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

COST 341

Habitat Fragmentation due to Transportation Infrastructure

National State of the Art Report, Denmark

European Commission
Directorate General Transport

A great deal of additional information on COST Transport is available on the World Wide Web. It can be accessed through the CORDIS server at the following address: http://www.cordis.lu/cost-transport/home.html

Cataloguing data can be found at the end of this publication.
Luxembourg: Office for Official Publications of the European Communities, 2000
ISBN xx-xxx-xxxx-x

Printed in Belgium

Table of Contents

Chapter 1. Introduction

Chapter 2. Key Ecological Concepts

Delete all explanatory text when filling in this template with your own text.

2.1. INTRODUCTION:

roads as some major components of modern landscapes superimposed on the natural (and man-made) structures – their effects refer to the landscape as a system and are not restricted to the road area – need for knowledge on the composite effects on landscapes and wildlife …

why are we concerned; why is this something to study from an ecological point of view ?

(Complementing Hans Bekkers introductory chapter!)

2.2. LANDSCAPE ECOLOGY

(definition of landscapes and landscape ecology; "sustainable" landscapes and biodiversity, roads change land structure and affect functions/processes

2.3. LANDSCAPE CHARACTERISTICS

(landscape structure, patchiness, heterogeneity, connectivity - all differs between the different landscape types: closed (urban, suburban), open (agricultural, rural and steppe), forested (semi-natural, pristine)

2.4. HABITAT FRAGMENTATION

(as compared between different landscape types and referred from the process of fragmentation; fragmentation = habitat loss (80%) and isolation (20%) – roads cause mainly isolation (?!)

2.5. METAPOPULATIONS, SINKS AND SOURCES

(=fragmentation effects; population dynamics, island theory, sink & source theory, importance of movements (migration, dispersal)

2.6. ANIMAL MOVEMENTS AND ECOLOGICAL NETWORKS

(green corridors and ecological infrastructure – use by species, significance to conservation,

species movements along corridors, type of movements: commuting, dispersal, migration)

2.7. SCALE AND HIERARCHY

(hierarchy theory – implies structured analysis of effects, processes create pattern a higher levels; scale – grain and extent, scale is inherent to species; road planning implies scaling; choosing adequate indicators for EIA implies scaling)

2.8. INDISPENSABLE PATTERN (SUMMARY)

(what is needed for sustainable landscapes, what is essential and thus sensitive to the effects of roads: focus on patchiness and corridors…)

Chapter 3. Effects of Infrastructure on Nature

(short introduction to this chapter – maybe with some simple data (road density) from some extreme countries such as Sweden and Holland or Belgium: what is meant by nature here and what is different between impact, effect and consequence (briefly)

3.1. DIRECT EFFECTS (5 EFFECTS)

(immediate effects or impacts that refer directly to the animal species)

overview: effects related to type of infrastructure (local road, regional road, national road, railways, channels) – different in different landscapes (?)

- apply scale and hierarchy theory!!!

3.1.1. Habitat loss and transformation

(direct habitat loss and habitat change due to construction – indirect due to isolation or barrier and changes in land use)

road verges as new habitats? – species population road verges and the importance of rich verge vegetation; chances for biodiversity (in plants mainly)

3.1.2. Corridor function

(road verges as new habitat corridors – see above)

(road verges as transition corridors – green corridors in urban landscapes…)

(roads as movement corridors – spread of new plants and animal, on road and by traffic)

3.1.3. Disturbance

(abiotic: local pollution due to traffic, salt, toxins (briefly); effect of noise on birds, ground water) (biotic: avoidance of roads, spread of species from roads, human activity = edge effects)

3.1.4. Fauna casualties

(estimations, statistics, studies: relevance to population, management, hunting

– relation to to time and place or road type – problem to animal rights and road safety)

3.1.5. Barrier effect

(main composite effect due to casualties, disturbance, habitat transformation (edge effects), physical hindrance)

3.1.6. Effects on vegetation (??? separate chapter ???)

(briefly on the same topics as under chapter 3.1.1 to 3.1.5 but for plants)

3.2. INDIRECT EFFECTS

(not directly effect on individuals in the first place, but on populations in the long run)

3.2.1. Fragmentation, network effects

(isolation and edge effects, habitat loss due to network, road density, thresholds in fragmentation at a landscape level)

3.2.2. Secondary effects

(mainly due to changes in land use, urbanisation, traffic,… probably the most important effect at all??!! – at least in natural landscapes)

3.2.3. Indicators of fragmentation

(depending on scale, road type and landscape: from large to small species)

Chapter 4. National context/European context

4.1. INTRODUCTION

Denmark covers 43094 km^2. The total length of the infrastructure network is listed in table 4.1.

Table 4.2 Total length of public roads and railways

Country	Public roads (km)	Railways (km)
Denmark	71465*	2343

*By 15 June 1998

In addition to these networks XXXX km roads are currently under construction or planned for the near future i.e. 10 years.

4.2. BIOGEOGRAPHICAL DESCRIPTION

Denmark is situated between the north European oceanic and continental climate zones. Most winters are mild and rainy, as are the summers, but some winters can be fierce and the summers occasionally hot. Despite the small size (43094 square km) there are large differences between the regions. The west has more oceanic climate with almost twice as much precipitation as the central parts. The landscape is made of quaternary deposits formed by the glaciations, of which the last withdrew 10000 years ago. The geology also differs from west to east, with sandy and peaty areas in the west and clays and limestone in the east. Finally, Denmark lies in the transition zone between the deciduous forests of Central Europe and the Scandinavian pine and spruce forests.

The vast regional differences support a relatively rich fauna and flora with about 30000 species, most of them insects.

The main ecosystems are semi-natural and formed as a result of historic and present land use. The most threatened habitats of national importance are oligotrophic lakes, extreme poor fens, grey dunes, raised bogs, extreme rich fens and paludella springs. Other, less threatened habitats, which are given conservation priority are: commons, heaths, bogs, lakes, coastal landscapes and watercourses. The forests have been protected for 200 years, but a number of natural habitats inside the forests have been selected for conservation, these are: stratified forests, coppice forests, forest edges, certain deciduous shrubberies, swamp forest, woodland meadows and stone fences.

Denmark has no mountains, and the only major natural barrier for the dispersal of species is the sea. Denmark consists of numerous (>500) islands and one peninsula. In the stone age, all was one land mass, forming part of mainland Europe. The landscape structure, with numerous small islands, causes a lack of species with poor dispersal ability on many islands. Some species of amphibians, reptiles and medium sized mammals are absent from many of the islands. On the other hand, some of the smaller islands are of great importance to water birds because of the absence of predators.

Lynx, bear and wolf are extinct in Denmark (the last mentioned in historical times) and there are no larger carnivores left. Other extinct mammals include: aurochs, bison and moose. The last mentioned occasionally finds its way to Denmark, swimming from Sweden. Wild boar has also migrated naturally to Denmark, but was eradicated. At

present, the largest terrestrial mammals are the red fox, the otter, the badger, the roe deer and the red deer. White tailed deer, and fallow deer have been introduced as has, since 1999, the beaver.

Since 1974 red data lists have been made, the latest update (1997) contains 476 endangered species, 880 vulnerable and 1146 rare species.

To monitor the state of the environment, counts have been made since 1976 for lapwing, skylark, barn swallow, whitethroat, linnet and corn bunting.

4.3. OVERVIEW OF FRAGMENTATION

Denmark is one of the most intensively cultivated countries in the world with less than one percent pristine natural vegetation, 64% is agriculture, 12% is managed forest, 12% is covered by roads, cities and buildings and a few percent consist of wetlands and heaths (Miljøministeriet 1997). Denmark is rather densely populated with about 120 people/km^2. The present intensive land use has resulted in fragmentation of the natural habitats to such an extent that these are presently found only as small "islands" in the intensively cultivated rural areas. The most authentic, untouched nature in Denmark is found along the 7300 km coastline.

The cultivation has been intensified especially since the 1950'ies leading to a rather uniform landscape of large monocultures with very little room for the natural fauna and flora, which is reduced to living in hedges, riparian areas, road verges, plantations, gardens etc. The use of fertilisers has increased about eight times between the 1950'ies and the 1980'ies, leading to an eutrophication of terrestrial as well as marine and freshwater ecosystems. In the same period, ground game, like hares and partridges have decreased to a third and an eighth, respectively, probably due to use of pesticides.

Animal populations, have during a long period, adapted to environmental changes in the mosaic landscape. However, today the fragmentation is one of more serious threats to the native fauna. Fragmentation of the landscape by intensive agriculture and urban development is believed to be more an important limiting factor to native flora than fragmentation by infrastructure.

