the barrier effect, the relative importance of the inhibiting factors on individual species must be established.

The barrier effect is a non-linear function of traffic intensity, which along with vehicle speed appear to have the strongest influence on the barrier effect. Infrastructure width, verge characteristics, the animals' behaviour and its sensitivity to habitat disturbances are also key factors (Figure 3.10). With increasing traffic density and higher vehicle speed, mortality rates usually increase until the deterrent effect of the traffic prevents more animals from getting killed (Oxley *et al.*, 1974; Berthoud, 1987; Kuhn, 1987; Van der Zee *et al.* 1992; Clarke *et al.* 1998). Exactly when this threshold in traffic density occurs is yet to be established but Müller and Berthoud (1997) propose five categories of infrastructure/traffic intensity with respect to the barrier impact on wildlife:

- Local access and service roads with very light traffic: can serve as partial filters to wildlife movements; may have a limited barrier impact on invertebrates and eventually deter small mammals from crossing the open space; larger wildlife may benefit from these roads as corridors or conduits.
- Railways and minor public roads with traffic below 1,000 vehicles per day: may cause incidental traffic mortality and exert a stronger barrier/avoidance effect on small species, but crossing movements still occur frequently.
- Intermediate link roads with up to 5,000 vehicles per day: may already represent a serious barrier to certain species; traffic noise and vehicle movement are likely to have a major deterrent effect on small mammals and some larger mammals meaning the increase in the overall barrier impact is not proportional to the increase in traffic volume.
- Arterial roads with heavy traffic between 5,000 and 10,000 vehicles per day: represent a significant barrier to many terrestrial species, but due to the strong repellence effect of the traffic, the number of roadkills remains relatively constant over time; roadkills and traffic safety are two major issues in this category.
- Motorways and highways with traffic above 10,000 vehicles per day: impose an impermeable barrier to almost all wildlife species; dense traffic deters most species from approaching the road and kills those that still attempt to cross.

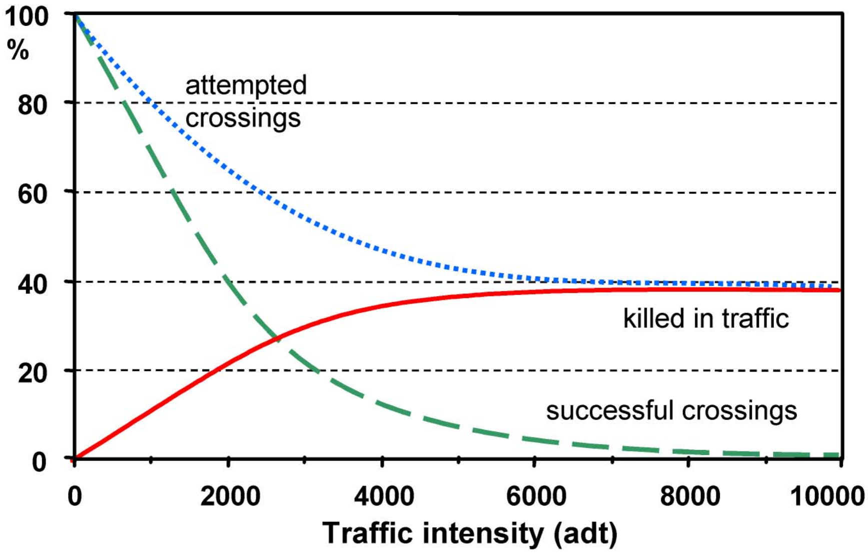

Figure 3.10 - Theoretical model illustrating the relationship between traffic intensity and the barrier effect: with increasing traffic, the number of roadkills increases in a linear fashion until noise and vehicle movements repel more animals from attempting to cross the road; at very high traffic volumes, the total mortality rate could decrease until the barrier effect reaches 100% *i.e.* preventing all crossings. (Redrawn from Müller and Berthoud, 1997)

3.6.2. Evidence from field studies

Transportation infrastructure inhibits the movement of practically all terrestrial animals, and many aquatic species: the significance of the barrier effect varies between species. Many invertebrates, for instance, respond significantly to differences in microclimate, substrate and the extent of openness between road surface and road verges: high temperatures, high light intensity and lack of shelter on the surface of paved roads have been seen to repel Lycosid spiders and Carabid beetles (Mader 1988; Mader *et al.*, 1990). Land snails may dry out or get run over while attempting to cross over a paved road (Baur and Baur, 1990). Also amphibians, reptiles, and small mammals may be sensitive to the openness of the road corridor, the road surface and traffic intensity (Joule and Cameron, 1974; Kozel and Fleharty, 1979; Mader and Pauritsch, 1981; Swihart and Slade, 1984; Merriam *et al.*, 1989; Clark *et al.*, 2001). Even birds can be reluctant to cross over wide and heavily trafficked roads (Van der Zande *et al.*, 1980). Semi-aquatic animals and migrating fish moving along watercourses are often be inhibited by bridges or culverts that are too narrow (Warren and Pardew, 1998).

Most empirical evidence for the barrier effect derives from capture-recapture experiments on small mammals. For example, Mader (1984) observed that a 6 m wide road with 250 vehicles/hour completely inhibited the movement of 121 marked yellow-necked mice (*Apodemus flavicollis*) and bank voles (*Clethrionomys glareolus*) (see Figure 3.11). Similarly, Richardson *et al.* (1997) found that mice and voles were reluctant to cross paved roads wider than 20-25 m although they did move along the road verge. Oxley *et al.* (1974) documented that white-footed mice (*Peromyscus leucopus*) would not cross over highway corridors wider than 30 m although they frequently crossed over smaller and only lightly trafficked forest roads.

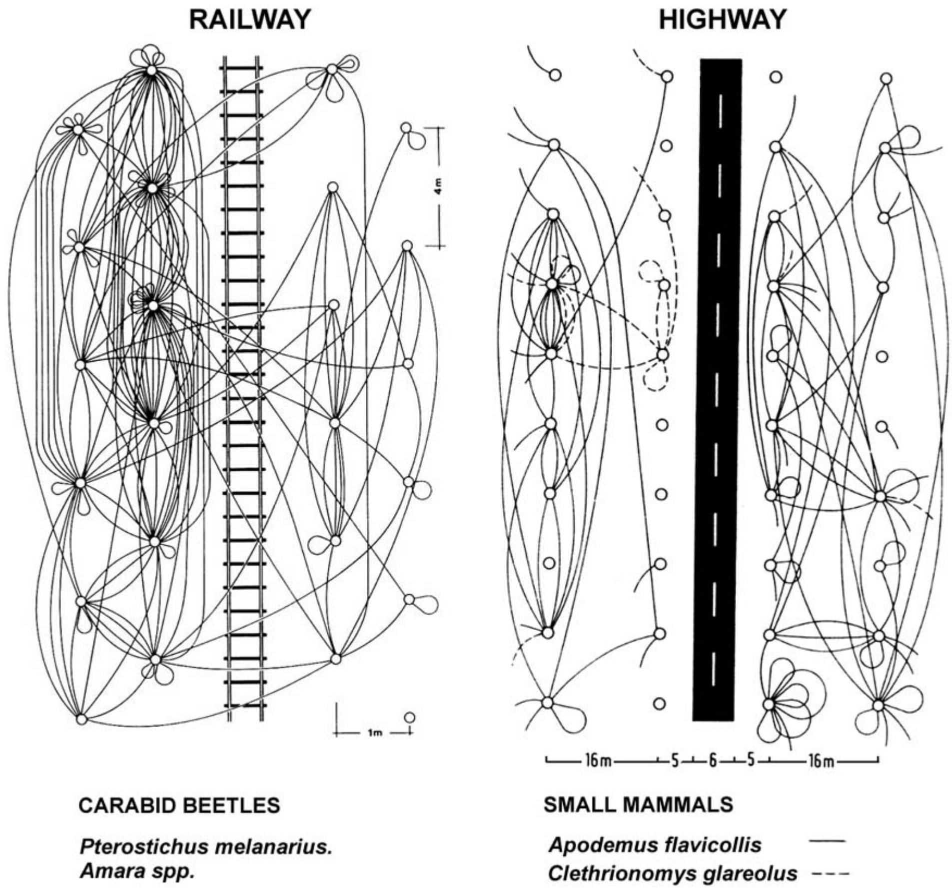

Figure 3.11 - Mobility diagram illustrating animal movements along and across a railway and road, based on capture-recapture data of: (left) carabid beetles (redrawn from Mader *et al.*, 1990); and (right) small mammals. (Redrawn from Mader, 1984)

For larger animals, roads and railways do not represent a physical barrier, unless they are fenced or their traffic intensity is too high. Most mammals, however, are sensitive to disturbance by humans and scent, noise and vehicle movement may deter animals from approaching the infrastructure corridor. For example, Klein (1971) and Curatolo and Murphy (1986) observed a strong avoidance of roads by feral reindeer (but not by domestic reindeer) and Rost and Bailey (1979) reported that mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) avoided habitats closer than around 100 m to trafficked roads.

However, to what extent this avoidance effect reduces the number of successful or attempted movements across roads is not clear. More data is required on the actual movements (spatial and temporal) of larger mammals in relation to infrastructure in order to judge the inhibitory effect of roads and traffic.

3.6.3. Consequences at a population level

When do infrastructure barriers really become a problem for wildlife conservation? How much permeability is needed to maintain sufficient habitat connectivity? How large a barrier effect can be tolerated by individual species and populations? To answer these questions, the consequences at population level must be considered. Depending on the number of successful crossings relative to the size of the population, the barrier effect can be significant to population dynamics, demographic or genetic properties. If the species does not experience a significant barrier effect and individuals still move frequently across the road, the dissected populations will continue to function as one unit. If the exchange of individuals is reduced but not completely inhibited, the populations may diverge in demographic characters, *e.g.* in terms of density, sex ratio, recruitment and mortality rate. Also genetic differences may emerge, as the chance for mating with individuals from the other side of the infrastructure barrier may be reduced. These changes may not necessarily pose a threat to the dissected populations; except for sink populations dependent on steady immigration for continued survival (see Section 2.3). If the barrier effect is even stronger, the risk of inbreeding effects and local extinctions will increase rapidly.

Evidence of the effect on population genetics derives from studies on rodents and amphibians. For example, Reh and Seitz (1990) observed effects of inbreeding, in the form of reduced genetic diversity, in small populations of the common frog (*Rana temporaria*) that were isolated by roads over many years. Merriam *et al.* (1989) found indications of genetic divergence in small-mammal populations separated by minor roads. However, populations dissected by one single barrier may not automatically suffer from inbreeding depression, unless they are critically small or do not have contact with other more distant populations in the landscape. To evaluate the consequences of a new infrastructure barrier, the combined isolation effects of all the existing surrounding infrastructure and other natural and artificial barriers must be considered. The denser the infrastructure network and the more intense its traffic, the more likely it will cause significant isolation of local populations. By definition, small isolated populations (particularly of rare and endemic species) are more sensitive to barrier effects and isolation than populations of abundant and widespread species. Species with large area requirements and wide individual home ranges will more frequently need to cross over road barriers than smaller and less mobile species.

It is the combination of population size, mobility, and the individuals' area requirements that determines a species' sensitivity to the barrier impact of infrastructure (Verkaar and Bekker, 1991). A careful choice between alternative routes for new infrastructure may thus help to prevent the dissection of local populations of small species, but cannot reduce the barrier effect for larger, wide roaming species. In most cases, technical/physical measures, such as fauna passages or ecoducts, will be required to mitigate against barrier impacts and re-establish habitat connectivity across the infrastructure.

3.7. FRAGMENTATION

The previous discussions show that the total impact of roads and railways on wildlife cannot be evaluated without considering a broader landscape context. Roads and railways are always part of a wider network, where synergetic effects with other infrastructure links occur, which cause additional habitat loss and isolation. Studies on the cumulative effects of fragmentation caused by transportation infrastructure must address larger areas and cover longer time periods than studies that simply address the primary effects of a single road or railway link. Evaluating the degree of fragmentation due to infrastructure is not a simple task. The significance of fragmentation is highly species-specific and dependent on the amplitude of barrier and disturbance effects, the diversity and juxtaposition of habitats within the landscape, and the size of the unfragmented areas between infrastructure links (*i.e.* the density of infrastructure). Forman *et al.* (1997) suggested the use of infrastructure density as a simple but straightforward measure of fragmentation (Figure 3.12). This measure could be improved by adding information on traffic density, speed, infrastructure width and design.

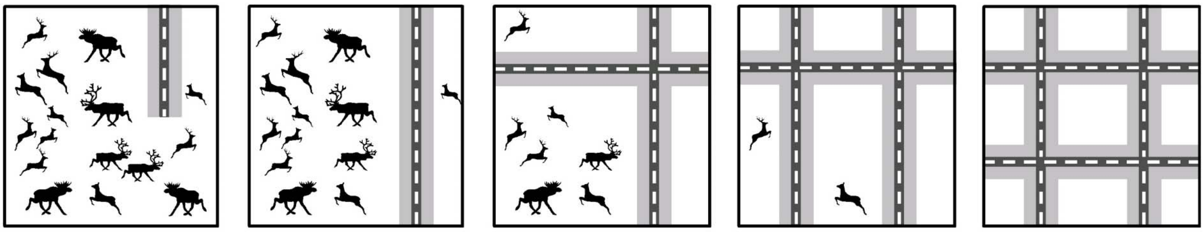

Figure 3.12 - Infrastructure causes a loss and degradation of habitat due to disturbance effects (grey corridors) and isolation. With increasing infrastructure density, areas of undisturbed habitat (white) are reduced in size and become inaccessible. Remnant fragments of suitable habitat may eventually become too small and isolated to prevent local populations from going extinct. The critical threshold in road density is species-specific, but will also depend on landscape and infrastructure characteristics.

Several studies have described critical thresholds in road density for the occurrence of wildlife species in the landscape. For example, Mladenoff *et al.* (1999) observed that wolves and mountain lions did not sustain viable populations in regions of Minnesota, USA with road densities above 0.6 km/km^2 (Thiel, 1985; Van Dyke *et al.*, 1986). Also, the presence of other large mammals in the USA such as elk, moose and grizzly bear, appears to be negatively influenced as road densities increase (Holbrook and Vaughan, 1985; Forman *et al.*, 1997).

The observed fragmentation effect may however not be associated with the direct impact of infrastructure and traffic, but rather with the increased access to wildlife areas that roads in particular (especially forest roads) offer hunters and poachers (Holbrook and Vaughan, 1985; Gratson and Whitman, 2000). In Europe, areas remote from roads or with only low road density, low traffic volumes, and a high proportion of natural vegetation, are considered as core areas in the ecological network (*e.g.* Jongman, 1994; Bennett, 1997). Determining how much undeveloped habitat is needed and how large the infrastructure-free landscape fragments need to be to ensure a given species survival is a task for future research. Clearly, the best option to counteract the fragmentation process is the reclamation of nature areas for wildlife through the removal of roads, or by permanent or temporary road closure. Road closure helps to reduce motorised access to wildlife habitat and enlarges undisturbed core areas, yet the physical barrier and its edge effects still remain. The physical removal of roads is the ultimate solution. In some countries, such as on federal land in the USA, attempts are being made to integrate road removal as a part of the Grizzly Bear Conservation Program (see Evink *et al.*, 1999; Wildlands CPR, 2001). To ensure the survival of grizzlies in the core areas of their distribution, it has been suggested to establish road-free habitats of at least 70% of the size of an average female home range. In regions designated for grizzly bear conservation and where road densities are higher than that required for the secure habitats, it is recommended that roads should consequently be removed.

In Europe, temporary closure of (local) roads is an action primarily applied in order to maximise the protection of seasonally migrating amphibians (Dehlinger, 1994). Applying speed limits on local roads can also offer a simple tool for changing traffic flows and reducing disturbance and mortality impacts in wildlife areas. In situations where roads cannot be removed or closed, or traffic reduced, technical mitigation measures such as fauna passages and ecoducts may be necessary to minimise fragmentation and reconnect wildlife habitats (*e.g.* DWW, 1995).

3.8. SUMMARY

In this chapter some of the major literature on the ecological effects of infrastructure has been reviewed. There is a growing concern about habitat fragmentation caused by roads and railways all around the world. The increasing demand for avoidance and mitigation makes it clear that there is still much to be understood before the cumulative potential impacts can be assessed in an efficient and practical way. A considerable amount of research has been carried out already, yet many of the studies are descriptive, dealing with problems of individual roads or railways, but without considering the more strategic issues integral in the planning of ecologically friendly infrastructure.

How much habitat is actually lost due to construction and disturbance effects of infrastructure? How wide is the impact zone along roads and how does the width of this zone change with traffic intensity and type of surrounding habitat? How can transportation infrastructure be integrated into the ‘ecological’ infrastructure in the landscape without causing an increase in the risk of animal-vehicle collisions? Where and when are mitigation measures against road wildlife mortality necessary or affordable? How much infrastructure is too much in areas designated for wildlife? What are the ecological thresholds that must not be surpassed and how can the best use be made of the potential in a road or railway project to improve the current situation?

Finding answers to these questions is a challenge to landscape ecologists, biologists and civil engineers alike (Forman, 1998; Cuperus *et al.*, 1999). To develop effective guidelines and tools for the planning of infrastructure, research needs to be focussed on ecological processes and patterns, using experiments and simulation models to identify critical impact thresholds. Empirical studies are necessary to provide the basic data that will help to define evaluation criteria and indices. Remotely sensed landscape data, GIS-techniques, and simulation models offer promising tools for future large-scale research (see Section 6.4), but they must rely on empirical field studies at local scales. Clearly, a better understanding of the large-scale long-term impact of fragmentation on the landscape is required, yet the solution to the problems will more likely be found at a local scale. Richard T.T. Forman, a pioneer in landscape and road ecology at Harvard University, Massachusetts, put it simply: We must learn to ‘think globally, plan regionally but act locally’ (*sensu* Forman, 1995).

Chapter 4. National context/European context

4.1. Introduction

Upon becoming a federal state Belgium was administratively split up in three regions: the Flemish Region, the Walloon Region and the Brussels Capital Region. The Flemish Region has 5 provinces: West-Flanders, East-Flanders, Antwerp, Flemish Brabant, and Limburg (see figure 4.1.). Now, the regions of federal Belgium have authorisation for the different domains relevant to this report (road construction, nature conservation and environmental planning). Ever since Belgium is participating in the COST 341 action the Flemish Region is trying to make contact with its Walloon counterpart for their filling-in of the « State of the Art report on Habitat Fragmentation due to Linear Transport Infrastructure ». Up to now the report is restricted to the situation of the Flemish region. As a result one has to take into consideration the difference in surface area size (surface area of Flanders is 1,352,225 hectares) when comparing to other European countries.

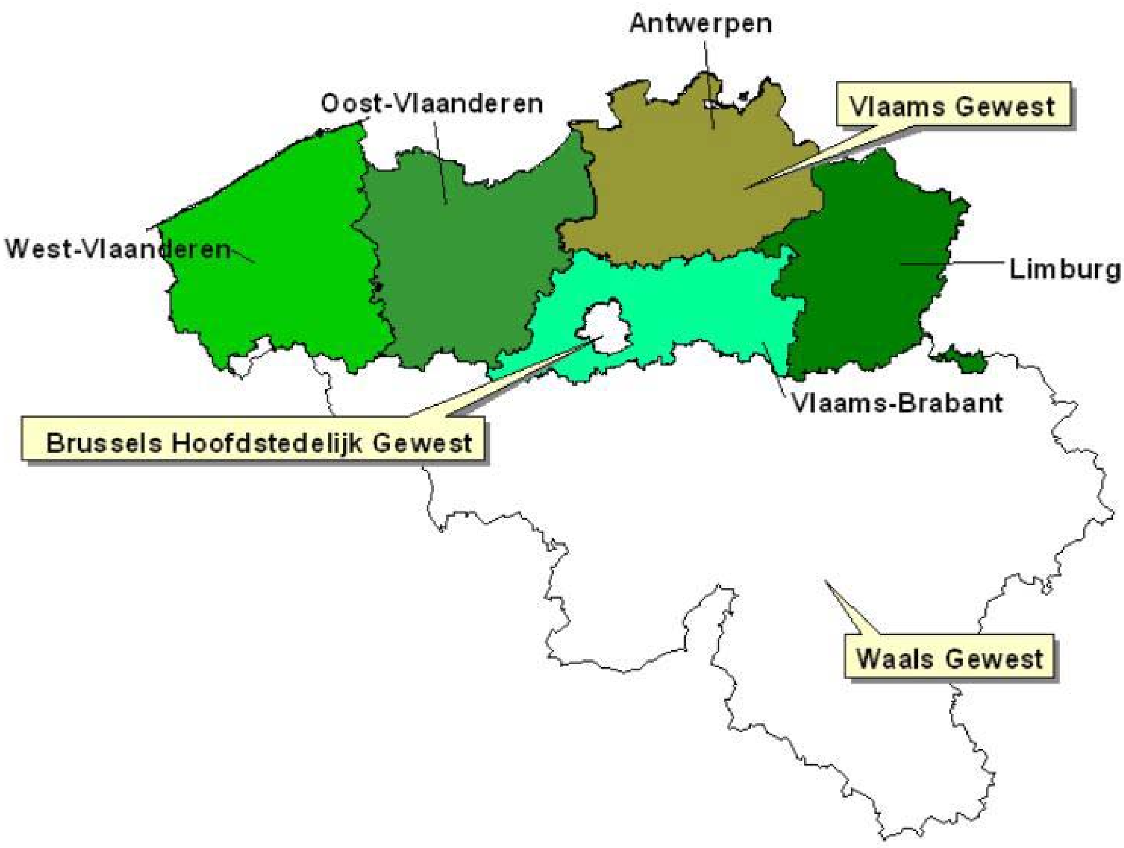

Figure 4-1 Belgian regions and Flemish provinces

Flanders is situated in the economic centre of the European Union: it surrounds Brussels and it lies at the crossroads of economic nerve centres such as Randstad Holland located in the north, London in the West, the Ruhr area in the East, and the French metropolitan areas Paris and Lille-Roubaix-Tourcoing in the South (figure 4.2). As a result transport is taking up much of the space. Total road length amounts to more than 60,000 km, ribbon development length takes up approximately 2,000 km. Flanders has the most dense railway network in Europe and has the second most dense waterway network with the Netherlands being number one. Land use is also very much fragmented; industrial areas and general building areas are strongly fragmented: 40% of building developments are located outside town areas, forestry and wildlife areas are as a rule small and isolated, quantity and quality of small landscape elements are diminishing continuously, river and brook valleys are regularly cut short by land development infrastructures, and bad water quality diminishes the natural linking capacity typical for watercourses.

