Habitat Fragmentation and Infrastructure in the Netherlands and Europe

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Abstract

Fragmentation of nature and the landscape by transportation infrastructure causes serious degradation of ecological values. All over Europe, the nature and scale of this problem is drawing growing attention. Nonetheless, new motorways are still cutting through valuable natural areas. In the Netherlands, one of the stated aims of nature policy as well as its integration in infrastructure policy is to control fragmentation. In the planning phase this is operationalized in the (Strategic) Environmental Impact Assessment procedure. During road construction a variety of means are employed to mitigate effects. The concept of ecological networks is of major importance for combatting fragmentation.

The Infra Eco Network Europe has been established to enhance defragmentation in Europe. One of the aims of this cooperative venture is to promote an exchange of information on developments in this field. Examples of collaboration and measures implemented in some of the countries involved demonstrate that the problem is widely recognized. A substantial amount of research has been carried out on impacts (dose - effectrelations) and predictive methods have been derived from these impactstudies.

Defragmentation measures require a national-level approach that must be elaborated at the regional level. A broad range of measures are available for reducing and mitigating fragmentation. Utilization of the measures differs with shape, design and connection with the surrounding.

Introduction

The International Symposium on Habitat Fragmentation and Infrastructure, organized in Maastricht in September 1995 by the Road and Hydraulic Engineering Division of the Dutch Ministry of Transport, Public Works and Water Management, has clearly demonstrated that fragmentation due to transportation infrastructure is a major problem in Europe and elsewhere (V&W, 1997). Fortunately, it has also made it clear that scientists worldwide are developing the knowledge required to analyse the problem and design effective mitigating measures. Over 140 participants from 26 countries demonstrated that there are also considerable differences among these countries in terms of available knowledge, recognition of the problem, nature and scale of infrastructure and the potential for taking countermeasures. In the Infra Eco Declaration drawn up at this symposium the participants concluded that: "there is a need for more cooperation on a global level" (V&W, 1997b).

The aim of this paper is to describe the extent to which fragmentation of nature and the landscape by transportation infrastructure constitutes a recognized problem and how this is reflected in policy, research and road-related measures. This is then illustrated with reference to currently available defragmentation measures, which are individually reviewed. The extent to which these measures are used by wildlife is also reviewed.

Many examples illustrate the approach taken in the Netherlands; where possible, the European situation is described.

What is fragmentation?

Fragmentation of nature and the landscape is one of the driving forces behind the contemporary decline in biodiversity. Increasingly, this problem is being recognized by conservationists as well as by researchers and politicians. Transportation infrastructure is one of the main causes of this problem, and since about 1980 a wide variety of measures have been taken to alleviate/mitigate effects.
Fragmentation is understood to mean: the break-up of ecosystems and/or habitats of plant and animal populations into smaller, more isolated units (Rijkswaterstaat, 1997). There is a decline in the aggregate area of habitat suitable for species and an increase in the distance between the remaining habitats. Ultimately, fewer species will be able to survive in the remaining fragments. Small populations face a high risk of extinction, whether through natural causes or as a result of activities associated with road construction and motorized traffic. Recolonization from elsewhere is only feasible if there is adequate access to the area in question. Whatever the case, the problem of fragmentation inevitably leads to a loss of ecological values.

In the context of infrastructure we distinguish four impacts on the natural environment. First of all the destruction of habitats: a certain area of nature simply disappears under the tarmac. Secondly, the ensuing traffic flow disturbs the area adjacent to the road, causing quantitative and qualitative changes to the area that influence a variety of population variables. Disturbance by noise and edge effects are examples of these changes. Thirdly, the barrier effect means that parts of a habitat are cut off, reducing the exchange of individuals within and among populations. And lastly, many animals end their lives as traffic casualties.

These effects may lead to a change in the species composition of the area in question. This holds true for the vegetation (Angold, 1997), for small animal species (Grutke, 1997) and for large animal species (Groot Bruinderink & Hazebroek, 1996). Traffic casualties are the most conspicuous consequence. These are described, inter alia, by Bekker (1997) for the badger, by Van der Tempel (1993) for birds and by Groot Buinderink & Hazebroek (1996) for larger mammals.

Policy

Nature policy

In all the 14 countries involved in the Infra Eco Network Europe, the problem of fragmentation is recognized by governments as well as by scientists and conservationists (Teodorascu, 1996). In many of these European countries, the Environmental Impact Assessment and/or Strategic Environmental Impact Assessment are the instruments used to incorporate environmental interests in the decision-making process. In the guidelines for the Trans-European Networks (TENs) road-building programme the importance of environmental protection has been stressed. It has been stated that the European Commission will develop "methods for strategically evaluating the environmental impact of the whole network, and methods for environmental assessment at corridor level" (Hans Koijer, 1997). The commission is actively engaged in 5 pilots for environmental corridor assessments.

In many European countries the concept of ecological networks has been accepted as a working basis for nature protection, providing major scope for transnational cooperation (Jongman, 1995). In the context of pan-European road planning, this can provide a basis for a coherent approach to the issue. In the Infra Eco Declaration the participants concluded that: "the European ecological network that is going to be developed should be compared with the planned infrastructural network to find the potential intersections. These may be conflict. So, in the planning, design and building processes full integration must taken place of environmental considerations on the one hand and transport policies and infrastructure developments on the other."

In the Netherlands the concept of an 'Ecological Main Structure' (EMS) was introduced in 1990 in the government's Nature Policy Plan (LNV, 1990). The EMS distinguishes core areas, nature-development areas and ecological connections. By enlarging and connecting natural areas, it is aimed to reduce fragmentation - or, in other words, enhance defragmentation. By creating larger units and improving overall environmental quality, vulnerability to external influences will decline. This concept was presented at the national level and requires elaboration at the regional basis. The timetable is to realize this network within 20 years. Implementation is in steady progress.

