Influence of Transport Infrastructure on Nature

Warszawa - Poznań - Lublin 2007

General Directorate of National Roads and Motorways

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Edited by Bogdan Jackowiak

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Preface

The book *Influence of Transport Infrastructure on Nature* is a result of the International Scientific-Technical Conference that was organized on the initiative of the General Directorate of National Roads and Motorways, under the patronage of the Polish Ministry of Transport and Construction, on 13-15 September 2006 in Poznań (Poland). The conference was jointly organized by the Adam Mickiewicz University of Poznań, the Agricultural University of Krakow, and the PKP Polish Railway Lines Company.

About 110 participants from 18 European countries came to the conference. There were 31 oral presentations, concerned with the most important problems associated with the impact of transport infrastructure (roads and railways) on the natural environment. According to the principles presented at the beginning, the oral presentations, discussion, and the field session organized by the Wielkopolska Motorway Company, focused on effects of the infrastructure on the organisms that live in the wild (fauna and flora).

This book is aimed to present the most important problems discussed by the conference participants. It includes 25 reviews and original articles, reflecting the current knowledge of the basic areas of the intensively developing research into the influence of transport infrastructure on nature. The set of articles presented in this book is interesting for several reasons. First of all, because they are devoted to general problems, including methodological ones, depending to a large extent on the geographic location of the study area. On the other hand, several articles describe examples of concrete problems and how they can be solved.

A detailed introduction to the issues discussed in this book is provided by B. Iuell, who summarizes selected problems presented in the book *Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions*, which is the major product of the COST 341 project, implemented since 1998 in 16 European countries. In the next article, J. Box *et al.* explain the goals and guidelines for ecological impact assessment (EcIA), which is developed in the United Kingdom and assumes a wider and deeper consideration of biodiversity within the procedures of environmental impact assessment (EIA). G. Mikusiński *et al.* write in the same spirit in their article on a literature search for the species that because of their life history, resources, behavioural patterns, and sensitivity to human impact, are the most predisposed for assessment of the influence of transport infrastructure on biodiversity and ecological balance. The necessity to synchronize spatial planning with the assessments of effects of transport infrastructure on the natural environment is strongly emphasized by M. Stojan and B. Ostojić, on the example of Croatia, which is one of the most environmentally valuable countries in Europe. An article by B. Jackowiak *et al.* draws attention to the underestimated importance of vegetation in EIAs, and suggests what actions should to be taken at successive steps of the assessment, i.e. identification, environmental valorization, and assessment of the negative impact of the planned motorway, at the level of plant populations, communities, and landscapes. A similar approach is presented by J. Maćkowiak-Pandera, who compares several methodological proposals for an international methodological model applied at the level of landscape and biotopes. At the end of part I of this book, H. Bekker *et al.* present the results of the Long-Term Defragmentation Programme implemented in the Netherlands, evaluated during an international workshop that was held in that country.

The detailed, multifarious part II of the book starts with two articles on Collserola Park, located in the Barcelona Metropolitan Area. In the first paper, S. Cahill *et al.* draw attention to the specificity of habitat fragmentation, resulting from the development of transport infrastructure in the strongly urbanized area. The second paper (by A. Tenés *et al.*) presents results of 15-year monitoring of wildlife roadkills in that area. Habitat fragmentation and animal mortality on roads are also the main subjects of the article by V. Hlaváč and P. Anděl. They show that in the Czech Republic the extent of these phenomena is remarkable. Those authors also emphasize the necessity to implement the currently prepared plan of restoring migration corridors for all the species that are sensitive to habitat fragmentation. The case of the Greek motorway Via Egnatia, presented in the next article, shows that interventions are sometimes necessary even at the final stage of road investments, if an environmentally important solution needs to be introduced (L. Georgiadis *et al.*).

The next four articles focus on remedial measures and monitoring. First, B. Iuell and O. Strand describe the course of large-scale modern monitoring aimed at analysing the influence of road traffic on reindeer in areas along motorway Hw7 in Norway. Next, R. Tilmans discusses problems associated with the control of effectiveness of the mitigation measures applied in the case of a threat to bats, posed by the building of two roads in the Netherlands. The following article presents results of an assessment of effectiveness of the mitigation measures applied to alleviate the negative effects of transport infrastructure on the environment in Germany (U. Tegethof). This group of papers is closed by a short communication by N. Bajo and A. Di Noi, who inform about efforts undertaken in Italy to develop guidelines for sustainable urban planning and actions alleviating the effects of habitat fragmentation by linear infrastructure.

In the specialist literature, the impact of railway transport is considered less often. In this book it is discussed in four articles. M. Buszko-Briggs and P. Pawlaczyk, on the basis of original research, present results and conclusions on effects of modernization of railway lines on the Natura 2000 network in Poland, while R. Kurek summarize the results of research on protection of wild animals and migration corridors along a section of a major railway line (E20, Moscow-Warsaw-Berlin-Paris). The issue of deterring the animals that cross railway lines is discussed theoretically by S. Kossak, and practically by M. Stolarski. Those two articles together form a self-contained whole and are particularly noteworthy, because they present prototypical equipment for deterring wildlife (UOZ-1).

The last six articles are focused on crossing structures for wildlife. P. Skriabine and J. Carsignol present results of over 40-year experiences in the use of wildlife passages in France, and emphasize the importance of their proper management and application of monitoring equipment. B. Georgii *et al.* write about the use of wildlife crossing structures by medium-sized and large mammals in northern Germany. A. Wysokowski *et al.* describe the general principles of construction of such crossings as well as advantages of various structures. J. Curzydło and J. Konopka show that only well-planned and well-built crossing structures can help to join the separated habitats and populations of animals. The specificity of crossing structures for amphibians, as well as difficulties and possibilities of their effective use are discussed by G. Smit *et al.* on the basis of Dutch investigations, and by J. Curzydło on the basis of experiences from southern Poland.

The recapitulation at the end of the book presents more general conclusions, resulting from discussions held during the conference. Apparently at least some of them can become subjects of further analyses and debates.

On behalf of authors and myself, I would like to express our gratitude to the General Directorate of National Roads and Motorways for initiation of this very interesting meeting, and to the CE2 Education Centre in Lublin, for coordinating the conference and a substantial contribution to preparation of this book for publication. We thank also all sponsors as well as all people and institutions involved in organizing the conference.

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Wildlife and traffic

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Abstract. Habitat fragmentation, the splitting of natural habitats and ecosystems into smaller and more isolated patches, is recognised as one of the most important global threats to the conservation of biological diversity. Habitat fragmentation is mainly a result of changes in land use, but a major impact also results from the barrier effect caused by the construction and use of linear infrastructure of transportation systems.

The project COST 341 *Habitat fragmentation due to transportation infrastructure* started in 1998, and 16 countries were officially involved in the initiative. The project produced a *European review* on habitat fragmentation on a European level, built upon national reports from the participating countries. The project found a strong awareness of the problem throughout Europe and that a diversity of solutions to the problem had been tried out. However, there was still a need for yet a systematically approach, retrofitting existing infrastructure where necessary, and integrating concerns on fragmentation in the planning of new ones.

The most important outcome of the COST 341 Action was the handbook *Wildlife and traffic – A European handbook for identifying conflicts and designing solutions*. It's a solution-orientated handbook, based upon the accumulated knowledge of a broad range of experts from the participating countries and from numerous international contacts. It gives practical guidance to the various actors involved in the planning, construction or maintenance of transportation infrastructures, on how to avoid, minimise, mitigate or compensate habitat fragmentation.

This paper presents the major findings of the European review and an overview of the contents of the handbook.

Key words: Handbook, infrastructure, wildlife, barrier, fragmentation, habitat

1. Introduction

1.1. The Problem

The consequences for wildlife of constructing transport infrastructure include traffic mortality, habitat loss and degradation, pollution, altered microclimate and hydrological conditions, and disturbance caused by increased human activity in adjacent areas. In addition, roads, railways and waterways impose movement barriers to many animals, barriers that can isolate populations and lead to long-term population declines.

Habitat fragmentation, the splitting of natural habitats and ecosystems into smaller and more isolated patches, is recognised as one of the most severe threats to the conservation of biological diversity globally. Fragmentation of habitats is mainly the result of different forms of land use change. The construction and use of transport infrastructure is one of the major agents causing this change as well as creating barriers between habitat patches (Fig. 1).

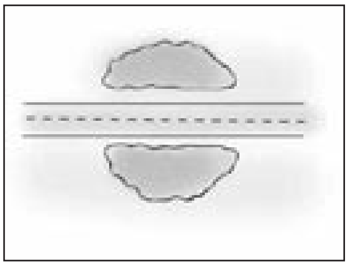

Fig. 1. A road fragmenting natural habitats

As transport systems have grown denser, their impact on fragmentation has increased (Fig. 2). The steadily growing number of animal casualties on roads and railways is a well-documented indicator of this problem. Barriers causing habitat fragmentation have on the other side, a long-term effect that are not that easy to detect.

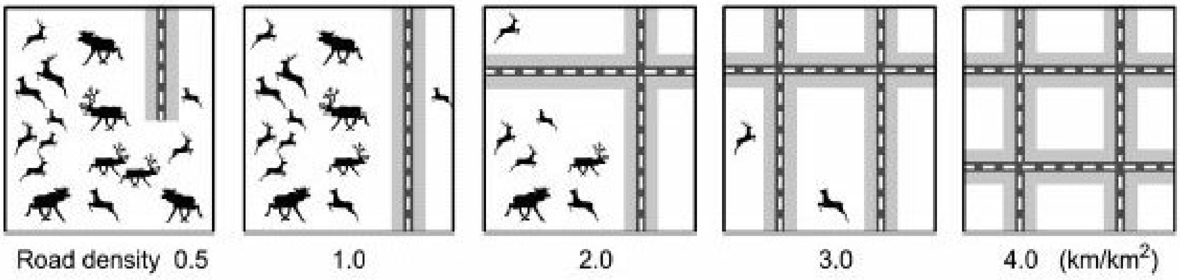

Fig. 2. Loss and degradation of habitat by infrastructure

Infrastructure causes a loss and degradation of habitat due to disturbance effects (grey corridors) and isolation. With increasing infrastructure density, areas of undisturbed habitat (white) are reduced in size and become inaccessible. Remnant fragments of suitable habitat may eventually become too small and isolated to prevent local populations from going extinct. The critical threshold in road density is species-specific, but will also depend on landscape and infrastructure characteristics. From Trocme *et al.* (2003).

Mitigation of these adverse effects on wildlife to obtain an ecologically sustainable transport infrastructure needs a holistic approach that integrates both the social and ecological factors operating across the landscape. Hence, one of the challenges for ecologists, road-planners and engineers is to develop adequate tools for the assessment, prevention and mitigation of the impacts of infrastructure. The task of the COST 341 Action was to address the issues associated with *Habitat fragmentation due to transportation infrastructure*. (COST is an intergovernmental framework for European Co-operation in the field of Scientific and Technical Research, allowing the co-ordination of nationally funded research on a European level. COST Actions cover basic and pre-competitive research as well as activities of public utility).

1.2. COST 341 Habitat fragmentation due to transportation infrastructure

In 1996 representatives from nearly 20 European countries in the **I**nfra **E**co **N**etwork **E**urope (IENE) underlined the need for co-operation and exchange of information in the field of habitat fragmentation caused by infrastructure at a European level. IENE also recognised the need of support at a European governmental level. This led to the development of COST 341 *Habitat fragmentation due to transportation infrastructure*, starting up in 1998.

16 countries (Austria, Belgium, Cyprus, The Czech Republic, Denmark, France, Hungary, Norway, Portugal, Romania, Spain, Sweden, Switzerland, The Netherlands, The Republic of Ireland, United Kingdom), and one NGO (The European Centre for Nature Conservation, ECNC) signed the *Memorandum of Understanding* and participated in the action.

The COST 341 Action had two major goals. *First*, to produce a State-of-the-Art report, describing the European situation and the main future challenges. *Second*, to develop a handbook presenting all known measures for how to avoid, minimise or mitigate the barrier effects caused by transportation infrastructure.

As a tool for distributing existing knowledge about habitat fragmentation, an on-line database was established. The *COST 341 Database* offers information about ongoing projects and project results, data on existing literature, and description of different measures. It is accessible through the IENE web-site (www.iene.info).

2. The European review

The European Review (Trocmé *et al.* 2003) describes the State-of-the-Art for Europe, and underlines the importance of taking habitat fragmentation into consideration in all stages of the development of transportation networks (planning, designing, constructing and maintaining the network). The review was built upon national reports from the participating countries, and most of these national reports were published separately in the countries themselves.

Throughout Europe the process of addressing the impact of habitat fragmentation due to transportation infrastructure is still in its infancy. Nevertheless, it is also clear that positive progress has been made in tackling the negative effects. Valuable experiences can be learned from densely populated and intensively developed countries like The Netherlands, where the problems of habitat fragmentation have long been recognised. Many other European countries have also developed national programmes of research into the effects of infrastructure on biodiversity, the findings from which must be used to inform the planning and design procedures for new infrastructure. But there is still a long way to go before ecological tools are fully developed and implemented in transportation planning.

Major findings

Habitat fragmentation was recognised as one of the most significant factors which contributes towards the decline of biodiversity in Europe, and should thus be a major concern for society. Transportation infrastructure is often considered to be a principal cause of fragmentation.

In general, species with large area requirements or strong dependence on a specific type of habitat will be most vulnerable to habitat fragmentation. Unfortunately, these are quite often the species that are of greatest conservation concern *e.g.* wild reindeer in Norway, badgers in the Netherlands, or the Iberian lynx in Spain.

In summarising the experiences of the COST 341 countries, the following principles and recommendations should act as guidelines for dealing with the issue of fragmentation of natural habitats by transportation infrastructure in the future:

Habitat connectivity is a vital property of landscapes, especially important for sustaining animal movement across the landscape. It should be a strategic goal in the environmental policy of the transport sector and infrastructure planning should be focused on the landscape scale.