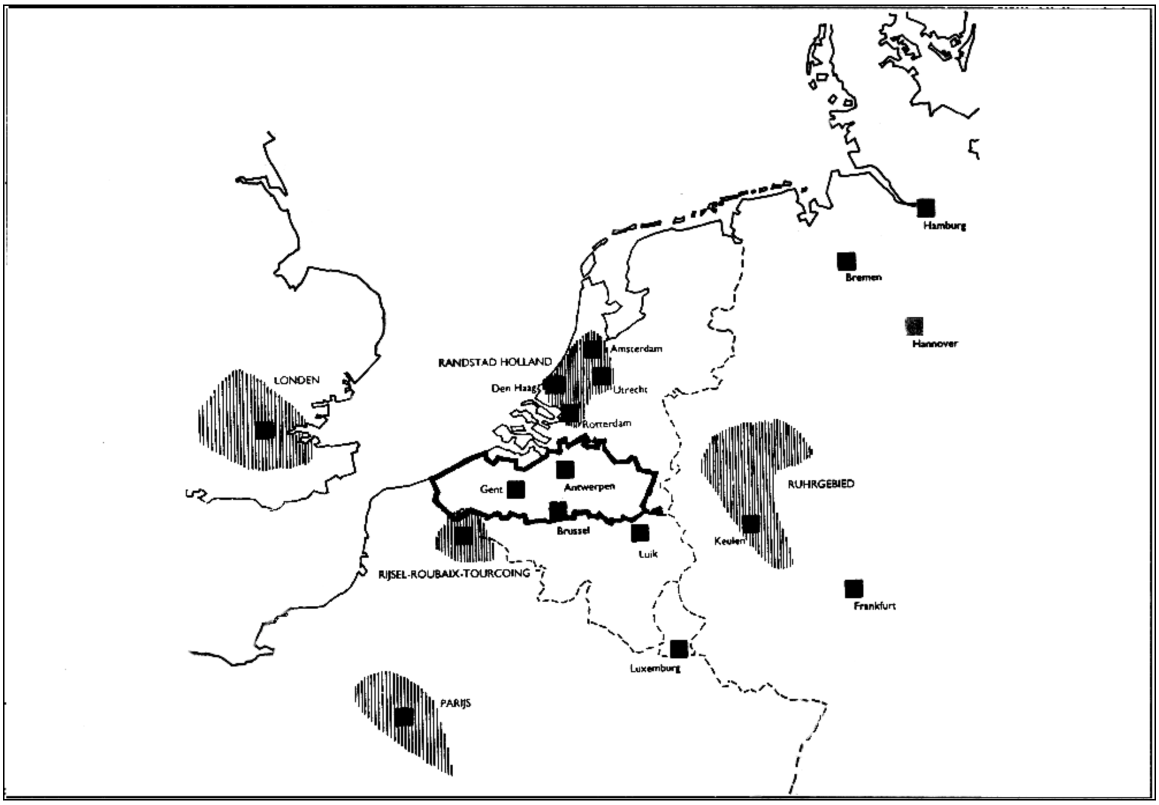

Figure 4-2 Location of Flanders in the context of Northwestern Europe (From RSV, complete version, 1997).

Nature management is very much aware of the continuing fragmentation of the Flemish landscape and has therefore been concentrating itself on the development of a coherent network of wildlife areas for some time already. The latter principle and open land conservation in general are essential goals of the Master Plan of Flanders (see later).

In 1990, the installation of the NTMB unit (NatuurTechnische Milieubouw – Naturally Engineered Environmental Development) of the Flemish Administration of environment gave concrete form to the realisation of those goals. That workgroup did the pioneering work for Flanders in that domain and has since then developed a standard methodology for defragmentation measures and for naturally engineered environmental development, which is published in two manuals (one for waterways and one for roads).

This report is a state of affairs on habitat fragmentation caused by transport infrastructure in Flanders. The first chapter gives a rough outline of the strongly fragmented Flemish landscape, the biogeographical districts and the major fragmentation sensitive fauna species with a national and international status. Furthermore, a survey of land occupation and land use in Flanders is given. From there, policy vision and policy realisations in the context of defragmentation and nature conservation are summed up. The final section of this chapter consists of a brief outline of the legislation on nature conservation and environmental planning so that the reader can situate the problems in the context of legislative organisation and authorities. International agreements that resulted in relevant decrees will also be brought up.

4.2. BIOGEOGRAPHICAL DESCRIPTION

According to the bio geographical classification of Europe in the framework of Natura 2000 (see 4.5) Flanders is located in the Atlantic zone. That zone is characterised by a sea climate: relatively modest temperatures with on the average a lot of precipitation. For the bio geographical description of the Flemish landscape it is opted from the nature conservation point of view to use the ecoregions concept (see figure 4.3). Ecoregions can be subdivided into ecodistricts (Antrop, 1993). More specifically, ecoregions are spatial units which are demarcated on the basis of natural, geographical areas that are homogenous to abiotic factors that are slowly changing in time, such as geology (lithology, soil conditions, geomorphology), relief, and groundwater system. Moreover, ecodistricts are characterised by specific ecological « key factors » which makes those areas have their own combination of environmental characteristics. Because of that fact one can expect specific vegetation with possibly like fauna within the same ecodistrict, if conditions such as a relatively constant and stable land use and environmental planning are met.

Also, we presuppose that a global sensitivity for the environmental changes acidification, overfertilisation, and dehydration can be given since the successive processes through which these environmental problems are developed occur in components that are precisely determining components when demarcating those districts.

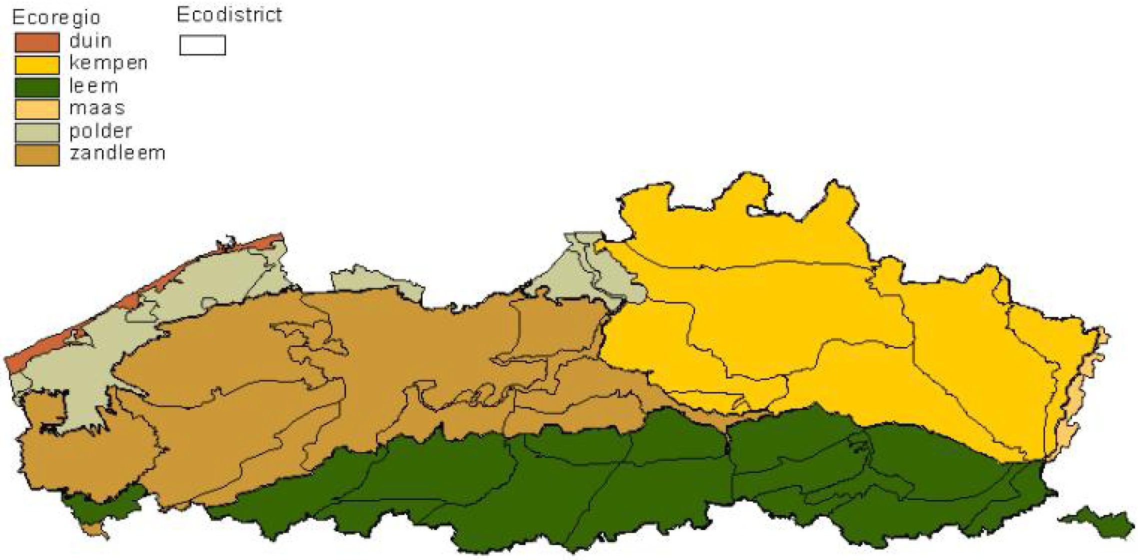

Figure 4-3 Ecoregions and ecodistricts in Flanders

With regard to disintegration that relation is visibly less strong due to the cultural-historical nature of the problem. For that reason a further elaboration needs to be added, more specifically the traditional landscaping concept (Antrop, 1989). That is to say, landscapes (figure 4.4) that have not or have only slightly been changed by large-scale interference after the industrial revolution. The major changes happened after WW II. That is why many of those traditional landscapes can only recognised as relics (or not even that) or not recognised at all.

While ecoregions describe the potential environmental qualities of nature, traditional landscapes are characterised by a spatial association often based on socio-economic factors from both past and present. The Flemish Region consists of some eight landscape areas made up of one or more traditional landscape types.

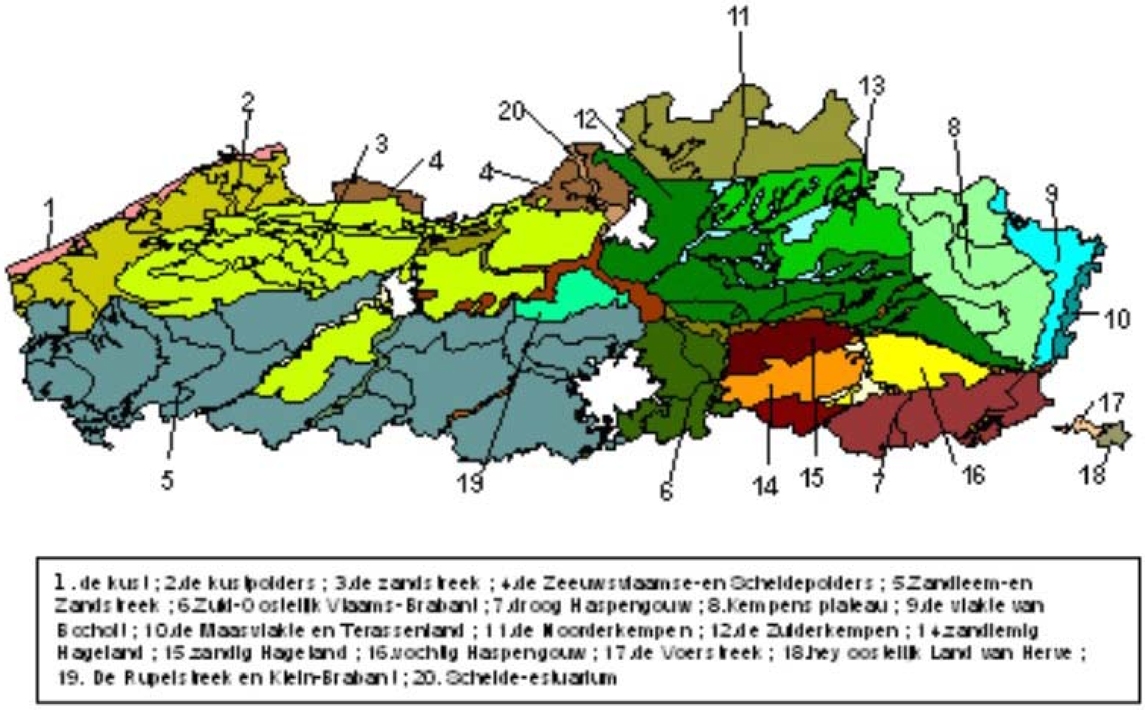

Figure 4-4 Traditional landscapes in Flanders (According to Antrop et al., 1989)

Especially after WW II many of those traditional landscapes were transformed by large-scale technological developments. For the first time, those « new landscapes » differ largely from natural areas because from then on it became possible to make radical structural landscape changes. What appeared were new agricultural landscapes through land consolidation, urban landscapes (complexes of residential areas, industry, and business areas) and housing landscapes (housing areas in green zones), road landscapes, industrial landscapes (industry areas), and recreational landscapes (by planning or naturally). Economic motivation thereof was sufficient while all other cultural sectors (history, ecology, psychology, sociology, …) showed themselves rather critical with regard to the subject.

By means of the Biological Valuation Map (BWK) we can give an overview of the biotopes of major importance in Flanders (see table 4.1). The Biological Valuation Map is an areal inventory list that has mapped biotope presence on a scale of 1 : 25,000 by using a fixed and standardised set of mapping units. The field data date from the 1978-1996 period; actualisation thereof was started in 1997. Actualisation has been finished for a limited part of Flanders so that a representation of the evolution of certain biotopes can be given of the past decade.

Table 4-1 Biotope surface area in Flanders grouped in key units. Since complexes of biotopes are often marked in mapped parcels, minimum and maximum values are given. (From the Nature Report 1999, Institute of Nature Conservation)

Biotope key units		**Surface area**		
	Minimum (ha)	Maximum (ha)	Minimum (%)	Maximum (%)
Heathland and peats (peat moors included)	9,800	18,900	0.72	1.4
Marshes	5,800	15,400	0.42	1.1
Water rich areas (still waters and salt marshes/mud flats)	8,925	11,985	0.65	0.88
Sand dune vegetations	1,440	2,940	0.11	0.22
Historically permanent grassland, of which:	29,050	42,630	2.1	3.1
seminatural grassland	4,640	8,870	0.34	0.65
species rich grassland	9,270	11,450	0.68	0.84
grassland with widespread biological value	15,140	22,310	1.15	1.51
Underwood	3,750	6,610	0.27	0.49
Brushwood	5,710	11,200	0.19	0.39
Mesophile forests	22,550	56,410	1.7	2.8

To select native fragmentation sensitive animal species one mainly uses the size-range theory. Largely simplified one can say that the larger the individuals of a species the larger their home range will be and the more sensitive the species will probably be to fragmentation. Furthermore, studies originating from the Netherlands are taken into consideration, because according to European standards our northern neighbours have « a similar fauna » and because they have performed species oriented research concerning disintegration for a longer period of time already. To list the status of the endangered species discussed the categories of the Red List of Flanders are used (see table 4.2) in table 4.3. Legal protection of the species implies an all-time prohibition to hunt, to catch, to damage or to deliberately disturb its hiding or living area, and to transport and to sell the species whether dead or alive. Some mammals and birds fall under the hunting legislation and may be hunted during the legally determined period of time.

Table 4-2 Red List categories with explanation (this classification first of all wants to make an assessment about the endangerment status in Flanders and not about its situation within the species area)

Category	Red List Status
Oa	Extinct
Ob	Supposedly extinct
1	Seriously endangered
2	Endangered
3	Supposedly endangered
4	Rare

MAMMALS

ROE DEER (Capreolus capreolus)

The last decades, the roe deer population has increased considerably in Flanders, more particularly in young (dry and wet) forests with much undergrowth. It nevertheless seems to maintain itself in rather more agrarian biotopes also. Roe deer predominantly appear in Antwerp, Flemish Brabant and Limburg, but they are most probably settling in East-Flanders and West-Flanders too. Little is known about the barrier aspect of roads on that species. In high population density areas habituation to disturbing factors (such as buildings, noise and light of roads, etc.) has nevertheless been observed. Often waterways and gravel roads are used for migration purposes. Grassy road verges may also attract individuals. With regard to mitigating infrastructure the species appears to prefer tunnels to crossings. Well-known are collisions between roe deer and motorcars. Especially in the April-May (territorial behaviour), July-August (during mating season), and November-December (after mating season) time period. Through insurance claim registration with insurance companies (Motor Security Fund, see 6) one can locate the hot spots. When doing research on fragmentation measures, roe deer are always used as the main subject species, although this cannot entirely be justified from a strictly nature conservation point of view.

FOX (Vulpes vulpes)

The fox population in Flanders is still increasing. Foxes follow culture and are therefore often traffic casualties, e.g. in the suburbs of big cities. Because foxes are held responsible for spreading rabies, hunting them down is still allowed during autumn and winter.

WILD BOAR (Sus scrofa)

Flanders is housing a small population of wild boars in the Fourron area. They are most probably a subpopulation of the wild boar living in the Ardennes. The species' European spreading area boundary approximately coincides with the language boundary. As the species is active at night and avoids any kind of disturbance, it hardly ever becomes a traffic casualty.

BADGER (Meles meles)

Badgers are the largest of the marten species living in the wild. With regard to other mammals its home range is rather large, making it especially sensitive to the mortality effect of transport infrastructure. The fact that the badger population in Flanders, ranging somewhere between 100 and 200 individuals, is limited to the south and middle Limburg area with some isolated cases in Brabant and East-Flanders, facilitated the species' research regarding defragmentation measures. As poaching and hunting have been restricted traffic remains the major cause of death for badgers. It is estimated that motorcars yearly kill up to 40% of the badger population, in other words the annual population growth is lost to the traffic toll. Waterways are no unbridgeable barriers for badgers since they are good swimmers. Artificial waterways are however often constructed with steep, concrete banks that make it impossible for animals to get out of the water. Considering the population status of the species defragmentation is a priority.

PINE MARTEN (Martes martes)

Concerning the population status of pine martens in Flanders there has been uncertainty for some time now. It is not known if there still is a liveable population. A recent traffic casualty showed that there appear to be living a few individuals in Flanders. It might also be a roaming individual coming from a population out of Southern Belgium, as the collision occurred in the surroundings of the "Hallerbos" located not far from Brussels. Given the species' rare occurrence in Flanders, loosing a badger to traffic is considered a heavy loss. It can be deducted from foreign studies that waterways are likely to be absolute barriers for the species as pine martens cannot swim. Linear landscape elements such as undergrowth are used as guiding elements for migration. The pine marten is legally protected in Belgium.

STONE MARTEN (Martes foina)

For the last five years the stone marten population has considerably grown in Flanders. From the east of Flemish Brabant and Limburg it is now colonising West-Flanders and East-Flanders. That fact is being reflected into an increasing number of road traffic casualties. It is unknown, however, if death to traffic exerts counterpressure on the population growth of the species. The stone marten is also legally protected in Belgium.

WEASEL (Mustela nivalis), ERMINE (Mustela erminea), and POLECAT (Putorius putorius)

Weasels and ermines belong to the smaller marten species that use verges and banks as passageways and hunting grounds. They have an overall occurrence in Flanders and that is why they probably are killed often by traffic. Because they are so small, hardly any of them are reported. Also, dead bodies do not remain on roads long enough because they are taken by scavengers such as crows. The polecat is somewhat larger and therefore can be found dead along roads. These species are known to make nightly trips of several kilometres throughout their territory. Especially during springtime (mating season) and autumn when the cubs leave their nests for good, they are often killed by traffic.

OTTER (Lutra lutra)

Otters are one of the most endangered species in Europe; in Belgium and its neighbouring countries the situation is extremely alarming and the species is about to disappear for good. The most recent range map (1987) gives one or some areas in each province where « reliable » observations have been noted. Apart from isolated or wandering individuals that were observed sporadically, it may be concluded that the otter population in Flanders is extinct. The species is disturbance sensitive and it needs vast water ecosystems of good quality. Its decline is closely related to the deterioration of the water quality and the ecologically irresponsible organisation and management of waterways.

BATS

Many bats seem to use linear landscape elements to move or to forage. For that reason small road verges and waterway banks are used for hunting and flying routes, with collisions as a possible consequence. Through attracting all kinds of flying insects, road lights indirectly attract some bat species to road infrastructures, e.g. the pipistrelle (Pipistrellus pipistrellus). For other bat species larger motorways would form a barrier since serotines (Eptesicus serotinus) do not cross open areas.