Infrastructure Policy

In the Netherlands the terms of infrastructure planning are laid down in the Second Transport Structure Plan (V&W, 1990). The road projects identified in this document are limitative and indicative; the necessity of implementing a road project must still be demonstrated. The combined procedure embodied in the Routing Act and Environmental Impact Assessment legislation is designed to achieve due balancing of interests in establishing the route to be followed. Public participation plays a major role here.

The strategy of the Second Transport Structure Plan consists of five elements (van Bohemen, 1996):

- tackling problems at their source
- managing and restricting mobility
- improving alternatives to the private car
- implementing selective accessibility on the roads
- strengthening the foundations with support measures.

The five elements of the strategy have been transplanted into 35 policy areas and grouped into four categories: environment and amenity, managing and restricting mobility, accessibility and means of support.

Fragmentation due to infrastructure is widely recognized as a problem in the Netherlands. In the aforementioned Structure Plan the target scenario for avoiding and reducing fragmentation of the countryside is described under the policy category 'Environment and Amenity'. In the short term there is to be no further fragmentation of the countryside; in the longer term fragmentation is to be reduced. This target scenario is elaborated in terms of operational targets, viz. that fragmentation of the Ecological Main Structure by the national highway network is to be reduced by 40% in the year 2000 and by 90% in 2010 (Piepers & Bekker, 1993). There are annual reports to parliament on progress with respect to these reduction targets, in the form of graphical reviews on the percentage of unresolved 'bottleneck' kilometres. A bottleneck is understood to mean a location where the EMS is intersected by an element of the national highway network (V&W, 1997a). Besides reducing disturbance, in the context of motorways defragmentation means above all creating safe connections between the natural areas intersected by the road. This must be accompanied by other local measures designed to enlarge natural areas and improve interconnections.

The explicit statement of this target by the three ministries involved - those with responsibility for Transport, Spatial Planning and Nature Protection - proves to be fairly unique in Europe, and probably elsewhere.

A Problem Still Growing

Despite recognition of the problem and the efforts of many people and organisations to combat fragmentation, the problem is still growing in scale (V&W, 1997a). Despite the existence of appropriate procedures in the Netherlands, new highways are still cutting through high-quality natural areas that form part of the Ecological Main Structure. There are similar signals from other countries. Over the past few decades, there has been a major expansion of the West European road grid, with serious consequences for nature (Kirby, 1997). The problem has been put on the European agenda because economic activity, encouragement of employment and increasing car use in Eastern Europe are continually leading to demand for improved transport connections. Plans on the economic agenda to expand the European road grid will have an impact on natural areas throughout Europe (Eisma, 1997). In 1990 the European Commission presented a major plan for improving the so-called Trans-European Networks (TENs). This programme entails an enormous expansion of motorways, waterways and high-speed rail links. The total length of motorways is scheduled to grow from 43,000 km to 58,000 km, for example. Of the many projects identified, 34 have been given priority and 14 super-priority. At the time, the planning of these links was not subjected to a Strategic Environmental Impact Assessment (SEIA), although it was stated that traffic and transport should be better attuned to environmental requirements.

Cooperation

Cooperation in a variety of fields is essential if fragmentation due to infrastructure is to be reduced. Collaboration between civil engineers and ecologists is of vital importance, and this implies learning to understand one another's terminology (Bekker, 1997; Bekker & Canters, 1997). The formation of the Infra Eco Network Europe (IENE, Fig. 1) represents a major step towards improved cooperation. This network was established on the basis of the Declaration of our International Symposium in Maastricht. The IENE links up, at the European level, national networks of planners, designers, administrators and researchers involved in transportation infrastructure and the fragmentation it causes. IENE brings together two sectors: transport and environment, and the diversity of disciplines involved implies a broader approach to problem-solving. A growing number of West and East European countries are participating in the IENE. There are also close contacts with the European Centre for Nature Conservation, the European Commission's Directorate-General VII - Transport, the World Road Association (PIARC), the World Conservation Union (IUCN) and the European Railway Union (UIC).

Figure 1. Logo IENE

Within the IENE framework, networks have been established in various countries, as illustrated by the following examples:

•In Estonia a cooperative agreement has been signed by the Technicentre of the Estonian Road Administration and the Faculty of Biology and Geography of the University of Tartu. The Estonian Green Movement is also involved. Under the terms of this agreement a number of financial problems have already been solved. The Ministry of Environment is showing great interest in the activities of IENE. Information on fragmentation is widely available.

• In Hungary a similar approach has been adopted. Here, the IENE has liaison officers employed at two ministries, 3 international organizations, 2 research institutes, 3 national environmental organizations and 4 consultancy agencies.

• In Italy an information system on defragmentation projects has been set up and a seminar organized to publicize the IENE initiative.

• In Russia the initiative has resulted in several meetings at which the problems associated with fragmentation were put to researchers, policy officials at the Transport ministry and administrators of natural areas. This has led to a wealth of debate. It has also already spawned concrete results along the circular road around Moscow, which is presently being reconstructed: besides facilities for pedestrians, passages for wildlife are also being implemented. One case involves the upsizing of a culvert for a small stream to a wide passageway approx. 2.5 metres high and 10 metres wide.

• In Slovenia a non-profit IENE organization has been set up by several individuals (Infra Ecolab Slovenia).

• In Switzerland there is now closer liaison between scientists, conservationists and the relevant ministries. A workshop was devoted to the issue of fragmentation at the international congress 'Nature for East and West' (Basel, 22-26 October, 1997).

One of the conclusions of the first assessment among the IENE-members is that measures to mitigate and/or compensate the losses and disturbance, caused by fragmentation are very scarcely implemented or planned (table 1).

Research?