- European and national nature protection legislation needs to be integrated in the planning process at the earliest possible stage. Only an interdisciplinary approach involving planners, economists, engineers, ecologists, landscape architects etc., can provide all the necessary tools for addressing fragmentation successfully. The approaches need to be integrated at all levels of the transportation network.
- Because of the complexity and widespread nature of the problem, an ongoing exchange of knowledge between countries is vital. A systematic and uniform approach to collecting information on mitigation techniques and measures is necessary if statistics are to be compared between countries.

- The disturbance effect created by infrastructure needs to be more widely studied and mitigated for so as to minimise habitat degradation adjacent to infrastructure.
- Mitigation measures such as fauna underpasses and overpasses have a proven record of success. However, mitigation should not only focus on the more prestigious passages for large animals. Much can also be done, at relatively low cost, to increase the permeability of the existing and future transportation infrastructure by adapting the design of engineering structures to wildlife.
- Monitoring programmes to establish the effectiveness of mitigation measures are essential and need to be standardised. The cost of monitoring programmes should be included in the overall budget for new infrastructure schemes.
- The fragmentation of natural habitats by transportation infrastructure is a problem which cannot be solved without an acceptance of the issue at a policy level, or without interdisciplinary co-ordination and co-operation at scientific and technical levels. Public involvement is also essential, to ensure the success of the chosen solutions.

3. The handbook

The main topic of the handbook *Wildlife and Traffic – a European handbook for identifying conflicts and designing solutions* (Iuell *et al*. 2003), is to minimize ecological barriers and fragmentation effects of transportation infrastructure. The primary target groups for the handbook are those involved in the planning, design, construction and maintenance of infrastructure, as well as decision makers at the national, regional and local levels.

The barrier- and fragmentation effects of infrastructure can be minimised during several phases of development and use, and even avoided if considered in the early phases of planning. The handbook takes the reader chapter-by-chapter through all the different phases, from the first steps of strategic planning, through the integration of roads in the landscape, the use of mitigation measures such as over- and underpasses for different animals, the more unknown field of compensatory measures, and to the use of different methods of monitoring and evaluation of the chosen solutions.

3.1. Roads, railways and waterways

As the title of the handbook indicates, the solutions and measures described in the handbook are designed to deal with different kinds of transportations systems, not only roads. Railways can also have a huge impact on nature and create barriers even though rail networks and traffic are far less dense than roads. In several European countries there is a massive network of waterways used for transportation, using both natural rivers and man-made canals. These can also create barriers for wildlife. Nevertheless, it is the road network and its traffic that constitute the major pressure on wildlife, and most of the examples and the measures explained in the handbook are related to roads. Many of the road related measures are, however, equally suitable for reducing the impact of railways.

3.2. New and existing networks

While habitat fragmentation is increasingly taken into account when new infrastructure is planned, there remain many existing stretches of roads and railway lines where mitigation measures are badly needed. This need often increases when new infrastructure is built, which may result in changing the ecological impact of existing infrastructure. When designing measures to counteract habitat fragmentation, the focus should, therefore, be on the impact of the infrastructure network as a whole. In several European countries de-fragmentation programmes have been established with the aim to restore the ecological infrastructure on the national or regional levels.

3.3. The European approach

The handbook is produced to cover the many different circumstances found across Europe. There are important differences between the countries regarding cultural, political and scientific contexts of transport infrastructure development at local, regional and national levels. A good solution in one country may be less effective or less suitable in another. Therefore, one of the big challenges in the production of the handbook was to deal with all these differences.

Mitigation of habitat fragmentation due to transportation infrastructure is a relatively new field of knowledge, combining engineering and ecology. The way infrastructure is placed in the landscape can be of great importance for wildlife. The handbook describes various aspects that should be considered both in the planning of transport corridors and the integration of the infrastructure in the landscape. Emphasis is placed on the building of fauna passages, like over- and underpasses, pipes, culverts and bridges for several different species.

The design of fauna passages and other mitigation measures used differs between countries, partly due to different traditions, and partly due to different physical and ecological contexts. As a result, there are few general formal standards for the design, construction and maintenance of mitigation measures in Europe. To date, only a small number of evaluations of mitigation measures have been carried out and further work that includes studies of effects of measures at the population level is needed. Based on experience and the evaluation of alternative structures, designs can be improved and eventually standards can be formulated. The ongoing exchange of knowledge and experience across Europe and beyond is necessary to develop these new standards.

With this as a background, it is important to underline that there are no 100% correct solutions. The advice provided in the handbook is based upon the accumulated experiences of the participating experts and the results of projects worldwide. It remains necessary to adapt and adjust measures to the geographical context, as well as to the specific needs and possibilities of the location. The handbook is, therefore, no substitute for the advice of local experts such as ecologists, planners and engineers and should be used in conjunction with their advice.

4. Integrated solutions

The barrier- and fragmentation effects of infrastructure can be eliminated or minimised in different ways and during several phases of its development and use. If the 'right decisions' are taken in the early phases of planning, fragmentation problems can be completely avoided. The barrier effect can be reduced by integrating the infrastructure into the surrounding landscape, or by building secure and sufficient crossing points for wildlife. Also during use and maintenance of existing infrastructure, consideration should focus on how to reduce the barrier effect of infrastructure and how to de-fragment landscapes.

The best practice approach promoted by the handbook for planning new or upgrading existing transport infrastructure adopts the following principles for coping with the threat of habitat fragmentation.

1. avoidance > 2. minimisation > 3. mitigation > 4. compensation

The basic philosophy is that prevention is better than cure in avoiding the negative effects of habitat fragmentation. Where avoidance is impossible or impractical, mitigation measures should be designed as an integral part of the scheme. Where mitigation is insufficient or significant residual impacts remain, the compensatory measures should be considered, but only as a last resort.

Within this system, two of the key questions to address are *when* measures are needed, and *what* are the criteria for success. This approach forces infrastructure planning to look outside the normal bounds of the transport corridor, and to examine the development of the whole infrastructure network and wider land use issues including national and international spatial planning strategies. Measures within the infrastructure corridor must include a consideration of the adjacent land use, and also planned development as this may severely reduce the efficacy of any mitigation or compensatory measures.

Finding integrated solutions to road planning requires information on how to plan the routes of transportation infrastructure to minimise impacts within the constraints of cost and engineering. Assessment of new infrastructure will increasingly focus on integrated solutions attempting to find the route and design producing the least impact and greatest benefit to the greatest number of interests. The integration process is especially difficult in geographic areas where the competition for space is very high such as narrow valleys, coastal strips etc. Such areas, already under pressure from housing, farming and natural drainage, are fragmented into linear strips by road and railway development with negative impacts on most interests.

5. Planning tools

Minimising habitat fragmentation should be done when planning new infrastructure or when planning upgrading of existing infrastructure. By carrying out a Strategic Environmental Assessments (SEA) on programmes and Environmental Impact Assessments (EIA) on projects it is ensured that environmental considerations are included already at an early stage. The overall aim of the SEA and the EIA is to identify possible environmental impacts of plans and projects before a decision about implementation is made.

Fragmentation issues in relation to existing infrastructure are somewhat different. For a great part of the existing infrastructure, mitigation measures may not have been taken into consideration at the time they were planned and designed. In these situations, the fragmentation brought about by the existing infrastructure may most likely already have affected the area, and other sources of fragmentation, unforeseen at the time of the study, could have appeared. Any environmental studies that may originally have been made may also be outdated, why new evaluation is necessary.

As pointed out in the handbook, the definition of the study area is crucial for a meaningful study of fragmentation issues, and in many cases it is necessary to evaluate the potential impact in a regional context. The handbook also describes different data and methods that can be used in the planning process, and how to define conflict points between ecological infrastructure and man made infrastructure for transportation.

6. Adapting to surrounding landscape

When the decision is taken to build new highways, railways or waterways, it is still possible to minimise the barrier effect and thus fragmentation by adaptation of the infrastructure to the adjacent landscape and ecology.

The construction of new infrastructure can have an impact on the biological diversity in a number of ways:

- Habitat loss and fragmentation of natural habitats.
- Changes to the water table and drainage patterns and systems.
- Physical barrier and visual intrusion due to: the infrastructure itself, large earthworks, embankments crossing valleys and low-lying land, cuttings which fragment habitats, junctions that form ‘wildlife traps’.

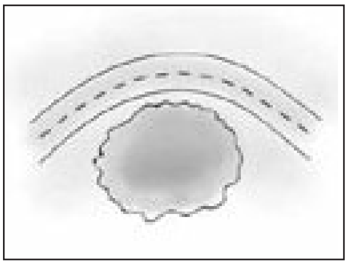

Fig. 3. Avoiding fragmentation by changing alignment

Good alignment and sensitive design can be employed to minimise the magnitude of these effects. Detailed advice is given in the handbook on how to:

- Choose a route which:
  - minimises the extent of habitat loss
  - avoids sites of nature conservation interest and, where possible, protects non-renewable resources (e.g. ancient woodland)
  - seeks to maintain habitat connectivity through the use of structures that 'carry the landscape over the infrastructure' or permit the landscape to 'flow under the infrastructure'(Fig.3).
- Design profiles which reflect the local topography.
- Aim to achieve the most sustainable use of excavated material i.e. create a balance of cut and fill material and minimize the need for off-site disposal.
- Ensure the new landform and its soil structure permits effective planting and/or restoration to an appropriate use.
- Planting design (pattern and species) should reflect the adjacent landscape – natural revegetation.
- Restore as much of the pre-existing pattern of field boundaries, woodland, heathland etc. as possible.

7. Mitigation measures

The most comprehensive chapter of the handbook describes individual technical measures designed to mitigate the negative effects of transportation infrastructure (Fig. 4). It includes landscape bridges, wildlife over- and underpasses, culverts and pipes for aquatic species, and several measures for reducing wildlife mortality. For each measure a general description is given, and important information on design and special attention points for that specific measure is added. Technical specifications such as the material to be used and technical design details are presented if they are of particular importance to ensure the functioning of the measure.

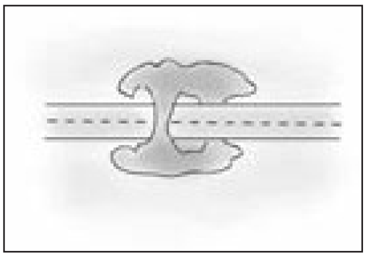

Fig. 4. Mitigating fragmentation effects

Some measures have been well tested and considerable experience has accumulated. Others are new and still being developed and tested. The amount of information presented for each measure reflects this disparity, but best practice according to current knowledge and experience is presented. This means that some recommendations may be different from those in existing handbooks, especially the earlier ones. In some cases, recommendations in a particular country may differ from the ones presented here because they take into account regional issues such as a specific climate or habitat.

Some measures that are still widely used have been shown not be effective. Such measures are mentioned in the handbook, but no design details are given, since their use is not recommended in future schemes.

7.1. Fauna passages as part of a general landscape permeability concept

Fauna passages and other structures adapted to increase the crossing of transportation infrastructure by animals should never be considered in isolation. They are part of a general 'permeability concept' to maintain the necessary contact within and between populations of animals. This concept emphasises the connectivity between habitats on at least a regional scale and considers not only the transportation infrastructure but the distribution of habitats and other potential barriers such as built-up areas. Fauna passages can then be regarded as small but important elements used to connect habitats by enhancing the movements of animals across a transportation infrastructure.

At a more specific level, a permeability concept can be produced for a particular road or railway project. All connecting elements, such as tunnels, viaducts or elevated roads, stream and river crossings, culverts, and passages designed specially for animals should be integrated in such a concept. Again, the primary objective must be to maintain the permeability of the transportation infrastructure for wildlife, to ensure the connectivity of the habitats at a larger scale.

Mitigation measures, and in particular fauna passages, are necessary if:

- A transportation infrastructure bisects important patches of habitat or creates barriers to migration.
- A road or railway line results in significant damage or loss of special habitats, communities or species.
- A road or railway line affects species particularly sensitive to barriers and traffic mortality.
- The general permeability of the landscape, i.e. the connectivity between habitats in the wider countryside, is significantly impaired by the infrastructure development.
- The road or railway line is fenced along its length.

The type of measure to be used, the location, the numbers, and how to make it effective, are all maters that will have to be dealt with in each specific project.

7.2. The choice of appropriate measures

Fauna passages and modifications to infrastructure that enhance the possibility of safe animal movements are the most important measures for mitigating habitat fragmentation at the level of a particular infrastructure (Fig. 5). The selection of the most appropriate type of fauna passage requires consideration of the landscape, habitats affected and target species. The importance of the habitats and species should be evaluated in a local, regional, national and international perspective as part of an EIA. In general, the more important habitat connectivity is to the species of concern, the more elaborate the mitigation measures have to be. Thus, where an internationally important corridor for movements of large mammals is cut by an infrastructure development, and this cannot be avoided, a large landscape bridge may be the only measure which may help to maintain functional connectivity. In contrast, a small culvert may be sufficient to maintain a migration corridor for a locally important population of amphibians. In practice, however, there is rarely just one measure required to effectively mitigate habitat fragmentation. Instead, a package of integrated measures is required that address problems at specific sites and for the infrastructure as a whole. A combination of diverse measures suitable for different groups of animals will often be the best solution.

It's essential that the purpose of the measures is clearly stated from the start. 'To maintain habitat connectivity' can be too general, it means different thing in different settings, and it is difficult to quantify. This is crucial both for the choice of measures, the numbers of measures and their location, and for the evaluation of the effectiveness of the measures afterwards.