OTHER MAMMALS

Among small animals the largest number of casualties found are hedgehogs (Erinaceus europaeus). The species is legally protected but up to 60% of the population is killed every year. One of the possible causes is the fact that hedgehogs do not appear to flee but rather curl themselves up when confronted with danger. Cars travelling at high speed make it seemingly impossible for the hedgehog to get out of the way quickly enough. Rabbits (Oryctolagus cuniculus) and hares (Lepus capensis) constitute a vast number of road traffic casualties found among mammals. Also, house shrews and garden shrews (Crocidura russula and Crocidura leucodon), which are legally protected, are often traffic casualties. And last but not least, squirrels (Scirius vulgaris), mainly living in the wooded areas of Antwerp, Limburg and Flemish-Brabant, are also found as traffic casualties. A foreign study has shown, however, that roads do not disturb the latter species, at least not in pinewoods.

Table 4-3 Survey of mammals on the Red List (category Oa not included) with their respective population status and sensitivity to traffic and fragmentation

Species	Endangered in Flanders (Red List)	Endangered in Belgium	Endangered in Europe	Sensitive to habitat loss and fragmentation	Endangered by traffic
Water shrew (Neomys fodiens)	2			*	
Garden shrew (Crocidura leucodon)	4				
Greater horseshoe bat (Rhinolophus ferrumequinum)	0b	*		*	
Whiskered bat (Myotis mystacinus)	3			*	
Brandt's bat (Moytis brandtii)	2	*		*	
Natterer's bat (Myotis nattereri)	3	*	*		
(Myotis emarginatus)	1	*		*	
Bechstein's bat (Myotis bechsteinii)	1	*		*	
(Myotis dasycneme)	2	*	*	*	
Mouse-eared bat (Myotis myotis)	1	*	*	*	
Nathusius' pipistrelle (Pipistrellus nathusii)	3	*			
Leisler's bat (Nyctalus leisleri)	1	*		*	
Brown long-eared bat (Plecotus auritus)	3	*	*	*	
Barbastelle (Barbastella barbastellus)	0b	*		*	
Common dormouse (Muscardinus avellanarius)	2	*	*	*	
Hamster (Cricetus cricetus)	1	*		*	
Pine marten (Martes martes)	3			*	*
Badger (Meles meles)	2	*		*	*
Otter (Lutra lutra)	0b	*	*	*	*

BIRDS

Although birds are less sensitive to the barrier effect of transport infrastructure, bird species living in heathland, forests, and dune areas are considered vulnerable in terms of habitat loss and isolation. Among others, tawny owl (Strix aluco), lesser spotted woodpecker (Dendrocopos minor), marsh tit (Parus palustris), nuthatch (Sitta europaea), hawfinch (Coccothraustes coccothraustes), sparrow hawk (Accipiter nisus), hawk (Accipiter gentilis) may be counted among that group. Many bird species are also disturbed by the presence of transport infrastructure. The density of breeding birds in the environment of roads appears to be drastically lower than in areas located further away from roads. The radius of influence caused by motorways may go as far as 1.5 km. Among the general species becoming traffic casualties are magpie (Pica pica), jackdaw (Corvus monedula), blackbird (Turdus merula), and wood pigeon (Columba palumbus). But also buzzard (Buteo buteo), kestrel (Falco tunninculus), bank swallow (Riparia riparia), partridge (Perdix perdix), redwing (Turdus iliacus), and grey heron (Ardea cinerea) are found alongside all types of roads. Apart from severe winters traffic appears to be the main cause of death for the common barn owl (Tyto alba). That can be attributed to the fact that they sometimes forage on motorway verges that are perfect habitats for field mice for example. It was found several times already that field mice density can be much higher in road verges than in agricultural areas.

REPTILES AND AMPHIBIANS

All reptiles and amphibians are legally protected in Flanders. Reptile traffic death appears to be rather limited since verges do not qualify for their habitats. Species such as slow-worm (Anguis fragilis) and common lizard (Lacerta vivipara) that like sunbathing on slopes and verges to warm themselves up, are in principle sensitive to road barriers. Since those species are rather disturbance sensitive they are only sporadically found as road casualties. Only grass snakes (Natrix natrix) may have problems locally because of its roaming behaviour. Except for one introduced population the species is extinct in Flanders. Amphibians, on the other hand, are very vulnerable compared to reptiles, particularly in areas where summer and winter biotopes are located on both sides of roads. Even though all species found in Flanders are legally protected, they are - depending on their rarity - often (e.g. common toad (Bufo bufo), common frog (Rana temporaria), and alpine newt (Triturus alpestris)) or sporadically (e.g. fire salamander (Salamandra salamandra) and palmate newt (Triturus helveticus)) found dead as traffic casualties.

INVERTEBRATES

Information on the effects of transport infrastructure on invertebrates is hardly available. Negative isolation effects on subpopulations are very probable for a large number of species. Some current projects should give more clarity on that.

4.3. OVERVIEW OF FRAGMENTATION

Open space surface area

The National Institute for Statistics (NIS) is the most precise statistical source for information on the surface area portion of open space. In 1980, open space area amounted to 84.4% of the total surface area of the Flemish Region (1,139,726 hectares) according to the NIS statistics on ground coverage. It is made up of farmland, forests and wasteland, recreational area and parks, waterways and roads (see table 4.4 and figure 4.5). In 1992, that surface area decreased to only 79.5% of the total surface area and it dropped even more in 1997. The reason for that drop is to be found in the decrease of agricultural surface area at the benefit of built-on surface area. The latter increased 1.9% in 1980 to 15.5% of the total surface area in 1997. The NIS land use categories do not present a clear image of the morphological urbanisation and of the open space portion in the whole context. Registered roads and recreational areas for example are categorised under open space area. Unregistered land being 6.7% of the total in 1992 does not fall under the open or built-on classification, but may comprise infrastructures.

Regional maps may also give an indication on land use in Flanders. According to those planning allocations open space in Flanders amounts to approximately 75% of the total surface area.

Table 4-4 Ground coverage in the Flemish region in 1980, 1992, 1997 (Source: NIS statistics)

	1980 (%)	1992 (%)	1997 (%)
Open	84.4	79.5	77.6
Built-on	9.9	13.9	15.5
Unregistered	5.7	6.7	6.8

Agricultural activity has gone down enormously since the beginning of our century: from 21.5% of the Belgian active population in 1910 down to 2.6% in 1989. That decrease went hand in hand with an overall farm expansion and a huge fragmentation of farmland. To stop that uneconomic farmland fragmentation land consolidation was introduced (the laws of 25 June 1956 and of 22 July 1970) resulting in an increase of land planning measures in the framework of land consolidation (Law of 1 August 1978). From the 1999 annual report of the 'Vlaamse Landmaatschappij' (Land Society of Flanders), it can be concluded that 148,196 hectares were consolidated, 55,000 hectares are under investigation and 22,000 hectares are in the process of consolidation. In a nutshell, approximately 1/3 of the total agricultural area is involved in land consolidation. Regardless of those measures the actual farm surface area strongly differs from region to region.

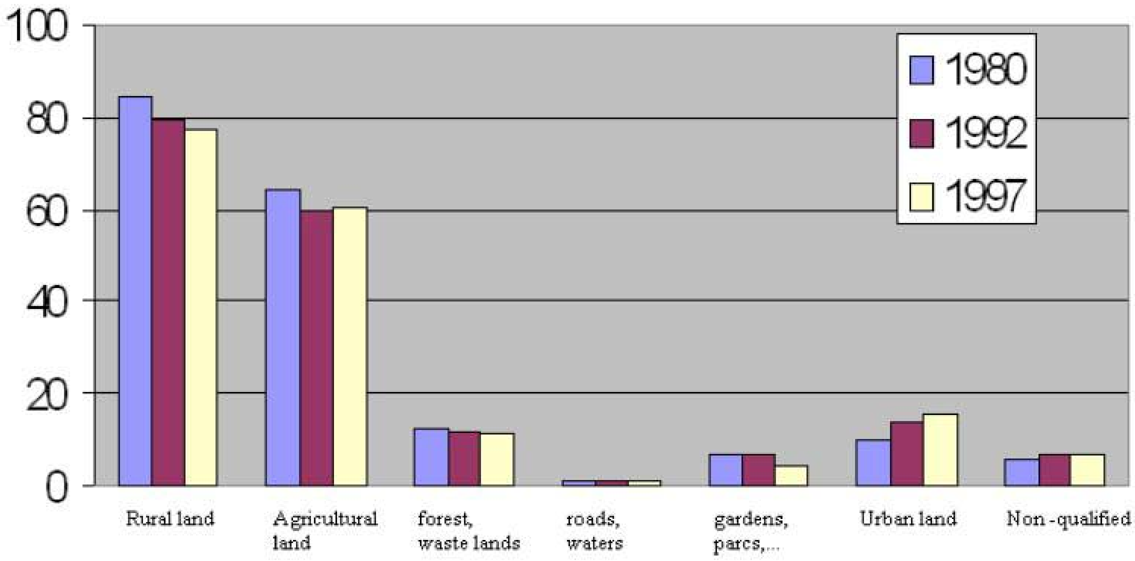

Figure 4-5 Evolution of land occupation between 1980 and 1997 (in % of total surface area of the Flemish region)

Fragmentation of overgrowth on parcel edges

One of the most remarkable aspects of changes in the Flemish landscape is that overgrowth on parcel edges, such as undergrowth and rows of trees, is thinning out and disappearing. Its visible effect is a visual « stripping off » of a somewhat closed-in landscape with hedges, as can be seen in Southwest England for example. Its ecological consequence clearly is a fragmentation and loss of small linear landscape elements, as well as numerous microclimatic changes and alterations in ground erosion. The conducting function of those landscape elements is assumed necessary for the survival of many animal species when migrating. In the sandy « Houtland » of the East-Flanders province a setback in property edge overgrowth of maximum 20,000 m/km^2 at the end of the 19th century down to less than 500 m/km^2 in 1986 was estimated, which is a decrease of 70% to 95%. That loss differs from town to town and depends on the natural condition and the active management or otherwise of environmental planning and nature conservation, especially with regard to adherence to the chopping prohibition.

Fragmentation by infrastructures

In 1989, motorised road transport used 15 m^2 per person transported and therefore is the largest space user of all means of transport in our country. From the environmental planning point of view road transport should have a competing disadvantage in relation to railway transport.

The proposed decade plan (1994-2003) for port infrastructures requires approximately 425 hectares, so that space occupation also weighs heavy as an effect on environment. We cannot, however, give a detailed summary of the diverse forms of fragmentation by transport infrastructure in Flanders due to the absence of an elaborate methodology for fragmentation measuring. A density map of motorways per km^2 (see figure 4.6), railways per km^2, waterways per km^2, building density, and combinations thereof is for example indicative.

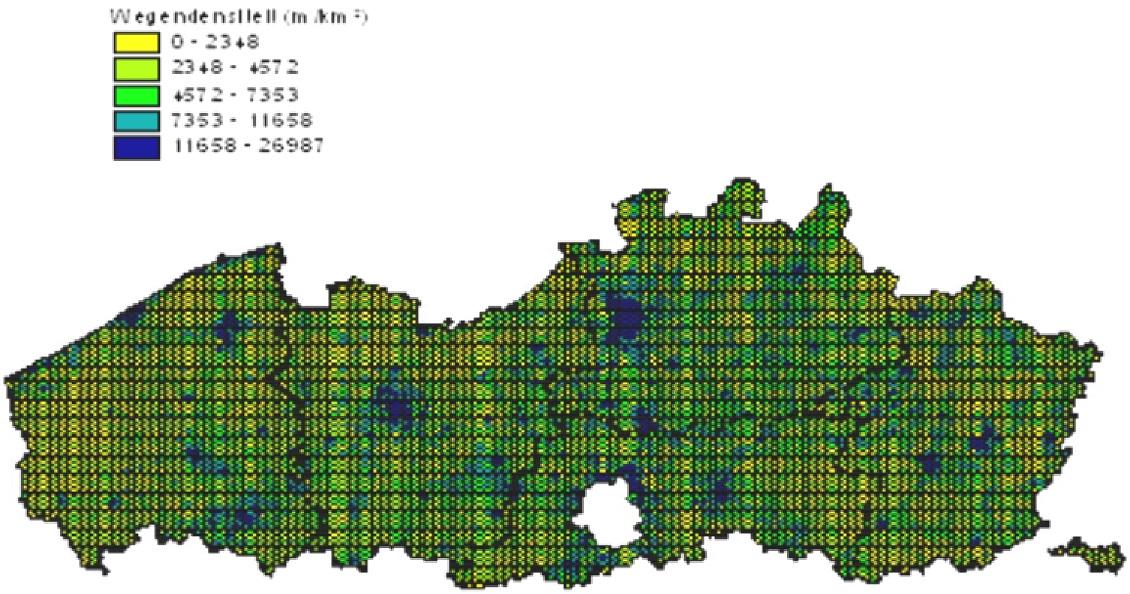

Figure 4-6 Road density for Flanders in meters of road per km2

Fragmentation of wildlife areas

The main historical tendencies, as far as spatial organisation in Flanders is concerned, may be summarised as follows:

- drastic fragmentation of wildlife areas through farming and forestry ;
- decrease in wood elements and small landscape elements in general ;
- disappearance of swampy brook valleys ;
- general fragmentation as a result of large infrastructure works and increasing building developments ;
- general fragmentation as a result of a decline in environmental quality.

In recent decades, fragmentation has mainly or even solely been caused by an increase in infrastructure and building development. Some indicative numbers: only two forests in Flanders are larger than 800 hectares, while 50% of the total forest area consists of units that are smaller than 60 hectares; the remaining heath areas in the « Kempen » area are on the average only a few hectares large, and even then they are mostly mixed with other habitat types.

Half of the Flemish nature reserves have a surface area of less than 10 hectares, one third is smaller than 3 hectares and only 6% is larger than 100 hectares. These data only give a raw estimate of the fragmentation extent because, on one hand, nature reserves may have different habitat types (internal fragmentation) and, on the other hand, nature reserves may often be located in a larger wildlife area that is not officially recognised as a nature reserve.

Fragmentation of waterways

Local pollution and physical barriers, such as dams, locks, and pumping stations heavily fragment Flemish waterways. Fragmentation by water quality may, of course, be deduced from water quality inventories. Stretches of good to superior quality are at all times limited to some ten kilometres of the upper course of the Flemish brooks and rivers, with the exception of the rivers « Grote Nete » and « Kleine Nete », having approximately 40 kilometres of good water quality (see figure 4.7). At this time no central databank on the presence of physical barriers is available, but it is being worked on.

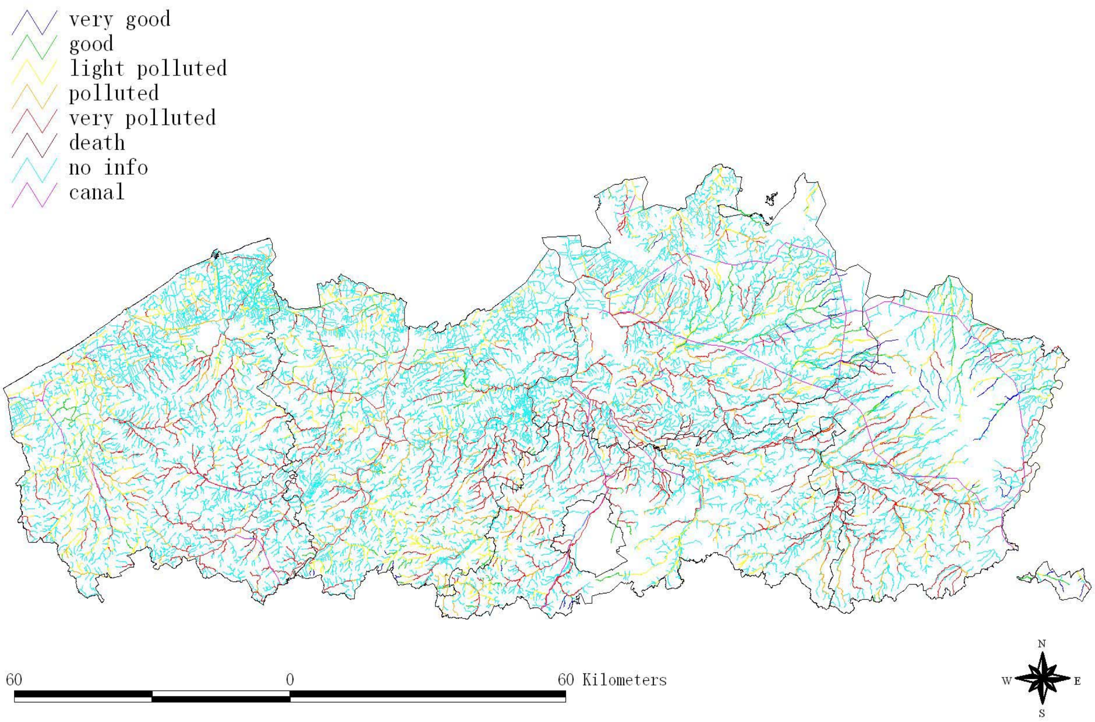

Figure 4-7 Water quality of Flemish waterways

4.4. ADMINISTRATIVE AND LEGISLATIVE FRAMEWORK

Besides having a heavily fragmented landscape Belgium is also heavily fragmented with regard to environmental management authorities. Upon its federalisation Belgium was split up in three regions: the Flemish Region, the Brussels Capital Region, and the Walloon Region. As was mentioned earlier in the introduction, this report will only describe the situation for the Flemish Region. All areas have been granted some powers. The federal government has reserved powers (the ones granted on the basis of the constitution) and residual powers (the ones that remain beside the powers of the regions). The only power of the federal government, relevant to this report, is consultation with the regional governments in preparation for the Council of the European Union. Moreover, those regional powers are exclusive, which means that the federal government cannot interfere in matters that have been assigned to regions and communities. Below is a summary of the powers of the Flemish Region that are relevant to the issues dealt with in this report:

- Environmental planning, monument management and environmental management;
- Land use and land consolidation;
- Nature conservation and nature management;
- Green areas, park areas and forests;
- Environmental protection (pollution, waste, …);
- Mobility and roads;
- Agriculture;
- Scientific research in the framework of those powers.

A number of so-called additional powers have also been granted to the regions: development of infrastructures, authority over some institutes and societies (e.g. the Institute for Nature Conservation (IN), the Institute for Forestry and Wildlife Management (IBW), the Flemish Land Society (VLM) The Flemish Environmental Society (VMM), etc.), funding of subordinate administrations, supervision of subordinate administrations, criminal authority and expropriation. Administratively speaking, all services of the Flemish region are concentrated in one ministry: the ministry of the Flemish Community. It consists of seven departments, each one of them divided up in administrations. Most environmental powers are found within the Department of Environment and Infrastructure, consisting of 6 administrations. (See figure 4.8):

- Administration for Environmental, Nature, Land and Water Management (AMINAL)
- Administration for Environmental Planning, Housing, Monuments and Landscapes (AROHM)
- Administration for Roads and Traffic (AWV)
- Administration for Waterways and Maritime Affairs (AWZ)
- Administration for Supporting Studies and Projects (AOSO)
- Administration for General Administrative Services (AAAD)

Provinces and towns have no specific individual environmental authority. They can, however, accept by-laws in connection to public health, safety and quiet. Their responsibility is thus limited to administrative tasks such as formulating permit procedures, drawing up special construction plans, etc.

But new provincial reference frameworks are being drawn up for environmental planning in the form of provincial and local structure plans (see 4.5). The local nature development plans (so-called "GNOPs") should also provide a number of directives for the spatial organisation and development of nature values.

The first globally elaborated legislation on environmental conservation came into effect with the law on nature conservation of 12 July 1973. That law was only partially executed especially with regard to area-oriented nature conservation. At the end of the eighties the necessity for creating a consistent network of wildlife areas and the necessity for integrating nature management in other social sectors was more and more felt. That resulted in the decree of 21 October 1997 on nature conservation and natural environment.

Among others, it regulates nature management planning, its general measures, ecological network realisation and its measures, nature reserves, management agreements, and the protection of (wild) plant species and their habitats. The first resolution of the nature conservation decree (23 July 1998) examines the definition of FEN (Flemish Ecological Network) and IASN (Integral Acquisition and Supporting Network), the right of pre-emption, the conditions for changing vegetation and small landscape elements, and nature planning projects.

Furthermore, the decree of 16 April 1996 - which stipulates the protection of landscapes - replaces the old law on monuments and landscapes. That decree uses the term « protection » instead of « classification » of landscapes. It also has a lot of thought for management and land use in such protected landscapes.