The discipline of landscape ecology has already provided adequate scientific underpinning of the serious impact of roads and traffic on ecological values. This knowledge is contributing to recognition of the problem and to implementation of defragmentation measures. Prioritization and identification of the appropriate measures to take constantly calls for new understanding of the nature and scale of the problem. There is thus a need for further research into the impacts on specific animal species. In the Netherlands our institute has initiated a variety of studies on the influence of roads and traffic on specific faunal groups, as illustrated by the following examples. Reijnen (1995) has investigated the influence on breeding birds in meadows, woodland and heathland (Fig. 2). Marcel Huijser (contribution to this symposium) is currently researching the effects of traffic on the hedgehog. Vos and Chardon (1994) describe how amphibians are suffering high mortality rates as a result of the high density of roads in the Netherlands. Vos (1995) indicates that field-frog occupation of marshland pools in the Dutch province of Drenthe is highly correlated with road density within a 750-metre radius. Work has recently started on building up knowledge on the effects on species of road illumination. In anticipation of the results, guidelines have been drawn up for road illumination in nature reserves (CROW et al., 1997).

For the purposes of EIAs it is necessary to use this knowledge to make predictions regarding the impacts of a given intervention on the natural environment. Development of predictive models requires empirical knowledge, supplemented by the existing body of literature. As an example, the above study on the impact of traffic on bird-breeding density has been used to design a predictive method (Reijnen, Veenbaas & Foppen, 1995). Verboom (1994) has modelled the influence of roads on wildlife dispersal. For badgers a simulation model has been developed in which mortality data can be used and which describes the extinction chance of (local) populations. The survival time of a network population can be predicted for various kinds of roads, numbers of badger tunnels and length of fencing (Apeldoorn, 1997). Practical experience and further research will be needed to improve these and similar predictive methods, so that they can be used for optimizing the planning and implementation of appropriate measures.

There is currently widespread interest in the evaluation of measures already in place. In the first place, such evaluation is necessary to assess whether investments are justified. At the same time, though, it leads to further optimization of the approach: an improvement in available mitigating facilities and an increase in the number and/or (combinations of) types of measure. In Switzerland the main focus of evaluative studies on fragmentation is on ecoducts, in Germany on provisions for amphibians, in Spain on co-use of large, now-dry culverts, and in the Netherlands on badger tunnels, wet underpasses and modification of existing engineerng works. These studies are geared mainly to utilization of passageways, with little consideration being given to the question of whether populations are being preserved. Only for the badger can certain conclusions be drawn in this respect (Bekker & Canters, 1997). The issue of utilization of the various provisions is considered below in the descriptions of the individual measures.

Defragmentation Measures

Strategy

In many European countries the first defragmentation measures to be taken were the result of confrontations between conservationists and planners, road designers or adminstrators. In the Netherlands it started out with a single badger tunnel installed under a new road, and proceeded via provisions implemented on existing roads until there was general acceptance that such measures are the responsibility of the road administrator. Where possible this is, or is being, incorporated in the appropriate procedures, in directives and in management plans (Bekker, 1997). The overall strategy can be summed up in the following four coherent activities: **prevention, mitigation, compensation and management.**

Prevention is very important in situations of building motorways, see the European TEN approach.

In the context of a great amount of existing motorways it is very important for mitigation that proper priorities be set. By way of illustration, the strategy adopted for alleviating the impacts of highways in the Netherlands is first described and then elaborated with reference to an example.

National

The Directorate-General of Public Works and Water Management, part of the Ministry of Transport, Public Works and Water Management, is working on implementation of relevant national policy (Rijkswaterstaat, 1992), as laid down in the government's Nature Policy Plan (LNV, 1990). Bottlenecks associated with the Ecological Main Structure (EMS) and problems affecting priority species are being given first priority. All sites where the EMS is intersected by a national highway are being treated as priority bottlenecks. Priority is also being given to projects that dovetail with integrated plans already drawn up by national, provincial and municipal authorities and water boards. Measures on national highways are particularly effective when measures have likewise been implemented on the subsidiary road grid and regeneration and protection of the surrounding countryside are also being tackled. High numbers of animal traffic casualties may also constitute a motive for priority action. It goes without saying that the safety of motorists may also prompt action. In Scandinavia, for example, this is a major factor. In Sweden over 50% of traffic accidents are due to collisions with moose, red deer, reindeer or roe deer (pers. comm. Folkeson, Sweden).

Regional

In order to fulfill its responsibilities under the terms of the Second Transport Structure Plan, the ministry's regional directorate for Gelderland has inventoried the bottlenecks in this province (Rijkswaterstaat directive Gelderland/Heidemij Advies, 1994). The following six-step aproach has been adopted to mitigate the effect:

1. selection of relevant animal species, based on two criteria:

- the species must occur in Gelderland and be vulnerable to fragmentation, and
- there must be measures available to eliminate road-related bottlenecks;

2. break-down of the national highway network into sections (Fig. 3);

3. description of these sections in terms of status (whether or not part of the EMS), characteristic ecotope of the area (stream, large-scale natural area) and present occurrence of the animal species selected under 1;

4. assignment of a score to the value of each section in the area in question; this score determines the ecological ranking of the bottlenecks (Fig. 4);

5. using a standard review of mitigating measures with their associated price tag, initial, approximate selection of mitigating measures (Fig. 5); this step proceeds from the following guidelines:

- small wildlife tunnels (diameter > 0.40 m): 1 per km in large-scale natural areas, otherwise 1 per 5 km;
- amphibian tunnels: in high-population areas 1 per km, elsewhere 1 per 5 km;
- roe-deer passages: 1 per 5 to 10 km;
- badger tunnels (diameter > 0.30 m): for local migration 1 per 200-250 m, for dispersion 1 per 1 to 5 km;
- ecoducts: at least 1 in each large-scale natural area;
- adaptation of existing engineering works: where feasible from an engineering angle and ecologically desirable;

6. establishing priority measures for each road section, based on ecological status of the bottleneck, costs and practical feasibility (preparation time, links with existing plans and anticipated effectiveness).