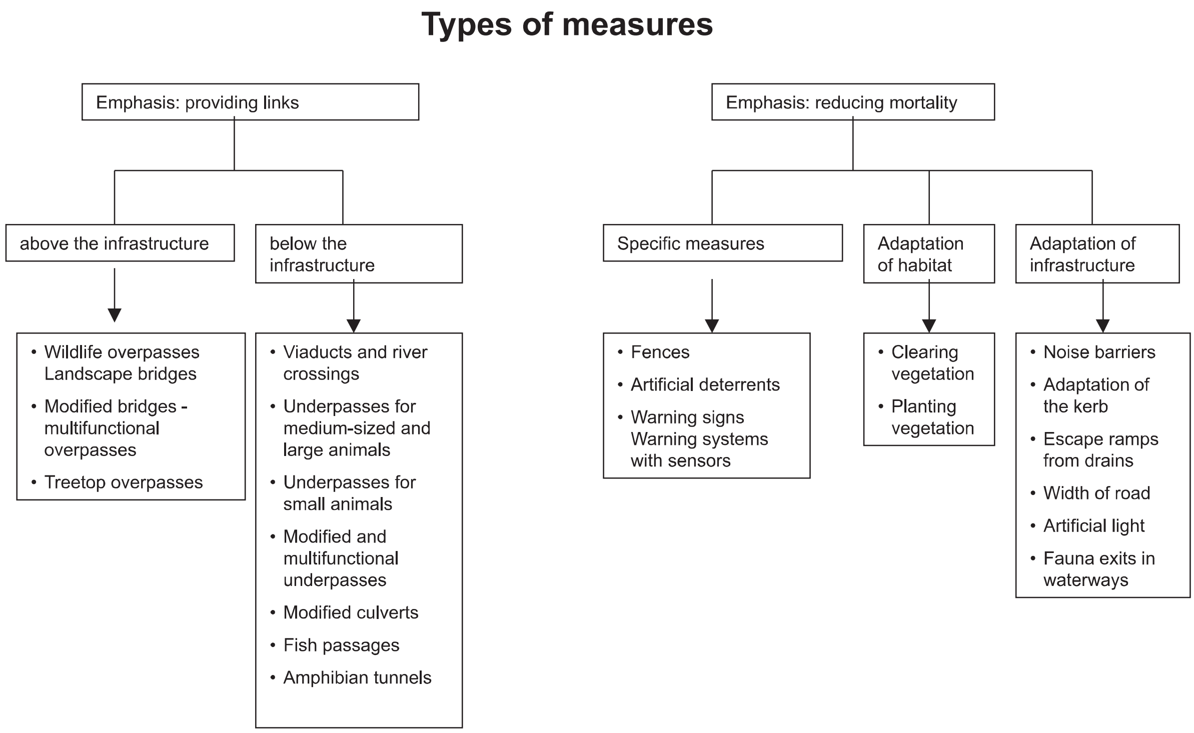

Fig. 5. Different types of measures to mitigate habitat fragmentation

7.3. Density of passages

The density of fauna passages required to effectively maintain habitat connectivity is a major decision in planning mitigation measures (Fig. 6). Deciding on the required number and the type of measures will depend on the target species and the distribution of the habitat types in the area. In some cases one or several wide passages will be appropriate whereas other problems will be better tackled by a larger number of smaller-scale measures. An additional argument for constructing several passages is to 'spread the risk' in case a passage is not used as predicted.

When determining the number of passages all opportunities for animals to cross an infrastructure have to be considered, including the ones that may already be available, e.g. due to a road being led through a tunnel.

In general, the density of passages should be higher in natural areas, e.g. forests, wetlands, and in areas with traditional agriculture, than in densely built-up or intensively-used agricultural areas. However, in areas where many artificial barriers due to transportation infrastructure or built-up areas exist, fauna passages can be essential for maintaining the general permeability of the landscape. In such cases, they could be integrated with all remaining open corridors.

7.4. Location of passages

The location of the passages has to be decided on the basis of sound knowledge regarding animal movements and the distribution of important habitats. Where clearly defined animal trails exist, passages should be placed as close to them as possible. Often topography and landscape structure can help to identify likely migration routes such as valley bottoms, streams, hedgerows, and continuous woodland. Where the principal aim of a passage is to link particular types of habitats, the passage has to ensure the connectivity to suitable habitat on either side of the planned infrastructure. Other barriers existing in the surrounding landscape have to be considered, too, when locating passages and access to the passage must be guaranteed in the future.

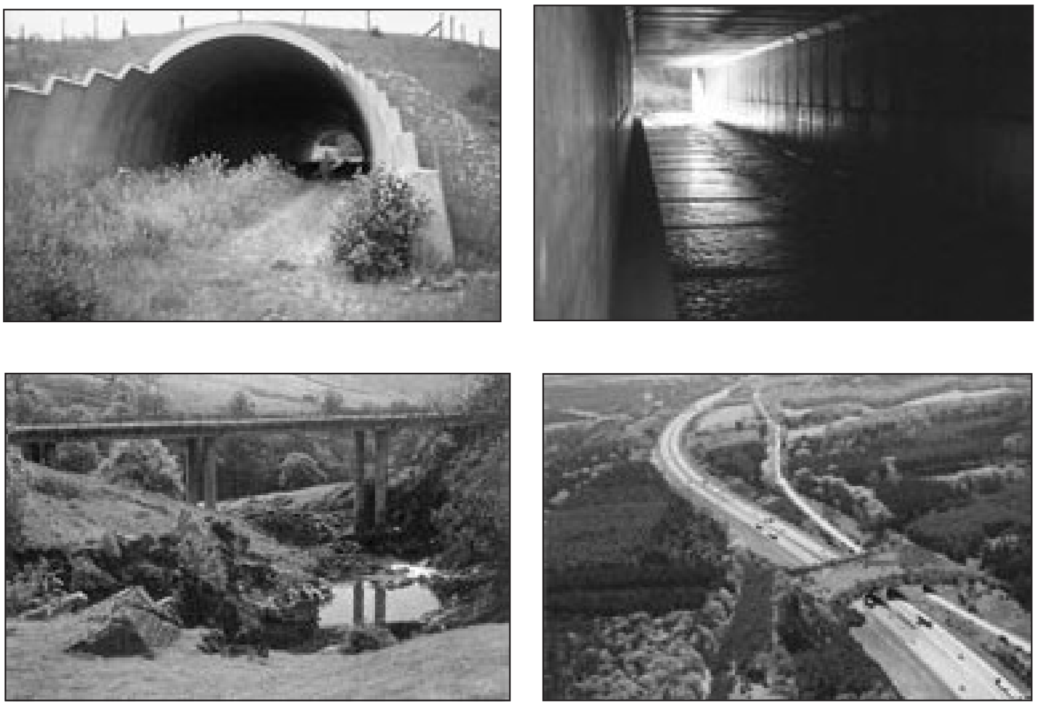

Fig. 6. Examples to reduce fragmentation effects

The type of measure to be used, the location, the numbers, and how to make them effective, are all maters that will have to be dealt with in each specific project. (Photos from the COST 341 Handbook)

Ensuring that passages are built at all known 'conflict points' must be the first step in defining the location of passages. If this result in a density of passages considered too low to create the necessary level of permeability of the infrastructure in the particular region, additional locations have to be found.

7.5. Integration into surroundings

Fauna passages should be well connected to the surroundings, either by way of habitat corridors leading towards passages for small animals or by way of guiding lines for larger ones. As a result of the channelling effect of guiding structures, the probability of an animal encountering a fauna passage can be improved considerably. Barriers that prevent or hinder animals from reaching passages need to be removed or mitigated. Where other infrastructure elements occur in the vicinity, an integrated approach to de-fragmentation, including all infrastructures is required.

7.6. Adapting engineering works for use by animals

Engineering works are designed and constructed for crossings between two different flows. These can be two flows of traffic (e.g. one road crossing the other with an overpass), traffic and water (e.g. a culvert leading water under a road or an aqueduct leading water over it), and more recently traffic and fauna. Road bridges or culverts are mostly not used by animals to cross a road or railway line, because they don't fulfil the requirements for more demanding species. However, if the demands of animals are taken into account, such traditional structures can often be adapted to serve as fauna passages. Such passages, combining the flows of fauna and traffic or fauna and water, are called joint-use passages.

7.7. Solving problems on existing roads and railway lines

In Europe, thousands of kilometres of motorways and other roads as well as railway lines have been built before people became aware of the potential problems they caused for wildlife. An obvious need for adapting existing structures arises when a high number of collisions between animals and vehicles are registered. High levels of animal mortality and the need to re-establish movement corridors may require measures to be taken while a road or railway line is in use.

When planning adaptive measures for existing infrastructure the general principles discussed in the handbook should be considered, not just the particular local situation. This is particularly the case when fences are installed to reduce the number of collisions between vehicles and animals. Fences will increase the barrier effect and should never be installed without accompanying measures. Most measures described in the handbook are also suitable for existing infrastructure or may be adapted accordingly.

The principles for dealing with existing infrastructure can be summarised as follows:

- Construction of new engineering works (passages etc.) above or below existing roads may give the best results but is often more expensive.
- Adaptation of existing engineering works that have been designed for other purposes (e.g. water, forestry) are often not an optimal solution, but in general less expensive. A large number of adapted passages may, in some cases, give better results for the same price as constructing one new specific passage.
- Modification of maintenance procedures (e.g. treatment of vegetation) may improve the situation.

7.8. Maintenance and monitoring of mitigation measures

All mitigation measures have to be routinely inspected and maintained to ensure their functioning in the long term. Maintenance aspects, including the costs of maintenance, have to be considered at the earliest possible stage, i.e. when a measure is designed. Planning should define the type and frequency of maintenance procedures and the organisation of maintenance in terms of responsibility. Specific maintenance aspects are dealt with in the sections on the different measures.

Maintenance of measures is closely linked to monitoring aspects. Monitoring procedures are mainly designed to check whether a measure fulfils its purpose, but at the same time they can identify maintenance deficits and needs.

8. Compensatory measures

Despite good planning and use of mitigation measures aiming to avoid or reduce adverse impacts on natural values, it is occasionally impossible to completely avoid negative effects of infrastructure development. This realisation has led to the principle of ecological compensation. Ecological compensation implies that specified natural habitats and their qualities, such as wetlands or old-growth forests, should be developed elsewhere when they are impacted by an approved project. When compensation is implemented, the measures should balance the ecological damage, aiming for a 'no-net-loss' situation that benefits both habitats and their associated species. Ecological compensation may be defined as creating, restoring or enhancing nature qualities in order to counterbalance ecological damage caused by infrastructure developments.

Compensatory measures are fundamentally different from the protection or enhancement of natural values (nature conservation policy). However, compensatory measures must be in line with local and national nature conservation targets. In contrast to landscaping and mitigation measures, ecological compensation is generally undertaken outside the construction area. As initiators of projects are held responsible for the implementation of the compensatory measures, developers should put serious effort in acquiring land in the neighbourhood of the infrastructure for compensation objectives. By locating the compensation sites properly, for example spatially linked to nature reserves or networks, ecological functions and relations may be protected or even enhanced.

Compensation may include conversion of land for the development of new nature qualities (woods, river beds, etc.). Habitat enhancement may encompass the adaptation of farming activities towards the development of nature qualities (e.g. meadow-birds or plants). Artificial wetlands (not necessarily ponds) may be created in order to attract species such as amphibians and reptiles. Research enabling compensation to be targeted for the benefit of specific species can also be considered as compensation. Ecological compensation can be applied to the complete spectre of impacts, including habitat degradation (habitat is still present, but impacted), and loss of functions such as nutrient and energy flows.

9. Monitoring and evaluation

To identify examples of good practice and to provide the basis for codes of good practice, we need to monitor the success of the various methods for mitigating the effects of habitat fragmentation. The handbook provides detailed guidelines on how to monitor the success of mitigation measures and gives advice on maintenance issues.

Monitoring requires clear definition of the objectives of the measures, and programmes should be planned in parallel with the design of the measures themselves.

After the construction of roads, railways and waterways the application of monitoring is of crucial importance as it is this mechanism that allows us to check the effectiveness of measures which have been applied in order to reduce the impact on habitat fragmentation.

A well-designed monitoring scheme will help to achieve several goals:

- to detect failures in the installation, construction or maintenance of measures
- to establish if the mitigation measures fulfil their purpose
- to evaluate if the measures provide long term mitigation for the species and the habitats.

In short, monitoring will contribute to establishing whether or not suitable and sufficient mitigation measures have been provided for during the planning and construction phases of a transport infrastructure, guaranteeing minimum impact on the fragmentation of animal populations and habitats.

The dissemination of monitoring scheme results is also very important for gaining knowledge for the development of more effective and less expensive measures. Therefore, an important objective of monitoring is also to help planners and road- and railway designers to:

- avoid repeating the mistakes
- provide new information for improving the design of mitigation measures
- identify the measures with an optimum relation between cost and benefit
- save money for future projects.

Monitoring schemes should be an integral part of the routine technical management that leads to the adaptation and improvement of the design of measures which avoid or reduce the effects of transport infrastructure on the fragmentation of habitats.

A wide number of methods can be applied for the monitoring of mitigation measures. In the handbook the description of most commonly used methods to record fauna casualties and to check the use of fauna passages is provided, giving information about the procedures, variables to be recorded and standards to be achieved. Standards of reference cannot be generalised because they depend on many factors such as the population level of target species, the landscape conditions or the objective of the measure. By this reason, only some orientations about which standards can be used for the evaluation are provided.

10. Closing remarks

A significant challenge to ecologists, road-planners and civil engineers alike is the establishment of an ecologically adapted, safe and sustainable transportation infrastructure system. The key to success is the adoption of a holistic approach that allows the entire range of ecological factors operating across the landscape to be integrated within the planning process from the start. The challenge of fragmentation and its solutions are universal, therefore joint research and combined international efforts are required. To develop adequate tools for assessing, preventing and mitigating the ecological impact of infrastructure, interdisciplinary work is required.

For countries with high density of transportation infrastructure de-fragmentation programmes can be necessary to mitigate fragmentation. In countries that are still developing their infrastructure networks the precautionary principle should be emphasized to prevent increased fragmentation.

The COST 341 Handbook *Wildlife and Traffic* gives practical guidance to the various actors involved in the planning, construction or maintenance of transportation infrastructures. A Spanish version was produced in 2005, and a French version will be presented in 2006. Several countries, not only in Europe, have produced national adapted handbooks based more or less on the COST 341 Handbook, and an increasing number of reports, papers, guidelines, books and conferences are slowly filling up the gaps in our knowledge. How this will affect the development of transport infrastructure and the fragmentation of natural habitats remains to be seen.

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Guidelines for ecological impact assessment in the United Kingdom

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Abstract. These Guidelines have been developed by the Institute of Ecology and Environmental Management (IEEM) to promote good practice in Ecological Impact Assessment (EcIA) for terrestrial, freshwater and coastal environments to the mean low water mark in the UK. EcIA is the process of identifying, quantifying and evaluating the potential impacts of defined actions on ecosystems or their components. EcIA may be carried out as part of a formal environmental impact assessment (EIA) or to support other forms of environmental assessment or appraisal. A common framework for EcIA will help promote better communication and closer cooperation between all ecologists involved in the process.