Five international legislative initiatives have effect on the area-oriented nature management in Flanders. These are: two European directives, the “Bird Directive” (1979) and “Habitat Directive” (1992), the Ramsar Convention (1971), the Bern Convention (1979), and the Benelux agreement on nature conservation and landscape protection (1982) (see also figure 4.9). In 1998, 23 bird directive areas were defined in the framework of the Bird Directive by the Flemish government. The decree of 1988, however, did not give any specific protective measures.

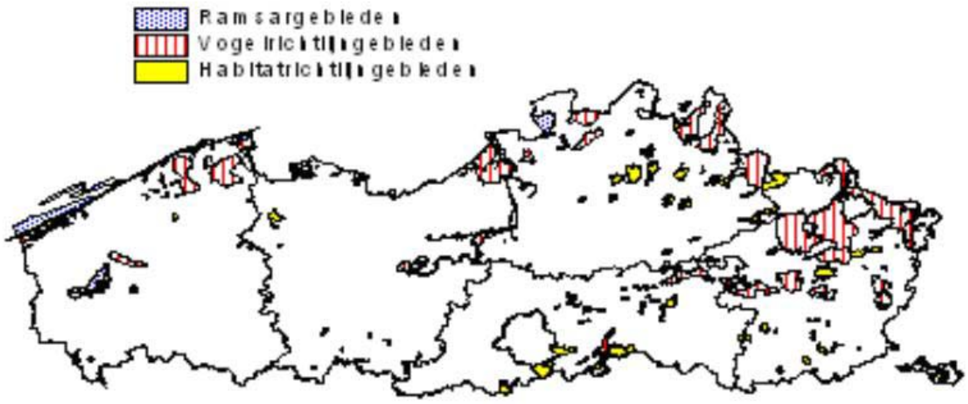

Figure 4-8 Bird Directive, Habitat Directive, and Ramsar areas in Flanders

Later on, protective measures were only to a limited extent taken in the framework of other nature and environmental legislations. Following measures are relevant to the problematic nature of fragmentation :

- an environmental effect report is required for the following projects : land consolidation, land planning, and water management ; it is also required when the construction of a main transport system within one of those areas is involved.
- certain parts are protected when realised through another set of rules and regulations (recognised nature reserves, nature reserves marked off in the area plan and mentioned in the forest decree)

In 1996, forty areas were marked off within the framework of the Habitat Directive. As part of the Ramsar Convention on water rich areas with international importance, Belgium marked off four Ramsar areas in Flanders. The Flemish government legalised some protective measures or limitations for certain activities, the following of which are relevant within the scope of fragmentation :

- a permit is required for vegetation alterations;
- an environmental effect report is required for activities that have an influence on water management, land consolidation, infrastructure works, etc.

In the short term these areas, together with the Bird Directive areas, need to be connected with the European network Natura 2000 (see 4.5).

The Bern Convention is an initiative from the Council of Europe and aims at protecting endangered wildlife and plants in their natural environment with special attention to migrating species. That convention was approved in Belgium by the law of 20 April 1989, but in reality Flemish nature management has so far paid no or hardly any attention to the Convention and its potential function as instrument for setting up area-oriented protective measures.

In the first place, the Benelux agreement was made up in view of an effective protection of barrier-crossing wildlife areas and valuable landscapes. So far that has only resulted in the following : of the 22 originally proposed parks, only two of them were realised, i.e. « Zoom-Kalmthoutse Heide » and « Stamprooierbroek-Wijffelterbroek-Laurabossen ».

4.5. LAND-USE PLANNING IN RELATION TO NATURE AND LANDSCAPE CONSERVATION AND TRANSPORT INFRASTRUCTURE

Legislation on environmental planning can contribute to nature conservation in two ways :

- by giving a nature allocation to a parcel of land on allocation plans with proper regulations coupled to those plans.
- by demanding specific permits for nature activities.

The law of 29 March 1962 sets up the legal basis for environmental planning legislation in the Flemish region. That law organises environmental planning and town and country planning. It was repetitively changed and was finally co-ordinated on 22 October 1996 as the environmental planning decree. Now there is a new decree on environmental planning, which was approved by the Flemish Parliament on 18 May 1999.

On the basis of that law on environmental planning area plans were drawn up. On these plans, diverse land allocations were juridically recorded to which certain town planning regulations were coupled. The regional plans became area covering for Flanders and were set in allocation plans in the period between 1963 and 1980. Important nature allocations are :

- green areas (greenbelt, wildlife area, wildlife area with scientific value or nature reserve)
- forest areas
- park areas
- buffer zones
- environmentally valuable areas
- agricultural areas

A special construction plan (BPA) covers part of the territory of one town. It is a very detailed plan that designates land allocation and contains detailed regulations as well. Since the eighties "BPA's" are used to deviate from the area plans that are getting more and more out of date. Below regulations on environmental planning are important for nature :

- agricultural areas of ecological importance
- valley areas
- agricultural areas of exceptional value
- source areas
- nature development areas
- wildlife areas with servitude
- forest areas of ecological value
- forest expansion areas
- areas with a nature allocation

According to the allocation plans, open space in Flanders amounts to approximately 75% of the total surface area. On 1 January 1998 following protective statutes are used in that open space : 11.2% green area (consisting of nature development area, wildlife area, wildlife area with scientific value and green area), 4.1% forest area (consisting of forest area, forest expansion area and forest area of ecological value), 3.1% park area and buffer area, 43.1% strictly agricultural area, 33.3% landscape valuable area, 1.7% agricultural area of ecological importance, 1.8% recreational area, 1.4% military area, and a small rest group of 0.3% with other allocations (development area, area for community facilities, flood area, et al.). Together the green and yellowish green areas (agricultural area with ecological value, valley area, agricultural area with special value) make out approximately 20% of the open area in Flanders. Theoretically one may expect a policy aimed at protection and development of nature, possibly in combination with other functions such as agriculture, forestry, and recreation. The intensifying agriculture, water extraction, building, fragmentation by road works and infrastructures, recreational pressure, the lack of nature-oriented recovery and maintenance management resulted however in a considerable loss of nature values, even within the regional plan areas. The planological protection of approximately 20% of the open space in Flanders could not prevent the general deterioration and degradation of nature in the areas located outside of the nature reserve areas.

When delineating « green areas » on regional plans, conservation or development of a coherent and functional ecological network was hardly paid attention to. The green allocations on the regional plan or a mosaic of predominantly small, fragmented areas. Joint wildlife areas are often split up artificially over several allocations and nearby wildlife areas are often separated by ground allocations which are strange to nature. On the average 48.3% of all green areas on the regional plan in Flanders are smaller than 5 hectares and 75.9% are smaller than 20 hectares. Merely 6.5% of all joint green areas in Flanders are larger than 100 hectares. In reality, the fragmentation of wildlife areas in Flanders is even larger. Green regional allocations are quite often severed by transport infrastructure.

After the establishment of these regional plans, the legally provided revision of those plans has never been set forth systematically. For that reason many valuable wildlife areas in Flanders are not or hardly being protected by planning rules at this time. Only 80% of the areas in Flanders with biologically very valuable ecotopes have the correct planning protection. What is missing in Flanders is a proper protection of grassland areas and marshlands. When the valuable ecotope standards are somehow changed, it appears that even 25% of the Flemish natural patrimony is not or insufficiently protected by the regional plans.

In order to remedy the disadvantages of static environmental management, the concept of environmental management planning was introduced. Master plans were provided at the level of the Flemish region, the provinces, and the towns. The Master Plan of Flanders, in short MPF (Ministry of the Flemish Community , 1998) is the result of that methodology on Flemish level. It gives the desired environmental structure of Flanders by means of a reference framework in which all-environmental developments up to the year 2007 will take place. Thus, master plans do not establish allocations. The Master Plan of Flanders is also the basis for environmental management through regulating plans and other measures.

Among other things, The MPF formulates as its main objective the maximum conservation of open space in Flanders and the creation of environmentally coherent, well-structured units for agriculture, forestry and nature. By way of the decree on environmental management, master planning - next to the existing regional plans - also received a juridical basis.

Ecological networks

In most European countries the idea of ecological networks has penetrated up to the management level for some considerable time already. At European level the « Pan-European Ecological Network » (EECONET) of the European Council and the Natura 2000 network of the European Union (of which the Bird and Habitat directives make part of) are being worked on as actual materialisation of the « Pan-European biological and landscape diversity strategy ». On the Flemish level the « Green Main Structure of Flanders » was developed in 1990, in imitation of the Dutch « Ecological Main Structure », with the intention to integrate the areas with an important ecological value that are insufficiently protected in a coherent and organised network. To this end a three-part classification was used: main areas, nature development areas and corridors (see table 4.5 and figure 4.10). For the demarcation of the planned buffer areas insufficient data were available at the time.

Table 4-5 Surface area summary of the different categories of the Green Main Structure

Green Structure	Surface area (ha)	% of the surface area in Flanders
Main areas	149,103	10.9
Nature development areas	204,118	14.8
Corridor areas	178,188	12.9
Total	**531,709**	**38.6**

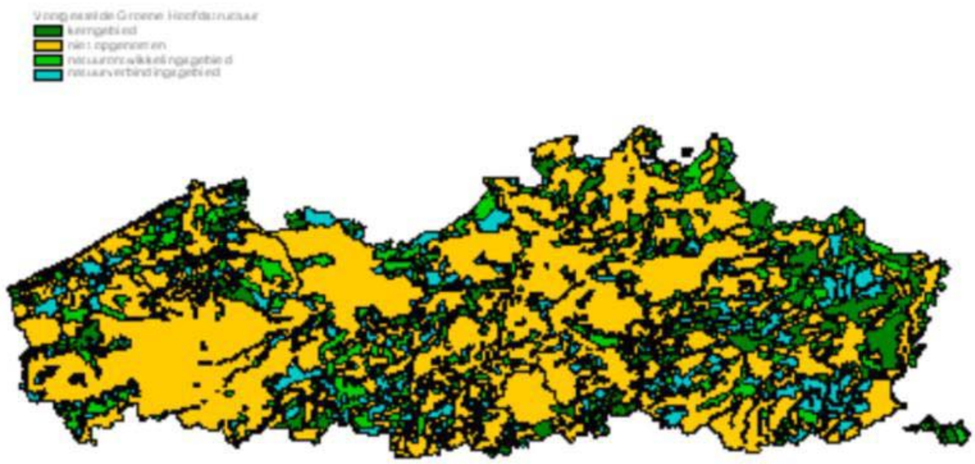

Figure 4-9 Proposed Green Main Structure of Flanders

The official public inquiry revealed a considerable amount of negative reaction going from a great lack of clarity regarding the procedure to a shortage of compensating allowances. Especially farmers, forest farmers, and landowners strongly oppose to the implementation of the Green Main Structure. So the plan was put aside. More recently, the idea got a juridical basis in the decree on environmental protection and natural environment and the binding regulations of the Master Plan of Flanders (MPF).

The binding regulations of the MPF provide in 10,000 hectares of additional forest area and 38,000 hectares of additional nature reserve area for environmental allocations. That measure can of course be utilised to unite as much as possible the actual fragmented green areas into a coherent structure.

The decree on environmental protection and natural environment provides in the delineation of a Flemish Ecological Network (FEN) and of an Integral Acquisition and Supporting Network (IASN). The most important and prioritised Flemish wildlife areas are subdivided in Large Nature Units (LNU) and Large Nature Units under Development (LNUD). That ecological main structure is completed and supported by the IASN, consisting of Nature Acquisition Area (NAA) and Nature Connection Area (NCA).

By the end of 2002 a surface area of 125,000 hectares of FEN and 150,000 hectares of NEA have to be demarcated and by 2007 these two will have to be realised. Following preconditions are imposed:

- It was determined what planological allocations are taken into consideration for both FEN and NAA.
- For the minimum surface area, the aim is to have joint areas of initially 20 hectares at the minimum and upon completion minimum 40 hectares in the West of Flanders and 100 hectares in the East of Flanders.

The FEN must be integrated in the “natural structure” of the MPF. Nature is the main function in a FEN while other functions can be co-ordinate in interweaving areas. For the demarcation of LNUs, following planological categories (of the regional plans) may be taken into consideration: green areas, park areas, forest areas, buffer areas, areas with community facilities and public utility facilities with a flood area as overpressure, water reservoirs and military domains, protected dune areas and other areas depending on the building plans. For LNUDs, parts of military domains, exploitation areas, (that have as suballocation one of the above allocations), valley areas, source areas, agricultural areas with ecological value, agricultural areas with special value and nature development areas.

The Flemish High Council for Nature Conservation, the Institute for Nature Conservation and the Flemish High Council for Forestry have to submit their recommendations on the above. For as much as it is relevant for some areas, the Administration for Agriculture and Horticulture and the respective water companies are requested for their opinion on the matter. Also a basic nature plan is being drawn up for all LNU and LNUD areas in which specific measures and standards for the degree of fertilisation are summed up. In those areas regulations are obtained that prohibit the use of insecticides and the altering of vegetation, small landscape elements, relief, groundwater level, and the waterway structure as from the temporary specification of the demarcation plan.

The IASN is a set of areas in which the government looks after the conservation of the nature values present and takes measures for the improvement and reinforcement thereof. Maintenance of biological diversity should also be observed. All this without influencing the existing agricultural and forestry exploitation unless by way of a management agreement.

Land consolidation

Land consolidation is a government instrument directed to improve external agricultural structures by grouping farm property into regular and better accessible plots that are located as close as possible to the farm. The waterway and road systems are also being dealt with. Many country roads are being lain again in land consolidation projects. These roads fall under juridical town management; some of these roads connect towns and hamlets. Mostly those are agricultural roads, field roads and forest roads and also hiking, biking, and bridle paths. In Flanders, the Flemish Land Society (FLS) is responsible for the planning and development of land consolidation plans. Since the latter half of the eighties, not only the agricultural and economic aspects but also other social aspects are taken into account, one of which is nature.

While for an initially long period of time land consolidation has effectively decreased and coarsely fragmented the environmental landscape, the “new style” land consolidation projects are employing the maintenance and creation of nature values as additional goal. The principles of the naturally engineered environmental development (“NTMB”) are taking shape in plots allocated for environmental management, nature and forest development. Out of landscape and cultural-historical considerations maximum usage of the existing road system is directed. By marking out roads alongside existing landscape elements such as valley edges, slopes, and overgrowth typical landscape characteristics are maintained. With relation to paving types an evolution is somehow visible over the last few years. Before 3-metre wide land allocation roads were nearly always covered with concrete. Now softer and even recycled materials are being used.

To optimise the ecology and nature partaking in the planning phase of land allocation there was need for a method that indicates what choices have to be made with regard to nature conservation.

That methodology was recently developed in the report for “Optimisation and Measuring of the ecological partaking in land consolidation” (De Blust and Van Olen, 1998) that resulted in a five-step plan:

- Nature type description and its function within the land consolidation area in connection with its surroundings.
- Value determination and control policy of the nature present.
- Development vision of the nature present.
- Materialisation of that vision by means of allocation plans.
- Monitoring of the realisations.

Such a report can be used as a manual by the land allocator because relevant ecological theories (metapopulation, island concept, gradient activity, buffers, source-sink, etc.) and models (LARCH, METAPHOR, etc. See 8.4) are gathered and analysed according to application possibilities.

4.6. SUMMARY

The fragmentation in Flanders is that high that a simple solution to the problem is no more possible. Located at the economic heart of Europe and having more than 60,000 kilometres of roads, habitat fragmentation problems due to transport infrastructures can no longer be denied.

For years now nature management is directed towards developing a coherent network of wildlife areas (FEN, IASN, Natura 2000, etc.). In 1990, the Flemish government installed the NTMB (Naturally Engineered Environmental Development) cell that, since then, has put a lot of energy into reducing the transport infrastructure effect on nature and landscape. Also the Flemish Administration for Roads and Transport has recently installed a project group that, among other things, is working on defragmentation. In the draft outline of the Master Plan of Flanders open space management and quality of life in town areas have the highest priority and development of an ecological network is actually being looked at.

On the other hand, planning and management instruments are insufficiently tuned to one another. The relevant legislation is maintained poorly and not all possibilities of the existing juridical framework are being used. There is a lack of interdisciplinary evaluation and guidance for defragmentation measures. The reduced quality of life in towns moreover stimulates living in a green, open environment.

At the moment, no global vision on landscape management exists, as a result of which there is little insight in the condition, processes, and reference values of fragmentation. Because no standards and indicators have been defined up to now, the need for data collection for an area-covering and detailed inventory of fragmentation effects in Flanders is clearly present. That inventory should cover the following aspects:

- Inventories of open areas, cultural-historical valuable landscapes and valuable biotopes with their current surface area and fragmentation situation. In the first place, methodological research will be required. Parameters such as surface area, isolation, and barrier presence will be of major importance for nature conservation.
- A list of problem areas with regard to physical barriers between (or within) ecologically valuable landscapes and valuable biotopes, waterways included. That list must be completed with a more general connectivity analysis that maps the landscape’s “resistance” against moving organisms.

- An inventory of the environmentally ecological relations within Flanders, especially by way of ground water and surface water flows.

When developing such a methodology one can moreover call upon many examples from other European countries (the Netherlands, Switzerland, France, Germany, etc.) that did the pioneer work some considerable time ago.

Chapter 5. Habitat Fragmentation due to Existing Transportation Infrastructure

5.1 INTRODUCTION

Mobility has for some considerable time now become a basic condition for the good and happy functioning of our society and for the further development thereof. Both the individual possibilities for development and the making of social contacts and the production terms and sales market possibilities of companies are largely dependent upon it. The social organisation of production is still in full evolution and is pushed by the increasing specialisation by the liberalisation of the European and world markets. In that context, Flanders has an important transit function because of the strategic position of its ports and its road infrastructure. Moreover, the traffic and transport developments are closely connected to environmental planning. Transport infrastructures are largely determining the existing environmental structure in Flanders. The Flemish road infrastructure is first of all characterised by its fine-meshed character. The total length of roads in Flanders amounts to approximately 63,000 kilometres, a density of 4.8-km road per km^2.

The parallel location of old regional roads, railroads (with intercity (IC) and interregional (IR) connections), and motorways is also characteristic for the existing transport infrastructure in Flanders. Their function is to open up areas and to connect concentration areas of economic activity.

The urbanisation process of the last two centuries is possibly the main cause for the actual transport problems in Flanders. That process came about in three phases: urbanisation (by increasing industrialisation instead of agriculture and rural industry), sub-urbanisation (move to city suburbs by public transport and deteriorating living conditions in cities), and last but not least, de-urbanisation (by means of a more accessible and expanded railway network and the general availability of motorcars).

A first part of this chapter describes the existing transport infrastructures in Flanders. The significant characteristics of road, waterway, and railway infrastructures will be summed up. The second part describes the effects of that infrastructure on nature. The last part gives an overview of relevant studies and research done at the institutes and universities in Flanders.

5.2 EUROPEAN TRANSPORTATION NETWORKS

Not for national reports

5.3 TRANSPORTATION NETWORKS

5.3.1 Highways/motorways

Motorways, regional roads, province roads, and town roads are considered to be part of the road infrastructure (see figure 5.1). The total road length per hectare differs per town from 19 m/ha in Heers up to 118 m/ha in Kraainem, with an average of 46 m/ha for Flanders.

Table 5-1 Overview of road infrastructure length (Steenberghen and Dufays, 1999)

Type of road	Length in km
Regional roads	5500
Motorways	828
Town roads	56600
Provincial roads	605
Total	**63633**

An increased intensity in road infrastructure use intensifies the barrier effect. Infrastructure follows traffic movement growth to a large extent. Figure 5.2 shows the evolution between 1985 and 1996. Between 1992 and 2007, a growth of motorcar traffic is expected from 35% up to 60%. For lorry traffic a growth of 45% up to 100% is expected.