The forestry is also intensive, but since 1990 small pockets of the least managed forest have been designated for conservation i.e. not to be managed or to be maintained by traditional management systems such as coppice and selection felling. The natural forest is deciduous forest with beech, lime, oak and hazel, but about 2/3 is grown with spruce. This proportion might change now after some serious windfalls and a less attractive economy in the forestry sector in general. It is planned to double the existing forest cover from 12% to 24% over the next 10-20 years, also for the benefit of recreation and groundwater conservation.

Wetlands have suffered intensely from draining, tillage, and application of fertilisers. The few large raised bogs in Denmark have been peat-dug. The former extensive bogs have decreased dramatically. As an indicator of the loss of wetlands the white stork has decreased from about 10000 pairs 100 years ago to 1 in 1999. It is estimated that more than 90% of the wetlands have disappeared in the last 100 years. The remaining wetlands are mostly polluted with nutrients and the rivers and streams are regulated. As small scale farming is being abandoned, small meadows and water holes are overgrown with willow.

Heaths used to cover a substantial proportion of Denmark. In Jutland they used to cover at least 20% of the land as opposed to less than 1% today (Jutland covers 2/3 of Denmark, but holds almost all the heaths). The remainder suffers from airborne fertilisers,

afforestation with conifers, disturbance by tourism and fragmentation. The majority of commons have been fertilised and used for intensive pasture, and the untouched usually develop into forest. As an example of the poor state of health, the extinction of black grouse in the 1990'ies should be mentioned.

All littoral meadows, heaths, moors, fens, commons, lakes, and meadows, are protected from changes in their present condition according to the nature protection law.

In the past 10 years the nature area in Denmark has increased. Approximately 16700 ha have been re-established through nature management and restoration. This amounts to 0.4% of the total area of Denmark. The distribution of re-established nature types is listed in table 4.3.

Table 4.4 Nature area re-established by The Forest and Nature Agency in the period 1989-1998.

Nature type	**Area re-established in the period 1989-1998.**
Freshwater meadow	1331 ha
Moors and fens	1079 ha
Heath	1421 ha
Lakes	1067 ha
Commons	484 ha
Alluvial meadows	460 ha
Forest	6377 ha

4.4. ADMINISTRATIVE AND LEGISLATIVE FRAMEWORK

4.4.1.1. Relevant legislation includes

- Nature protection law
- Law on planning (planning act)
- Law on watercourses
- Law on forestry (forestry act)
- Habitat directive

The purpose of the nature protection law is to protect wild flora and fauna, cultural heritage, and scientific interests. The purpose is also to provide access for the public to nature areas.

The purpose of the planning act is to ensure an integrated physical planning of different interests on land use.

The law on watercourses shall ensure drainage of water, e.i. surface water, and waste water, with consideration to the environment.

The forestry act shall ensure a permanent area of forest with a sound forestry management regarding wood production, biodiversity and recreational value.

Most major transport infrastructure projects are initiated by a special law for each project (law on construction = "Anlægslov"), which can overrule all other relevant laws in force for the particular project area. In the case of county roads, the county administration can adopt a so-called regional plan addendum ("Regionplantillæg"), which in practise has the same force as a law on construction. All major roads must be approved according to the nature protection law, while county roads and municipal roads must be approved by the county administration.

4.4.1.2. Relevant authorities

The Ministry of Environment and Energy is the central organ for all questions on environmental protection and use of natural resources. The National Forest and Nature Agency is the primary authority on nature protection.

The Ministry of Transport is overall responsible for traffic policy and planning, as well as for operation and maintenance of state roads, state railways, state harbours, and major fixed links. The Road Directorate, for instance, is in charge of the national road network.

The counties undertake regional planning. Every county issues a regional plan, which is valid for a period of 12 years. The plan is revised every 4th year. Denmark is divided in 14 counties (listed in Annex I). The municipalities undertake urban and local planning. Denmark has 277 municipalities.

Denmark has a wide variety of non-governmental organisations, representing particular groups of species, certain types of recreational users and/or broader ecological issues and traffic planning issues. Some NGO´s are concerned with broader landscape and countryside matters, these includes The Danish Society for the Conservation of Nature (Danmarks Naturfredningsforening), which has the right to advance conservation proposals for nature areas. Other major NGO's are listed in Annex I.

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

Denmark has a long tradition and well-developed tools for planning in both rural and urban areas. The counties undertake rural planning while the municipalities usually undertake urban planning. The counties are also responsible for the planning of recreation.

The protected nature types, conserved areas (i.e. areas covered by a conservation declaration), and areas covered by the habitat directive (i.e. Ramsar areas, EU-birdprotection areas and EU-habitat areas) must to be kept free from future infrastructure projects. The same pertains for major nature areas appointed by the counties, where planning of new infrastructure is, in principle, illegal. If, however, social circumstances involve an imperative necessity, roads can be planned and constructed in these areas.

The counties have designated a number of corridors for the dispersal of flora and fauna between the major nature areas. The designation of major important nature areas comprises mainly river valleys, major wetlands and forests. The purpose of these dispersal corridors is to avoid further deterioration of the population of wild species by strengthening the possibilities for species to migrate between habitats. The function of dispersal corridors is often sustained by a large number of small biotopes, living fences and/or non-cultivated borders along rivers and recreational paths. At present, no legislation protects the designated corridors from barriers, for instance larger constructions of transport infrastructure.

The Road Directorate, the counties, and the municipalities are responsible for planning, designing, construction and maintaining the road network. Private road traffic is encouraged by building new and better (high-classed roads). Danish National Railway Agency undertakes the planning, design, construction and maintenance of the public railways.

The purpose of a well-developed infrastructure network is to increase the accessibility of the regions in order to sustain a decentralised public service of high standard. It is also a national aim to show extensive consideration to nature and environment when planning and designing new transportation infrastructure. Today all infrastructure projects are therefore subject to EIA (Environmental Impact Assessment) according to the planning act.

The purpose of the EIA is to identify impacts of projects and to plan and monitor their mitigation. The assessments comprise all environmental compartments, such as air, soil, surface and ground water, and take into account both physical and chemical impacts on ecosystems, flora and fauna as well as effects on landscape, recreational value and cultural heritage.

The purpose of the mitigation plan is to reduce the direct negative impacts during construction arising from land take, changes in topography and landscape aesthetics, drainage, stream and river straightening, earthworks and associated site damage. Other mitigation measures aim at reducing impact from the traffic, for instance noise, light, air and water pollution, increased ecological isolation etc.

4.6. SUMMARY

- Denmark covers 43094 ha and has 71465 km public road and 2343 km railway.
- The Danish flora and fauna includes about 30000 species. The red data list contains 476 endangered species, 880 vulnerable species and 1146 rare species.
- 64% of the area is covered by agriculture, 12% is forest and urban areas, buildings and infrastructure cover 12%.
- Denmark is rather densely populated with about 120 people pr. km^2.
- The 14 counties undertake regional planning, and the 277 municipalities undertake urban and local planning.
- The Road Directorate, the counties and the municipalities are responsible for planning, designing, constructing and maintaining the public road network.
- The Danish National Railway Agency undertakes the planning, design, construction and maintenance of the public railways.
- Today, all new infrastructure projects in Denmark are subject to EIA (Environmental Impact Assessment) according to the planning act.

Chapter 5. Habitat Fragmentation due to Existing Transportation Infrastructure

5.1. INTRODUCTION

Fragmentation due to the present transportation infrastructure is substantial in Denmark. The drastic increase in road traffic density in recent years has increased the barrier effect of roads by increasing fauna casualties and thereby decreasing the likelihood of many species crossing the roads. This can for some species result in negative effects on the populations.

5.2. EUROPEAN TRANSPORTATION NETWORKS

The Trans European Network (TEN) has a number of designated transport links in Denmark (Official Journal of the European Communities, L228, vol 39, 9 September 1996). The TEN links include motorways/major highways from Helsingør to Rødby and Gedser (north - south), from Copenhagen to Esbjerg (east - west) and from Aalborg to the border to Germany (north - south). The Motorways from Frederikshavn to Aalborg and Aalborg - Hirtshals have been constructed recently. The Øresund fixed link (motorway and rail) is presently under contruction and planned to be opened in July 2000. Other planned TEN- transport links include the Fehmarn Belt fixed link (motorway and rail).

The existing state railways from Esbjerg to Copenhagen, from Copenhagen to Rødby and from Padborg to Aalborg are planned to be upgraded to high-speed lines.

5.3. TRANSPORTATION NETWORKS

The public road network in Denmark with a total length of 71465 km consists of motorways (2-3 lanes in each direction), major state highways (1-2 lanes in each direction), county highways (1-2 lanes in each direction), county secondary roads and municipal roads. Further, a large number of small private roads are found in both urban and rural areas.

The 277 municipalities are responsible for the majority i.e. 59860 km road. 9955 km road is maintained by the counties and 1650 km is maintained by the state. 27 km belong to the Storebælt and Øresund fixed links.
Further, the state road network consists of 1305 bridges and tunnels of various sizes.