Around the Veluwe natural area, part of which is a national park, this approach has led to a list of 114 scheduled measures, 41 of which have been given priority. In terms of finance, a budget of approximately 45 million guilders is required for all these measures and 23 million guilders for the priority measures.

Types of Measure

Table 2 reviews the range of measures utilized in the Netherlands. Know-how on these measures, as applied in this country, has been brought together in a manual (DWW et al., 1995). A distinction can be made between dedicated provisions created specifically for wildlife and measures on existing engineering works having some other primary function. Such co-use of modified engineering works means a substantial increase in corridor potential, since highways have a large number of intersections with watercourses and local roads (Bekker, 1989).

Specific Fauna Passages

Ecoducts

An ecoduct is a viaduct designed specifically to serve as a wildlife corridor by joining landscape elements on either side of the road. Ecoducts were first introduced by French game-hunters, at sites where the migratory routes of game species were intersected. These passages, which are often parabolic in shape, are generally 8 to 12 metres wide at their narrowest. In the Netherlands 50-metre-wide ecoducts were later constructed and in Switzerland even as wide as 140 and 200 metres; subsequently, 15-20 metre ecoducts were built in these countries. In Germany 35-metre ecoducts have been constructed and in Hungary two 20-metre ecoducts.

Although it is known that all ecoducts are used by wildlife, the degree of utilization is still unclear. Use by several individuals does not mean that an ecoduct is an effective means of guaranteeing the survival of an entire population. Population studies and long-term site-usage studies are required to pronounce on this issue. Keller & Pfister (1997) have investigated ecoduct usage. They conducted a field study at 5 ecoducts in Germany, focusing on mammals and ground beetles and grasshoppers and at 4 ecoducts in France, focusing on use by spiders. They supplemented their findings by making video recordings of springtime mammal movements across ecoducts in France, Germany, the Netherlands and Switzerland. Their aim was "to evaluate the effectiveness of wildlife overpasses for conservation in general and as corridors in particular". They conclude that ecoducts are an effective measure to mitigate the effects of habitat fragmentation by roads. The width of an ecoduct appears to be crucial for its effectiveness. Narrow ecoducts are associated with fewer wildlife movements and animals that do use them do so with greater haste. For certain species, a wide ecoduct functions as (part of) their habitat. In its design, an ecoduct should reflect the variation occurring in the surrounding area so as to provide appropriate opportunities for local species. There should be open space as well as cover, dry as well as wet patches, and sunny as well as shady places. If the specific focus is on woodland species, then it is desirable for the woodland to connect up with the ecoduct, on which there should also be a woodland climate. In addition, it has been demonstrated that corridors from core areas to an ecoduct are of major importance for protecting the status of specific species. In summary, an ecoduct is not an isolated engineering work but a link in a coherent landscape. (See Fig. 6)

Large Wildlife Tunnels

Many large wildlife tunnels were not specifically constructed or designed with a view to providing corridors for deer. In the Netherlands, a flat country with most of the roads on the same level as the surrounding landscape, there is currently debate as to whether certain such provisions should be created, given the fact that an ecoduct costing the same may possibly constitute a more effective measure.

If such tunnels are opted for, their dimensions depend on the animal chosen as target species. Although roe-deer are not under threat in the Netherlands, they constitute a good target species. Roe-deer are found virtually nationwide, as well as throughout Western Europe, and there is extensive information on the species. When it comes to design specifications, these animals are critical. A passage that is suitable for roe-deer will be suitable for a wide range of other species, too. Roe-deer are, moreover, of interest to broad sections of the population: conservationists, hunters and the public at large. Lastly, roe-deer are also a significant factor for motorist safety.

For roe-deer, the rule of thumb is that tunnel height times width divided by length should exceed 0.75. For other species such as red deer or moose, this rule will obviously be different. The rule of thumb is based on the results of studies in Germany (Olbrich, 1984), Denmark, France and the Netherlands.

This study by Olbrich investigated 824 tunnels in Germany, with consideration being given, inter alia, to their use by large game species. Here, too, it was found that the ratio between tunnel cross-section and length was of crucial importance.

Small Wildlife Tunnels

In the Netherlands many culverts with a diameter of 0.30 - 0.40 m have been installed for use by badgers. In this country the badger is a protected species that is under serious threat of extinction; the main cause of mortality is road traffic (20 - 25%). This formed the motive for creating such tunnels (Bekker & Canters, 1997). If they are to achieve their function, these tunnels must be complemented by fences and other structures to serve as guides ('funnels'). These tunnels are well-used, even though management of the associated provisions forms a vulnerable element (Janssen, 1995). They are also used by many other animal species (Derckx, 1986).

In Scotland and England several tunnels have been constructed specifically for otters (Bekker, 1987). Besides size, location is also important in this case, viz. at the site of shortest distance between two bodies of water.

In Germany many amphibian tunnels have been created and much research has been conducted on their design, including 'funnel' provisions (Vos & Chardon, 1994). These tunnels should have a large diameter: 100 cm or more, depending on their length. For all these tunnels it holds that they should link up well with their surroundings, that 'funneling' screens or fencing improve the degree of utilization and that their base should be covered with a moist substrate. There are three types of amphibian tunnels, 'ranaduct' (Müller & Berthoud, 1996) or 'bufoduct':

- a tunnel that can be used in both directions;
- two adjacent tunnels, each of which can be used in one direction only;
- as above, but with a concrete cully at the tunnel entrance for 'compulsory funneling' to the entrance.

The last of these designs is found to work very well. Carsignol (1985) describes its use on a local road in Kruth-Wildenstein, in France. In Germany 70% of amphibians are found to make use of such passages if they are appropriately constructed and located (Verkehrsministerium Baden-Württemberg, 1991). Nonetheless, larger tunnels permitting two-way passage are to be preferred, as these are not associated with 'compulsory funneling', which is of importance for species for which the tunnels are not primarily intended.