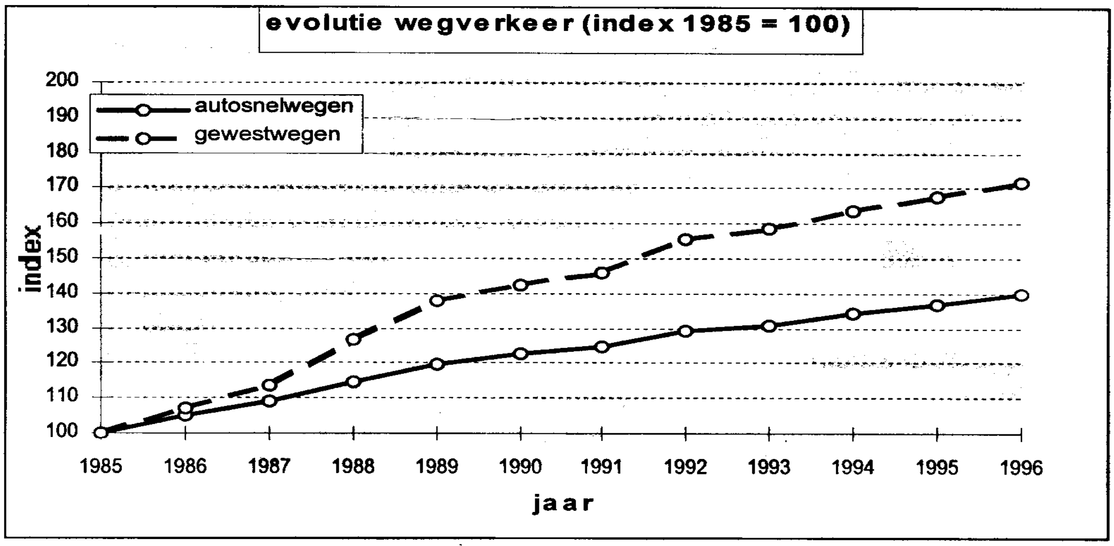

Figure 5-1 Evolution of road traffic 1985-1996 (from "MIRA" (Environment and Nature Report) 1999)

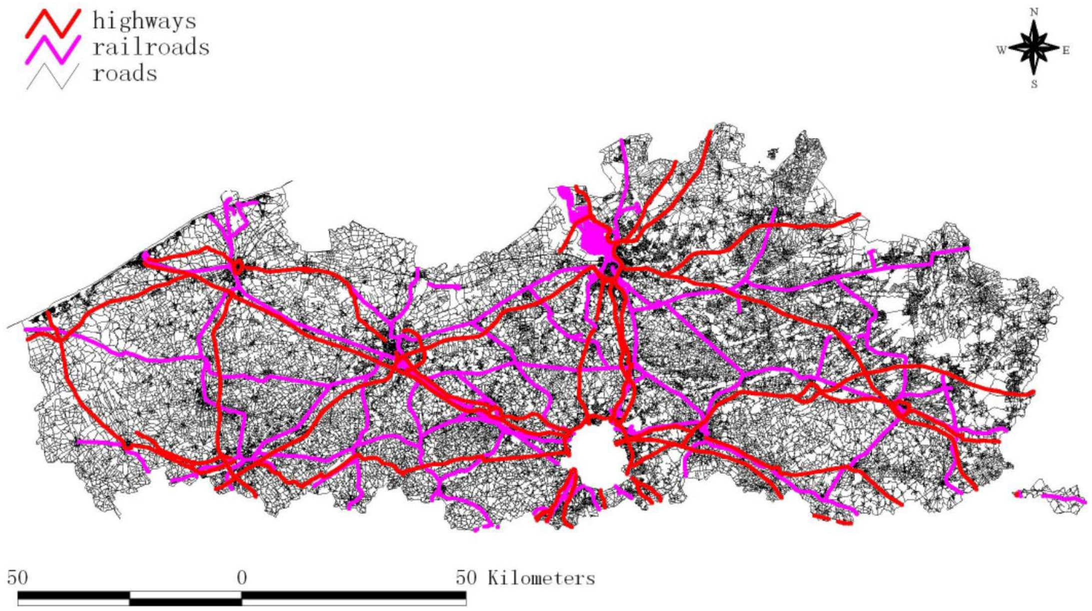

Figure 5-2 Survey map of the road infrastructure in Flanders

5.3.2 Railways

The total railway network in Flanders is approximately 1,700 km long (or 0.12-km rail/km^2). Approximately 60% of that network is electrified (see figure 5.2). Only goods trains run on 480 km of a total of 730-km non-electrified lines. Railway infrastructure is also characterised by its heavy orientation to Brussels. The development of the intercity and interregional network slightly weakens that radian structure. At the Flemish level, following lines and connections are of primary importance:

International lines and connections: Ostend-Bruges-Ghent-Brussels-Louvain-Liège-Koln (passengers), Brussels-Halle-Paris (passengers), Brussels-Namur-Luxembourg (passengers), Brussels-Antwerp-Roosendaal (goods and passengers), Antwerp-Ghent-Courtrai-Lille (passengers and goods), Zeebrugge-Ghent-Wetteren-Ottignies-Paris (goods), Antwerp-Aarschot-Hasselt-Montzen (goods), and Antwerp-Muizen-Schaarbeek-Ottignies-Luxembourg (goods). These international railway lines connect the large and regional Flemish cities (with the exception of Roeselare, Turnhout, and Hasselt-Genk) and the concentration areas of economic activity with large and regional cities in Wallonia, France, the Netherlands, Germany, and Luxembourg.

IC-connections for passenger transport. On the one hand, the stations with an international function such as Antwerp-Central and Brussels-South (the Brussels Capital Region). Brussels-South is structure determining for the whole of Flanders because of its international traffic and transport function and its economic importance. On the other hand, the main stations of large and regional towns are structure determining for their immediate surroundings: Aalst, Berchem, Bruges, Ghent-St-Pieters supplemented by Ghent-Dampoort, Hasselt, Courtrai, Leuven, Mechelen, Mechelen-Nekkerspoel, Ostend, Roeselare and St-Niklaas. Regional city stations such as Turnhout and Genk are located at the end of a railway line and are served at inferior level by railway traffic.

The stations for goods transport, such as Antwerp-North, Merelbeke, and Schaarbeek (the Brussels Capital Area).

Multimodal centres, more specifically, railway and road terminals for combined traffic. Block and shuttle trains run goods transport between these traffic junctions. With regard to lorry traffic on roads railway terminals have an influence radius from 80 up to 100 km. The railway route that is mainly run at night takes a minimum distance of 500 to 600 km. Railway terminals are installed at the port of Antwerp (between dock 6 and the Churchill dock) and at Antwerp-Schijnpoort. The seaport of Zeebrugge also has extensive loading and unloading facilities. Next there is the dry terminal of Muizen (Mechelen) (where multimodal transport to Great Britain is organised through the Chunnel) and the multimodal terminals for railway traffic with specific destinations (Hermes, Belstore, Eurologics, etc.).

The major passenger movement, approximately 30,000 passengers per day is mainly directed to and from Brussels. Goods transport by railway (both import and export) are predominantly internationally oriented. The National Society for Belgian Transport ("NMBS") aims as much as possible at getting the control of a separate goods network.

Table 5.2 gives an overview of the Belgian railway network during the period from 1970 to 1991. The length of the Belgian railway network has gone down during that period with an average of 0.8% per year, due to a decline of the goods transport network. The network for mixed transport, however, increased during that period.

Table 5-2 Evolution of the length of the Belgian railway network and the number of crossroads, stations, and stopping places from 1970 to 1991

	1970	1980	1991
Network solely for goods transport (km)	2255	1012	669
Mixed network for goods and passengers (km)	1910	2959	2797
Total	**4165**	**3971**	**3466**
Number of unguarded crossroads	3420	3092	2232
Number of guarded crossroads	598	206	78
Number of stations and stopping places	1109	1003	693

The total railway network was finalised by the end of 1993. A new planning of the NMBS is included in the STAR 21 plan (Railway future 21st century), an ambitious project with a long-term planning from 1991 to 2020. It may be stated that an optimisation of the existing lines is strived after and some new lines will be realised, such as the infrastructure construction for the High Speed Train (HST). Since the end of 1994, Eurostar connects Brussels and London via the Chunnel. In 1995, the first HST connections between our capital, Paris and the South of France followed. In June 1996, Thalys officially started running. Except for running to Paris, Thalys also runs to Amsterdam with a stop in Antwerp and to Germany with a stop in Liège. A HST connection is planned for Ostend with a stop in Ghent. There is a HST connection from Brussels to the Alps and Perpignan. Also Bordeaux and Quimper at the Atlantic Ocean will be directly linked to Brussels. The HST project should be finalised by mid 2005. For that reason a new HST line along the motorway E40 direction Liège is constructed, as well as another new one along the E19 motorway to Antwerp. Both stations (Antwerp-Central and Liège-Guillemins) will be drastically renovated.

5.3.3 Waterways

The waterway infrastructure forms a network of diverging technical characteristics and of different importance for the environmental and economic development in Flanders. The classification of waterways, of the standard measurements of ships, of works of art, and of the corresponding cargo capacity of ships is stipulated in resolution 8 of the European Conference of Ministers for Traffic (ECMT). As a result of the development of push towing and container transport the ECMT and the Economic Commission for Europe of Geneva have started studies in view of a new and more general typology. For the time being the older Geneva classification is used in which class VI is reserved for international routes.

The waterway infrastructure in Flanders is largely directed towards the seaport of Antwerp (and in lesser extent towards the one of Ghent) and it has a junction function in the waterway network of Northwest Europe (see figure 5.4). The seaports of Zeebrugge and Ostend, however, are badly connected to the international waterway network.

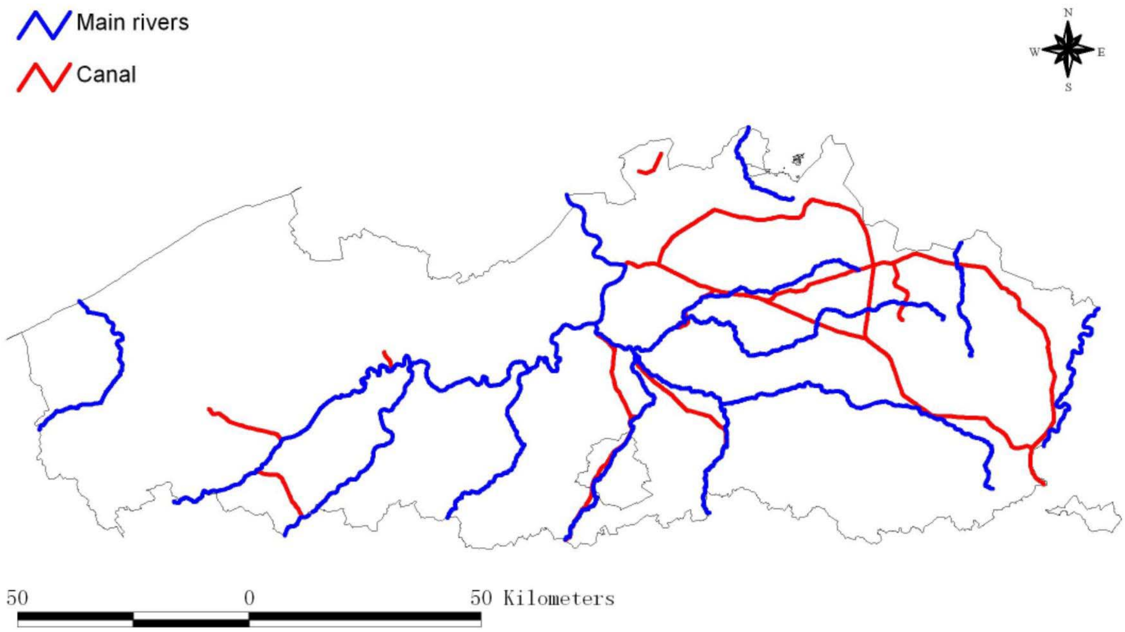

Figure 5-3 Survey map with the navigable waterways in Flanders

At the Flemish level following waterway infrastructure is structure determining:

- The international waterways with an important transit function for goods:
    - o The river Scheldt-Rhine canal and the docks in the seaport of Antwerp (class VI – more than 2000 tons) that connect with the Dutch waterway network (such as Rhine and Meuse).
    - o The Sea Scheldt-Upper Scheldt (class IV – 1350 tons except for sections between Dendermonde and Ghent up to 600 tons), Ring canal Ghent (class V – up to 2000 tons) and the river Leie and the diversion canal (class IV – 1350 tons except for sections up to 300 tons when passing Courtrai and at

the river Grensleie) making the connection possible with the French waterway network (such as the basin of the river Seine).

- o The Canal Ghent-Terneuzen (class IV – more than 2000 tons) with the port of Ghent.
- o The Albert canal (class IV – more than 2000 tons except for the section Wijnegem-Schoten) making the connection possible with the Juliana canal (the Netherlands (class V – up to 2000 tons), the inner harbour of Liège, and internationally with the German hinterland, the so-called Rhine route.

- The waterways with an important significance for goods transport to and from the concentration areas of economic activities. Those are, more specifically, the Brussels-Rupel sea canal (class IV – more than 2000 tons), the Brussels-Charleroi sea canal (class IV – 1350 tons) and the Ghent-Bruges canal (class IV – 1350 tons except for a section between Beernem and Bruges up to 600 tons).

In table 5.3 the characteristics of Flemish waterways are summed up, with an estimation of the surface area in used-up space. Almost all waterways are of class II (600 tons) at this moment. Only the canal from Ostend to Bruges has a class V gabarit (up to 2000 tons). The basin of the river Yser, the river Dender (partly), the river Leie (between Astene and ring canal Ghent), and the "Moervaart" canal only have a class I gabarit (300 tons).

Table 5-3 Characteristics of waterways in Flanders

Class	Navigability (tons)	Average width (m)	Length (km)	Estimated surface area (hectares)
0	Geen garantie	40	10	40
I	250-400	60	252	1509
II	400-650	80	246	1967
III	650-1000	-	-	-
IV	1000-1500	90	248	2233
V	1500-4500	130	93	1209
VI	>4500	160	226	3611
Total			**1074**	**10570**

Table 5-4 Overview of the length of the Flemish navigable waterways

Basin	Length of navigable rivers and streams		Canal length		Total length of navigable water infrastructure	
	in meters	% total	in meters	% total	in meters	% total
Basin of the coast and the Yser	43,570	7.4	130,744	16.2	174,314	12.5
Basin of the “Bovenschelde”	147,920	25.1	219,894	27.3	367,814	26.4
Basin of the “Zeeschelde”	352,728	59.4	42,560	5.3	395,288	28.3
Canals of Brabant			71,222	8.9	340,343	24.4
Basin of the “Kempen”			340,343	42.3	71,222	5.1
Basin of the Meuse	46,242	7.8			46,242	3.3
Total	**590,460**	**100**	**804,763**	**100**	**1,395,223**	**100**

The below table (table 5.5) gives an overview of the goods transport on the Flemish navigable waterways and canals in 1998. (data come from the Management and Exploitation Cell of the Administration for Waterways and Maritime Affairs).

Table 5-5 Annual overview of 1997 and 1998

	1997	1998	Evolution 98/97
Tonnage transported (t)	21,334,981	15,281,046	-28%
Loads	3,779,599	1,512,388	-60%
Unloads	11,744,307	6,929,749	-41%
Number of ships loaded	33,993	30,312	-11%
Number of empty ships	23,984	17,170	-28%

5.4 EFFECTS OF THE EXISTING TRANSPORTATION NETWORK ON NATURE

5.4.1 Habitat loss

The transport sector occupies a considerable amount of space with its 3 million means of transport and its vast infrastructure. Road construction obviously results in a direct loss of open space. A motorway with two lanes in both directions quickly becomes 50 meters wide. With the latter width a motorway takes up at least 5 hectares of road per km. A large part of that space is metalled and consequently lost forever as a natural habitat for plants and animals. Below table 5.6 shows the calculation of the direct space coverage by transport infrastructure in Flanders.

Table 5-6 Existing transport infrastructures and estimate of direct space coverage (source: Environment and Nature Report 1994)

Type of infrastructure	Total length (km)	Average width (m)	Area occupied (ha)
Motorways	841	50	4,205
Regional roads	5,717	30	17,151
Provincial roads	605	30	1,815
Town roads	56,600	9	50,940
Railway network	1,718	25	4,295
Canals	1,074	100	10,740
Total	**66,555**		**89,146**

5.4.2 Corridor function

Linear habitat (verges and banks) located next to transport infrastructure may have a positive influence on animal movements. Both migration within the home range of the individual and migration between different metapopulations of one species may be improved. Especially the medium-sized species use verges and banks with well-developed shrubs and tree areas to get guided. Research has shown this for squirrels, tree martens, badgers, and bats. Linear biotope use, however, increases the chance of traffic death. For smaller species verges and banks quickly become some kind of permanent habitat making dispersion and colonisation of new areas possible. For a number of mice species that type of colonisation and migration was already proven in the past.

Plants also seem to colonise new areas along road verges. Analysis of two kilos of mud from a tractor appeared to contain 2,284 germinative seeds of 45 species. Best represented are the pioneer species of the strongly antropogene disturbed areas with poor calcium quality, such as fields, road verges, and damp rough areas (42%). Of minor but nevertheless substantial importance are the pioneers of the more natural disturbed locations with changing environmental conditions (20%). For the rest six species of fertilised grasslands on humid soil were present.

5.4.3 Disturbance

Both the construction and use of roads have a disturbing influence on environment. It often happens that during road construction works the yard environment is reclaimed, the soil stratification is disrupted, and the environmental microclimate is changed. As a result the area is less suitable or unsuitable as habitat for specific plant and animal species. Such a site will be dominated by very tolerant, eurythaline (and from a nature conservation point of view less interesting) generalists.

If necessary, ground water is temporarily pumped away, resulting in a strongly diminishing ground water level (depending on soil type and nature of construction) and some moisture demanding vegetation (marsh and water plants) might disappear.

Traffic noise influences the behaviour of some animal species. Grassland and forest birds are disturbed by traffic noise during the breeding season. Moreover, that type of environment is being avoided during forage. The influential ambience of motorways may vary from 500 up to 1000 meters depending on the species of research and the road traffic intensity.

Rain water coming from the road surface of rather busy roads is often heavily polluted with oil and tar rest material and heavy metals, such as lead, mercury, etc. In Flanders, drainage water is neither being collected separately nor being purified. It directly flows to brooks and ditches by way of drainage ditches and sewerage. Furthermore, the drainage water contains very high concentrations of salts for icy roads in winter. These first of all damage verge vegetation.

Table 5.7 gives a survey on the appearing disrturbances per infrastructure type and during the different stages of life thereof.

Litter gives roads, verges, and slopes a dirty and unattractive view. Removing that enormous and diverse amount of litter is moreover labour intensive and therefore expensive. Mowing grass from verges which contains fragmented and diverse litter cannot be used as green waste and therefore has to be moved to a dumping ground. (Litter might block sewer drains and will consequently cause excessive water flow and traffic accidents.) These last few years, the number of sensibility campaigns have been increased but they will never take away all problems with regard to litter. Surveillance and punishment of offenders remains necessary. As of 1994, some 600 public servants of the Environment and Infrastructure Department have the authority to book people that dump litter illegally.

The presence of a road with its verges causes a gradient in a number of abiotic factors and in the local microclimate. That has its effect on vegetation. Steep verges oriented to the south are often a valuable environment for special habitats.

Table 5-7 Appearing disturbances per infrastructure type and during the different stages of life thereof. (0: not or only negligible; +: incidentally; ++: often or always). (Source: Environment and Nature Report 1994)

Effect group	**Stage of life**	**5.1. ROADS**	**Railways (and stations)**	**Waterways (and ports)**
Waste production	production	++	++	++
	use	+	+	+
	demolition	++	++	++
Water pollution	production	+	+	+
	use	+	0	++
	demolition	0	0	0
Soil contamination	production	+	+	+
	use	+	+	+

	demolition	0	0	0
Soil degradation	production use demolition	++ ++ +	++ ++ +	++ ++ +
Quiet disruption and noise nuisance	production use demolition	++ ++ +	++ ++ +	++ + +
Air pollution and stench nuisance	production use demolition	+ ++ 0	+ + 0	+ + 0
Increase of insecurity and calamities	production use demolition	+ ++ 0	+ ++ 0	+ ++ 0
Hydrological changes	production use demolition	+ + +	+ + +	++ ++ +
Fragmentation of open space	production use demolition	++ ++ 0	++ ++ 0	++ ++ 0
Barrier effect	production use demolition	++ ++ +	++ ++ +	++ ++ +
Impact on visual landscape	production use demolition	++ ++ 0	++ ++ 0	++ ++ 0
Loss of landscape and cultural history values	production use demolition	++ ++ ++	++ ++ ++	++ ++ ++
Microclimatological effects	production use demolition	+ ++ +	+ ++ +	+ ++ +
Biotope loss	production use demolition	++ ++ +	++ ++ +	++ ++ +

5.4.4 Fauna casualties

An inventory campaign for traffic casualties (vertebrates) was organised by the Royal Belgian Society for the Protection of Birds ("KBVBV") during the European Year of Nature Conservation. More than 100 volunteers participated, a number of which continued the inventory in 1996.

After a first results analysis distinction is made between amphibians, birds, and mammals. Reptiles were not found. Table 5.8 shows the results.