5.3.1. Highways/motorways

Denmark has 870 km of motorway. Maximum allowed speed on motorways is 90-110 km/t. Average annual daily traffic in 1998, was 84900 vehicles on the busiest stretches in the Copenhagen area.

Before December 1997 the Road Directorate was responsible for approximately 4575 km state highways. But by January 1998 3000 main roads were transferred to county authority. Maximum allowed speed on highways 80-90 km/t

5.3.2. Secondary road infrastructure

The standard of secondary roads is high and only small private roads in rural areas are usually unpaved. Many of these small roads have disappeared during the past decades due to increase in farm size and closing of small farms.

5.3.3. Railways

The state is responsible for 2343 km railway, run by the State Railway Company (Banestyrelsen) which belongs to The Ministry of Transport. 500 km railway is privately owned and run by a number of companies. The present traffic intensity amounts to approximately 600 trains per day on the busiest streches.

The railway network is at present being upgraded and modernised, for instance the planned extension of the section from Copenhagen to Ringsted. High-speed trains can result in larger barriers, as the high-speed lines must be designed in a special way, which can not be adjusted to the landscape.

5.3.4. Waterways

There are no artificial waterways in Denmark.

5.4. EFFECTS OF THE EXISTING TRANSPORTATION NETWORK ON NATURE

5.4.1. Habitat loss

Construction of new roads has resulted in an increasing road density and a more fragmented landscape. The road density in Denmark has increased by 9% form 1975 to 1998. In rural areas the road density was 1.26 km/km^2 by 1996. The roads, intersections and other road installations occupy an area which covers 1.3% of the country. The public road network in rural areas covers 68480 ha and the total area of the railways is 7158 ha (Groth et al. 1998.). At present no data exists on the area of habitats lost due to transport infrastructure.

During the last 40-50 years nature types such as heaths, moors, fens, ponds, lakes, salt marshes and meadows have decreased in number and area due to the intensive cultivation, drainage, ceased grazing and afforestation. In this context the habitat loss caused by roads and railways is of minor importance, even if the interference in some nature areas has been serious, for instance the conserved nature area Vestamager in the vicinity of Copenhagen.

5.4.2. Corridor function

Most animals tend to move along linear structures in the landscape such as watercourses, dikes, ditches, forest edges and hedges. Road verges, ditches and slopes have great value as habitats and dispersal corridors for flora and fauna. This is a result of the increasingly intensive land use where only few areas are left without tillage, fertilisation and spraying. The road verges becomes a refuge for a few wild species, which are able to survive under the sometimes extreme conditions with high degree of disturbance, application of de-icing salt, and discharge of contaminated water from the road surface.

Due to their line shaped structure roads and railways function as dispersal corridors for flora and fauna, depending on the traffic intensity and the size and structure of the verges, intersections, cuttings and embankments. Studies show that fox and roe deer use the verges when moving between habitats (Salvig 1991).

Roads and railways can also act as dispersal vectors for plants, as many plant diaspores are transported with vehicles, either in soil and mud on the wheels or by blowing in the slipstream.

Road verges and railway embankments can act as dispersal corridors between meadows, commons and other light dominated habitats, in the same way as living fences, hedges and wooded embankments and verges act as corridors and routes for moving between plantations and forests.

5.4.3. Fauna casualties

Every year thousands of animals are killed when trying to cross roads in their search for food, new habitats etc. There are no central statistics on fauna casualties, but a number of separate surveys have tried to estimate the extent of the problem. Results of three different surveys are shown in Table 5.1. The numbers can not be compared directly, due to different sampling methods. The difference between the estimates appears to be very wide, almost a factor 10, and the value of these estimates is therefore questionable.

Table 5.1 Fauna casualties in Denmark, result of three different surveys.

Species/Taxonomic groups	Survey 1 Hansen (1982)	Survey 2 Thomsen (1992)	Survey 3 Bruun Schmidt (1994)
Amphibians	**3,086,000**	**250,000**	**2,956,000**
Small birds	-	100,000	949,000
Birds	-	250,000	149,000
Birds, total	**3,237,000**	**350,000**	**1,099,000**
Small mammals	710,000	-	678,000
Hedgehog	80,000	73,000	55,000
Hare	308,000	55,000	31,000
Fox	-	18,500	29,000
Badger	-	3,600	1,000
Cat	-	13,000	70,000
Other mammals	403,000	14,400	17,000
Mammals, total	**1,501,000**	**177,500**	**882,000**
Total	7,824,000	777,500	4,937,000

Table 5.2 Number of mammals killed on different types of public roads in Sønderjylland County (Madsen et al. 1998).

	Motorways	Highways	Secondary roads	All roads
Traffic (mio. km driven)	1287	1588	2029	4904
Length of roads (km)	101	326	833	1260

Number of fauna casualties in the period Nov. 1995- Aug. 1997				
Roe	6	19	34	59
Fox	93	75	132	300
Badger	33	22	31	86
Hare	56	198	423	677
Hedgehog	43	313	764	1120
Total	231	627	1384	2242
Casualties/mio km driven	0.18	0.39	0.68	0.46
Casualties/ km road	2.3	1.9	1.7	1.8

In Sønderjylland County the number of mammal casualties has been counted in the period November 1995 to August 1997 by the road authorities on their daily inspection and maintenance. Results from this survey are listed in Table 5.2.

The areas of conflict occur especially in connection with interchanges whereas a far smaller number of animals are killed in the traffic on stretches without junctions. Part of the explanation of this fact can be found in the design, afforestation, and fencing of the interchanges. The animals are attracted by the afforestation and fences are not only barriers but may also form conduction lines for the animals (Madsen et al. 1998).

There are no estimates of the number of animals killed by trains, but it is assumed that it is much lower than the numbers killed by road traffic (Vejdirektoratet 2000).

5.4.4. Barrier effect

Transport infrastructure forms massive barriers in the landscape and decreases the habitat areas as well as the possibilities for dispersal of many species. In the worst cases the barrier effect can result in total isolation and extinction of a population.

The negative effect on dispersal is due to avoidance of the roads by animals and traffic casualties. Studies have shown that roads (especially motorways) and railways are effective barriers to the dispersal of arthropods, snails, amphibians and small mammals. For very sedentary species such as dormice, bank voles and amphibians any alien structure, even a narrow road is a barrier. Very mobile species can generally cross roads with little difficulty other than the risk of vehicle collision. On railways the rails are difficult obstructions to amphibians.

Transportation infrastructure cutting through river valleys has serious adverse effects on the dispersal of species in the landscape, because a lot of species use the valleys as dispersal corridors. As an example three bird species (kingfisher, dipper and grey wagtail) associated to running water, can be obstructed by dams, which will force the birds to cross the road/railway with the risk of being hit by vehicles (Salvig et al. 1997).

Birds are often believed to be independent of dispersal corridors due to their flying ability. Studies show that many bird species are very much dependent on corridors for their migration and even birds suffer from fragmentation due to loss of habitats.

Transport infrastructure has a general limiting effect on plant species which rely on animals for their dispersal, especially those species that depend on ants such as (corydalis,

melic grass, hairy woodrush, dog's mercury and hedge violet). Plants (such as rowan, bird cherry and hawthorn) relying on birds for their dispersal will probably not be limited by infrastructure. The birds are very mobile, even if a large number of birds are killed by traffic each year. Plants adapted to wind and water dispersal will hardly be obstructed by transport infrastructure (Salvig et al. 1997).

Table 5.3 Outline of barrier effects on plants, described according to adaptation to specific dispersal strategies (Salvig et al. 1997).

Dispersal strategy	**Dispersal vectors**	**Species examples**	**Barrier effect**
Wind dispersal	Wind	Rose Bay *(Chamaenerion angustifolium)*	No barrier effects except for very high dams
Water dispersal	Water	Marsh Marigold *(Caltha palustris)*	No barrier effect if the flow of water is not obstructed
Epizoic dispersal	Mammals	Goosegrass *(Galium aparine)*	Most larger roads will be barriers
Endozoic dispersal	Birds	Hawthorn *(Crataegus laevigata)*	No barrier effects even if many birds are killed by traffic
Synzoic dispersal	Ants	Hedge Violet *(Viola rechenbachiana)*	Even a very narrow road (<2 m) will be a barrier
Ballistic dispersal	The plant itself	Wood Sorrel *(Oxalis acetocella)*	Even a narrow road (<5 m) will be a barrier
Dispersal by censor mechanisms	Wind	Milfoil *(Achillea millefolium)*	Traffic infrastructure broader than 10 m will have barrier effect
Dispersal without special adaptations	Humans*	Red Clover *(Trifolium pratense)*	No barrier effects if human passage is possible

* Species without adaptations to a specific dispersal strategy are only dispersed with great difficulty, if humans do not move them.