The IEEM guidelines were launched in 2006 and the key issues are: (*i*) seeking biodiversity enhanc ments from the start of the EcIA process; (*ii*) the value of ecological features which can comprise biodiversity value, social/community value and economic value should be determined within a defined geographical context; (*iii*) legal protection should be separated from biodiversity value; (*iv*) significant ecological impacts depend on positive or negative effects on the integrity of defined sites or ecosystems and the conservation status of habitats and species.

Key words: Ecological Impact Assessment, good practice, Guidelines, biodiversity, United Kingdom

1. Introduction

Ecological impact assessment (EcIA) is the process of identifying, quantifying and evaluating the potential impacts of defined actions on ecosystems or their components. If properly implemented, it provides a scientifically defensible approach to ecosystem management (Treweek 1999).

The Institute of Ecology and Environmental Management (IEEM) has developed and published its *Guidelines for Ecological Impact Assessment in the United Kingdom* which relate to terrestrial, freshwater and coastal environments to mean low water mark with the objective of promoting a scientifically rigorous and transparent approach to EcIA. The Guidelines provide a common framework for EcIA in order to promote better communication and closer cooperation between all of the ecologists involved in any EcIA – whether working for a developer, for local authorities or other statutory organisations, for NGOs or for a local group.

Overall, the aim of EcIA is to obtain the best possible outcomes for biodiversity from changes in land use. Beneficial outcomes depend on input from all stakeholder ecologists at all stages from the early design of a project through to decision-making and its implementation.

EcIA can be undertaken in a wide range of situations, for example, to provide environmental information to accompany an application for a consent (which may be incorporated in an Environmental Statement prepared as part of a Environmental Impact Assessment), to guide a evelopment brief or to inform a management plan. The purpose of EcIA is to provide decision-makers with relevant information about the ecological impacts associated with a project, including those that are positive as well as those that are negative.

These guidelines extend the boundaries of current EcIA practice on five key fronts:

- identifying and evaluating ecological features;
- characterising and quantifying impacts and assessing their significance;
- minimising negative impacts and maximising positive outcomes through the project design process;
- identifying legal and policy implications and their consequences for decision-making;
- identifying the role of all ecological stakeholders in achieving maximum benefits for biodiversity through the EcIA process.

2. Identifying and evaluating ecological features

The identification of ecological features and their importance is first carried out at the scoping stage of an EcIA in order to support decisions about how to focus the resources that are available for ecological survey and assessment on those impacts that are likely to be significant. A geographic zone of influence needs to be identified which contains all those ecological features that may be affected by the various biophysical changes caused by the project that is being assessed. This zone of influence will often be larger than the project site itself.

The Guidelines encourage an approach to evaluation that involves teasing apart the different values that can be attached to ecological features. The values that are identified are biodiversity value, social/community value and economic value; legal protection needs to be considered separately. Features that are important for social or economic reasons should be identified as part of assessments of the social or economic effects of a proposal. Impacts on these features should be assessed by the ecologist but the significance of the impacts should then be determined by the social or economic specialist.

It is recommended that the levels of value that are used should be based on a common geographical scale that is designed to facilitate the determination of the legal and policy consequences of significant impacts. The following geographic frame of reference is proposed for use in any EcIA: international, United Kingdom, national (i.e. England / Northern Irland / Scotland / Wales), regional, county (or Metropolitan – e.g. in London), district (or Unitary Authority, City, or Borough), local or parish, the zone of influence (the project site or a larger area).

It is generally straightforward to evaluate designated sites against these categories, although for sites of less than district-level importance there are often no predetermined levels of value. Evaluating habitats and species can be also be difficult, although there are exceptions *e.g.* recognised ways of defining internationally/nationally important populations of waterfowl.

Sustained attempts were made during the development of the Guidelines to define how habitats and species could be assigned to different levels of value. However, such definitions proved to be unworkable in that they cannot accommodate all of the factors that should influence the definition of value, for example the size or conservation status of species populations or the quality of habitats. Furthermore, the value of a species or a habitat may change depending on whether it is being assessed in, for example, the south of England or the north of Scotland. Consequently, it is not possible to define boundaries between different categories of value for habitats or species that are applicable throughout the UK.

The Guidelines therefore propose an approach to valuing features that involves professional judgment, but makes use of available guidance and information together with advice from experts who know the locality of the project and/or the distribution and status of the species or feature under consideration.

3. Characterising and quantifying impacts and assessing their significance

The concept of significance lies at the heart of EcIA and subsequent decision-making. AnEcIA carried out as part of an EIA must identify the significant impacts that a proposed development is expected to have on flora and fauna; significance assessment is also an important part of EcIAs undertaken for other purposes.

Initially information about potentially significant negative impacts is used to determine whether there is a need to refine the project proposals in order to avoid, reduce or compensate for such impacts. Confusion should be avoided between the concept of ecologically significant impacts above a given value that would make them worthy of inclusion in an EcIA and impacts that would be sufficient to trigger the formal statutory process of EIA as part of 'screening' (Troman & Fuller 2003).

Once any negative impacts have been avoided, reduced or compensated during the design process, the revised project is subject to detailed assessment. The conclusions about the significance of the impacts of the final project design are used by the authority that is responsible for determining whether to give consent to a particular project. The authority may also decide to impose planning conditions or to negotiate legal agreements in order to safeguard ecological resources.

The starting point for any EcIA is to determine which ecological features are of sufficient value that a significant impact upon them would be worthy of mention or discussion in the assessment. This should involve using the results of the evaluation (as described above for biodiversity), and applying a threshold level of value below which no reference, or only passing reference, would be made to them in the assessment. The threshold will normally be set by the level and detail of planning policy under scrutiny. Added to these should be any ecological features that have been identified as being important for social, community or economic reasons – together with legally protected species.

For all of those features above the selected threshold value it is necessary to determine whether the changes that are likely to be brought about by the development could result in a significant impact. For those impacts that are likely to be significant, it is necessary to characterise the impacts as fully as possible, making explicit reference to aspects of ecological structure and function on which the feature depends. The assessment should consider: confidence in predictions (levels of uncertainty), extent (area of an impact), magnitude (size of an impact), duration, reversibility, timing and frequency and cumulative impacts.

There are a number of approaches for determining significance in current use. Most typically, significance is defined using a matrix in which ecological value and magnitude of impact are combined to determine different levels of significance.

The term 'magnitude' in this context is in reality short-hand for the integration of a number of factors which characterise the impact, including extent (area), magnitude (size of an impact), duration and reversibility. In such matrices 'magnitude' is ranked into categories such as 'major/moderate/minor' or 'high/medium/low'. However, given that 'magnitude' in this context is an amalgam of a number of very different factors, it is difficult in practice to define these categories and their boundaries with precision. This obstructs a clear understanding of the EcIA process and, typically, results in an EcIA lacking rigour.

Using a wholly subjective link between value and 'magnitude', matrices generally assign diferent levels of significance to various cells in the matrix. Decision-makers using the results from such a matrix then have to distinguish between, for example, an impact of 'medium significance' against one of 'low significance' without any guidance other than an intuitive understanding of these terms, which are inevitably subject to individual interpretation.

The Guidelines promote a more transparent approach in which a positive or negative impact is determined to be significant or not, in ecological terms, in relation to the integrity of a defined site or ecosystem(s) and/or the conservation status of habitats or species within a given geographical area which relates to the level at which it has been valued (see below). The decision about whether an impact is significant or not is independent of the value of the ecological feature (other than in the context of the threshold described above). Subsequently, the value of any feature that will be significantly affected can be used to determine the implications in terms of development control or other policies.

Using this approach, there will be some situations when an ecologist concludes that a defined site is of sufficient value that it could be significantly affected, but then, having undertaken further analysis, concludes that the integrity of the site will not be affected (i.e. there will be no significant impact on the site itself). However, this will not preclude there being habitat features or species present on the same site that are also of sufficient value that they could be significantly affected and for which the ecologist concludes that an impact will be significant in relation to their conservation status. This will trigger the policies and/or legislation that apply to features/species populations of that level of value. For example, whilst a particular impact may not be considered to have a negative impact on the integrity of an SPA, it may be considered to be significant in terms of the conservation status of the population of a species of value in a county context within the SPA that is not a qualifying species relating to the SPA classification.

It should be noted that the concepts of integrity and conservation status are not always relevant to assessments relating to legally protected species, for which the EcIA has to demonstrate why the project will not result in the law being contravened. However, for legally protected features that are also of high biodiversity value, it may be necessary to carry out an assessment of the significance of any impacts as well.

Integrity

The EC Habitats Directive (Article 6) introduces the term 'integrity' in considering the ecological significance of an impact with reference to European sites. Integrity is not defined in the Directive, but a definition is given in official EC guidance in relation to European sites: *'The integrity of a site is the coherence of its ecological structure and function, across its whole area, that enables it to sustain the habitat, complex of habitats and/or the levels of populations of the species for which it was classified'.*

The concept of 'integrity' was originally applied to ecosystems but can be applied to defined sites that can reasonably be considered to represent an ecosystem. In order to understand impacts on integrity it is necessary to take account of ecosystem processes and functions. Use of the concept of ecological integrity must recognise that ecosystems are inherently dynamic and can change in both time and space and that their boundaries are not fixed but are both dynamic and permeable. It is also necessary to take an integrated approach and to look at specific impacts in the context of the overall functioning of the whole system. There may be components of an ecosystem/site that appear to have little value in themselves, when considered in isolation, but which nevertheless play an important part in maintaining or supporting the overall value of the ecosystem/site.

All ecosystems/sites have a certain 'freeboard' in terms of biophysical change that can be a sorbed before their fundamental ability to support characteristic habitats or species populations is compromised. Clearly there will sometimes be an element of doubt as to whether the predicted change is sufficient to cause changes to the integrity of an ecosystem/site. This should be reflected in the confidence levels attached to the prediction. In some cases, it may be appropriate to incorporate mitigation measures into the project design that are designed to increase the level of confidence in the prediction that has been made.

Conservation Status

The Habitats Directive provides definitions of 'conservation status' for habitats and for species [Council Directive 92/43/EEC, Article 1, sections (e) and (i)]. The IEEM guidance uses slightly modified versions of these definitions such that evaluation of conservation status can be applied to habitats or species within any defined geographical area and will relate to the geographical scale at which the feature is considered important:

- for habitats, conservation status is determined by the sum of the influences acting on the habitat and its typical species that may affect its long-term distribution, structure and functions, as well as the long-term survival of its typical species within a given geographical area;
- for species, conservation status is determined by the sum of influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within a given geographical area.

When assessing potential effects on conservation status, the same reasoning should be applied as set out above in relation to integrity. The known or likely trends and variations in population size should be considered. The level of ecological resilience, in terms of the quality of physical and biotic conditions, that would permit the given population of a species or area of habitat to continue to exist at a given level, or continue to increase along an existing trend, should also be estimated.

Finally, the determination of the significance of positive or negative impacts in relation to both integrity and conservation status may be assisted by reference to the conservation objectives for any ecological feature where these are available or can be agreed.

4. Minimising negative impacts and maximising positive outcomes through the project design process

There is a growing body of opinion that new developments should deliver net ecological gain rather than simply being designed to achieve mere damage limitation. Right from the start, proponents of any project should therefore incorporate, as part of the project design and its implementation, measures that are required to deliver ecological enhancements as well as measures to:

- avoid negative impacts - especially those that could be significant;
- reduce negative impacts that cannot be avoided through the design of the project;
- compensate for any remaining significant negative impacts.

The objective should always be to agree the identified measures with the proponent of a pr ject so that they become part of the project that is subject to detailed assessment. An EcIA is effectively meaningless if it provides an assessment of the significance of the residual impacts of a project based on the proposed mitigation measures being implemented even though these measures have not been agreed by the proponent. Similarly, a shopping list of 'proposed mitigation' at the end of an EcIA is of very little value as it requires the authority making the decision about a consent to enter into discussion with the proponent to agree what will be implemented. Such a discussion may lead to agreement over certain measures being included in the project, but these should then be subject to further assessment work to define the ecological impacts of the amended project. These changes may also have implications for other assessments that have been undertaken by other technical specialists (e.g. landscape architects and acousticians), who would then need to revisit their assessments, introducing further costs and delays to the decision-making process.

In agreeing how a project can be changed to include mitigation measures or ecological enhancements, it is important to ensure that any uncertainty associated with the implementation of ecological aspects of the project design is adequately reflected in the assessment of impacts and their significance. It is also important to identify any requirement for monitoring, for example to allow aspects of the project to be adjusted during construction and/or operation to improve positive outcomes or reduce negative impacts.

Environmental Action or Management Plans are often a very effective means of incorporating into one document all those aspects of the project that are being taken forward for ecological or other environmental reasons, including monitoring. Such plans can be subject to enforcement through a condition attached to a consent or through a legal agreement.

5. Identifying legal and policy implications and their consequences for decision-making

The scoping stage presents the first opportunity to make explicit the legal and policy context in which the EcIA process should take place. All those involved in the overall design, planing and implementation process should be fully aware of this context. Failure by a proponent to take account of the legal and policy context, and to provide sufficient information to comply with these, may result in an application being refused.

The EcIA will have identified the significant impacts and the value of the ecological features affected by the proposal. Those making decisions in relation to a project involving an EcIA have to test whether the project (together with all of its constituent parts that have been designed to deliver environmental enhancement, mitigate negative impacts or compensate for unavoidable negative impacts):

- complies with legal requirements (e.g. a licence for any work affecting legally protected species or a Land Drainage consent);
- conforms with national and local policies;
- requires conditions to be attached to the consent or legal agreements to be negotiated.

It is important that a proponent is able to demonstrate commitment to the full implementation of the proposed mitigation, enhancement and compensation measures. Commitment can be demonstrated through the submission of designs and supporting information including a detailed explanation of what is to be done, how it will be achieved, where and when it is to be carried out, and who is responsible for ensuring that works are undertaken as proposed.

Planning conditions or legal agreements can be used to require the delivery of the proposed mitigation. The willingness of the proponent to enter into such arrangements will influence the assessment of the likelihood of success of the mitigation.