Table 5-8 Traffic casualties found per class (category)

	Amphibians	Birds	Mammals	Total
1995	116	3074	2870	6060
1996	25	952	669	1646
Total	141	4026	3539	7706

Comparison of data from the Netherlands and France shows that the mammals/birds relation depends on the degree of forest area present in the investigated stretch: more mammals are traffic casualties in closed-in landscapes. In open landscapes, however, birds are the main traffic casualties. In Belgium the relation is roughly 1/1 (see figure 5.5).

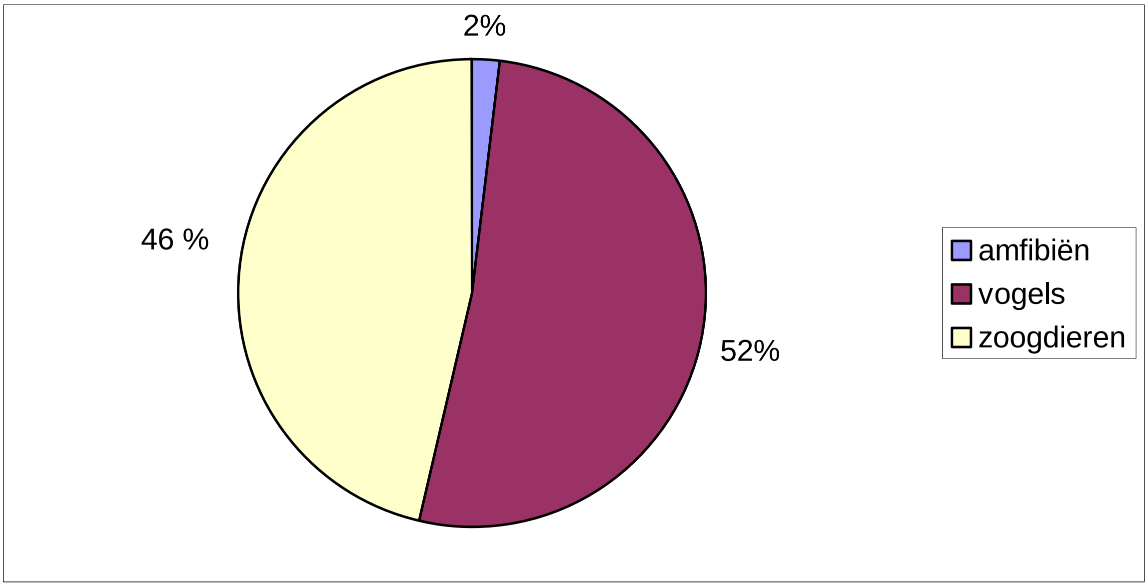

Figure 5-4 Partition of the number of casualties among the different classes (from Animals under our wheels)

Approximately 73% of all road casualties were annotated in the April-September time frame, i.e. during spring and summer. This is an obvious result of the procreation activity in springtime, the swarming out of young animals during the next period, and the strongly reduced activity of some species in winter. Peak time for birds is spring, while peak time for mammals is summer. The majority of traffic casualties among amphibians are found during their massive migration in springtime. Peak months are March and April, depending on the weather conditions (temperature and humidity).

31 mammal species were found. The ten most important species, amounting to 97% of the total, are: hedgehog, rabbit, hare, squirrel, polecat, brown rat, muskrat, fox, mole, and weasel. The lack of mice and shrews may be explained by the fact that counts are mainly performed from a car. 95 bird species were found, the most important ten of which (blackbird, house sparrow, pheasant, wood pigeon, moor hen, wild duck, magpie, black-headed gull, black crow, and thrush) constitute 96% of the total number of bird casualties found. The low number of casualties among amphibians can be attributed to the fact that most counts are done in atypical amphibian biotopes. Toads, for example, know that thousands of them will be killed by traffic during spring migration, when moving from their area of hibernation to the pools for procreation. For a long time already, nature association volunteers have been very active in helping toads to cross important barriers in that particular period of time. Table 5.9 shows a survey of data collected in Flanders by "HYLA", a reptile and amphibian workgroup of the nature society called "De Wielewaal".

Table 5-9 Traffic casualties in Flanders in 1995 and 1996 (data collected by HYLA)

SPECIES	1995	1996	TOTAL	%
Common toad	3,307	4,224	7,531	89.1
Common frog	79	397	476	5.6
Green frog	2	5	7	0.1
Salamander species	167	274	441	5.2
Total	3,555	4,900	8,455	100

The number of frogs among traffic casualties is remarkably low because their spring migration is less definite than that of toads. Figure 5.6 shows the evolution in the number of toads being helped to cross barriers since 1987. However, the long-term goal should be to take more structural measures like, first of all, amphibian tunnels that can replace labour intensive cross-over actions.

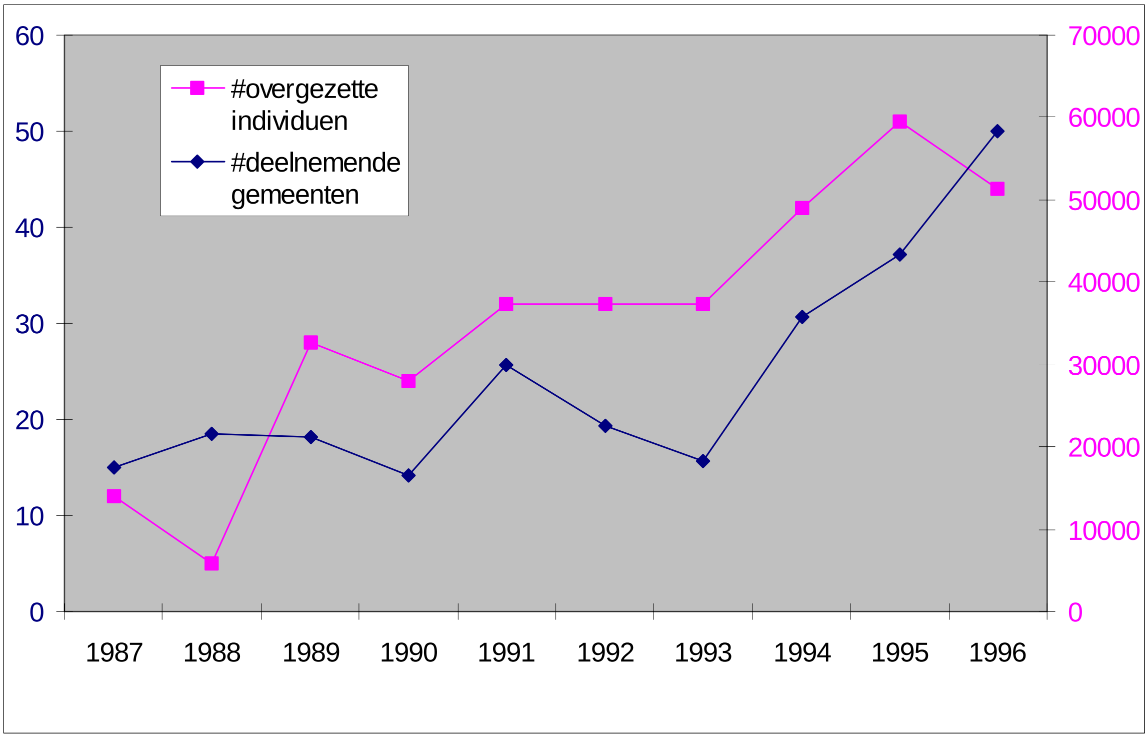

Figure 5-5 Evolution in the number of common toads (Bufo bufo) taken across roads and the number of towns participating in the cross-over actions

Railway traffic also takes it toll. The National Society for Belgian Railways ("NMBS") could only supply us with data on large-animal collisions, since damage files are made up for those incidents only. We are talking about cattle, horses and pets. Sporadically (especially in Wallonia) mention is made of collisions with roe deer and wild boars. Which casualties and how many there are from railway traffic is difficult to estimate without a specific study of inventory.

Data of death by drowning in artificial waterways are not systematically kept, but it seems to be a real problem, as appeared after an inquiry with the different districts of the Service for Shipping Traffic. Annually, around ten dead roe deer are fished out of the Albert Canal between Hasselt and Bilzen. These data are clearly incomplete since not all drownings are reported to the guards. Also smaller animal species, such as foxes, rabbits, and mice are often found.

5.4.5 Barrier effect

A road is a barrier that is difficult to cross for some animal and plant species. An intensive use of roads increases that effect. To what extent a barrier effect will occur will first of all depend on the type of road. Beside that, there is also a species specific sensitivity for fragmentation caused by transport infrastructure. Concrete New Jerseys are an unassailable obstacle for small mammals, while roe deer can cross that type of obstacles. Grass snakes can bridge a water surface area of 2 to 3 km, but a canal with steep concrete banks is an unbridgeable barrier.

When talking about fish migration, one usually considers migration over long distances. Fish migration may also take place on much smaller scale. Depending on the species and the stage of life in which they are, migration over several kilometers is essential for the survival of many fish species. Fish migrate to find spawn places, to find better feeding areas, or to hide from predators. Sometimes migration happens because of water pollution or because brook segments are running dry. Problem areas for fish migration are both setback and unattainability of habitats and antropogene influencing of fish migration routes: all types of works of art, i.e. dams, water mills and bottom traps, straightening out of waterways, etc..

5.4.6 Effects on populations

Habitat fragmentation results in a reduction of population size and in a larger isolation of the remaining subpopulations. A smaller population size increases the chance of extinction directly. Reason being the fact that changes in environmental conditions have to be intercepted by a smaller group of individuals and also indirectly because of the reduction in the subpopulation’s genetic diversity. In the long term the actual population size in isolated populations is less buffered with respect to environmental parameter fluctuations than in populations in which a continuous exchange of individuals exists (the so-called source and sink populations in a metapopulation structure). Populations in a fragmented landscape are often too small to survive. By making links between suitable habitats, e.g. by means of mitigating interference, a metapopulation of subpopulations comes about that will constantly inhabit other places in the course of time through a successive and local extinction and colonisation process.

The traffic death effect of one individual on the population level should be considered. When an adult polecat dies after the birth of her cubs, her territory will most probably be occupied by her offspring. If that process repeats itself long enough the possibility exists that a genetic impoverishment sets in locally that will make the population more sensitive to extinction.

It is clear that the above mentioned effects of habitat fragmentation are species-bound. First of all there are the scale effects: organisms with large habitats (home range, action radius) will be more sensitive to habitat fragmentation effects than species having smaller habitats, at least with regard to the direct and indirect effects on population size. With regard to population-genetic effects the vagility factor is also important: species with a large dispersion capacity will show a less strong tendency for genetic isolation than species with a small dispersion capacity. Dispersion capacity is often positively related to the size of organisms, so that the dispersion capacity and habitat effects are sometimes hard to distinguish. There are also many species whose dispersion capacity is not related to the size of the individuals. In the0e cases, the effects of dispersion capacity can be assessed separately (e.g. the differences in dispersion capacity among ground-beetles depend on the different phases of wing development and have been observed both among different species and among different populations of one species).

Also other species-bound characteristics can play a role in the context of habitat fragmentation effects on the genetic structure and the evolution potency of populations.

Differences in procreation strategies have important consequences for the population structure of local populations, the speed with which evolutionary changes can appear, and the speed with which new habitats can be colonised. Next to species-bound characteristics the habitat characteristics also have their importance. These nevertheless always go together: the habitat size effect and the degree in which geographical isolation is considered important or the degree in which an area, located between two biotopes, is experienced as a barrier are to a large extent species dependent. Other important habitat characteristics are, among others, the habitat age and stability. Organisms will often be specialised (stenotope) and have a rather small vagility in very stable environments. Such characteristics make a species extra sensitive to habitat fragmentation. In dynamic environments, organisms are more oriented on dispersion between (temporary) suitable habitats, which strongly reduces the genetic isolation tendency caused by habitat fragmentation.

5.4.7 Overview of environmental bottlenecks

In the next phase a land covering inventory of the problem areas is made for Flanders. For that purpose a first exploratory methodology was developed at the Institute of Nature Conservation. On the basis of the Biological Valuation Map, localisation of large to medium large green surface areas that are cross-sectioned by roads has been made possible. Moreover, both the way of cross-sectioning and the cross-sectioned wildlife surface areas are accounted for. Another possibility is mapping the cross-sectioning of waterways with large roads. Such bridging is often a barrier for various waterway and bank-dependent fauna species if not constructed by way of natural engineering. Geographical information systems are an outstanding means for setting up such signal maps for disintegration problem areas.

5.5 SECONDARY EFFECTS OF TRANSPORT INFRASTRUCTURE

The amount of sand, gravel, and other soil types that come from the construction and management of infrastructures is enormous. Annually, a large amount of dredging cement comes from the maintenance of maritime access roads, ports, canals, and other waterways. Up to 40 million m^3 of dredging silt was dredged from the entrance waterways of Flemish seaports. The biggest amount thereof is deposited again in the sea or in the “Westerschelde”. Nevertheless, approximately 4 million m^3 silt is annually deposited on land. Assuming a raising thickness of 2.5 to 3 meters, it equals to a space coverage of 135 to 160 hectares per year. In 1989, Flanders had 28 dumping grounds for dredging cement maintenance. With a total capacity of 12.1 million m^3 it took up a surface area of approximately 450 hectares. These problems will get worse in the future due to the planned expansion and storeys of the waterway system.

Ribbon building is widespread and has been done for a long time already. Especially after WW II, ribbon building has quickly and thoroughly affected open space. Distribution chains have settled alongside roads and business centres have been erected alongside main traffic axes because of the “just-in-time” production or because of the transport, storage, and distribution combination within one business. Ribbon development intensifies, both visually and functionally, the disintegrative influence of linear transport infrastructures. The length of ribbon development is estimated to be at least 2,000 km.

For a long time already the waterway structure has been adjusted by man. Before, mostly small-scale interference, such as deepening, heightening, water mills, etc. was performed. The present management of waterways holds all types of large-scale maintenance and development interference. Examples are the normalisation and canalisation of waterways for the benefit of navigability. The objective of normalisation is to give waterways a more continuous flow both in its lengthy direction and in its crosswise profile. Canalisation is done by both straightening a river and by increasing its water level using dams.

Consequence of all the above is a decrease in the water holding capacity of the river; heavy rainfall may cause valley flooding.

5.6 ON-GOING RESEARCH AND REVIEW OF RELEVANT STUDIES

Studies

In order to formulate fragmentation possibilities for the E314 motorway between exit Genk and exit Maasmechelen, a research study was done by the Technum and Econnection research consultancies in cooperation with the Forest, Nature, and Landscape Lab of the Catholic University of Leuven by order of the AMINAL Nature department of the Limburg province. Since its construction between 1969 and 1976 the E314 motorway has had an enormous influence on the fragmentation of the surrounding wildlife areas and their fauna elements. The E314 motorway cuts the green north-south axis in the east of the Limburg province. In a first phase of the study, an ecologically found argumentation is developed to show the defragmentation necessity and to map the problem areas between exits 32 and 33. It is no longer possible to localise the original animal changeovers. By way of terrain characteristics (relief, overgrowth, human influence, etc.) and dispersion data of relevant animal species (roe deer and badger) a choice can be made of potentially interesting crossover areas. Biological Valuation Map, Habitat and Bird Directive areas, Common Motor Guarantee Fund, Green Main Structure draft plan, Regional Plans, Regional Nature Development Plans ("Kempen" and "Maasland"), and Master Plan of Flanders are for example referred to.

In a next phase, defragmentation proposals are formulated on the basis of a number of actual structures (bridges and tunnels) and on a number of structures yet to be constructed. Those are mainly adjusted to the roe deer and badger species. It is important for those animals, which migrate on large distances, that the proposed measures are tuned to other developments in that region. Further, a description is given of what conditions those constructions have to comply with for optimum fauna passage. Different scenarios are deduced from those possibilities, one of which is picked to be technically developed. Further, a rough price estimate is made of the scenario. The last part of the study shows that expansion of the present living centres through ribbon development and increased traffic along secondary roads causes an importance hindrance for the species in the research area. Meanwhile the study resulted in the contracting-out of the first ecoducts in Flanders (see 7.3.2).

A second and third large defragmentation study have started respectively in November 1999 and in January 2000 called "defragmentation proposals for the E19 motorway" and "defragmentation proposals for the E34 motorway". Both projects are done by the Technum - Econection environmental study agencies.

In 1999, the Aeolus environmental and nature advice agency did a study called "Fauna elements on road verges along the E314 motorway" by order of the AMINAL Nature Department. The research was situated in the verges between exits 29 (Zonhoven) and 33 (Maasmechelen) and runs from the west edge to the east edge of the "Kempen plateau". That motorway stretch cuts three important heath grounds: first "De Teut" and "Tenhaagdoornheide", second "Mechelse Heide" with the nature reserve called "Kikmolenbron", and third the heath of "Opgrimbie".

The study goal is threefold. In the first place, the verge fauna was inventoried with emphasis on invertebrates: spiders, ground-beetles, butterflies, and grasshoppers. Beside the former, attention is given to three groups of vertebrates: reptiles, amphibians, and mammals.

A second part of the study wants to present suggestions towards road verge management from inventory results and conclusions. For that reason all types of verge vegetation were included in the study: grasslands, dry heath, blackberry and broom bush, deciduous and coniferous wood. By taking a number of Red List species as indicative for a valuable vegetation type, one can determine what kind of management will be the most worthwhile one. On the basis of temporary data, it is obvious that dense blackberry bush has little value while grassland with blackberry bush spots is quite interesting. A number of arid grassland verges are interesting for both spiders and ground-beetles. That type of vegetation seems to have lost a lot in habitat surface area (through eutrophication). Its presence is now limited to road verges and nature reserves.

A third aspect of the research study is gathering indirect indications for the verge corridor function. Road verges that connect with heath areas, do they have many species of the heath type or not?

On 26 April1996 the Committee of Ministers of the Benelux Economic Union approved a decision on free fish migration of fish species in the hydrographical river catchments of Benelux. That decision contains a program for the protection of fish populations that should result in free migration of all fish species in all hydrographic catchment basins by 1 January 2010, irrespective of the manager. The term migration covers:

- Free migration: movement of fish using two or more habitats separated in space. That movement often takes place with a predictable periodicity during the life cycle and depends on the species;
- Anadromic migration: fish moving from the sea to sweet water spawning areas.
- Catadromic migration: fish moving to spawning areas located in the sea.

The Environment and Nature Plan (see 7) also emphasises by different points of action the importance of getting rid of those migration problems. Financial means are provided for that purpose:

- Action 74: further development and implementation of naturally engineered environmental buillding techniques for waterway design and management. Construction of fish passages at dams and locks is of foremost importance.
- Action 93: repair and improvement of migration possibilities in and alongside waterways.
- Action 101: solve fragmentation problems that have priority in which habitats of species are cut by waterways, railways, and/or pipes. Problem areas are inventories and prioritised in function of animal species, type of area cut, and type of infrastructure.

The provincial fishery commissions started up studies for fish migration improvement on priority waterways in different river basins. Those were done by the Institute for Forestry and Wildlife Management in co-operation with the Institute for Nature Conservation and with the AMINAL Water, Nature, Forestry, and Green sections. Because of the difference in ecological value between different brooks and rivers, a number of priority waterways were indicated so that problem areas can be tackled there first.

For organisational purposes, the choice was made to start research per river basin or sub-basin. Following order was assumed:

- The river Meuse basin including the basins of the rivers “Dommel”, “Mark”, and “Witbeek”.
- The river “Nete” basin.
- The river “Demer” basin.
- The river “Opperschelde” basin.
- The river “Dender” basin.
- The basins of the rivers “Dijle” and “Zenne”.
- The river “Benedenschelde” basin.
- The river “Yser” and its polders.
- The polders of Bruges.
- The canals of Ghent and the polders and coves of the East-Flanders province.
- The river “Leie” basin.

Meanwhile, the research studies for the river Meuse basin, the river Nete basin, the river Demer basin, and the river Yser basin have started.

An extensive problem area inventory was made of each priority brook from the basin researched (culverts, grids, drops, bottom traps, siphons, water mills, dams, pump stations, fyke nets, etc.) so that the major problem areas can be tackled in the next phase.

The AMINAL Forestry and Green section conducted a research at the Water Engineering Lab on some specific fish migration problem areas in co-operation with the Institute for Forestry and Wildlife Management. Above research is also part of the earlier mentioned Benelux decision. The study specifically checked whether and to what extent culverts, locks, and siphons might impediment free fish migration. A thorough study of literature on fish migration with reference to the above infrastructures also gave extensive information on the swimming capacities of the different species. The major problem appears to be the extremely high water velocity in locks and siphons. Only little information was found on locks.

The practical research section covers three subprojects:

- Experiments in a water drainpipe with controlled capacity and flow rate. The critical values of these variables were measured for a number of species. The willingness to swim through a dark pipe was also examined.
- Migration of downstream released fish is followed by catching the fish in a pond in which siphon and culvert were installed.
- Evaluation of a real situation, i.e. vault and ground culvert crossings. The fish fauna present is used for the experiment.