Adapted Engineering Works

Animals always make some use of existing road-engineering works such as tunnels, viaducts and bridges. Usage is more frequent and appropriate for more species if the works have sufficient space for safe passage, if noise levels are reduced and if there is soilsubstrate and shelter available. If these conditions have not been met, fulfillment thereof represents an attractive option (Bekker, 1989, Veenbaas & Brandjes, 1997). Obviously, the intended purpose of such works goes a long way to determine the scope for co-use by wildlife.

Underpasses: viaducts and tunnels

Viaducts and tunnels are used by a wide variety of species. Extra substrate cover and shelter encourages their use by small mammals; a wall of tree-stumps, surplus sewerpipe segments and/or soil are found to work effectively. This was demonstrated by Van der Linden (1997) under the Zandheuvel viaduct on highway A27, where a reserve lane originally intended as an additional lane on a local road has been modified with a tree-stump wall and vegetation. By studying tracks and using repeat-capture methods, it was demonstrated that the facility was used intensively by numerous small mammals. For some species it even constituted an extension of their habitat. Usage is enhanced (DWW et al., 1995) by removing hard surfaces such as tiles and clinkers, by providing protective screens, by sheltering stumps and by planting bushes (Fig. 7).

Overpasses: viaducts and bridges

Only occasionally have animals been observed to cross little-used viaducts and bridges. Modifications designed to promote such co-use, in the form of shielding or soil with vegetation have been implemented at several sites. A viaduct over highway A27, between Utrecht and Hilversum, has been modified with a 'soft shoulder' for fauna. The extent of utilization is not known. In France a study has been made of narrow zones of vegetation on a viaduct. As yet, little use appears to be made of the provision (SETRA, 1993).

Underpasses: bridges and culverts

In the Netherlands there are numerous places at which roads cross canals and ditches. In cases where the bank continues under the bridge, use of such passages has been observed (Bekker, 1989, Sips, 1994). If the road and bridge structure interrupts the bank, it will form a barrier for animal species requiring the bank for passage. The situation can be improved by installing uninterrupted banks and ledge walkways: 'fauna ledge' or 'catwalk' under bridges and in culverts (Fig. 8). The desired shape of the fauna ledges and the animal species using these provisions has been investigated at 20 sites by Brandjes and Veenbaas (in prep). For the purpose of this study into passageway use, a special track-recording method has been developed (Brandjes et al, in prep.). The tracks are recorded with the aid of track beds, preferably using silver sand, and ink pads containing carbon in liquid paraffin. The tracks of ground-dwelling animals are then transferred to paper. The major advantage is that tracks can be analysed and measured in the greatest detail and are, moreover, permanent so that they can validated later if necessary. Track analysis is supported with a census of passing animals using an infra-red detector designed specially for this research project. It has been found that many different species use these fauna ledges and continuous banks: rat, several mice, stoat, polecat, stone marten, amphibians as frog toad and salamander and the domestic cat. The extent of use is obviously dependent on the local environment and the species occurring there. The dimensions of the underpass, the location of the fauna ledge and the 'funneling' provisions to the underpass appear to be critical parameters.

Conclusions

Roads fragment natural areas. Although wide recognition of this problem is leading to implementation of defragmentation measures, expansion of the road grid is still creating new intersections with natural areas. However, research into impacts, development of new predictive methods and the implementation, development, evaluation and improvement of defragmentation measures are attracting the attention of a growing number of scientists, conservationists, civil engineers and, last but not least, politicians.

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Biographical Sketch

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Table 1
Current situation number defragmentation measures in Europe

Countries	measures	ecoduct & large wildlife tunnels	small fauna culvert	modified engineering works
Austria	-	-	-	-
Belgium	+	+	-	-
Estonia	-	-	-	-
Denmark	+	+	+	-
Finland	+	+	+	-
France	++	++	+	+
Hungary	+	+	+	+
Germany	++	++	+	+
Italy	-	-	-	-
Netherlands	++	+	++	++
Rumenia	-	-	-	-
Russia	+	-	-	+
Slovenia	-	-	-	-
Spain	+	+	-	+
Sweden	+	+	-	-
Switserland	++	++	-	-
United Kingdom	+	-	+	-

++ = high value, + = week value, - = lack of value

Table 2 *) Review of types of fauna passages on Dutch national highways

	amphibians	red deer boar	roe-deer	fox	martin	rabbit	mouse
specific fauna passages							
OVERPASSES							
ecoducts	+	+	+	+	+	+	+
UNDERPASSES							
amphibian tunnels	+			?	?	?	?
small wildlife tunnels	+			+	+	+	+
large wildlife tunnels	?		+	+	+	+	+
Modified engineering works							
VIADUCTS							
vegetation/cover on viaduct	?			?	+	?	+
TUNNELS							
modified design	+		+	+	+	?	+
BRIDGES							
with fauna ledge	+			?	+	?	+
with continuous bank	+			+	+	+	+
CULVERTS							
with fauna ledge	+			+	+	+	+

(shaded) = target group   + = used by species   ? = use not (yet) demonstrated

*) after Veenbaas & Brandjes, 1997

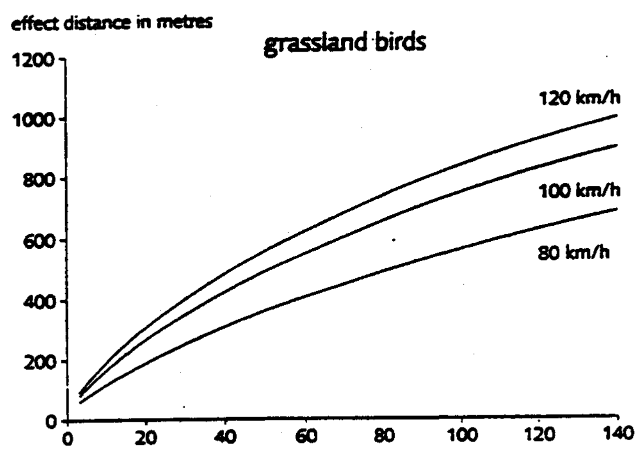


Figure 2

Figure 2.
Traffic intensity in motor vehicles per day x 1000.