Transport infrastructure is also a barrier to human beings. Roads and railways limit the access from urban areas to forests and the open landscape, and they cut through the recreation infrastructure, i.e. footpaths, bike lanes, bridle paths and navigable watercourses. A number of new major roads are presently under construction. At the same time a number of level crossings on railway lines are closed for security reasons. This will increase the number of barriers to recreation.

The barrier effect of transport infrastructure depends on:

- Width of construction
- Traffic density (increasing barrier effect with increasing traffic density).
- Speed of traffic (increasing barrier effect with increasing speed of traffic)
- Design of infrastructure (dams, steep slopes, intersections)
- Fencing

5.4.5. Effects on populations

Fragmentation results in a reduction and isolation of many plant and animal populations. How small or large habitat patches should be to ensure survival of a sustainable population depends on the species requirements. Fragment areas, distance to nearest similar habitat, habitat quality and diversity have great effect on the number and distribution of species in a fragmented landscape (Hammershøj & Madsen 1998).

Species that suffer maximun effects of fragmentation caused by roads are more likely to be adversely or even critically affected by the isolation. Fragmentation influences the genetic variation of the populations, but negative effects depend on whether fragmentation results in a complete cessation of dispersal between fragments. Dispersal corridors improve the possibility for the recolonisation of vacant areas by small populations. If, however, corridors are obstructed due to fragmentation, the possibility of survival of the metapopulation decreases.

Some species are in general very vulnerable to barriers, for instance

- Toads. In Denmark some local toad populations have been extinct due to increased traffic on roads (Salvig 1991).
- Hare. Studies suggest that the traffic casualties are a limiting factor to the spring breeding population (Danmarks Statistik 1996).
- Otter. The traffic is assessed to be the most important threat to the Danish population of otter as collision with vehicles is the most frequent cause of death among otters (Skov og Naturstyrelsen 1996).

Traffic casualties are considered to be of minimal importance among hedgehogs in relation to the total annual mortality. Access to good wintering places is generally of greater importance than traffic casualties as a regulation factor for the population size (Madsen 1993).

Scarce recordings of traffic casualties among bats indicate that the conflict between bats and traffic is of slight importance to the bat population (Madsen 1993).

The bird species occurring in greatest number along the roads are also the species most frequently killed by the traffic. Detailed studies of pheasant, partridge and blackbird show that traffic casualties do not reduce the breeding populations considerably (Madsen 1993).

The otter have been one of the most threatened animals in the Danish fauna. Their habitats i.e. the uncultivated areas around streams and lakes have disappeared. Their food,

especially eels, disappeared. The otter drowned in eel traps or were killed by cars when crossing roads in their nightly wanderings along the banks of the streams. Now the population of otter is increasing. One of the reasons might be that making otter passages under bridges prevents death in traffic, and that top gratings are being fitted into eel traps. Viborg County has, during the last two years, established 27 passages (Skov og Naturstyrelsen 1999)

It is very difficult to quantify the importance to animal population of confrontation with traffic, as basic knowledge on the species population size and reproduction is still missing. In the absence of hard evidence on adverse effects on populations, it would be advisable to apply the precautionary principle and assume adverse effects until more research has been undertaken.

5.4.6. Overview of environmental bottlenecks

The term environmental bottleneck has been used for very vulnerable as well as for "narrow" dispersal corridors. There is great difference between wide and narrow dispersal corridors. In a highly fragmented landscape the broad corridor is of highest value as the sensitivity to externally induced disturbance is higher and the edge zone effect is less prevalent than in the environmental bottelnecks (Salvig et al. 1997). Gaps in corridors have a significant negative effect on the dispersal of mammals and snails (Hammershøj & Madsen 1998).

Hammershøj & Madsen (1998) suggest the following issues to support and develop environmental bottlenecks into well functioning dispersal corridors:

- Further fragmentation should be minimised, and the establishment of effective barriers (e.g. roads and railroads) should not be carried out unless adequate fauna passages are built.
- Corridors should be preserved, enhanced and provided, partly because the corridors will act as dispersal routes for some species and partly because corridors permit certain species to thrive where they otherwise would not.
- Corridors should be as wide and continuous as possible.
- The environment in the corridors should match the requirements of the target species.
- New biotopes should be established before changing and/or reducing existing biotopes.

5.5. SECONDARY EFFECTS OF TRANSPORT INFRASTRUCTURE

Apart from the direct effects of habitat fragmentation, loss of natural habitats, barrier and corridor effects the transport infrastructure has other consequences for the environment. The impact from traffic involves the following issues:

- Noise
- Light
- Changes in microclimate
- Changes in ground water table and ground water quality
- Discharge of road surface water to watercourses
- Contamination with heavy metals, dioxin and other chemicals
- Pollution with plant nutrients and de-icing salt.

Negative effects of roads on large mammals and birds reach some distance from the road. How far depends on the impact in question, for instance, the effects of de-icing salt can be measured 30-40 m from the road surface (Randrup & Pedersen 1996). Scare effect on birds can for some species such as pink-footed goose occur up to 400 m from a road with dense traffic. The deposition of plant nutrients from traffic exhaust cause increased growth of an uniform vegetation dominated by a few nitrophilous grasses. This effect can be measured up to 200 m from motorways.

5.6. ON-GOING RESEARCH AND REVIEW OF RELEVANT STUDIES

The dispersal strategies for a number of vertebras and vascular plant species were described in order to estimate the barrier effects of transport infrastructure (Salvig et al. 1997). The species/groups of species in question were amphibians, fish, insects, hedgehogs, hare, small mammals, small carnivores (mustelidae), squirrel, otter, fox, badger, roe, red deer, fallow deer, and white tailed deer. Dispersal strategies were likewise described for a number of Danish plant communities i.e. heath, oak forest on sandy acidic soil, dune/saltmarsh, freshwater meadow/fen, commons, broad-leaved forest on calcarous soil and weeds in arable fields.

NERI (Danmarks Miljøundersøgelser) has conducted studies on habitat fragmentation and fauna passages. Salvig (1991) conducted the first survey on fauna passages. This study was followed by several other conducted by Madsen (1993), Madsen et al. (1998) and Hammershøj & Madsen (1998). These studies are ongoing.

There is at present no research on plants. Overview of corridors for plant dispersal and dispersal strategies for a number of species in the most common plant communities (vegetation types) was undertaken by Salvig et al. (1997).

The Danish Forest and Landscape Institute have conducted studies on fragmentation and barrier effect on recreation (Kaae et al. 1998).

5.7. SUMMARY

- Average annual daily traffic in 1998 was84900 vehicles for the busiest stretches in the Copenhagen area and the present traffic intensity amounts to approximately 600 trains per day on the busiest sections.
- The road density in Denmark has increased by 9% form 1975 to 1998. In rural areas the road density were 1.26 km/km^2 in 1996. The roads, intersections and other road installations occupy an area which covers 1.3% of the country.
- As a result of intensive land use, road verges, slopes and ditches have great value as habitats and dispersal corridors for flora and fauna.
- Every year thousands of animals are killed by traffic, but there are no central data on fauna casualties. Results form separate studies indicate that the numbers range from 777500-7860000. One study from Sønderjylland County showed 1.8 mammal casualties per km road in a two-year period.
- The barrier effects of infrastructure depends on: width and design of infrastructure construction, traffic density (increasing barrier effect with in creasing traffic density), speed of traffic (increasing barrier effect with increasing speed of traffic), and presence/absence of fencing.
- For some species/group of species the barriers can have adverse effects on populations. Toads, bumblebees, hare and otter are found to be very vulnerable.

- Secondary effects of transport infrastructure includes: noise, light, changes in microclimate, changes in ground water table and ground water quality, discharge of road surface water to watercourses, contamination with heavy metals dioxin and other chemicals, as well as pollution with plant nutrients and de-icing salt.

Chapter 6. Traffic Safety in Relation to Fauna Casualties

The number of road traffic accidents involving animals is registrated by the Road Directorate, which keeps accident data from state and county roads (data from VIS = Vejsektorens Informations System). It is assumed that animals cause a total number of 203 traffic accidents in a 5-year period (1992-97). 21 of the accidents occurred on the state motorways and 182 on major highways (county roads). There are at present no statistics from the municipal road network.

2/3 of the involved animals is not wild species but livestock and pets. It is not specified in this account, how many of these accidents are caused by drivers swerving to avoid collisions.

Fauna collisions between trains and native species do not imply risk of personal injury and only in very few cases risk of damage on rolling stock.

Traffic accidents caused by wild fauna collision are generally a minor problem in Denmark. Livestock is generally more of a problem than wild animals. This is probably due to the lack of major mammals such as moose in the Danish fauna. Further, fauna collisions are probably avoided, as all motorways are fenced for security reasons.