From the research study it appeared that a dark pipe does not cause any problems for the majority of the species. However, brook trout and tench do not migrate through the pipe. Neither culvert nor siphon are barriers with the exception of brook trouts.

The dams of Asper, Oudenaarde and Kerkhove located on the river "Bovenschelde" have to be replaced soon. They date from 1922 and offer insufficient operating security. The river "Bovenschelde" department of the Waterway and Maritime Administration has the following view: "Even though no fish stock is present at the moment, one should at least provide space for possible future fish populations when building new infrastructures.". In other words, one wants to provide dams with fish passages. After a first advice from the Institute for Forestry and Wildlife Management (a V-shaped fish ladder construction) a project group of biologists and hydraulic engineers was set up to work out the details. The major problems were:

- Location of the fish passage entrance with respect to the dam's turbulence zone caused by the overflow rate?
- Overflow rate required on the fish passage so that sufficient and efficient tempting flow is created from the fish passage?

Foreign research has shown that many constructions do not function properly because fish do no find the passage entrance. In literature, a ideal calculation of the future fish passage was made. To test its efficiency, a scale model of the new dam was constructed with a V-shaped fish passage.

Construction of a new dam and lock at the Ring Canal around Ghent is planned by the Waterway and Maritime Administration. They also want to keep the prospect of fish migration. For that purpose the Institute for Nature Conservation will do a radio telemetry study on another Ring Canal lock to examine whether locks and dams are passable obstacles for a number of fish species or not. The Institute for Forestry and Wildlife Management will also make an inventory of the fish population in the Ring Canal of Ghent.

Research

In 1996, a genetic ecological research project for the benefit of nature conservation started in the framework of VLINA-projects (Vlaams Impulsprogramma Natuurontwikkeling – Flemish Incentive Programme for Nature Development). Several research groups, such as the Ecology and Aquaculture Lab (Catholic University of Leuven), the Institute for Nature Conservation, the Biology Department (Ruca - University of Antwerp), the Invertebrate and Entomology Department (Royal Belgian Institute for Natural Sciences – KBIN), the General Botany and Nature Management Lab (Free University of Brussels) have all contributed. The project's main goal is bringing in the population-genetic knowledge necessary for a well- considered planning of environmental development scenarios.

Knowledge on the genetic structure of natural populations (relation between genetic differentiation and the extent of population isolation, relation between effective population size and genetic diversity, minimal size of liveable populations, presence of relict populations) are very important for a well-founded landscape management and for the maintenance of the specific species under research. Furthermore, its results might be useful to formulate well-balanced indicators for genetic biodiversity as natural value. The project's specific aim is to see how much populations – which have a varying degree of isolation – vary genetically, if a relation can be found between population size and genetic diversity, and what the possible influence might be of species specific and habitat specific factors on these relations. All this based on research studies done on a number of different terrestrial and aquatic model organisms. Quantification of genetic differentiation between populations is relevant to answer questions such as local adaptation, species reintroduction, and population structure. Research on genetic polymorphism within populations allows to make statements with regard to evolution potency, including the populations' opportunity to react to changes in habitats (of local, regional, or global nature; going from local ecosystem disruption to global climate changes) orchestrated by man. Upon evaluation of the patterns and relations obtained the influence of species characteristics (such as size, action radius, and dispersion capacity) and habitat characteristics (such as stability, age, dynamics) will be taken into account. Although particular attention will paid to the study of (quasi) neutral markers (allozooid and DNA polymorphisms) research will also be conducted on genetic variation in ecologically relevant characteristics.

Furthermore, much attention will be paid to comparative research of organisms with different action radius and dispersion ability. Because it is expected that the effects of the nature reserves' size and the scale on which connecting elements are used depend on action radius and dispersion ability of the species considered. To make a good comparison of the results possible it is important that different sub-studies direct themselves by and large to the same areas. The different research groups jointly sample natural populations from their model organisms in well-defined areas with specific ecological characteristics (salt marshes, water rich areas, forests, etc.)

A second relevant VLINA project is presently running at the UIA (University of Antwerp) within the Animal Ecology research group. The project is called: Quantitative evaluation of the connecting function of landscape elements from connectivity models." Partners in the project are the Forestry, Nature and Landscape Lab from the University of Leuven, the Evolutionary Biology research group of RUCA (University of Antwerp), and the Institute of Nature Conservation. In two areas of research ecological data are collected on five species: speckled wood butterfly (Pararge aegeria), great tit and blue tit (Parus major and P. Caerulus), squirrel (Scirius vulgaris), and roe deer (Capreolus capreolus). All of those species are committed to an increasing overgrowth but generally appear in even smaller forest fragments (smaller than 5 hectares); They strongly differ in their use of space and in their extent of mobility. The two research study areas are made up of an archipelago of small forest fragments with numerous undergrowth and other small landscape elements.

A model of landscape opposition on the basis of species specific input parameters was picked to investigate the relation between landscape structure and ecological data. Such a model computes the accessibility of landscape points from previously chosen central areas. Connection of field data to the spatial file is done via the following repetitive process:

- the resistance map is deducted from the basic map (in the simplest case a land use map) by giving a resistance value to each pixel.
- that map is subject to a dispersion algorithm which generates an accessibility map. That map gives the accessibility from one or more areas for every landscape point. The dispersion algorithm is a growth model that starts from central areas with a fixed initial value. That value is reduced per pixel crossed with the resistance value of the pixel concerned. In a homogenous landscape that would result in concentric circles with a decreasing accessibility going outwards.

- by taking different central area combinations different accessibility maps are generated. From there connectivity is computed for different parameters. Possible parameters are:
    - Per landscape point: accessibility from all fragments where a species is present, eventually weighed by population size.
    - Per fragment: accessibility from all other forests (i.e. a measure for global isolation of the fragment).
    - Per combination of two fragments: accessibility of one fragment from the other (i.e. a measure for a specific isolation between the fragments considered).
- what connectivity parameters or combinations thereof have the highest predictable value for specific population data is finally investigated.
- process repetition allows model adaptation and control of correlation improvement with field data.
- a parameter sensitivity analysis to determine dependability of suppositions and precision of input data.

In the Forestry, Nature and Landscape Lab Olivier Honnay and his PhD students investigated fragmentation of old forests.

First they investigated the relative importance of habitat quality and habitat diversity on the one hand and fragment surface area (as surrogate for population size) on the other hand on forest plant species' dissemination over 234 forest fragments located in the historical County of Flanders. The major conclusion was that forest fragment surface area is merely of secondary importance when explaining variation in species abundance and its composition. Habitat diversity (soil and relief variability) and habitat quality (measured as the fragment age) are particularly determining factors. That has a number of interesting and far-reaching implications for nature conservation. Since as a standard small fragments have small populations, these smaller fragments do actually not appear to be more sensitive to extinction than the larger ones in larger fragments. For various reasons, the appearance of stochastic extinction processes (demographically, genetically, and/or environmentally stochastic processes) is probably of minor importance for forest plants in fragmented habitats. The forest plant species' dispersion across various habitat fragments is mainly determined by the extent of habitat specialisation of the species and by the appearance of nested habitats (see figure 5.7). Under specific conditions it opens perspectives for species conservation in small fragmented forests. Also the forest fragment age has a large impact on species composition. Old forests (older than 200 years) have after all a characteristic group of species (so-called old forest plant species) that appear significantly less abundant in younger forests. A method of analysis following from the nested subsets theory made it possible to deduct a series of forest plants that are perfect bio-indicators for fragment species richness.

Analysis of an additional data set of some 50 forest fragments from the strongly urbanised Sint-Katelijne-Waver surroundings (North of Belgium) at first sight produced results that were not consistent with the above views. Fragment surface area remained by far the most important independent variable that explained the fragment species richness in spite of having used more refined measures for habitat diversity. Additional research showed that most probably disturbance and the associated increased invasion capacity of the American bird cherry (Prunus serotina Ehrh.) were the cause of the fact that fragment surface area puts a limit to species richness. Because of various factors small fragments appeared to be more sensitive to disturbance, invasion, and overgrowth by the American bird cherry, which strongly reduces species richness even with large habitat diversity. Another aspect of the forest fragmentation process is the ever increasing environmental isolation of different habitat fragments resulting from the former. Habitat isolation effects on forest plant species' composition were first of all researched at intrafragment level since it was assumed that the majority of characteristic forest plant species have largely limited dispersion capacity and have difficulty crossing the hostile landscape matrix between two fragments. At local scale (‘t Ename forest close to Oudenaarde), the interaction between the dispersion capacity and the quality interaction of the habitat to be colonised on the former farmland forest plant recolonisation capacity was evaluated. Species specific colonisation speeds were also deducted. Even in ideal conditions the recolonisation speeds measured came to no more than a few meters per century. Especially a high phosphate level of the soil (typically for formerly intensively used farming land) showed a negative result correlated with the forest plant capacity to recolonise former farmland.

Old forest edges appeared to be perfect places of refuge for a number of valuable forest plant species. Not only places of refuge in the form of old forest edges are good colonisation sources for forest plants. Also forest waterways may play an important role in the spreading of forest plants. The very characteristic species' composition of dendritically branched brook systems in forests was colonisation determining. The substudy's conclusions move in the direction of a colonisation process consisting of a stochastic component (initial colonisation of the species in a dendritic network) and a deterministic component (downstream species spreading and accumulation). Continuous migration processes have the ability to compensate the consequences of locally competitive exclusion (the so-called mass effect).

The role of competitive exclusion cannot always be neglected in fragmented forest fragments, more specifically in edge habitats. Strongly fragmented forest landscapes are characterised by a relatively high density of edge habitat opposed to central habitat. In that framework research was conducted in the loam area of Brabant for the “weeds” invasion into old forest edges, for the penetration depth of abiotic edge effects (microclimate soil chemistry), and for the possible consequences of those processes on wood plant species' composition located at the forest edges. By immision of forest edge agricultural nutrients it was expected that competitive and ruderal species could have a competitive advantage to the more stress tolerant forest plant species. Especially alongside edges oriented to the south the penetration depth of edge effects (both biotic and abiotic ones) are prominent. The research area nutrient immission effects both on the plant species' composition and on the soil chemical condition were rather limited.

5.7 SUMMARY

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Chapter 6. Traffic Safety in Relation to Fauna Casualties

At the GMWF (Gemeenschappelijk Motorwaarborgfonds – Common Motor Insurance Fund), an insurance company that makes financial settlements for accidents with animals, 3,962 accidents with main cause crossing wildlife were reported between January 1992 and December 1996. The Fund paid 168 million BEF, 90% of which for material damage to vehicles. For both driver and vehicle collisions with animals are limited to material damage. Experience has shown, however, that not all collisions are reported to the GMWF. And since 1997, the majority of compensation claims are refused and petitioners are referred to the towns where the collisions took place.

Chapter 7. Avoidance, Mitigation, Compensation and Maintenance

7.1 Introduction

Avoiding additional fragmentation requires new instruments and a framework as regards to content with a number of accompanying directives. Directives with regard to maintenance responsibility, compensation, integration with other management fields, etc. The decree on nature conservation gives the initial impetus but let it be clear that a distinctly coherent management for problem prevention is lacking so far.

7.2 Avoidance of habitat fragmentation

Project level EIA

At the initiative of the EIA unit (Environmental Impact Assessment – cel Milieu-effectrapportage) of the AMINAL (Administration for Environment, Nature, Land, and Water Management) section (Environment and Infrastructure Department) a research study was done on the composition of technical EIA Guidelines in 1995. It gives practical and clear directives and methodological suggestions for all activities subject to EIA, including motorways and railways. Spatial attention was made to mitigation measures.

First of all, distinction is made between 'the classical' environmental aspects that will be influenced by the construction of a new infrastructure such as noise and vibrations, air, soil, water, man- health, fauna and flora, landscape, and man-environment aspects. Fauna and flora is a so-called integrating aspect ('end-effect') because many effects on the abiotic environment are assessed by their impact on fauna and flora. Effects are expressed by plant or animal species' disappearance from a specific area. Criteria used are approximately the same as the ones used for nature conservation. Rarity can also be used at the habitat or biotope level next to the species (population) level. In that way other criteria can be used for diversity, natural quality, or replaceability. Rarity, however, will always remain the basic criterion. For cases in which it is difficult to predict effects, for having only little basic data on habitat requirements and dispersion, vulnerability can be used for the effect in question. It is of course impossible to discuss all species in an Environmental Impact Statement. Therefore, one concentrates on a number of so-called species of interest by using the Red Lists.

The book of directives was presented to group effects and to describe possible methodologies per group. With regard to infrastructure works, following are the effect groups:

- Immediate space occupation by motorways and railways, and the works of art, slopes, and earthmoving resulting from the former: destruction of existing ecotopes (and their vegetation) and habitat spots or complete biotopes.
- Barrier effects.
- Disturbance by road use, more specifically vibrations and noise but visual stimuli just as well (nightly road lighting, motorcar and train lights).
- Water and soil pollution (soot, oil, other hydrocarbons, dust, rust, heavy metals, salt for icy roads, etc.) with indirect effects on:

  - Verges and their fauna and flora
  - Waterways, ditches, and dikes by the run-off water from roads.
- Ecotope and biotope changes by the lowering of groundwater level as consequence of (temporary or permanent) drainage for the construction of works of art or by breaking soil layers that are difficult for water to penetrate, or by drainage (permanent).
- Overfertilisation and acidification because of NO_x and SO_2 emission by road traffic.
- Ecotope and biotope changes as result from soil disturbances (close concentration, structural changes, pollution, etc.) because of motorway and railway construction.
- Higher order effects: due to ecotope changes or disappearance of specific species habitat requirements of other animal species are no longer met or they do no longer have sufficient prey (food chain – food web).

7.3 Overview of mitigation measures

7.3.1 Fauna passages

Amphibian tunnels

More and more amphibians become traffic casualties when crossing roads during migration from hibernation area to procreation area. The construction of amphibian tunnels can largely reduce that number. Such tunnels are pipes running in one or two directions under roads. Amphibians are, however, not inclined to voluntarily use dark and dry passageways. For that reason it is best to combine such tunnels with conductive screens and trap systems. The correct location of those conductive screens is – possibly in combination with a specially-adapted planting - very important for the above defragmentation technique's efficiency. On the other hand, that type of infrastructure increases the road's barrier effect. In spots where tunnels cannot be fitted in at the underground level these can be built in speed ramps, which at the same time reduces traffic speed in the tunnel's surroundings. In some cases small mammals also use amphibian tunnels. Those tunnels need an annual check for accessibility: litter obstructing the tunnels' entrances needs to be removed.

Badger tunnels

Badgers use regular tracks to move through their habitats. Where such tracks cross roads badgers often become traffic casualties. A badger tunnel is usually made of concrete pipes with a diameter of 30 to 50 cm. Other animal species can also use that type of infrastructure. It is best to make a bend in the tunnel so that it is dark and animals cannot see its end. Since bats often use linear landscape elements to move around, adapted planting can strongly increase the defragmentation infrastructure's efficiency.

The tunnel's entrance is best put at ground level at the extension of the badger's regular track. Badger tunnels are also combined with a conductive structure: a badger screen that forces the animals to go underneath and not across roads. Badger screens must have badger gates at regular distances so that animals eventually getting on roads can get off them too. Often existing subtunnels for road drainage can also be altered to become efficient badger tunnels.

Ecotunnels

Ecotunnels constructed particularly for roe deer. The animal's use of such tunnels largely depends on the local situation: planting in its surroundings, quiet and/or disturbance in the area, fencing, the tunnel's measurements, etc. Its minimum height is 2.50 m and its minimum width is 5 m and depends on the tunnel's length. Again, the tunnel's entrance needs to be made at the extension of regular tracks and at ground level. Sufficient quiet and a well-installed screen are essential for the technique's well-functioning.

Ecoducts

When roads cut an area in which there is a lot of fauna, special bridges, so-called ecoducts, can be constructed. The ecoduct's minimum width is 50 m and its edges need to be visually covered by planting. Noise screens can be installed on ecoducts for annoying traffic noise reduction purposes. A continuous wildlife screen should be connected to the ecoduct for its efficient functioning.

Wildlife mirrors

Wildlife mirrors are specially installed structures that bend the light of motorcar headlights towards road verges to scare of animals.

In Flanders, wildlife reflectors are mainly used for roe deer. The method's advantage is that it does not increase the barrier effect as screens do. However, it's main disadvantages are:

- Wildlife mirrors only function at night.
- Wildlife mirrors do not have effect on busy roads.
- There is a chance for adaptation, especially with large animals.
- Installation of wildlife mirrors needs to be done quite accurately, the height level is especially important.
- Wildlife mirrors demand regular cutting of the road edges.

7.3.2 Survey of mitigation infrastructure in Flanders

The province of Limburg

The province of Limburg is known for some time now to have the largest barrier problems. Among other things the province houses the last badger population of Flanders and has a large number of valuable nature reserves. Following projects were finished or will be started in the near future.

Ecoraster and ecotunnel alongside the E314 motorway at Houthalen-Helchteren

Because of the E314 motorway's construction the large wildlife area called "De Teut-Tenhaagdoornheide" was cut. Construction of a screen to guide the animals to tunnels in nature reserves "De Teut" and "Tenhaagdoornheide" will benefit both animals and traffic safety. For the screen's location line and the ecotunnel's position see map x. A combined screen of 7,500 m long has been installed alongside the E314 for roe deer, smaller mammals, and amphibians. It is a fine-meshed screen with a height of 80 cm (for small wildlife and amphibians) onto which a second coarse-meshed screen is attached with a height of up to 2 m for roe deer. Alongside the road, recesses with steps are provided for the animals to facilitate their return in case they get on the road. (see figure). The ecotunnel (46 m x 5 m x 3 m) was installed without open trench so that traffic was not obstructed during its construction. This way of "tunnel element injection" is considerably more expensive. Its total construction cost amounted to 32 million BEF. Work started on 1 April 1999 and it was completed in September 1999. The tunnel will also be used to facilitate grazing management of nature reserves with sheep.

Defragmentation of the E314 motorway between Genk and Maasmechelen

As a research study for defragmentation possibilities has shown (see 5.6), the E314 motorway needs defragmentation between the Genk and Maasmechelen exits since it cuts through approximately 9,000 ha of continuous wildlife area.

A first important part of the defragmentation argumentation is the discussion of the area's ecological value (large area at the north and southside of the E314 between Genk and Maasmechelen). It is shown that a green axis consisting of nature, forest, and nature reserve area extends itself from Kinrooi to Lanaken. The Biological Rating Map also shows a concentration of valuable to very valuable parcels. Nearly the complete area is coloured as main nature area on the Green Main Structure map. The area surrounding the "Mechelse Heide" is annotated in the EC's Bird and Habitat Directives. The allocation of a number of parcels in the region can exert an increasing defragmentation pressure: reallocation of a military installation and of a service rendering area, and expansion of a sand quarry. There is also an increasing disturbance in the region due to passive and active recreation.

A second part of the argumentation is spreading a number of relevant animal species (roe deer and badgers) in the surrounding area. Measures that will be taken for these species may obviously be useful for a wide variety of other animal species.

Roe deer generally appear nearly in the entire province of Limburg. There are only a few sporadic indications that confirm the badger's actual presence in the research area.

It is certain that badgers used to live there and that colonisation from other areas (for that reason the Albert Canal also needs defragmentation) is within the bounds of the possible. The area's defragmentation will take place by adaptation of the already present infrastructure, such as drainage pipes and bridges in combination with the construction of new ecoducts and badger tunnels. The results of a defragmentation research study show that reconstruction of the existing bridge over the N730, the construction of two new ecoducts, the construction of several small badger tunnels, and the rebuilding of a number of existing passageways would strongly reduce the defragmentation effect of the E314 for both roe deer and badgers. A number of secondary roads appear to have a barrier effect too, though less absolute than the E314 motorway itself. Consequently, more collisions take place on those locations. Here, defragmentation plans also need to be drawn up in the near future.

Ecoscreen alongside the N75 at Dilsen

Badger screens alongside the E313 motorway, the Tongeren-Liège railway, and the Visé-Lontzen railway

All sorts of defragmentation interventions are also required in the middle of the last main badger area of South-Limburg and Voeren. Annually, 20 to 25 badgers become traffic casualties in that area. That number is approximately equal to the expected annual growth of the badger population amounting to some 120 specimen. After many years of inventorying the badger traffic casualties, done by LIKONA (Nature Study Organisation of Limburg), the problem areas with transport infrastructure are very well known within the province. Now, badger screens are installed alongside the E313 between the Walloon border and the Bilzen exit. The same will be done alongside the Tongeren-Liège railway in Tongeren (Nerem), and alongside the Lontzen-Visé railway in Sint-Martens-Voeren. Interventions are also planned alongside specific town roads in Tongeren and Voeren.