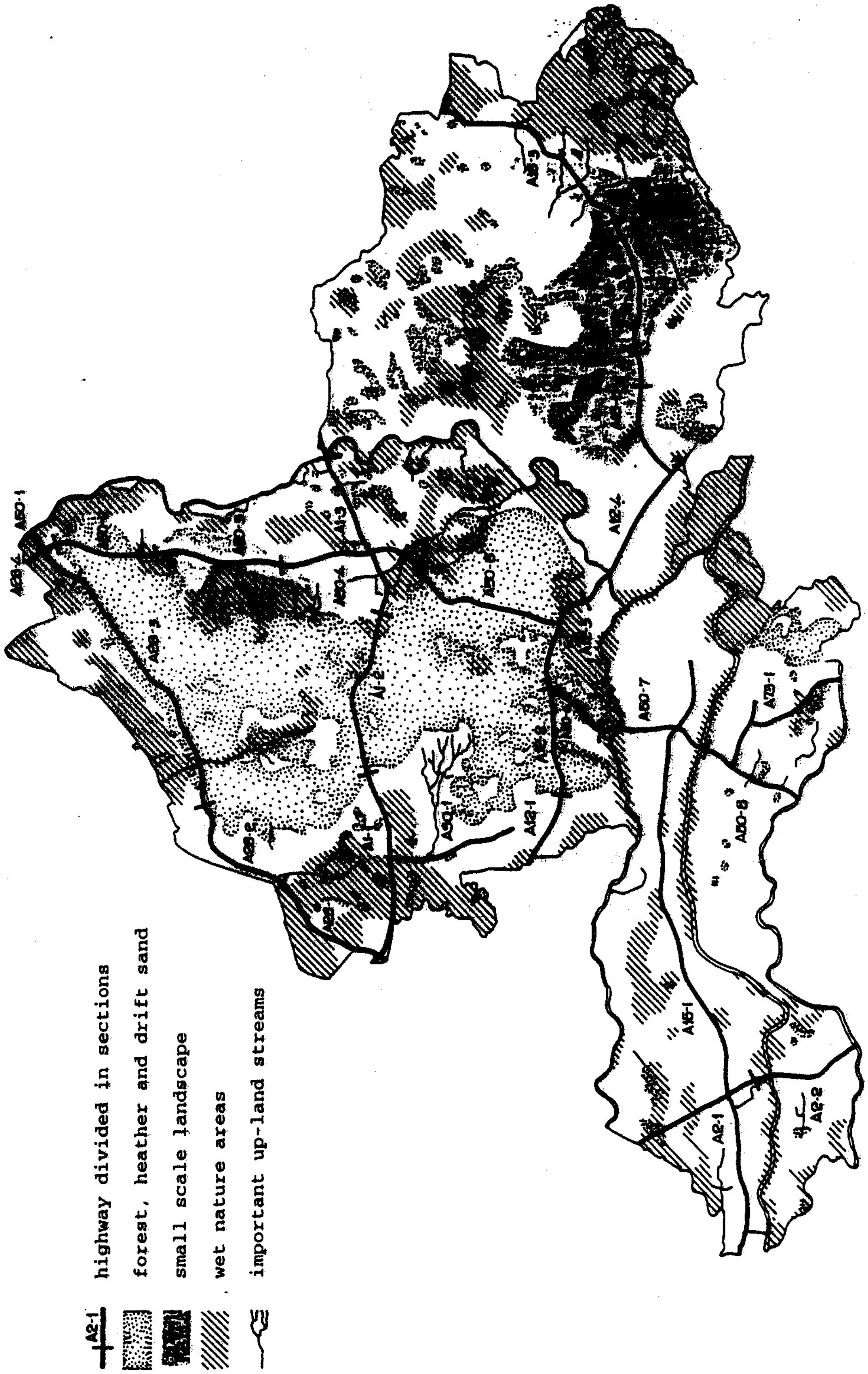


Figure 3.
Highway Sections.