Chapter 7. Avoidance, Mitigation, Compensation and Maintenance

7.1. INTRODUCTION

Avoidance of valuable nature areas has high priority when planning new roads. By conducting Environmental Impact Assessments (EIA) for all major infrastructure projects this has been accomplished for a number of stretches. Today, passages for animals and people are an important part of the design of modern infrastructure.

The development of knowledge has occurred simultaneously for recreation and fauna as regards mitigation measures. The experience on compensation measures is still rather limited.

7.2. AVOIDANCE OF HABITAT FRAGMENTATION

During the planning and the EIA-process, most conflicts between transportation infrastructure and nature are avoided by careful planning of the line tracks. In this planning process extensive consideration is shown to the landscape, flora, fauna, cultural heritage, and recreation. But it is impossible to avoid all environmental impacts.

As a basis for decisions on avoidance, or mitigation and compensation the following is used in priority of the efforts:

- Rare and vulnerable species (i.e. species on the red data lists)
- Special areas for conservation (EU-habitat areas, conserved areas etc.)
- Unregulated river valleys and watercourses (The aim is to remove all obstructions from watercourses)
- Important ecological infrastructure
- Dispersal corridors in fragmented areas.

Except for the above-mentioned considerations the economy plays an important role in the decisions on planning of avoidance and/or other mitigation and compensation measures.

7.3. OVERVIEW OF MITIGATION MEASURES

Where valuable habitats are destroyed or affected by new infrastructure, some species may be supported by establishing mitigation measures.

The mitigation measures currently applied in Denmark comprises overpasses (only one has so far been built), underpasses, level crossings and fencing.

On less busy roads with good sight conditions, speed limits and warning signs have been used to reduce the risk of fauna collisions.

Measures, which reduce the risk of animal crossing the road, such as ditches, embankments, fences etc. will increase the barrier effect.

In Denmark the efforts on mitigation measures have been concentrated on animals such as otter, amphibians and roe deer.

Other mitigation measures such as light reflectors and warning by spraying with repellents (such as carnivore urine) have been tried. Results from studies show that the animals get used to these measures, and the effects is therefore limited (Ujvari 1998).

The number of traffic killed birds and mammals can be minimised by changing the practice of planting in areas close to the roads. (Madsen 1993).

7.3.1. Fauna passages

Fauna passages are used to reduce the barrier effects of roads and railways. The purpose of the fauna passage is to enable the animals to cross the road/railway without any contact with the traffic. A fauna passage can be constructed in the following ways:

- Bridge across a river valley
- Tunnel under roads or railways
- Artificial banks alongside a river in an underpass
- Small tubes for small animal species e.g. tunnels for toads
- Small bridges between treetops above the road for squirrels
- Large overpass (fauna bridge) with vegetation constructed over a larger infrastructure.

In the period 1988-1994 approximately 60 fauna passages were constructed in Jutland (Skov & Naturstyrelsen 1996).

7.3.2. Recreational passages

Passages for pedestrians, cyclists, riders, roller skaters, wheelchair users and other non-motorised users are increasingly important, due to a high demand for access to forests and open landscape. According to Kaae et al. (1998) the need for recreational passages depend on:

- Barrier effect of the traffic construction
- Recreational attraction on the other side of the construction
- Connectivity of trail systems
- Traffic safety.

The functionality/accessibility of recreational passages also depends on the dimensions, design and surface of the passage. A good passage provides access for all relevant user groups. Other relevant criteria for recreational passages are:

- Traffic safety
- Experienced security
- Visual quality
- Adaptation to the landscape.

7.3.3. Joint use passages

The value of joint use passages is still uncertain, as the influence of human disturbance on the use of fauna passages by wildlife has not yet been documented. However human smell, noise and dogs can have a very negative impact on some species.

Animals living in urban areas are often used to human activity and will therefore have no objections on using, for instance, trail passages. Further, most wild mammals are nocturnal, while most people will use the passage in daytime.

For economic reasons it can, in some cases, be necessary to combine fauna and human passages, as it is the only possible way to create passages for the fauna.

To optimise the function, joint use passages must be as wide as possible to consider both people and wildlife. Animal tracks and recreational trails must be divided, and separated by tall vegetation, shrubbery, fences or ramparts.

7.4. OVERVIEW OF COMPENSATION MEASURES

The compensation measures currently applied in Denmark comprise establishment of compensation habitats, for instance:

- Digging of new waterholes and ponds, where these are lost by the construction of a road or railway.
- Planting of new forest to substitute areas cleared due to infrastructure projects.
- Planting of shrubbery with fruits and berries to replace the wood edges destroyed during the construction phase.

Experience shows that habitats for amphibians can be secured by the construction of new waterholes (Salvig et al. 1997).

It is not possible to consider all native species by the establishment of compensation habitats. Some habitat types will be impossible to recreate, for instance:

- Very old "pristine" nature types such as raised bogs, nature forests, and commons
- Nature types where the typical vegetation has poor dispersal ability.
- Nature types depending on special soil conditions, such as dunes and springs.

7.5. EXISTING QUALITY STANDARDS FOR MEASURES; JUSTIFICATION, MINIMUM REQUIREMENTS

The Road Directorate operates with four standard levels for fauna passages (underpasses) (Vejdirektoratet 2000).

Level A: Passages for roe deer and reed deer must fulfil the minimum sizes listed in table 4.1 in order to meet the demands of the species. The so-called tunnel index is calculated as height x width/length of the passages. In wet passages the width of the banks must be at least 3.5 m.

Table 7.1 Demands for minimum sizes by roe and red deer (Salvig 1991)

Species	Tunnel index	Height	Width
Roe deer	>0.75	>4 m	>6 m
Red deer	>1.50	>6 m	>10 m

In very vulnerable and/or very important dispersal corridors (environmental bottlenecks) establishment of a so-called valley bridge will be required to keep nature areas clear from transportation infrastructure. The valley bridges must fulfil the requirements listed in table 7.1.

Level B: By watercourses belonging to the designated dispersal corridors the banks along the river must have a minimum width of 1.5 m. Species associated with freshwater

habitats such as otter or beaver need banks that are designed so they rarely will become flooded. For dry passages in dispersal corridors the fauna tube must have a minimum diameter of 1.5 m with 20-40 cm of sand at the bottom. For passages shorter than 20 m tubes with a diameter of 1m can be sufficient.

Level C: Banks along the watercourses must have a minimum width of 0.5 m. For dry passages the fauna tubes must have a minimum diameter of 0.5 m with 5-10 cm of sand at the bottom.

Level D: Fish and other organisms living in water need free passage of the water beneath the roads. The speed of water should not exceed 0.6 m/s at average flow rate and minimum water depth must be 0.25 m. The tubes must be dimensioned so they are never filled up.

When designing fauna passages it is necessary to show considerations and take into account the possibilities of a rising water table in the surroundings due to future nature restoration.

Table 4.2 and 4.3 provides at rough overview of the efficiency of different wet and dry passages to different fauna groups. The suitability is described as follows. XXX: most suitable for the fauna group in question, XX: very suitable, X: suitable and (X): less adapted to the species/group of species in question.

Table 7.2 The suitability of underpasses by water courses (wet passages) for different fauna groups (Vejdirektoratet 2000)

Fauna group	Landscape bridge	Level A	Level B	Level C	Level D
Freshwater invertebrates	xxx	xxx	xx	x	(x)
Fish	xxx	xx	xx	x	(x)
Amphibians	xxx	xxx	xx	x	
Hedgehogs	xx	x	x	x	
Small mammals	x	x	x	x	
Hare	x				
Small carnivores	x	(x)	(x)	(x)	
Squirrel	x				
Otter	xx	xx	xx	x	
Beaver	xx	xx	xx	x	
Badger	xx	xx	xx	x	
Fox	xx	xx	xx	x	
Deer	xxx	x			

Table 7.3 The suitability of dry passages for different fauna groups (Vejdirektoratet 2000)

Fauna group	Overpass, fauna bridge	Landscape bridge	Fauna tunnel A	"Toad tunnel" B	Fauna tube, level B	Fauna tube, level C
Amphibians	x	xxx	xx	xx		
Hedgehog	xx	xx	xx	xx	xx	xx
Small mammals	xxx	x	x	x	x	x
Hare	x	x				
Small carnivores	x	x	(x)	(x)	(x)	(x)
Squirrel	x	x				
Badger	xx	xx	xx	xx	xx	xx
Fox	xx	xx	xx	xx	xx	xx
Deer	xxx	xxx	xx			

Fencing or plantings guiding the animals to the passage must accompany fauna passages:

- Fences for toads must be at least 30-40 cm high.
- Fences for badgers must be at least 1 m high, with a mesh size of 5 cm, and be dug 20-25 cm into the ground.
- Fences for deer must be at least 2 m high, with a mesh size of 15 cm. It is very important to make sure that no animal will be trapped between the fences and the traffic, this can be accomplished by double fences and/or automatic shutting gates etc.