6. Identifying the role of all ecological stakeholders in achieving maximum benefits for biodiversity through the EcIA process

This guidance seeks to achieve maximum benefits for biodiversity through the EcIA process by identifying all the ecological stakeholders including those:

- advising the proponent of the project;
- advising the Local Planning Authority and other statutory organisations who are making decisions and/or consents;
- representing statutory consultees, such as country conservation agencies and environment agencies;
- representing non-governmental organisations, such as Wildlife Trusts or the RSPB, or local groups.

If the knowledge and expertise of all the relevant individuals and bodies is applied to a project with the objective of seeking to achieve the best for biodiversity, the result is likely to be better than if co-operation and information is withheld. It is important that all those involved understand both the role of other stakeholders and the possible consequences of a lack of co-operation.

7. The IEEM Guidelines

These Guidelines have been endorsed by the Association of Local Government Ecologists, the Countryside Council for Wales, English Nature, the Environment Agency, the Environment and Heritage Service, the Institute of Environmental Management and Assessment, the Scottish Environment Protection Agency, Scottish Natural Heritage and The Wildlife Trusts.

The Rural Development Service (RDS) is responsible for the Environmental Impact Assessment (Uncultivated Land and Semi-natural Areas) (England) Regulations 2001. Whilst fully endorsing the processes for Ecological Impact Assessment as set out in this document, RDS recognises that some of the recommendations may be disproportionate or inappropriate for the determination of likely significance for some smaller agricultural projects.

The Guidelines are available online on the IEEM website (www.ieem.org.uk/ecia/index.html) from which they can be downloaded as a pdf. The website will host examples of EcIA undertaken using the Guidelines.

The online format of the Guidelines will allow them to be updated at appropriate intervals to take account of changes in legislation and policies as well as developments in the science that underpins the EcIA process.

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Indicators and focal species for evaluating ecological effects of transport infrastructure

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Abstract. Knowledge on dose-response relationships in the ecological effects of transport infrastructure is a crucial prerequisite for the development of evaluation tools to be used in sustainable landscape planning. The impact of transport infrastructure on wildlife depends on many factors including characteristic of transport infrastructure itself, the transportation intensity, landscape pattern and the ecological traits of species. In this paper, we review scientific literature in the quest for species that due to their life-histories, abundance, occurrence pattern, and sensitivity to anthropogenic disturbance are most suitable for assessing the impact of transport infrastructure on biodiversity and sustainability criteria. We focus on disturbance, barrier and mortality effects with ultimate goal to provide set of indicators that relate to the specific requirements that focal species or species groups (theoretical model species, ecotypes) impose on habitat quality and connectivity.

Key words: bioindicators, focal species, transport infrastructure, wildlife, INCLUDE

1. Introduction

Achieving an ecologically sustainable transport system is part of the overall attempt towards attaining a sustainable development of landscapes and regions. One of the basic requirements for ecological sustainability is safeguarding the diversity of species, land cover types and structures that provide functional habitats to these species, and of the processes and functions that link species to habitats (Noss 1990). The impact of traffic and transport infrastructure on these qualities is very complex and includes many dimensions at different spatial scales and organisational levels (Spellerberg 1998; Forman *et al*. 2003; Seiler 2003b). The physical presence of roads and railways in the landscape has both direct and indirect effects. These transport infrastructures disrupt directly natural processes and dissects habitat and migration corridors. Road maintenance and operational activities degrade the surrounding environment with a variety of pollutants and noise. In addition, infrastructure and traffic impose movement barriers to most non-flying terrestrial animals and cause the death of millions of vertebrates each year. Reduction of habitat quality and connectivity through disturbance and barrier effects characterise the environmental impact of the transport infrastructure. Additionally, by making natural resources accessible, an important indirect effect of the development of transport infrastructures is that the overall degree of naturalness and cultural authenticity is affected (Tsamboulas & Mikroudis 2000; Angelstam *et al*. 2004). Thus, compared with other land use forms, transport infrastructure occupies a small fraction of the land, yet it affects the ecological functionality at multiple spatial scales from road-sides and road corridors to entire landscapes and regions.

Typically, infrastructure management focuses on individual road or railroad corridors rather than addressing the entire network of infrastructure facilities in a landscape or a region. This is the practise in the management of public roads, and certainly true for private roads for agriculture or forestry. As a consequence, the combined impact on habitat suitability, and landscape connectivity in particular, caused by the entire infrastructure network is often underestimated, if not completely overlooked (Seiler & Eriksson 1997). The cumulative impact will ultimately lead to a loss of different elements of biodiversity at the regional scale (Angelstam *et al.* 2004). To overcome this deficiency, cumulative impacts should be assessed and evaluated not only in strategic regional and spatial landscape planning, but also be part of environmental impact assessment (EIA) at project level (Eriksson & Skoog 1996; Piepers *et al.* 2003). However, tools and concepts for integrating landscape ecology, sustainability, and biodiversity issues in EIA are rarely implemented and usually not appropriate to support this broad-scaled evaluation (e.g., Treweek *et al.* 1993; Seiler & Eriksson 1997; DeJong *et al.* 2004). Spatially explicit models of selected species, habitat requirements and responses to landscape pattern can provide such tools (Scott *et al.* 2002; Store & Jokimäki 2003, Gontier *et al.* 2006), especially if the direct effects of infrastructure and traffic on these species can be integrated in the model. Knowledge on dose-response relationships in the ecological effects of transport infrastructure is a crucial prerequisite for the development of evaluation tools to be used in sustainable landscape planning.

We review scientific literature in the quest for species that due to their life-history traits, abundance and occurrence pattern, sensitivity to anthropogenic disturbance, economic value or public interest are most suitable for assessing and communicating the impact of transport infrastructure on biodiversity. We focus on barrier, disturbance and mortality effects with ultimate goal to provide a set of indicators that relate to the specific requirements of focal species or species groups on habitat quality and connectivity. In this paper, we present a first analysis of which focal species are commonly used in research related to infrastructure effects. We discuss the need for ecologists to understand the planning processes involved with transport infrastructure, and select adequate indicators. This paper is an introductory step into further analyses aiming at finding appropriate tools for planning and for ecological assessment of transport infrastructure within the new Swedish research programme INCLUDE (www.includemistra.org) as part of the Swedish 'Sustainable Mobility Initiative'.

2. Using species as tools in spatial planning

Habitat Suitability Index (HSI) modelling (Scott *et al.* 2002) for focal species (*sensu* Lambeck 1997, 1999) is a useful tool that may help to incorporate the issue of biodiversity maintenance into spatial planning (e.g., Angelstam *et al.* 2004; Gontier *et al.* 2006; Mörtberg *et al.* in press). By combining empirical or hypothetical data on habitat requirements of species or species groups and their responses to infrastructure with data on land cover and transport infrastructure, spatially explicit computer models can be used to produce HSI maps that may guide planning decisions. At a broad scale, infrastructure density or other summary indices (Forman *et al.* 1997, Jaeger 2002) may be used as predictor variables in HSI models with habitat suitability (in a broader sense – species presence/fitness/population viability/persistence) as the response variable. HSI models can be combined with rule-based movement models describing least-cost paths of individuals through a landscape. Habitat quality, connectivity and mortality risk can be translated into spatially explicit movement (or presence) cost for an individual (e.g., Adriaensen *et al.* 2003). Together, these spatial models provide a means to (*i*) evaluate the cumulative and long-term impact, (*ii*) illustrate the outcome of alternative scenarios, and (*iii*) communicate consequences of actions to decision-makers.

3. Which species are commonly addressed?

The number of studies that looked upon the effects of transport infrastructure on wildlife is quite impressive and encompasses a variety of taxonomic groups, spatial scales, infrastructure types and traffic intensities. From this bulk of available literature, we selected 234 articles that focused primarily on barrier effects of roads and railroads and on noise disturbance. This selection was made by aid of literature search engines such as Wildlife & Ecology Studies Worldwide, Biosis, CAB, and Web of Science. In our search, we used following pairs of key-words: "road* AND barrier*", "railway* AND barrier*", "road* AND noise*", "railway* AND noise*".

Among the different taxa dealt with in the selected studies, mammals clearly dominated (55%) (Fig. 1). Among mammals, large carnivores and ungulates were most commonly addressed, followed by rodents and other smaller species (Fig. 2). Studies specifically concerning bear (*Ursus* spp.), wolf (*Canis lupus*), caribou (*Rangifer tarandus*), hedgehog (*Erinaceus europaeus*), and badger (*Meles meles*) were the most common ones.

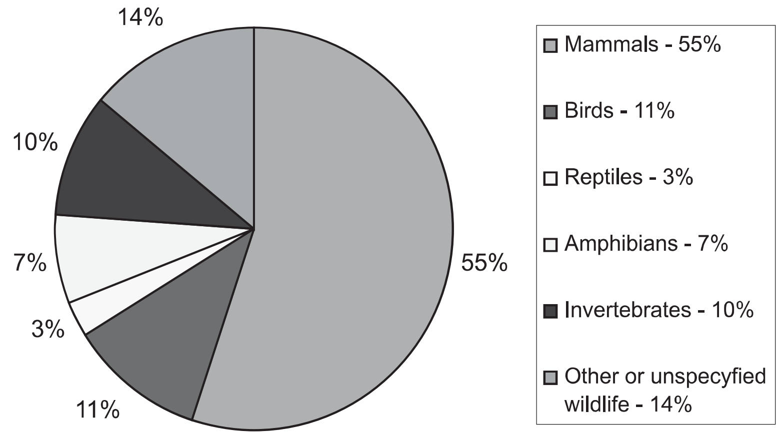

Fig. 1. Different groups of organisms being subject to papers and reports dealing with effects of transport infrastructure (n=232)

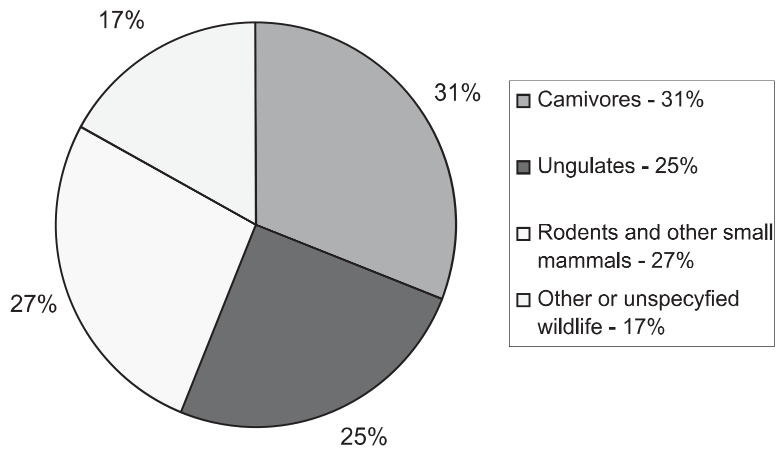

Fig. 2. Mammals as subjects of papers and reports dealing with effects of transport infrastructure (n=124)

Our preliminary analysis indicated differences concerning the spatial scale of the investigation and groups of organisms studied. The articles concerning amphibians were most often linked to the local scale while articles on carnivores and ungulates related to regional scale.

The reviewed articles also considered different landscape types (Table 1). Interestingly, most studies on amphibians were linked to forested landscapes. The problem of mortality linked to transport infrastructure was mentioned in 71 articles and was almost exclusively occurring in articles on vertebrates. More than half these articles concerned mammals, but articles on amphibians, birds and reptiles were also present. Almost one-third (75) of the articles considered population processes (i.e. effects of transport infrastructure on population persistence/viability). Some of them examined barrier effects on genetic structure of populations and found such impact in small mammals, large carnivores, one ungulate species and ground beetles. Effects of transport infrastructure on the dispersal of individuals were considered in 48 articles. Here, the share of amphibians and invertebrates was higher than expected from their share in all reviewed articles. Among invertebrates, dispersal studies on insects (flies, beetles and butterflies) were most common. Issues of habitat fragmentation and habitat alteration were explicitly discussed in 23 respectively 37 reviewed articles. Finally, 16 out of 23 articles that dealt with effect of traffic noise concerned birds.

Table 1. Proportion of articles that linked group of species with particular landscape types

	Forest [n=44]	Farmland [n=24]	Urban areas [n=46]
Carnivores	0.14	0.08	0.11
Ungulates	0.09	0.08	0.22
Small mammals	0.23	0.17	0.15
Birds	0.23	0.21	0.20
Amphibians	0.14	0.04	0.02
Other species	0.17	0.42	0.30

The great majority of the reviewed studies revealed negative effects of transport infrastructure on wildlife. These effects included barrier, disturbance, and mortality effects demonstrated for different groups of organisms, different spatial scales and varying degree of anthropogenic impact. However, only a few studies were able to estimate the cumulative impact of transport infrastructure on species persistence/viability. Moreover, several articles found that closely related species showed contradictory, species-specific responses to transport infrastructure. We acknowledge that results presented above are based on the limited set of publications and as such shall be treated as provisional.

4. Looking for indicators and focal species

Because ecosystems are complex and the effects of transport infrastructures on them need to be communicated effectively there is need to develop indicators as short-cuts (Busch &Trexler 2003). As the impacts of roads and railroads occur at multiple spatial scales, and charismatic species are interesting to a wide range of actors, so called focal species can be used (Lambeck 1997; Roberge & Angelstam 2004). Species as indicators need to be selected according to their response to the direct and indirect effects, to the spatial scale at which they utilise the landscape, to their land cover preferences (forest, agricultural land, stream habitat), and to the value of these species as proxies to illustrate and communicate the overall impact, and last but not least to aid decision making in the complex planning process for transport infrastructure. With 'knowledge' about the behaviour and ecology of the focal species or species groups, their requirements on habitat quality and habitat structure (size, dispersion, connectivity of habitat patches) and their response to traffic and infrastructure, rule-based, spatially explicit models can be developed using land cover and infrastructure data in a Geographic Information Systems.

Our analysis as well as several earlier reviews (e.g. Spellerberg 1998; Forman *et al.* 2003; Seiler 2003b) demonstrated that many species with different ecologies are clearly affected by transport infrastructure. Which of those species would make a good indicator species to be used in planning and assessment of transport infrastructure?