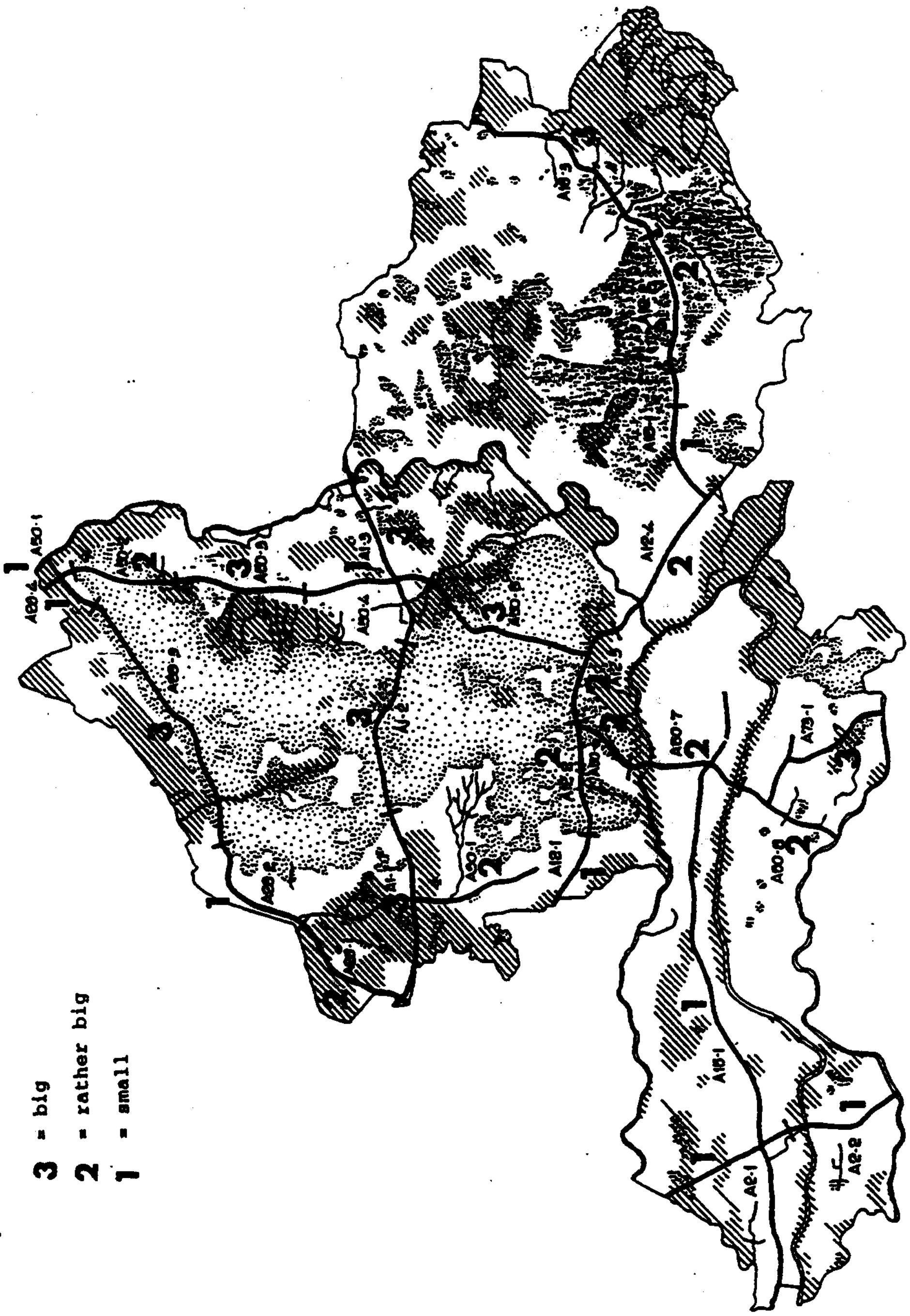


Figure 4.
Ranking Bottlenecks.

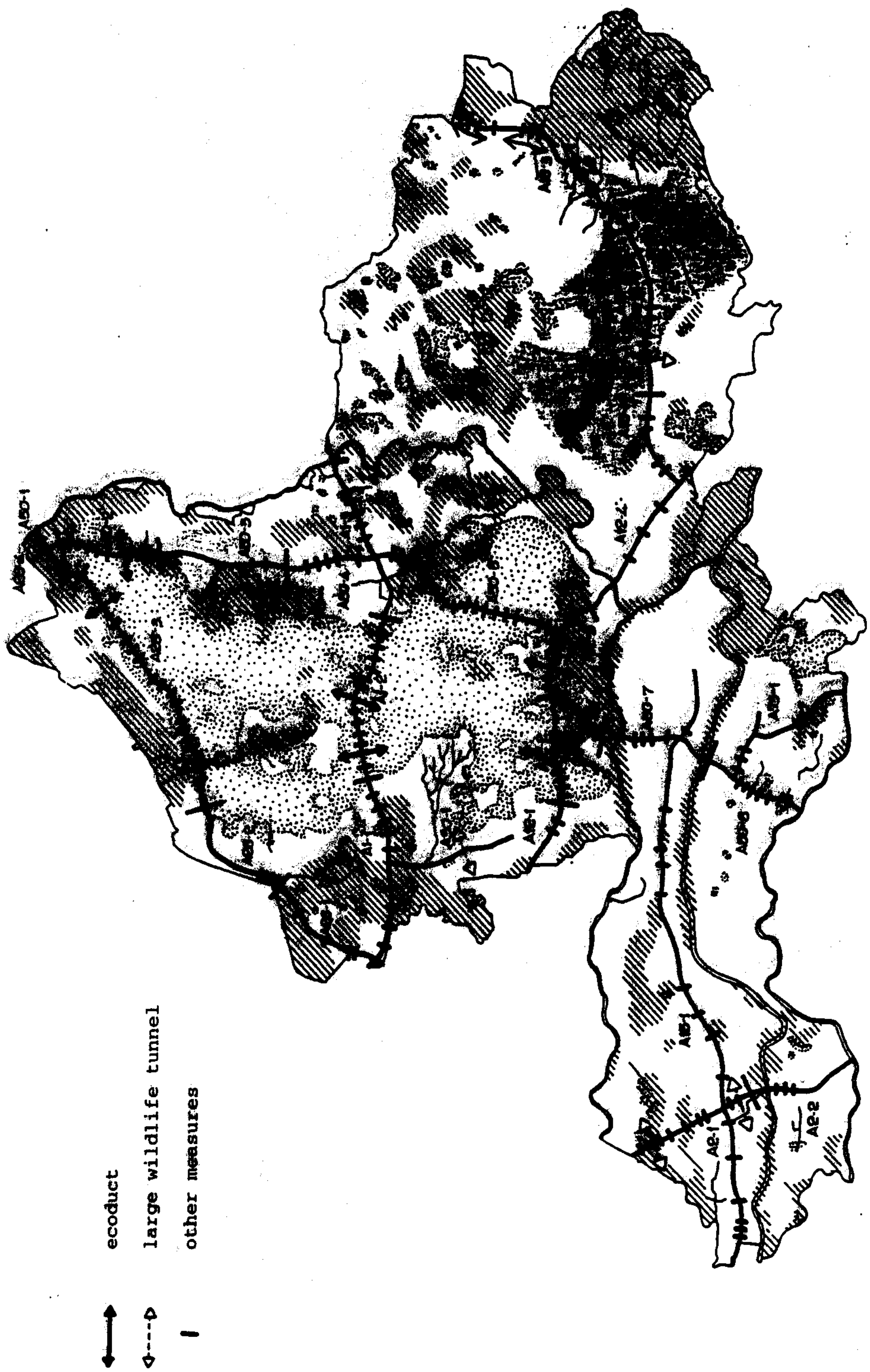


Figure 5.
Measure Locations.