7.6. MAINTENANCE ASPECTS

7.6.1. Verge management

The existing transportation infrastructure is planned and constructed without consideration to wildlife and native flora, but it nevertheless contributes an important part of the habitats in the intensively exploited rural landscape in Denmark. In spite of the planting of cultivated grasses and exotic trees and shrubs, the road verges and railway embankments act as habitats, refuges and dispersal corridors to the wild flora and fauna. Some verges contain a rich herb flora and therefore provide a valuable habitat for invertebrates, birds, and small mammals. Some carnivores and scavengers are frequently foraging by the major roads.

The maintenance of railway embankment is to a large extent carried out as a very extensive nature management. Intensive maintenance is only carried out on rail areas and around signals for safety reasons. The maintenance consists of:

- Pruning of woody species once every five years
- Dead leaves and twigs are left on the ground for natural decomposition
- Forested areas are managed by selection felling which ensures a continuously leaf canopy.

The road verges are subject to regular maintenance and the primary purpose of the maintenance is to obtain traffic safety and proper road conditions. For this reason cutting of vegetation is always done within 1m from the paved road surface and around road signs, traffic signals etc.

The Road Directorate has taken initiative to the preparation of so-called biological road maps for the Danish state roads (Moeslund & Lindberg 1999). The purpose of the biological road maps is to show where the locations of special biological value are situated, and to assess how these locations should be managed to improve their value to the wild flora and fauna. The plants were selected as the primary indicator, as the vegetation is the basis for the occurrence of a variety of other organisms.

Registration of flora on state road verges was conducted in July 1998. 816 km road equivalent to 1632 km verges was investigated and 335 locations were found to have special nature values, based on the floristic survey. Locations with occurrence of rare vulnerable and/or protected plant species, locally distributed plant species, rare plant community or vegetation type, and profusion of flowers were classified as having special biological values.

A large number of road verges are characterised by a high density of uniform grass vegetation dominated by a few, very common species. This is due to the pollution with plant nutrients from the traffic and the adjacent cultivated areas.

For each location with special biological value, the most appropriate maintenance practise was assessed and selected. Examples on maintenance are:

- Type A, cutting each autumn + cutting in the summer every 5^{th} year.
- Type B, cutting each autumn
- Type C, cutting in summer, beginning of July
- Type D, cutting in summer, end of July
- Type E, no cutting
- Type F, other maintenance than listed above.

For about 50 % of the locations, cutting each autumn (type B) was recommended. 30 % of the location were classified as rich in nutrients and as a result Type A maintenance was recommended. For the rest of the locations, other types of maintenance were recommended, as special precaution to vulnerable plant species, insects etc. (Moeslund & Lindberg 1999).

Most counties have, in the past few years, ceased the use of herbicides in the maintenance of road verges.

7.6.2. Management of other surfaces

Use of de-icing salt in Denmark has increased concurrently with the increasing number of roads as well as the quantity and speed of traffic. At present, Danish road administrators do not recognise any alternative to sodium chloride (NaCl). The recognition of the consequences of de-icing salt has, had the effect that salt is no longer applied uncritically.

De-icing salt is spread to thesurrounding environment by surface run-off, wet spraying and air borne drifting (Randrup & Pedersen 1997). The first and most common symptom of salt damage on trees and shrubs is reduced growth. This is usually followed by early autumn colours and premature leaf fall. The majority of trees and shrubs subjected to high salt concentrations, typically shows necrosis at the edges for leaves or needles. Damages due to de-icing salt are difficult to cure. Therefore, preventive precautions are carried out

at the specific locations where trees and shrubs are growing near major roads with high traffic intensity.

7.6.3. Coordinating land-use in adjacent areas

Only in very rare cases, co-ordination between the roads and the land use in adjacent areas, is seen in Denmark.

When constructing the new motorway (1994) between Århus and Randers the State acquired 220 ha of cultivated land from local farmers. 170 ha of land surrounding the new motorway were planted with new forest (Skov og Naturstyrelsen 1999).

7.7. EVALUATION AND MONITORING OF THE EFFECTIVITY OF MEASURES

The effectiveness of fauna passages is mainly associated with the position of the passage in relation to animal dispersal routes rather than the design and dimensions of the passages (Vejdirektoratet 2000).

The effect of five fauna passages with a length of 90-120 m and a diameter of 5-7 m situated in a small plantation was examined. The survey was based on search and determination of tracks on the use of infrared video monitoring and on direct observations (Madsen 1993).

Water vole, fox, stoat, badger, otter, water bats, dipper and grey wagtail made little use of the fauna passages. Brown hare and roe deer have not been recorded using the fauna passages at any time. Lack of conduction planting and fencing in connection with the fauna passages was stated as the reason for the lack of effectiveness of the fauna passages. Further, the size of the passages was probably not adequate for roe deer.

The use of 11 underpasses by larger animals was examined by print identification in constructed sand beds (Jeppesen et al. 1998). Seven of these underpasses were wet, containing a stream with one or two man-made banks. The rest of the underpasses were dry. The most frequently used underpass was a wide and high passage at Spørring Å. The least used passages were four dry underpasses, and a wet underpass with only one man-made bank. Fox, badger, otter, marten, polecat/mink, stoat, hedgehog, water vole/rat, heron, dipper and duck used the underpasses. Roe deer and hare were only recorded in the underpass at Spørring Å.

Lack of fencing at most underpasses and inexpedient placement in relation to the movement of animals in the landscape, may cause the wild animals to cross the road with consequent risk of collision with vehicles. Jeppesen et al. (1998) showed habituation to underpasses, especially for species such as fox, otter, and polecat/mink in the course of a 5-year period. Behavioural studies at the Spørring Å underpass using infrared video surveillance revealed that the predators did not show nervous behaviour when moving through the underpass.

Long underpasses in wide and high dams are generally not the most optimal solution for wildlife. The dams effectively block the vision and movement of animals in the landscape. Where roads and railways cross a river valley, a bridge (pier bridge, suspension bridge etc.) is a more optimal solution, given that a clear view is ensured and the landscape guidelines are not broken.

7.8. SUMMARY (7.8)

- The development of knowledge has emerged simultaneously for recreation and fauna as regards mitigation measures. Today passages for animals and people are an important part of the design of modern infrastructure.
- During the planning and the EIA-process most conflicts between transportation infrastructure and nature are avoided, by careful planning of the line tracks. In this planning process extensive consideration is shown to the landscape, flora, fauna, cultural heritage, and recreation.
- Fauna passages are used to reduce the barrier effects of roads and railways. The purpose of the fauna passage is to enable the animals to cross the road/railway without any contact with the traffic.
- The Road Directorate operates with four standard levels for fauna passages: Level A: large passages, landscape or fauna bridges for roe deer and reed deer. Level B: large tubes for dry underpasses or wet underpasses with broad river banks. Level C: Smaller tubes for dry underpasses or wet underpasses with narrow banks along watercourses. Level D: Tubes for fish and freshwater invertebrates.
- The effectiveness of fauna passages is mainly associated with the position of the passage in relation to animal dispersal routes rather than the design and dimensions of the passages.
- The functionality/accessibility of recreational passages depends on the dimensions, design and surface of the passage. A good passage provides access for all relevant user groups.
- The value of joint use passages is still uncertain, as the influence of human disturbance on the use of fauna passages by wildlife has not yet been documented. For economic reasons it can be necessary to combine fauna and human passages, as it is the only possible way to create passages for the fauna.
- The compensation measures currently applied in Denmark comprise establishment of compensation habitats, for instance: Digging of new water holes and ponds, planting of new forest to substitute cleared areas, planting of shrubbery with fruits and berries to replace the wood edges.
- The Road Directorate has prepared of so-called biological road maps for the Danish state roads. The purpose is to show locations of special biological value, and to assess how these locations should be maintained to improve their value to the wild flora and fauna.

Chapter 8. Habitat Fragmentation and Future Infrastructure Development

8.1. INTRODUCTION

The present need for transport amounts to 35 km per person per day. This is an increase by 60% since 1980. As a result of the increased need for transport new roads have been provided. This has caused many habitats to become more fragmented in recent years. Development of international traffic network through Jutland and construction of the Øresund fixed link can result in a comprehensive change of land use in the areas in question. Further extension of the motorway network can be expected soon, as the Danish Parliament in 1998 passed a law on construction of four new motorways (or the Danish type "semi-motorways"). The construction of circulars can result in increased development of urban areas, especially commercial areas between the rural landscape and the city centres.

The problems of fragmentation and barrier effects are primarily connected to the existing road network, while the new and planned roads are generally of higher standard as regards reduction of environmental impacts.