Large carnivores appear to be very good candidates for use in planning at regional scale because their distributional patterns often strongly reflect regional-scale population processes and individual behaviour. However the choice of species is crucial. Carroll *et al.* (2001) demonstrated for instance that among 4 large carnivores in the Rocky Mountains two species (grizzly bear and wolverine) were clearly affected by roads while two other (lynx and fisher) were not. Ungulates also have characteristics that fit into requirements for good focal species at regional and landscape scale (e.g. Bruinderink *et al.* 2003). Ungulates are usually in public focus because of the large number of deer-vehicle collisions occurring annually, and because of the economic and recreational (hunting) value of these species (Seiler & Helldin 2006). On the other hand, among species that appear to be suitable in landscape to local scale planning, amphibians are interesting candidates (Fahrig *et al.* 1995). An attempt to organize focal species as indicators of various disturbance and barrier effects at the different spatial scale at which they utilise the landscape, and to their land cover preferences is presented in Table 2.

Table 2. Examples of possible focal species as indicators for the study of disturbance and barrier effects at regional, landscape and local scales

	Disturbance effects (noise, pollution, human activity, mortality, edge effects) = affecting suitability of adjacent habitat	Barrier effects (avoidance, physical barriers, traffic mortality) = affecting habitat connectivity and movement pattern
Regional- or continental scale	large mammals	large mammals
Landscape scale	breeding birds	large and semi-aquatic mammals, fish (salmon)
Local scale	breeding birds, amphibians	Small mammals, amphibians, arthropods

In all of the reviewed papers, animal species were selected a priori to study a certain effect of transport infrastructure without intend to serve as indicator in a planning case. Before focal species can be used in models applied to decision processes, dose-response relationships in their responses to disturbance and barrier effects must be understood and parameterized (Muradian 2001; Angelstam *et al.* 2004; Seiler 2005). A key task is therefore to define variables and parameter values for these effects on the selected species. This can be done either through empirical field studies or through simulation studies that help identifying potential limit values in the response (e.g., Jaeger & Fahrig 2004).

In addition, the models and hence the selected species, must match in scale and result, the requirements of the particular stages in the hierarchical planning process of infrastructure (e.g. Eriksson). A study of butterfly movements may be irrelevant at the first scoping level in the planning process, but highly adequate during the design planning level. Modelling occurrence pattern in large carnivores may help to predict regions sensitive to infrastructure development, but may not help during road alignment and design.

5. Understanding planning processes

Landscape ecology, which focuses on the spatial aspects of ecological patterns and processes, provides important guidelines for mitigation of the adverse effects of transport infrastructure on the living landscape (Dramstad *et al.* 1996; Forman *et al.* 2003; Seiler 2003a). However, the science of landscape ecology is a new research discipline. Hence, the broader public, spatial planners, and stakeholders may not readily understand its principles and applications that combine land cover information, variables and parameters in a models expressing landscape functionality using Geographical Information Systems (Sandström *et al.* 2006; Manton *et al.* 2005). Therefore, it is of paramount importance that we (*i*) understand the extent to which planners and professionals involved in Environmental Impact Assessments (EIA) and Strategic Environmental Assessment (SEA) dealing with transport infrastructure already apply landscape ecological knowledge in their work, and (*ii*) help to develop planning tools and concepts that integrate landscape ecological principles (e.g. Seiler & Sjölund 2005). It is obvious that recent scientific and technical achievements for applying this discipline need to be better incorporated into planning process (e.g. Seiler & Eriksson 1997; Sandström *et al.* 2006), both by policy-makers, road planners who commission EIA and SEA, as well as the consultancy bureaus and their employees. Such research must be international as the value systems of planners vary among both sectors and regions (Angelstam *et al.* 2005).

6. Programme INCLUDE

In the research programme INCLUDE (Integrating ecological and socio-cultural dimensions in transport infrastructure management), we will, among others, develop and apply spatial modelling approaches that match the respective planning levels and ecological scales at different stages of infrastructure management process (e.g., strategic level planning, project level planning, road maintenance). For this, adequate indicators and focal species shall be selected that help infrastructure planning decisions in terrestrial as well as in aquatic environments. We will further evaluate, by interviewing actors and stakeholders in a suite of case studies, the extent to which GIS application techniques, and landscape ecology principles are implemented in the transport infrastructure planning process. INCLUDE will thus contribute to the understanding and active mitigation of negative effects of transport infrastructure on the functionality of habitat networks needed to maintain viable populations of species with landscape ecological requirements.

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Survey of environmental protection methods in process of motorway planning and project making in Croatia

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Abstract. Croatia is a country of great biodiversity, rich in endemics and unique karstic phenomena. It is also a region in which numerous communication routes of European significance intersect. Against a background of those natural values, the work presents main stages of a development of environmental impact assessments. A special attention has been paid to their connection with spatial planning. On the basis of a critical analysis of previous experiences, the directions for the future progress of environmental impact assessments have been proposed.

Key words: biodiversity, environmental planning, environmental protection, Environmental Impact Assessment, karstic phenomena, Croatia

1. Introduction

Presently, traffic activities in general and traffic infrastructure construction are one of the most important and recognizable space consumers and users. After the Croatian war and certain economic stabilization in 1997, motorway construction becomes the priority in the country. Approximately 900 km of motorway and two-lane roads have been built so far. The planned length of the motorway network is about 1500 km.

Environmental Planning Strategy of the Republic of Croatia (1997) and Environmental Planning Program (1999) define the disposition of the motorway network on the territory of the country. These documents are unique and adopted by the Croatian Parliament. They are considered to be the top documents for physical planning in Croatia. The documents define two basic ideas: (*i*) the development of traffic infrastructure from the point of significance and progress of the country in Europe (connecting Croatia with the countries of Central Europe and Danube region, Adriatic Sea and Mediterranean) and (*ii*) efficient traffic connection of all the areas, centers of development and other important parts within the country [1].

Traffic Development Strategy of the Republic of Croatia (1999) is the first long-term development document proposed after the independent and sovereign Republic of Croatia was established. The planned road network is to connect the following European, Trans-European and state corridors (Fig. 1):

- direction Ljubljana, Maribor-Zagreb and further to Sava Region corridor towards east to connect West Europe and the East;
- direction (Trieste) Rijeka (and/or Istria Y)-Gospić-Zadar-Šibenik-Split-Dubrovnik further toward Albania and Greece to connect West and South Eastern Europe;
- direction (Hungary)-Goričan-Zagreb-Rijeka through Bosiljevo entering Adriatic bypass route (Lika Y) to connect Central Europe and Mediterranean [1].

The 2005 year is a very important for Croatia. The project of connecting Croatian north and south (Zagreb-Split Motorway) (Fig. 1.) was completed in that year. Construction of that route is considered one of the largest investments and construction project ever in the country. The motorway is extremely complex and expensive construction due to its characteristics and the specificities of the ground where it spreads. There are about 26000000 m^3 of hollowed material on the 380 km route. 292 transport structures have been built (tunnels, bridges, viaducts, overpasses, underpasses, passes, green bridges). The calculation says that 18.6% of the route goes to the various transport structures which is a high percentage by comparison to the other motorways [2].

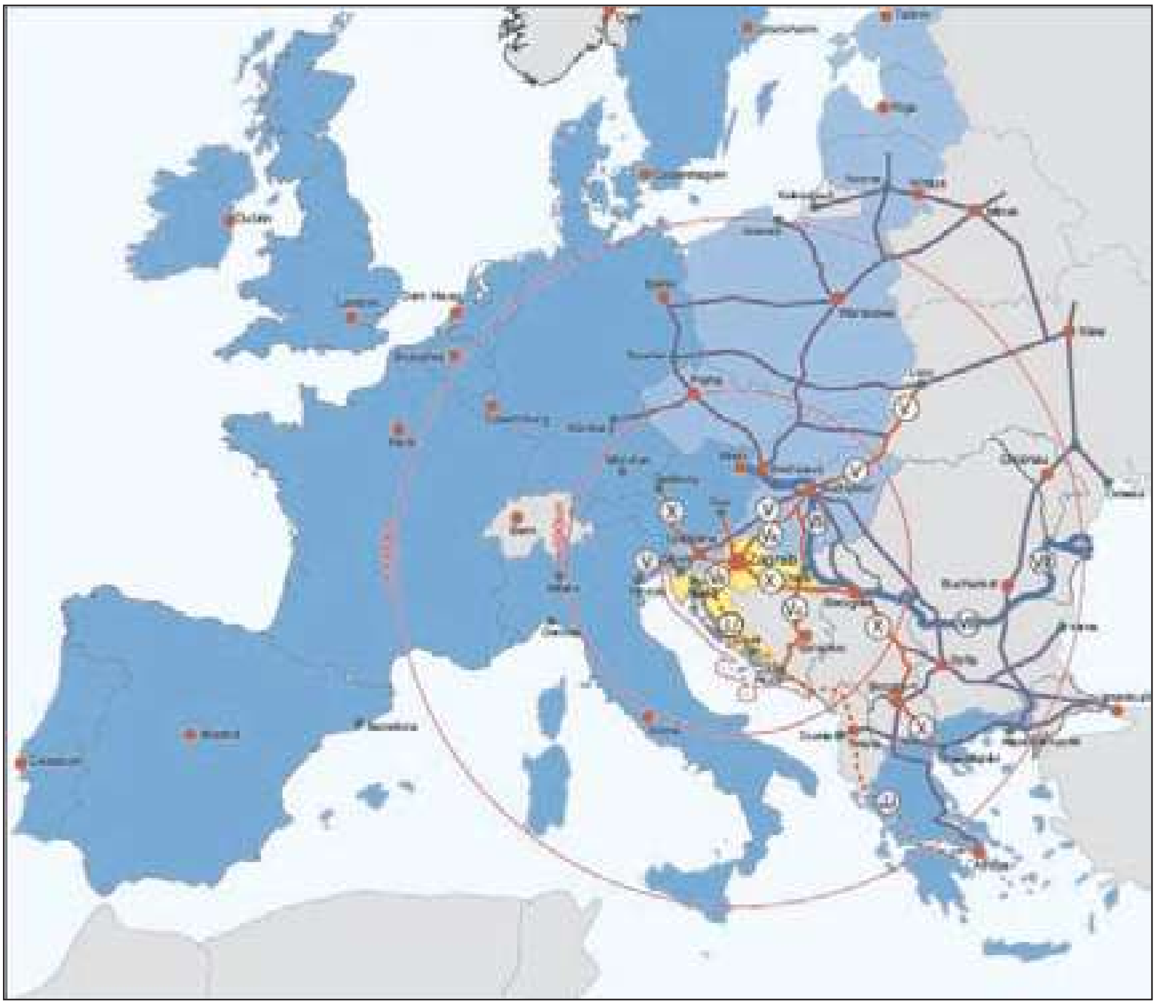

Fig. 1. European framework – Strategic and traffic – related position of the Republic of Croatia; Eurostat and Ministry of Environmental Protection, Physical Planning and Construction (MEPPPC), Department for Physical Planning. Explanation in the tekst. (Source: Report on the State of the Environment in the Republic of Croatia 2003)

In the assessment process of opportune road setting into the certain space along with the above mentioned factors – the basic 'initiators' of motorway construction process [3], the factor of protection is an indispensable element. It acts as a 'reflex' for possible negative consequences of the motorway in the space.

It is very hard to perform an optimal setting of contemporary traffic routes, especially motorways, in the area without negative influence on the environment. The main reasons are traffic- technical and construction demands (wide roadways and separation track, large radius of ground-plan distortion, service road facilities etc.).

By expanding into area, contemporary traffic routes take large areas, cause conversion of the ground use, destroy and fragment habitats and cause pollution of terrestrial and water ecosystems.

The aim of this article is to present the historical frame of the aspects of protection implementation as a consequence of the planning and traffic routes construction in Croatia, the way the aspects formally function, and mechanisms which are to become reality and not only theory.

2. Principle discussion: biological diversity in Croatia

Specific geographic location on the intersection of few biogeography regions, characteristic ecological, climatic and geomorphology conditions make Croatia one of the richest countries in Europe from the point of view of biological diversity. A large diversity of terrestrial and underground habitats resulted in numerous species and subspecies as well as a large number of endemic species.

There are 37 000 known species in Croatia, but it is assumed that the real number is much higher – 50 000 to even 100 000 species. That is an extremely large number for a country with such a small territory. One of the reasons for numerous endemic species in Croatia (especially tertiary relicts) is the fact that a glaciation had not affected these areas [4].

In Croatia one can find a considerable number of endangered species in European frames. They can be found on large, preserved areas, on a characteristic habitat for those species. Spacious woods of beech and fir-tree are habitats of population of three wild animal species: bear, wolf and lynx. Wetland areas and flooded woods are important areas where European wading birds and other birds living near wetland, nest, winter and migrate. Considerable biological diversity of the sea, islands and rocks hides a large number of endemic species. That makes Croatian coast interesting on international level. Destruction and loss of habitat, as well as transformation of natural habitats into construction sites or agricultural areas, are the biggest threat for wild life in the country. Habitat fragmentation occurs in the process of traffic construction [5-7].

According to the Nature Protection Law [8], there are 9 categories of the protected areas in Croatia. At the moment, there are 444 protected areas taking 5124,80 km^2, which is 9,05% of total Croatian territory (size of the country is 87609 km^2 – 56 542 km^2 is land and 31 067 km^2 sea). The largest part of the protected areas goes to the categories of nature parks or national parks. There are 2 nature reserves, 8 national parks, 10 nature parks with Lastovo archipelago in the process of becoming the 11th nature park. There are also some other areas in the process of preserved areas pronunciation.

Three out of eight national parks (Brijuni, Kornati, Mljet) are islands. Their main chara teristic is a rich sea world life. National parks Sjeverni Velebit, Risnjak and Paklenica are mountain areas. Numerous limestone rocks, slides, high mountain meadows and vast wood areas are characteristic relief in the national parks mentioned above. Habitat diversity and geographic isolation made the development of specific vegetation and numerous endemic species possible.