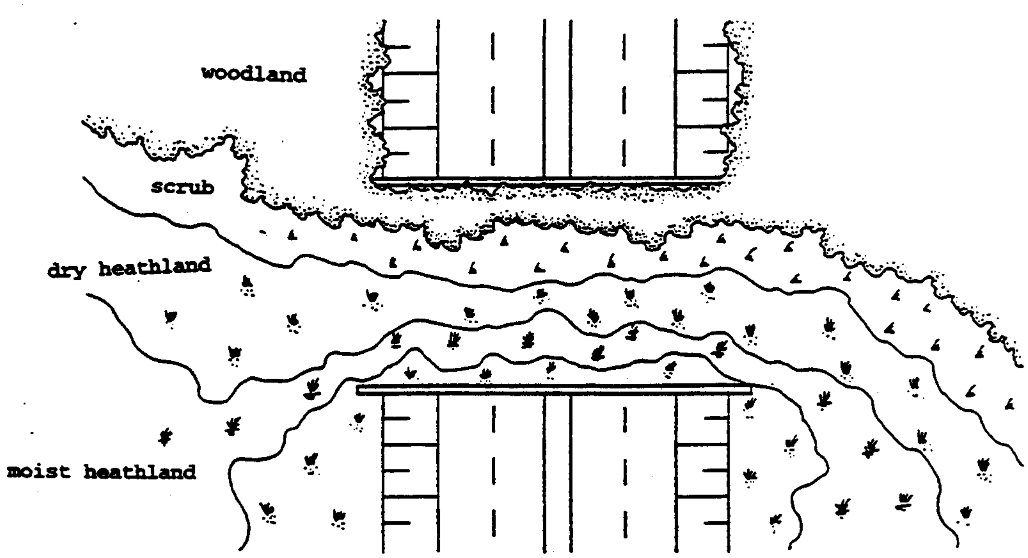
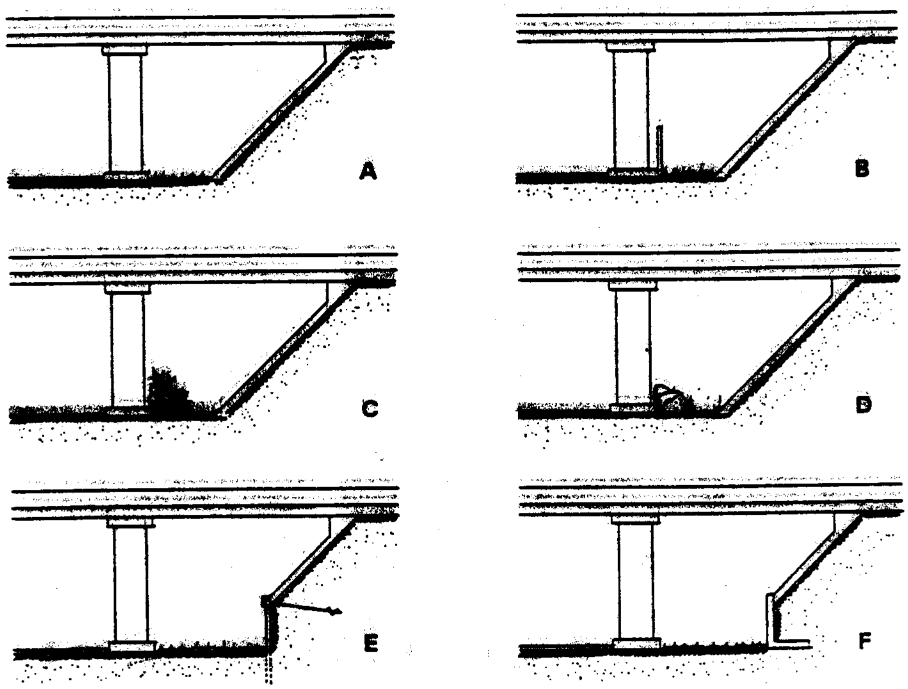
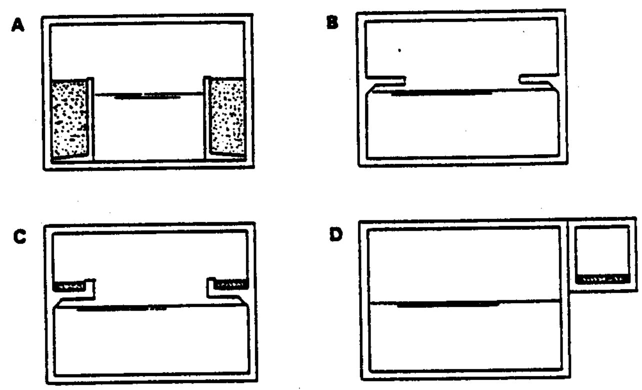


Figure 6.
Design of an ecoduct according to the 'ecotope approach', whereby the ecoduct connects the vegetations, structures and transitions occurring in its vicinity, making it suitable for numerous animal species.



Possibilities for creating a wildlife passage under a viaduct.
A: Soft shoulder
B: Soft shoulder with fence or screen
C: Soft shoulder with stump wall
D: Soft shoulder with boulders
E: Widened soft shoulder using sheetpiling/palisade
F: Widened soft shoulder using a breast wall

Figure 7.
Possibilities for creating a wildlife passage under a viaduct.



Possibilities for integrating a wildlife passage with large, newly installed culverts
A: Overdimensioning in combination with artificial soft banks for fauna
B: Integrated concrete fauna ledges
C: Integrated concrete fauna ledges with raised edges and soil cover
D: Creation of wildlife tunnel parallel to culvert

Figure 8.
Possibilities for integrating a wildlife passage with large newly installed culverts.