8.2. POLICIES AND STRATEGIES/TRENDS

The aim of the national transport policy comprises the following issues (Trafikministeriet 1993):

- Decrease the use for road transport via physical planning, for instance by placing of major commercial centres near public transport.
- Increase the use of an environmentally friendly form of transport by "green taxes".
- Support of sustainable transport development in regional and local planning.

For existing infrastructure and traffic the political aim is to:

- Decrease energy consumption and CO_2 emissions by 25% by the year 2010.
- Decrease emissions of other atmospheric pollutants such as CO, NO_x, CH by 60% before year 2010.
- Reduction of emission of other pollutants to surface and ground water.
- Continue the research on fauna collisions, fauna passages and fragmentation.

The National Forest and Nature Agency has the following guidelines for planning and location of transport infrastructure:

- Infrastructure should be kept in transport corridors
- No new infrastructure in major undisturbed areas
- No new infrastructure in the coast protection zone (i.e. within 3 km from the coastline)
- No transport infrastructure alongside watercourses
- Landscape bridges should be constructed when crossing river valleys

- New transport infrastructure must be adapted to the landscape, for instance, all crossing of river valleys should be perpendicular.

8.3. INDICATORS/INDICES OF FRAGMENTATION

At present there are no operational indicators on the area of nature lost due to transportation infrastructure.

Some species are much more sensitive to fragmentation at a particular scale than other species, depending on mobility, behaviour and habitat requirement of the species concerned. A wide range of indicator species with different mobility, dispersal strategy, ecology and behaviour are needed to understand the effects of fragmentation.

Hammershøj & Madsen (1998) have conducted a review of literature in the context of a major research project on habitat fragmentation. The project is still in progress and no indicator species has so far been appointed.

8.4. MODELS TO PREDICT FRAGMENTATION BY NEW INFRASTRUCTURES

Danish Forest and Landscape research institute has developed a model to illustrate the barrier effect of infrastructure on recreation (Kaae et al. 1998). In this GIS-based model barrier effect is measured as loss of accessibility to the landscape.

The basis for analysis is comparison of accessible area with and without the presence of barriers. Accessibility was in this context exemplified by using 30 minutes walking distance, but can be measured for other types of transport and periods of time. Both loss of accessibility to nature areas from residential areas and loss of accessibility within areas were analysed. The results were presented on maps showing the degree of barrier effects in the landscape.

8.5. DATA ON TRANSPORTATION NETWORKS DEVELOPMENT

New motorways are planned to be constructed in the coming years. These include Route 9, Route 15, Route 18 and Route 21 of the state road network. Furthermore, the counties are planning a number of semi-motorways in rural areas as well as circulars around cities. But no new railways are planned in the near future.

8.6. ON-GOING RESEARCH AN REVIEW OF RELEVANT STUDIES

In 1996-97 the existing fragmentation of nature areas due to traffic barriers in Vejle County was mapped, described and mitigation measures were assessed for a number of conflict areas in the county (Salvig et al. 1997).

A minor study of a number of the impact of transport infrastructure corridors in Copenhagen County was undertaken in 1998-99 (COWI 1998).

The Road Directorate has taken initiative to a comprehensive survey of possible conflict points between the state road network and dispersal corridors/major nature areas.

The Road Directorate has launched a project called "the good road". The purpose of the project is to test methods for optimising roads as regards fragmentation, environment, aesthetics and traffic safety. This demonstration project will be conducted using a major road in the Copenhagen area (Frederikssundsvej) as study object.

8.7. SUMMARY

- Several new roads are planned for construction in the near future, but at present all plans on construction of new railways are suspended.
- On the other hand, it is a national aim to decrease the need for road transport.
- At present no indicators on the effect of fragmentation is applyed in Denmark.
- A model to predict the barrier effect of infrastructure on recreation has been developed.
- Several studies on fragmentation and/or need for mitigation measures on the present barriers caused by transportation infrastructure are in progress.

Chapter 9. Economic Aspects

At present, the investment in mitigation measures has solely been undertaken by the road authorities, according to the owner pays principle. The results of the studies on the efficiency of fauna passages show that the most expensive constructions i.e. landscape bridges are also the most efficient. A rough calculation of prizes on fauna passages indicates that it is much cheaper to make fauna and recreational passages when constructing new roads and railways than it is to decrease the barrier effect of existing transport infrastructure.

During the last 10-15 years many farmers and hunters have on their own initiative and at their own expense, dug water holes. But most of the new and re-established water holes are the work of the counties. Many good examples show that is has been of benefit to the common spade-foot and the green tree frog.

In the future, it is possible that the economic means for nature management (Naturforvaltningsmidler), provided by the state and administrated by the Forest and Nature Agency and the counties, can also be used to improve the function of the dispersal corridors. For instance, by constructing fauna passages where the designated corridors are obstructed by transport infrastructure.

Chapter 10. General Conclusions and Recommendations

- Animal populations have during a long period adapted to environmental changes in the mosaic landscape. However, the fragmentation is today one of the more serious threats to the Danish native fauna.
- Transport infrastructure forms massive barriers in the landscape and decreases the habitat areas as well as the possibilities for dispersal of many species. In the worst cases the barrier effect can result in total isolation and extinction of a population. Amphibians, hare and otter are found to be the most sensitive species.
- Roads and railways are of minor importance as regards fragmentation of nature areas in Denmark, loss of habitats and decrease of biodiversity, compared to other major land consuming activities such as agriculture and urbanisation.
- Transportation infrastructure cutting through river valleys causes serious interference in the landscape, as the valleys are important habitats and dispersal routes for wild flora and fauna. Therefore the general policy in Denmark is to build landscape bridges as large as possible when crossing of river valley is unavoidable.
- Efficiency studies show that the location/placing of fauna passages are more important to the use of the fauna passages, than the design and dimensions of the passages. The effectiveness of passages is mainly associated with the position of the passage in relation to animal dispersal routes.
- The value of joint use passages is still uncertain, as the influence of human disturbance on the use of fauna passages by wildlife has not yet been documented. However, human smell, noise and dogs may have a very negative impact on some species. For economic reasons it can, in some cases, be necessary to combine fauna and human passages, as it is the only possible way to create passages for the fauna. More knowledge on joint use passages is needed.
- It is not possible to consider all native species by the establishment of compensation habitats. Danish experience show, that especially the survival of amphibians can be secured by the digging of new waterholes. Some habitat types will be impossible to recreate, and further research in the field of nature restoration and establishment of compensation habitats is needed.
- An integrated approach must be applied in the process of planning new transport infrastructure. Studies on optimising roads regarding minimising fragmentation, adaptation to landscape, fauna and recreational passages, aesthetic value, traffic safety and handling of traffic, will play an important role in the future planning process.
- Today all major infrastructure projects are subject to EIA. The best results for nature are obtained when the EIA is an iterative process, where road engineers, planners, landscape architects and biologists all participate in the design and outline of new roads and railways.
- It is generally much more expensive to make bridges and other type of passages through existing infrastructure than it is to build in passages for recreation and wildlife in the design and construction of new roads and railways.
- As a basis for planning of new passages for wildlife and recreation, the following surveys are recommended:
  - Mapping of dispersal corridors and ecological infrastructure

- Registration and location of fauna casualties
- Assessment of the demand for recreational passages
- Mapping of recreational attractions
- Assessment of the connectivity in the trail system
- Assessment of the barrier of the construction in question
- Assessment of traffic safety.

Chapter 11. References

Bruun-Schmidt J. (1994). Trafikdræbte dyr. Specialerapport, Odense Universitet.

COWI 1999. Spredningscorridorer i Københavns Amt. Rapport udarbejdet for Københavns Amt.

Danmarks Statistik 1996. Vildtudbyttet i 1994/95. Danamrks Statistik 1996:5.

Groth, N.B.; Hedegaard, M.B.; Holmberg, T., Höll, A. & Skov-Pedersen, H. (1998). Arealanvendelsen i Danmark 1995-2025. Forskningscentret for Skov- og Landskab. By- og landsplanserien nr. 2. 135pp.

Hammershøj, M. & Madsen, A.B. (1998). Fragmentering og korridorer i landskabet. En litteraturudredning. Danmarks Miljøundersøgelser, faglig rapport fra DMU nr. 232. 107pp.

Hansen, L. (1982). Trafikdræbte dyr i Danmark. Dansk Ornitologisk forenings tidsskrift 76:97-110.

Jespersen et al. (2000). Nøglebiotoper i skovene. Skoven, Januar 1/2000.

Jeppesen, J.L.; Madsen, A.B.; Mathiasen, R. & Gaardmand, B. (1998). Faunapassager i forbindelse med større vejanlæg, III. Danmarks Miljøundersøgelser. Faglig rapport fra DMU nr. 250. 69pp.