Plitvice lakes – the oldest Croatian national park, and Krka river are proud of their unique karst morphology and hydrology, calcareous travertine barriers and cascades. Six out of ten nature parks are situated in mountain areas – Medvednica, Žumberak – Samoborsko gorje, Učka, Biokovo, Velebit and Papuk. Nature parks Kopački rit and Lonsko polje are large flooded areas of Pannonia valley with ornithology reserves included in both of them. Rivers surrounding and flooding these areas are responsible for habitat diversity and life diversity, especially bird life. Vransko Lake is a nature park on the coast, near Zadar. It is the largest natural lake in Croatia and it is very important for bird nesting and wintering.

On behalf of their biological and landscape diversity some protected areas in Croatia earned status of international protection as the extremely valuable locations. Plitvice lakes is included in UNESCO's world heritage area. Velebit – nature park plus national parks Paklenica nad North Velebit – is UNESCO's biosphere reserve. Nature parks Kopački rit, Lonjsko polje, River Neretva delta and special ornithology reserve Crna Mlaka are included in the list of internationally important wetland areas according to Ramsar Convention.

There are types of habitats specific for Croatia – subterranean karst habitats. Karst area takes 54% of Croatian territory. It is relief specificity which cannot be found anywhere else in Europe. It spreads along the whole Adriatic coast and in the continental part of the country. Those dimensions make karst in Croatia 'locus typicus' of exceptional geological structure and hydro geological characteristics. These characteristics reflect not only on surface morphology, but also on the subterranean crack system arrangement with permanent or temporary subterranean water strains. Rich diversity of subterranean fauna with a large number of endemic species is strong dependence with the karst relief. Karst is a habitat sensitive to environment influences. Ministry of Environmental Protection, Physical Planning and Construction (MEPPPC) and World Bank made a project KEC (Karst Ecosystems Conservation Project). It is implemented on the basis of National strategy and biology diversity protection action plan (NSAP) [9]. The strategic objective of NSAP is to preserve existing values of biological and landscape diversity in the karst areas valuable on global level in the way to protect karst and subterranean ecosystems. It should also ensure harmonic management of all natural goods in this area. The estimated project time is 2002-2007.

Besides karst habitats, there are other numerous endangered habitats in Croatia. The preservation is defined according to the ecology network made by overlapping species distribution map and protected areas and habitat map. The areas with the largest density of priority species and habitat types give the most endangered areas. The habitat types in Croatia are described in CORINE – (COoRdination of INformation on the Environment) (2002-2005). Like other countries, Croatia also developed its National habitat classification (NHC), to point out the diversity on its territory and specificities in the sea world, subterranean areas and karst areas. There is a key for conversion of one habitat classification type into another. It is used for conversion of the national classification into any other European standard [10-11]. Croatian Environment Agency (AZO) uses and services the base on the national level.

In 2005 the State Institute for Nature Protection completed the project 'The National Ecological Network' LIFE CRO NEN. European Commission LIFE III fond co financed the project with the aim to make the proposal of national ecological network. This proposal is a basis for National Ecological Network decree which must be enacted by the Government. National Ecological Network is a first step in preparation of proposal NATURA 2000 network – the obligation of Croatia in the process of accession to the European Union.

LIFE III CRO NEN analyzed the distribution and representative quantity of every NATURA 2000 habitat type and species. There are 269 species and 65 habitat types. Croatia is the area of distribution of priority species such as wolf, brown bear, monk seal, sea turtle, two types of sturgeon and human fish. The most represented are birds. There are some 130 enumerated in the Appendix 1 of Council Birds Directive in Croatia. The most endangered habitat types in Croatia are: *Posidonia oceanica* medows, Pannonia dunes, periodical Mediterranean pools, calcareous wells, *Caricion davallianae* bogs, floodedalder woods, etc.

The State Institute for Nature Protection continues to gather and process the data needed for completion of NATURA 2000 network in Croatia. The European Environment Agency and European Council created EMERALD network which, along with PHARE project, are included in the above mentioned activities.

In 1997 the Republic of Croatia made the National Landscape Strategy, prior to ratification of the European Landscape Convention [12]. The basic intention of the Strategy is model structuring for landscape inventory [13]. There are 16 basic landscape units structured according to natural characteristics and based on anthropogenic influence.

Fig. 2. Composite map of protected areas in Croatia and interaction with the existing and planned motorway network

The natural resources (natural diversity and relatively high preservation degree of vast Pannonia lowlands, narrow area of the high Dinarides and impressive indented Adriatic coast) are, logically, an imperative in the development process and no matter what it takes it must be kept as a value of prestige on the European level [1]. Accordingly, the motorway route planning and construction has represented a great challenge for professionals and scientists. The example of the adjustment of motorway construction and protection of natural territories is the correlation of Zagreb-Split (A1) motorway section and the areas protected by law (Fig. 2.). The route in a shape of system of viaducts crosses over the protected water area and Gacka valley [14]. The tunnel Mala Kapela makes it possible to preserve valuable animal and plant species. Sveti Rok tunnel passes through Velebit (National Park and UNESCO biosphere reserve). Finally, at the very end of the section, the Krka bridge 'concurs' the canyon situated near the Krka National Park border. The route mainly bypassed the protected areas. However, there are habitats, animal and plan species, valuable landscapes and wood edges which preservation should be integrated into the protection aspect in a better way.

3. Results and discussion

This article is about environmental protection in the process of planning, project making and construction of motorway infrastructure. In that context we tried to define the phases of the process, the ratio and representation of those protection factors. Unlike the beginning phase of the protection implementation, these days there are numerous disciplines included in the process. Also, an overall legislation aspect is settled [15-32]. But, formally, it is of high importance to define traffic roads in a planning context from the environment protection point of view. Since the physical planning is the initial phase of decision making about positioning of a certain intervention in space 'the optimal order for optimal use should be decided on', because '…traffic road construction process does not begin with the cost analysis, construction expenses and technical project, but with planning; the first step is not technical aspect or engineering, but culture and planning'[33].

When the theoretic and legislative (practical) frame for protection implementation is discussed, Croatia stands next to the countries following world trends. In the sixties, physical planning activities and territory protection come into the light. Environment protection becomes important in the seventies. Consciousness on limited natural resources and need for preserving eco balance grew (at least in theory) with environment protection ideas. Questions of environmental pollution (especially water, air and ground) change the conceptual and politic approach, means of action, social and individual responsibility [34]. Space is seen as a unit of dependable processes. The idea of 'sustainable development' gradually took shape.

3.1. The EIA role in route design, project making and motorway construction in Croatia

Before the location and construction permits are issued, EIA (Environmental Impact Asessment) must be implemented. 'Law on physical planning and space design' from 1980 requires EIA implementation. The details were defined in 'Regulations for Drafting Environmental Impact Study (EIS)' [17]. Not before 1985 did the European Community issue a 'Directive' with EIA implementation guidelines for the member states. So, it can be deduced from that fact that Croatia was one of the countries first to introduce EIA into their legislation. It cannot be said that there was no environmental protection in the country before that, but fulfillment of technical and traffic conditions was a primary thing, and then environmental protection was considered, but mainly water protection [35].

Till 1980, the period before EIA, there was a small number of constructed motorways, fortunately. At the time when 'regulation' was issued, preparations for construction of those types of roads began. During the EIA implementation process the new propositions and demands occurred. Those are the demands of the commission in charge of EIS assessment and are directed to make the traffic roads embed properly in the environment. For example, there were additional demands for better animal protection on the Zagreb-Rijeka route. For brown bear (*Ursus Arctos* L.) protection, instead of 330 m long notch 'Dedin' the green bridge was constructed. It is 100 m wide [36]. On the area where 30 m high and very long 'Gložac' notch was planned, the 1080 m long tunnel is built to preserve a natural habitat of already endangered wolf (*Canis Lupus* L.) [37]. The demands for 'Kamačnik' canyon protection were created [37]. Viaducts on high columns were planned for construction, but the foundations would ruin natural configuration, ground and vegetation. It was decided on the much better solution – the road bridge can 'concur' the canyon with less landscape violation.

The additional conditions of technical nature, occurring during the EIA process, can be included in the project and documentation. However, so far there were mostly demands for altering traffic routes to adjust route to the specific characteristics and values of the area or already existing content in the area. Those changes are not easy to make. The question of the relationship of the route and other contents is solved by deciding upon route position in physical plan. Sometimes, though, EIA has better solutions for route positioning than those in physical plans. In that case physical plans change in favor of EIA.

When the route is established and charted in the physical plan, by legislative, EIA must be made for traffic road structures (National Physical Plan, County Physical Plan, General town planning scheme). During the years of EIA for traffic roads implementation, it has become clear that the results outgrew the objectives set by the legislation. The main role of EIA was finding preventive solutions and ways of environmental protection prior to road route construction. But spontaneously, it started to analyze more convenient route positioning, which means that EIA intruded into physical planning [38]. For example, on Zagreb – Maribor motorway, there were three solutions for Krapina – Macelj route in the physical plan. EIA estimated that not one of the three suggested routes is acceptable. Further investigation brought to the new route and the altering in the district physical plan [39]. There were changes on four locations on Zagreb – Varaždin – Goričan motorway compared to the physical plan. That was the time when EIA for motorways hardly existed, so there were no alterations in the physical plan. The reason is the new generation of physical planning which started at about the same time of development of motorway construction projects. In that context EIS was a planning tool. Since 2004 only interventions defined by physical planning (not taking into consideration alternative solutions) can be assessed.

Presently, the environment impact assessment process does not influence possible strategic decisions on an optimal route corridor. All the mentioned above brings us to conclusion that, in the sequence of legislative duties, EIA is included too late in the physical planning process. To avoid damaging consequences, EIA should definitely come before final route positioning in the physical plan. That can be at the same time or before physical plan construction process, but it must be the part of strategic environment impact assessment domain. So far EIA proved to be an efficient tool for preventive environmental protection. The results were always positive, no matter lacks in the legislative regulations. The development of the EIA should be continued and new ways of organizing, cooperation and use within legislation should be found; especially in relation to physical planning. The main objective is better environmental protection.

CARDS 2003 'Environmental Impact Assessment (EIA) – Guidelines and training project' will contribute to it. The objective of the project is to support the Croatian Government's objective of the EU accession by increasing the environmental sustainability of development projects in line with the EU standards [40]. The project's objective is also enhancement of screening process, scoping and revision of the previous EIA, enhancement of assessment tools (cost benefit analysis, etc.) and transparent EIA process for all the included parties. Positive international experiences show that EIA should be implemented in the earliest preparatory phase – when the Physical Planning Strategy and Program are being drafted. In that phase it is possible to consider complex economic, energetic, infrastructure, physical and other problematic in the context of environmental protection.

We hope that strategic environmental impact assessment will help to solve the above mentioned problematic. CARD 200 'Strategic Environmental Assessment (SEA)'/2006-2007/ will contribute to it with its objective to enclose the Directive 2001/42/EC into the legislation, to adopt complete methodology and form administrative capacities for SEA implementation in Croatia.

3.2. Project making and environmental protection implementation mechanisms due to traffic infrastructure construction in Croatia

Figure 3 shows the sequence of certain phases of documentation preparation. It also shows the ratio and phases in which protection aspect is represented.

The protection aspect representation mostly depends on project documentation preparation after the route is defined in physical planning documentation. The EIS is drafted at the same time of concept design. The assessment process is applied based on concept solutions (usually M 1:5000). After the Study is drafted and the route adopted, the following environmental protection projects are included within the concept design, main and design for motorway construction: landscape planning project, noise protection project, hydro-technical project, notch and causeway reparation, biotechnical motorway slope reparation project, green bridge construction project.

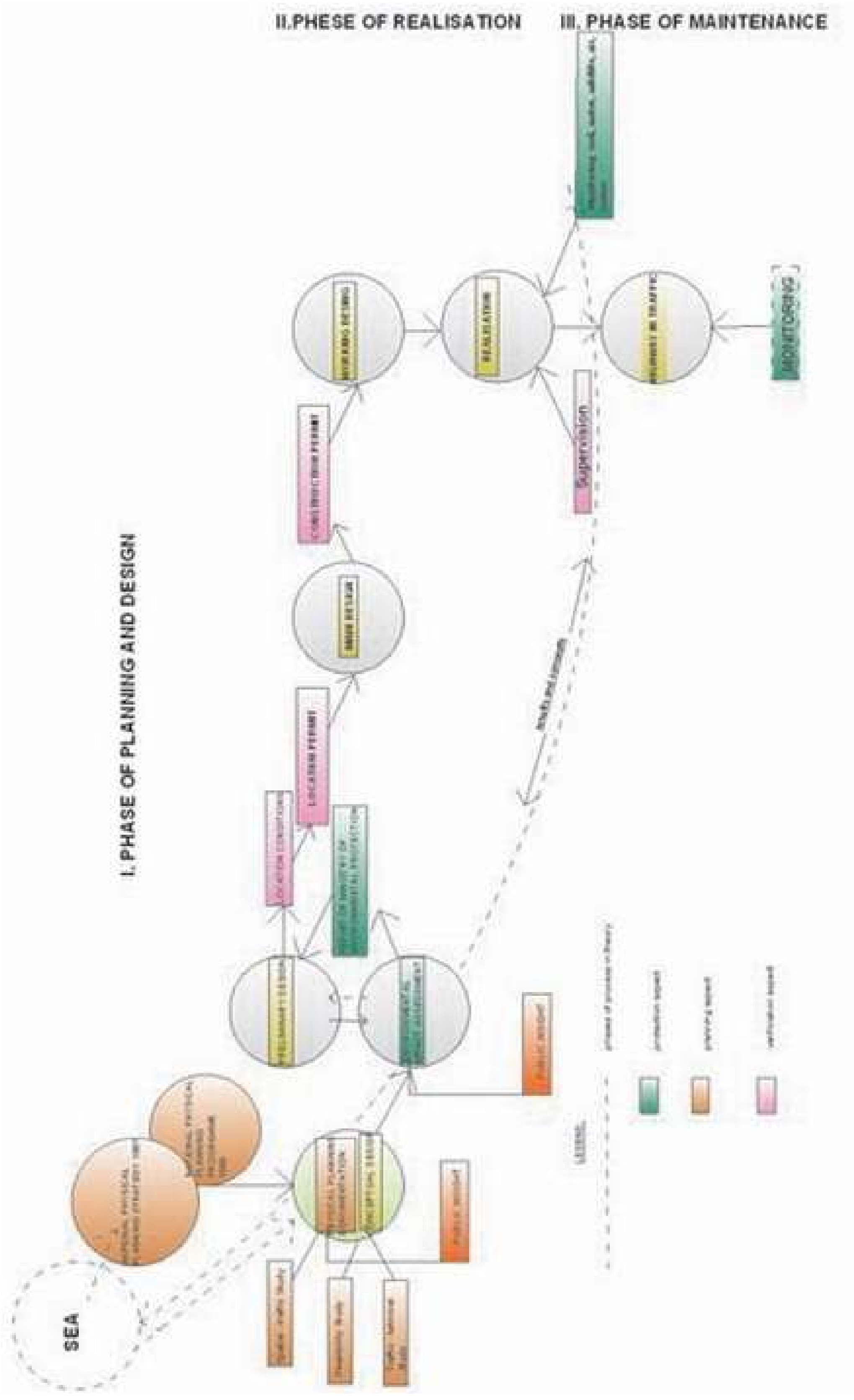

Fig. 3. Planning, project making and environmental protection diagram due to traffic infrastructure construction in Croatia

Landscape planning projects for motorway routes are very important [41-45], even though wider landscapes of the route are not properly protected due to the width of the zone bought over. The projects tend to include the following protection categories: crown notch bio reparation, slope bank landscape reparation, tunnel portal reparation, erosion prevention reparation, wood edge bio reparation, green bridges and passes landscape planning, visual adaptation of noise protection barriers, material repository reparation, reparation of devastated manipulative areas and especially service facilities (platforms for rest) accommodation according to natural and cultural characteristics of the area.