Fauna exiting areas alongside the Albert Canal between Riemst and Bilzen

The Albert Canal between Riemst and Bilzen cuts the Jeker plateau with steep slopes that have a wide variation in soil composition and exposition. On the average they have a very high nature value and some of them are colored as wildlife areas on the allocation plans. Several inhabited badger castles are present in inclines and their immediate surroundings. The Albert Canal, however, is an absolute barrier for the badger species.

Moreover, the canal area acts as a connecting area for migration between main nature areas in the north (Gellik, Lanaken, and Zutendaal) and border crossing wildlife areas located more to the south in the Jeker valley and in the surrounding area of Tongeren.

Concrete banks are often very steep or even vertical. Badgers and roe deer getting into the water cannot get out of it anymore.

By making fauna exiting areas at regular distances the number of drownings should be limited. Also pine marten populations that are increasing in that environment will most probably profit from these provisions for the colonisation of new areas. Exiting areas are made with an underwater platform bordered by a soft slope so that animals can easily jump ashore. An ecologically more interesting way of fragmentation reduction by artificial waterways is the introduction of nature friendly banks. The latter is impossible due to lack of space in many locations between Riemst and Bilzen.

Exiting areas are mostly built backwards. In areas where bank fortification is anchored into the bottom forward building is opted for. A total of three different types of fauna exiting areas are required for the defragmentation of the Albert Canal between Bilzen and the Walloon border. To determine the location of the exiting areas recent spreading data, tracks, inhabited badger castles, and drowning data of roe deer and badgers were looked at. In priority areas large exiting area at every 250 m at both banks of the canal and small exiting areas halfway in between the large ones will be constructed. In areas with less priority the latter will be left out.

<u>Other initiatives:</u>

Wildlife mirrors alongside specific parts of the A2 in Flemish Brabant.

Amphibian tunnels

At present there are three amphibian tunnels beneath the N223 at Tielt-Winge. In the framework of the LIFE project "Green Ring of Three Valleys" an existing culvert is planned to be used as fauna passageway.

Apart from that, amphibian tunnels were installed a.o. in Overijse, Tervuren, Houthalen, Tienen, Sint-Pieters-Leeuw, Oudenaarde, Bilzen, and Genk. Such projects often took place in the framework of subsidised environmental town development plans (GNOPs) The towns of Kruishoutem and Willebroek are planning the installation of amphibian tunnels for the near future.

Fish ladders

Fish ladders have been constructed e.g. on the "Velpe" and "Kleine Gete", on the "Laarse beek" in "Peerdsbos", on the "Dalemans loop" in Geel, on the river "Dijle" in Leuven, on the "Rode Loop" in Wamp, on the "Kleine Nete" in Kasterlee, on the "Zwalm" and on the "Asbeek". Not all of those fish ladders have proven their efficiency so far.

The only roe deer bridge of Belgium is constructed over a railway bridge in the town of Tournai located in Wallonia. When constructing the High Velocity Railway line consideration is made for the planning of a similar infrastructure, i.e. one bridge across both lines alongside the E40 and E19 motorways, while dozens of other mitigating measures were put first and foremost in the environmental effect report.

Fauna passageways

A few badger tunnels with adjusted screens were located alongside the N79 between Borgloon and Tongeren.

Badger tunnels and screens were also installed during the "Kolmont" land consolidation.

Courses on defragmentation projects

7.4 Overview of compensation measures

Effect mitigating measures never fully counteract the negative effects of transport infrastructure. That is why the concept of compensating measures was introduced. The essence is that, with those measures one intends to compensate the loss of nature in an area where transport infrastructure was set up and to intercept the infrastructure's negative impact on the remaining natural environment by introducing nature "of equal quality" in that environment. If nature is lost because of road construction it is compensated by nature protection and development in the surrounding area. Compensation must also be made when an area becomes partially or completely unsuitable in the road's vicinity. In practice, however, determination of the lost biotopes' effective value is not easy. Surface area is one aspect, but it might take several years before a full alternative has been developed.

Moreover, no or hardly any experience on compensating measure development is present in Flanders up to now. Applications are usually too theoretical and they do not result in practical development. Compensating measures are only developed in a limited number of cases and hardly ever one can speak of real compensation. The most obvious situation is the one in which new structure development destroys the local amphibian population's water for procreation. Compensation can be made by simply digging a new pool in the surrounding area and by introducing specific fauna and flora species. It will get more difficult when making compensations for specific biotopes because in that case one needs to set some kind of standard of comparison.

7.5 Existing quality standards for measures; justification, minimum requirements

Action 96 of the MINA plan (Environment and Nature plan), which was started at the end of 1999, gives a directive for large fragmentation effect interventions. It starts from a limited inventory of examples and experiences in other countries. Three countries with a similar situation as Flanders with regard to problem areas and social context are opted for: the Netherlands, Germany, and France. Research is directed to the diverse policy making elements: juridical, institutional, and technical aspects of the "defragmentation approach" are being looked at. Inventory is made by means of literature research and later on completed via contacts with foreign experts. If necessary, attention can be paid to important projects in other countries. The foreign policy context will no doubt give insight into a more efficient approach of the defragmentation problems in Flanders. Following elements need to receive the required attention when developing such a directive in Flanders:

- A clear definition of powers.
- What indicators will be used for priority setting.
- Way of co-operation between the different authorities.
- The minimum number of partners required.
- Tuning with other instruments: planning instruments (land use, land consolidation, regulations on infrastructure, etc.) concessions, environmental effect reports, the decree with regard to nature conservation, etc.
- Need for result contracts.
- Need for a compensation or defragmentation fund.

7.6 MAINTENANCE ASPECTS

7.6.1 Verge management

In June 1984, the "Verge Order for Flanders" was issued. It came into effect in January 1985. It wants to stimulate a nature friendly verge management through an adjusted mowing management using appropriate material and no biocides. The order applies to verges and slopes alongside roads, waterways, and railways of which the mowing management falls under the authority of artificial persons in public law (public government, public institutions, etc.). Grassy verges with herbaceous plants must not be mowed before 15 June and a possible second mowing must be performed after 15 September. The mowed grass will be removed within 10 days so that the soil becomes poorer resulting in the development of a species-rich verge flora. Before, consequences of ecological mowing were insufficiently assessed (removal of mowed grass, composting, etc.). In practice some managers only do ecological management of the better verges at the moment. Often mowing data of the verge order are respected but mowing grass is not removed. Other towns do not apply the verge order's regulations.

As of late 1998 the project group Verge Management and Defragmentation of the Road policy and Management section is working on proposals for verge management alongside Flemish motorways. Those proposals combine environmental aspects, traffic safety, technical feasibility, financial affordability, and ecological considerations into a realistic verge management plan. As of 2000 one verge management project per province should be started. One pilot project has been completed at the moment, i.e. the ring around Brussels.

Landscape analysis emphasises interchange between open and closed landscapes and strives for a stronger relation between roads and their surrounding areas by regular planting of transparent vegetation. Ecological analysis particularly accentuates a (presupposed) corridor function of verges. Ecological analysis was started with an existing plant inventory. Exposition of the different verges was also listed. Traffic authority analysis a.o. considers verges where mowing is dangerous or difficult (zones with no hard shoulder, soft verges, traffic islands, etc.), verges that need frequent mowing for safety reasons, and woody planting. The latter might be a safety hazard for road users when these reduce visibility or hang over road surfaces and road signs.

The verge management plan for the ring around Brussels resulted in the following partition:

- 8 ha is mowed
- 0.5 ha is managed as lawn
- 1.6 ha is managed as brushwood and mowed every three years
- 10.7 ha is managed as forest
- 23 km edge planting will be managed as edge.

Mowing always takes place in September. Parcels that one wants to grow scantier need a second mowing in springtime.

7.6.2 Management of other surfaces

<u>Planning of residual grounds</u>

Part of the A12 in Antwerp direction the Netherlands has not yet been turned into a motorway. One part is called the "Leugenbergbocht", a busy intersection direction Ekeren, Kapellen, Hoevenen, and Kalmthout (see figure). Roads Section Antwerp wants to reconstruct and organise that problem area as a motorway access road. Construction of that new access road will cut the nature reserve called "Ekers Moeras". The new motorway will also cross the "Verlegde Schijn", a wide polder ditch with a healthy reed vegetation. That will need covering over 200 meters. As a result of the Environmental Impact Assessment study a number of lenient measures were demanded by the Nature section of the Administration of Environment. That resulted in the construction of a number of ecotunnels, in the construction of a nature friendly sedimentation basin, and of a separate sewerage system. The zone located between the old and new bend will be replanted with local species to compensate for grubbed up trees. Fauna passageways will be constructed at the height of the encased river "Schijn", i.e. a 200-meter long tunnel in the bridge's concrete construction. Slowly draining buffer basins are constructed so that the rainwater coming from the motorway is not directly drained into the "Schijn". To compensate spatial loss in the "Ekers Moeras" a flood-control installation will be constructed that will regulate the nature reserve's water level.

7.6.3 Coordinating land-use in adjacent areas

7.7 Evaluation and monitoring of the effectivity of measures

Since no defragmentating infrastructure evaluation has been performed in Belgium (at least not in a consequent manner) up to now, this chapter will be limited to giving possible research methodologies that are not labour intensive and easy to execute. Only recently the Naturally Engineered Environmental Development cell issued a research study for efficiency determination of the existing amphibian tunnels in the Flemish region and for the localisation of hot spots where amphibian provisions are initially needed.

First of all, such evaluating research study requires a technical evaluation; Has the passageway's construction been done correctly? Is it installed at the correct spot? That can be checked during and after its installation by the section responsible for the implementation of the works.

Furthermore, evaluation of the defragmentating provision's use is needed. For larger mammals inventory can be quite easily made through identification of tracks in sandbeds applied before and after tunnels or passageways. From the nature conservation point of view the effect on population level is of major importance. Such effects, however, are the most difficult ones to investigate. In table 7.1 a survey is given of other possible research methods.

Table 7-1 Research methods survey for the evaluation of fauna passageway usage

Method	Relevant species	Observations
Inventory of the surrounding area	All species	Gives a broad first impression
Track beds	Small Mustelidae to larger animals	Gives a clear insight
Track tubes	Mice, shrews, weasels	Gives a clear insight, but species' recognition is often not possible
Barbed wire (hair)	Badger, fox	No information on frequency
Hair tubes	Mice, shrews, weasels	Species recognition is very difficult
Trap boxes	Mice, hedgehogs, small Mustelidae	Gives a good insight in species' composition but is labour intensive
Trap buckets	Amphibians	Gives a good insight in species' composition but is labour intensive
Trap pots	Ground-beetles, insects, and other invertebrates	Gives a good insight in species' composition but is labour intensive
Video registration	Small Mustelidae and larger animals	Gives insight in the degree of use and in the behaviour of users, but is an expensive technique
Electronic registration	All species	Gives an idea of the frequency in use
Observation (night	All species	Insight in use and behaviour, possible influence observer, labour intensive

7.8 Summary

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Chapter 8. Habitat Fragmentation and Future Infrastructure Development

8.1 INTRODUCTION

The present evolution of our landscapes, and consequently that of open space, takes place in the area of tension of urban influential spheres and the interaction between those urban centres that are materialised by road infrastructure. The infrastructure fragmentation map clearly confirms the former. The future development will be situated between two extreme tendencies. The first being the one of spontaneous and uncontrolled development, in the course of which the leftover open space will be "consumed" further to supply the need for mobility, employment, housing, and recreation. The second being the one of the "stand still" principle in which the objectives of the Master Plans will be realised through a more severely implemented legislation and in which nature conservation observations will be more integrated in the economic growth process.

8.2 POLICIES AND STRATEGIES/TRENDS

Fragmentation is one of the 13 themes of the Flemish Environment and Nature Policy Plan 1997-2001 (MINA plan 2). A four-way strategy is suggested to avoid additonal fragmentation and to reduce existing fragmentation:

- Make the avoiding of extra fragmentation a priority.
- Obtain behavioural change of perpetrators.
- At the same time reinforce ecological structures and deal with fragmentation problems that have priority.
- Fill gaps in knowledge through research.

Below is the state of affairs for the different actions of the Environment and Nature Policy Plan 1997-2001:

Completed initiative in 1998:

- Initiative 95: Enter fragmentation in the directive book for environmental reporting.

Running actions/initiatives in 1999

- Action 92: Extend and execute pilot projects for waterways and roads; make and update standard specifications.
- Action 93: Execute projects for river recovery, for the improvement of fish migration, and for the construction of spawning places.
- Initiative 94: Make directives for fragmentation prevention of the environmental organisation armamentarium and extend the permit requisition file.
- Action 99: Support projects for the improvement of general nature quality; improve the co-operation between local authorities, environment and nature associations, and other partners.

- Initiative 100: Simplify and adapt land consolidation rules and regulations to broadened objectives; maximise input of multifunctional possibilities within projects.

Planned actions for 1999

- Action 96: Develop a directive for large fragmentation effect intervention (see 7.2).
- Action 97: Inventory landscape elements of Flemish importance and develop a vision for those landscape elements.
- Action 98: Fill in and realise nature connections in view of the FEN and IASN connection.
- Action 101: Solve fragmentation problem areas of priority in which habitats of species are cut by waterways, railways and/or pipes.

8.3 INDICATORS/INDEXES OF FRAGMENTATION

Simple and functional fragmentation indicators may be:

- The number of traffic casualties per unit of time for a road segment.
- Type of road.
- Contrast between joint units (e.g. eutrophic vs oligotrophic).
- Migration barriers in river networks.

8.4 MODELS TO PREDICT FRAGMENTATION BY NEW INFRASTRUCTURES

DISPERS, METAPHOR, LARCH, HIS, and a number of metapopulation models: flashing models, local dynamics models, models on the basis of regression analyses can be used to predict fragmentation through new infrastructures. See table 8.1 for a survey of the required input data and for the objectives and problems of those models.

More specific are connectivity models, such as CONNEC (Villalba et al, 1998), whose objective it is to have a predictive and explanatory value for ecological phenomena under the influence of fragmentation. GRIDWALK and POLYWALK are simulation models for research on fauna expansion in land use scenarios (Bakker et al, 1996). RAMAS, METAPOP, and POPDYN are metapopulation models that are already available or under development.

Table 8-1 Survey of usable models for the prediction of fragmentation

Model	Level	Goal	Literature
DISPERS	Regional	To simulate accessibility of areas with respect to source areas for a specific animal species or group of species.	Dijkstra (1992)
LARCH (Landscape ecological analysis and directives for habitat configuration)	Regional/local	Simplify fauna introduction in land development projects	Kalkhoven & Meeuwsen (1997) Vanacker et al. (1998)
Flashing models	Regional/local	Compute extinction and colonisation possibilities of a specific fauna species in a specific area	Lankester (1989) Verboom (1991) Verboom et al. (1993)
Local dynamics models	Regional	Look at connections between environmental structure and species distribution	Schotman et al. (1990)
METAPHOR		Compute the chance of survival of a network population as consequence of the habitat's spatial arrangement.	Kalkhoven & Meeuwsen (1997) Verboom (1996)
HSI (habitat suitability index)	Regional/local	Quality assessment of the suitability of areas as fauna species habitats.	Duel (1992) Vanacker et al. (1998)

8.5 DATA ON TRANSPORTATION NETWORKS DEVELOPMENT

Roads

The Environment and Infrastructure Department of the Ministry of the Flemish Community has planned construction of the following roads that 'fits' within the Master Plan of Flanders:

- A number of large and new infrastructure works: the R2 (large ring) of Antwerp, the AX (Bruges-Westkapelle), extension of the E40 between Deurne and the French border, extension of the A19 from Ieper to the E40, and extension of the A24 in Limburg.

- Conversion to motorway of the remainder of the N49 between Antwerp and Maldegem.
- New connecting roads (the so-called ‘missing links’): the N37 (Roeselare-Ieper), the N382 (Waregem-Ingelmunster), the N41 (between the N70 and the N49), the N10 (Mechelen-Heist-o.d.-Berg).
- Dozens of smaller connections, urban and municipal diversion and ring roads.

Waterways

The Environment and Infrastructure department of the Ministry of the Flemish Community has proposed to develop the Flemish waterway network according to European standards to increase its functionality.

Following are the priorities concerning infrastructure for Flanders:

- Finalisation of the Albert Canal modernisation for convoys up to 9,000 tons. The intended capacity is limited to push-towing convoys of maximum 4,500 tons for the Wijnegem-Antwerp section.
- The partial widening of the river “Leie” to a 1,350-tons capacity.
- Finalisation of the lock at Hingene and completion of the Brussels-Rupel Canal modernisation.
- The opening-up of the port of Zeebrugge through modernisation of the Gent-Bruges Canal and through the construction of the Northern Canal (Schipdonkkanaal).
- Modernisation of the Kwaadmechelen-Dessel-Bocholt-Lozen waterway
- Widening of the Juliana Canal.

In the framework of the water control works and dams priorities are made in Ghent at the connection Ghent-Bruges, along the different tidal rivers and along the river Meuse.

Railways

The NMBS’ (National Society for Belgian Railways) plans for infrastructure works were set in the STAR 21 plan, in the strategic plan, and in the management agreement with the federal government.

Globally the options are:

- Extension of the High Speed Rail Network for the High Speed Train that for the main part will run on the existing lines. Exceptions thereof are the Leuven-Liège trajectory that will follow the E40 and the trajectory north of Antwerp to the Dutch border that will follow the E19 for which new infrastructure is planned.
- Capacity and velocity improvement between large cities;

8.6 ON-GOING RESEEARCH AND REVIEW OF RELEVANT STUDIES

A third VLINA project that was started at the Institute for Nature Conservation in 1998 is called " Draw up and assess ecosystem vulnerability maps with regard to biotope loss and barrier effect" and it will run until the end of 2000. The project's objective is to develop a vulnerability approach starting from ecological information and knowledge on measure-effect relations and effect predicting models. In that context, vulnerability can be defined as the "sensitivity" integration of a cartographic object (mapping unit) and a social evaluation, in this particular case from the nature conservation sector. For a vulnerability assessment one has to take into account both the actual and potential importance of nature conservation. This research study investigates two effect groups, that is biotope loss and barrier effect.

Biotope loss can be subdivided in two separate effects, that is biotope loss sensu stricto and biotope change. Biotope loss s.s. contains all effects from irreversible ecotope (vegetation) and biotope (animal habitat) destruction or the loss of communities (plants and animals) and their habitats. Biotope change is defined as the degree in which an existing biotope with a certain biological value does not develop or settle itself again or only partially after the completion of the works.

Barrier effects relate to obstruction of animal migration routes or make them impossible. Further distinction can be made between barrier effects within the home range of a species or barrier effects on dispersion.

Two approaches can be distinguished in the project's methodology, i.e.:

- Vulnerability analysis from the species approach
- Vulnerability analysis from the ecotope approach

Since both approaches are often complementary, they will be combined with each other in the further development of the vulnerability maps.

The basic information supported on is as follows:

- Biological Valuation Map: a standard inventory and evaluation of the biological environment on a cartographic scale of 1/25,000. Inventory is done on the basis of cartographic units, largely consisting of ecotopes characterised by specific vegetation units. Other units represent the more structural characteristics of the landscape (e.g. rows of trees, sunken roads, slopes, etc.) or only give the land use (orchards, parks, industrial areas, residential areas, etc.).
- Ecological Typology of Waterways: This survey databank contains an assessment of the biological water quality and physical characteristics of watercourses, distribution data of organisms and aquatic communities, and a general assessment with regard to nature conservation of the watercourse.
- Species distribution data: a so-called IFBL grid (1 and 4 km grid) for flora and herpetofauna and the UTM grid (1, 5 and 10 km grid) for the remaining fauna groups (mammals and fish).

The species habitats selected from the Biological Valuation Map in combination with some relevant ecological parameters (home range, dispersion capacity, habitat preferences, areal size, etc.) of the same species are used to produce habitat maps. These show in an ideal case all presently and potentially important areas for the species considered in Flanders. On the one hand, by combining habitat maps for different object species a regional degree of vulnerability can be given for the effect group barrier effects. On the other hand, by projecting one (or a combination of several) habitat map(s) on an infrastructure map a signal map for fragmentation problems is drawn up. Such instruments are vital for an efficient policy on the prevention of further fragmentation and on the cancelling out of existing fragmentation.

8.7 SUMMARY

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Chapter 9. Economic Aspects

There is no experience whatsoever in Flanders concerning cost-benefit analyses of ecological infrastructures.

Chapter 10. General Conclusions and Recommendations

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Chapter 11. References

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