Kaae, B.C.; Skov-Petersen, H. & Larsen, K.S. (1998). Større trafikanlæg som barrierer for rekreativ brug af landskabet. Park- og Landskabsserien nr. 17. Forskningscentret for Skov & Landskab, Hørsholm. 165pp.

Madsen A.B. (1993). Fauna passages in connection with large roads systems II. Hedgehogs, bats, birds and research of effects. Danmarks Miljøundersøgelser. Faglig rapport fra DMU nr. 82, 54pp.

Madsen, A.B.; Fyhn, H.W. & Prang, A. (1998). Trafikdræbte dyr i landskabsøkologisk planlægning og forskning. Damnarks Miljøundersøgelser. Faglig rapport fra DMU, nr. 228, 42pp.

Miljøministeriet, (1994). Tal om natur og miljø. Miljøministeriet, Miljøstyrelsen; Miljøministeriet, Skov- og Naturstyrelsen og Danmarks statistik.

Miljøministeriet (1995). Biologisk mangfoldighed i Danmark - status og strategi.

Miljøministeriet (1997). Natur og miljø. Påvirkninger og tilstand. http://www.sns.dk/publikat/netpub/NM97/landskabet.htm

Moeslund, B & Lindberg, R. (1999). Biologiske Vejkort. Vejdirektoratet. Rapport nr. 176. 18pp.

Randrup, T.B. & Pedersen, L.B. (1996). Vejsalt, træer og buske. Vejdirektoratet. Rapport nr. 64. 69pp.

Salvig, J.C. (1991) Faunapassager i forbindelse med større vejanlæg. Danmarks Miljøundersøgelser. Faglig rapport fra DMU nr. 28.

Salvig, J.C.; Andersen, U.V. & Therkelsen, J. (1997). Veje og jernbaner som spredningsbarrierer. Rapport udarbejdet af COWI for Skov- og Naturstyrelsen, Vejdirektoratet og DSB.

Skov- og Naturstyrelsen (1996) Forvaltningsplan for Odder, Lutra lutra i Danmark.

Skov- og Naturstyrelsen, (1999). Naturforvaltning gennem ti år - 1989-1998

Thomsen, K. (1992). Projekt vildtregistrering. Rapport udarbejdet for Falck Danmark.

Trafikministeriet (1993) Trafik 2005. Trafikpolitisk redegørelse. Problemstillinger, mål og strategier.

Ujvari, M. 1998. Vildtspejle - fup eller fakta. DYR nr. 1. pp. 15-17. Zoologisk Museum.

Vejdirektoratet (1999). Miljøindikatorer for vejsektoren 1998. Rapport nr. 185, 46pp.

Vejdirektoratet 2000. Fauna og Menneskepassager - en vejledning. Vejregelforslag januar 2000. 132pp.

Annex I.

I) Directory of organisations and competent authorities:

National authorities

Miljø-ogEnergiministeriet(Ministry of Environment and Energy)
HøjbroPlads4
1200KøbenhavnK
Telefon:33927600
Telefax: 33 32 22 27

Homepage:http://www.mem.dk/http://www.mem.dk/
E-mail: mailto:mem@mem.dkmailto:mem@mem.dk

Skov- og Naturstyrelsen (The National Forest and Nature Agency)

Haraldsgade 53
2100 København Ø
Danmark
Tlf. 39 47 20 00
Fax 39 27 98 99
e-mail: sns@sns.dk

Trafikministeriet (Ministry of Transport)
Frederiksholms Kanal 27
1220 København K
Telefon: 3392 3355
Telefax: 3312 3893
Telex: 22275 trami dk
E-mail: trm@trm.dk
Homepage: www.trm.dk

Banestyrelsen (Danish National Railway Agency)
Sølvgade40
1349København K

Tlf.:33765000
Fax:33775001
Homepage:www.bane.dk
E-mail:post@bane.dk

Vejdirektoratet(RoadDirectorate)
NielsJuelsGade13
Postbox1569
1020KøbenhavnK
Tlf.:33933338
Fax:33156335
Homepage:www.vd.dk
E-mail: vd@vd.dk

Research institutions:

Forskningscentret for Skov & Landskab

The Danish Forest and Landscape Research Institute (DFLRI) is a sector research institute under the Ministry of Environment and Energy.
Hørsholm Kongevej 11 -
2970 Hørsholm
Danmark
Telefon:45763200-
Telefax:45763230
E-mail: fsl@fsl.dk

Danmarks Miljøundersøgelser

The National Environmental Research Institute (NERI) is an independent research institute under the Danish Ministry of Environment and Energy. Frederiksborgvej 399 - Postboks 358 4000 Roskilde

Danmark
Tlf:46301200

Fax:46301114
E-mail: dmu@dmu.dk

Regional authorities

Bornholms Amt (Bornholm County)
Ullasvej 23
Postboks 160
3700 Rønne
Telefon: 56 95 60 00
Telefax: 56 95 73 97

FrederiksborgAmt(FrederiksborgCounty)
KongensVænge
3400Hillerød
Telefon:48205000
Telefax: 48 20 51 49

FynsAmt(FynCounty)
Amtsgården
Ørbækvej100
5220OdenseSØ
Telefon:65561000
Telefax: 65 56 10 56

KøbenhavnsAmt(CopenhagenCounty)
Stationsparken27-33
2600Glostrup

Telefon:43222222
Telefax: 43 22 29 71

NordjyllandsAmt(NordjyllandCounty)
NielsBohrsvej30
Postboks8300
9220AalborgØ
Telefon:96351000
Telefax: 98 15 20 09

RibeAmt(RibeCounty)
Amtsgården
Sorsigvej35
6760Ribe
Telefon:75424200
Telefax:75424911

RingkjøbingAmt(RingkjøbingCounty)
Østergade41
Postboks152
6950Ringkøbing
Telefon:96753000
Telefax: 96 75 30 80

RoskildeAmt(RoskildeCounty)
Amtsgården
Køgevej80
4000Roskilde
Telefon:46323232
Telefax:46373618

StorstrømsAmt(StorstrømsCounty)
Parkvej37
4800NykøbingFalster
Telefon:54844800
Telefax: 54 84 44 09

SønderjyllandsAmt(SønderjyllandCounty)
Amtsgården
Skelbækvej2
6200Aabenraa
Telefon:74335050
Telefax:74335151

VejleAmt(VejleCounty)
Damhaven12
7100Vejle
Telefon:75835333
Telefax: 75 83 16 75

VestsjællandsAmt(VestsjællandsCounty)
Alléen15
4180Sorø
Telefon:57872533
Telefax: 57 87 20 25

ViborgAmt(ViborgCounty)
Amtsgården
Skottenborg26
Postboks21
8800Viborg
Telefon:87271700
Telefax: 86 62 39 33

ÅrhusAmt(ÅrhusCounty)
Amtsgården
LysengAllé1
8270Højbjerg
Telefon:89446666
Telefax: 89 44 69 90

Amtsrådsforeningern
(The Association of County Councils in Denmark)
Dampfærgevej 22
Postbox 2593
2100 København Ø
Tel: +45 35 29 81 00
Fax: +45 35 29 83 00
e-mail: arf@arf.dk

Kommunernes Landsforening
(The National Association of Local Authorities in Denmark)
Gyldenløvesgade 11
1600 København V
Tel: +45 33 70 33 70
e-mail: kl@kl.dk

Danmarks Naturfredningsforening
(The Danish Society for the Conservation of Nature)

Masnedøgade20
DK2100CopenhagenØ
Tel.+4539174000
Fax+4539174141
dn@dn.dk
www.dn.dk

Dansk Ornitologisk forening
Danish Ornitological Society
Vesterbrogade138-140
1620KøbenhavnV
Tlf.3334404
Fax:33312435
Skriv til: dof@dof.dk

Danmarks Jægerforbund

Danish Hunters Association

Højnæsvej 56
2610 Rødovre
Tel: +45 36 73 05 00
Fax: + 45 36 72 09 11
www.jaegerne.kd

Friluftsrådet

The Danish Outdoor Council

Scandiagade 13
2450 København SV
tlf: 33790079
fax: 33790179
E-mail: fr@friluftsraadet.dk

Foreningen Dyrenes Beskyttelse

Danish Animal Welfare Society

Alhambravej 15

1826 Frederiksberg C

tlf.: 33 22 32 22
Fax: 33 25 14 60
www.dyrenes-beskyttelse .dk

Falcks Redningskorps

Falcks Rescue and Security Company
Falck A/S
Falck-Huset

Polititorvet
1780 København V.
Tel: 33 15 83 20
Fax:33910026
E-mail kontakt@falck.dk

Dansk Landskabsøkologisk Forening

Danish national branch of International Association for Landscape Ecoogy

Rolighedsvej23
1958FrederiksbergC
35282213
e-mail: lokr@kvl.dk

Maps

III) Infrastructure network

Annex II.