In Croatia the monitoring phase (the last phase of the process – included in the construction and maintenance phase) is still at its beginning. We consider the results and concepts of regular ground, water, air and wild life monitoring should serve to planning phase, physical-technical studies, EIAs for new motorway sections, and setting standards in the project planning phase.

The question of adequacy and sufficiency of protection aspect in planning and traffic infrastructure construction and planning in general is recently very popular in Croatia. The reasons are complex and multiple. The rapidity of traffic roads construction in few last years is positive from the development point of view, but it restricted certain research, some protection disciplines and implementation of proper protection. For example, according to the time plan, the estimated time period for preparation of total project documentation with all the permits in case of the route Josipdol – Mala Kapela tunnel (the longest tunnel in Croatia, 5730 m long) on 'Dalmatina' (Zagreb – Split motorway) was 14 months (June 1999 – September 2000). For the Study itself with research projects two months were planned. This demanding route was opened to traffic in 2005.

From the ecologic point of view, digging a tunnel on Kapela mountain massif preserved valuable wood associations, habitats of numerous species (brown bear *Ursus Arctos* L., wolf *Canis Lupus* L., rich bird life), hydrologic values – stream flows, quality drinking water. The fact is that lots of objects were built on the sections because of the relief diversity of the area. Those object, certainly, preserved the areas where the rout runs. However, we must conclude that the research for certain planned routes are insufficient. The reasons are mostly, the rapidity of construction, the fact that motorways are the important infrastructure, which make a network in the area in linear and continual way due to geographic reality and influence the elements of the area. There are special categories which are not adequately integrated in the planning and project making system: valuable landscape, habitats, certain plant and animal species. The landscape elements quality assessment is introduced to the practice of traffic road project making in the second half of the 20th century. But, in the project making phase, the landscape elements are put to the physical minimum defined by expropriation area width (approximately 2,5 m from the final construction intervention line). As it is obvious, we cannot mention the motorway landscape protection and planning in the process of project making. Unfortunately, not even on the level of planning is it not clear that the landscape (the sum of natural space characteristics and human artifacts with specific quality over the time) is a value which must be protected. More important, the new traffic road construction is a challenge in the process of the existing landscape values protection and their possible enrichment.

4. Conclusion

In short, the protection aspect should be adequately integrated in the planning, project making and road construction system. The existing flaws should be avoided:

1. Physical planning level

- The environmental protection profession underrepresented
- Bases for studies which are responsible for charting the road corridors are mostly technical and of traffic character

– Relatively slow drawing up of plans and the possibility to modify them
– Insufficient definition of certain protection segments.

2. Legislation

Laws

– Laws concerning construction, especially road construction, hardly include the protection aspect
– The array of the protection laws with no coordination and practical use
– Signed conventions and laws are not coordinated with Croatian legislative – the procedure is pending.

Environmental Impact Studies

– Studies are drawn up based on the given solution – no possibility to influence the solution
– Question of scale (construction project scale vs. needed protection aspect scale) and influence definition
– Insufficient exploration of certain areas, question of data and their accessibility
– Partial evaluation of impact – Study is just a legal frame
– The study results are not used in further phases of planning and project making – not tested.

3. Project implementation level

– Non-transparent protection measures implementation, unknown research results (the reason can be partly the short period of implementation)
– Various protection implementation corridors, measures of protection defined in documentation and the study – impossible to perform (private ownership problem)
– Changes in social system, complex relations, ‘collective property’ and ‘collective interest’ do not exist any more, market battle in the physical planning and EIS drawing up – more challenges for profession protection.

The mapped valuable locations, habitats, karst areas, categories which are about to be mapped, as well as diverse values of the areas must be taken into consideration. That makes the overlapping and interdisciplinary evaluation of the areas necessary, due to traffic infrastructure construction.

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Influence of transport infrastructure on habitats and vegetation: methodological grounds for analysis and an attempt at assessment

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Abstract. In the previous practice of Environmental Impact Assessments (EIA) plant cover and natural habitats were treated as a matter of secondary importance. It has not been in accordance with the methodological assumptions of EIA, which indicate that such assessments should have a comprehensive, holistic character. On the basis of long standing experience connected with the project of A2 highway construction in the western part of Poland, this article presents a methodical proposal comprising the most important stages of evaluation of such enterprise impact on plant cover and natural habitats. Identification, valorization and collision assessment of the planned highway involves the following levels of natural environment organization: population, phytocoenotic and landscape. The basis for identification of plant communities are the methodological guidelines of Braun-Blanquet phytosociological school. In the process of valorization characteristics of species and plant associations, including, among others, their uniqueness and the degree of threat in different spatial scales, are taken into account. For the collision assessment of the enterprise, on the one hand, the natural values of plant cover and habitats and their susceptibility to anthropopression and on the other, a route of the highway and its constructional characteristic are considered. The work proposes also several ways of mitigation of the investment impact on natural environment, including means for minimization and compensation of losses resulting from the realization of the enterprise.

Key words: highways, environmental impact assessment methodology, plant cover, mitigation, compensation, habitats, Natura 2000

1. Introduction

The natural environment functions as an integrated and dynamic system, which is composed of various type ecosystems occupying a certain area (e.g. Kostrzewski 1986). In general, two basic groups of components are distinguished: abiotic (soil, air, water) and biotic (plants, animals, fungi, microorganisms). All of these components, due to economic and social development, are subject to ever-increasing anthropogenic impact. Although depending on the type and intensity of anthropogenic impact, individual components of ecosystems might change to various degrees, in the end, the entire structure and functioning of the whole natural environment are changed. For this reason, in applied sciences (including the assessments of environmental impact), as in fundamental sciences (e.g. ecology), the assumption that the assessment of 'man-environment' interaction should have a comprehensive-holistic character was adopted as the methodological foundation (Kostrowicki 1992). Only then is it possible to know the mechanisms underlying environmental changes and work out effective methods of counteracting or minimising negative effects.

Contrary to these assumptions, in practice the reductionist approach predominates in environmental assessment, focused on individual components of ecosystems and not seeing the whole picture. Still all too often it is the case that focusing on some elements is accompanied by total disregard of the other elements or treating them as secondary. Until not so long ago, at least in the Polish environmental assessment practice, more attention was paid to abiotic (land relief, soil, hydrological conditions, air, acoustic climate) than to biotic elements. On the other hand, when the impact of an investment on animate components of the environment was assessed, attention was focused in the first place on fauna. Flora and vegetation are given less attention, which is not only surprising but also inadequate considering the role that these components play in the functioning of natural environment. The vegetation cover, taken as an element of the natural environment, in a synthetic way reflects the remaining ecological factors, both natural and anthropogenic (e.g. Roo-Zielińska & Kostrowicki 1995).

The purpose of this paper to emphasise the importance of flora and vegetation in environmental impact assessments, and in particular: (*i*) to specify the methods of the analysis of the impact of a highway on vegetation and habitats; (*ii*) to present an attempt to classify the vegetation in its relation to road investments.

The methodological proposals presented below stem first of all from experience gained during the work on the effect of the planned A2 highway on the natural environment of Wielkopolska.

2. Basic methodological assumptions and the procedure of the assessment of the effect of the highway on plant cover and habitats

The methodological concept presented below, which is an extension of the proposal from the year 1995 (Jackowiak *et al.* 1995), adopts the following methodological assumptions:

- The subject of the assessment is the effect of the designed undertaking on spontaneous vegetation, characterised in accordance with the theoretical assumptions of Braun-Blanquet's phytosociology school and by means of the methods it proposed (Pawłowski 1977; Matuszkiewicz 1981, 2005). The basic operating unit of analysis is the plant community, which is subject to hierarchical and exclusive syntaxonomical classification.
- Every plant community (as a typological unit) has a specific composition and floristic-characteristics, and – which is very important – specific habitat requirements in relation to abiotic factors. Owing to the latter characteristics, vegetation is the best indicator of a habitat. What is more, habitats are usually identified by means of narrow or broad vegetation units (e.g. Herbich 2003, 2004). Plant cover is also a sensitive indicator of environmental changes taking place under anthropogenic impact.
- Patches of plant communities, really existing in nature, create complexes repeatable in space, referred to as sigmassociations (Tüxen 1973) or aggregations of phytocoenoses (Matuszkiewicz 1978; Solon 1983). At this level of organisation of the natural environment, vegetation, or rather complexes of plant communities, are edificators of landscapes. This is their crucial property, utilised in cartographic studies, because plant communities usually exist as small surface patches and are difficult to present on a medium or small scale map.
- Valorisation of the natural environment and assessment of the effects of a highway on plant cover are conducted in accordance with the assumptions and principles of the assessment of the relation of 'man and environment' laid out by Kostrowicki (1992). In particular, it accounts for techniques that limit to the minimum the subjectivism of environmental valorisation and assessment of the effects of road infrastructure on plant cover and habitats.

The proposed assessment procedure covers five stages differing in purpose and type of proceeding as well as the manners and effects of operation (Table 1).

Table 1. The procedure of assessment of the influence of highway on plant cover

Assessment stage (type of procedure)	Method of operation	Effects of operation
Identification of plant communities (habitats), complexes of plant communities, and vegetation landscapes.	(1) Field mapping of complexes of plant communities existing in the strip of the foreseen impact of highway on the environment. (2) Field relevè covers an area uniform in terms of the predominating type of potential natural vegetation or its characteristic, repeatable mosaic, forms of land use and land relief.	(1) Qualitative and quantitative listing and characteristics of vulnerable plant complexes (communities), habitats, and species. (2) List, characteristics, and map of complexes of plant communities at scale 1: 10000.
Overall and spatial assessment of the environmental value (valorisation) of complexes of plant communities.	(1) Classification of complexes of plant communities, taking into account their structural and functional environmental qualities. (2) Valorisation criteria: the degree of naturalness of plant communities; frequency of occurrence and the degree of endangerment in the region; share of species of plants that are rare and endangered. (3) The 5-grade scale covering the complexes of the following values: extraordinary, very big, big, moderate, and slight.	(1) Overall assessment of environmental value of the assessed area. (2) Map of environmental values in the strip of influence of the planned highway at the scale 1: 10000.
Overall and spatial assessment of conflict of the planned road investment with environmental qualities at the level of complexes of plant communities.	(1) Recognition and specification of localisation, technical, and technological solutions of the undertaking (highway) and the assessment of their impact on habitats, vegetation, and plant landscapes. (2) Principles and criteria of assessment of conflict: the possibility of occurrence of conflict (sure, probable, possible); the manner of impact of external factors (direct and indirect); duration (short and long-term impact); duration of negative effects (reversible, irreversible). (3) In all partial assessments, the construction and exploitation phase of the highway are taken into account.	(1) Overall assessment of conflict of the undertaking with qualities of plant communities (habitats) as well as of plant complexes and vegetation landscapes. (2) A map of collisions located in the impact strip of the planned investment at scale 1:10000 or 1:25000.
Specifying measures minimising and compensating for environmental loss at the level of habitats, vegetation, and vegetation landscape.	(1) Analysis of effects of the conflict of the planned undertaking with habitats, populations of endangered, vulnerable, and legally protected species, as well as with communities, their complexes, and plant landscapes. (2) Specifying the ways (measures) to reduce the effects of the conflict. (3) Indicating the ways to compensate for loss in the case of unavoidable conflicts.	(1) Overall assessment of the measures minimising and compensating for environmental loss at the analysed levels. (2) Maps at a scale suited to the analysed object, indicating the directions of the localisation changes and technical solutions for minimising the loss, as well as places of compensation measures.
Specifying the principles and places of monitoring of natural environment (habitats, flora, and vegetation).	(1) Specifying the area in which habitats, populations of plant species, and vegetation will be most endangered during the construction and exploitation of the highway. (2) Specifying the principles and methods of conducting systematic observation, including compensation areas. (3) Delimiting the observation areas.	(1) Map of distribution of monitoring area at scale 1:10000. (2) Situational plans of permanent areas. (3) Adjustment of the solutions introduced.

3. Selected aspects of the assessment of the effect of A2 highway on plant cover and habitats of Wielkopolska

The goal of the study was to assess the effect of the A2 highway on plant cover and habitats. The A2 highway is part of the international road E30: Berlin-Moscow. Field mapping was performed in the years 1994-1995 in the Świecko-Września (210 km) section, during the phase preceding the issuance of the building localisation decision and in the year 2006 again in the Świecko-Trzciel (100 km) section. The section under the study divides Wielkopolska almost latitudinal; the region located in western Poland and that is a representative area of the Northern European Lowlands.

3.1. Identification of habitats and components of plant cover

According to the procedure outlined above, the basis for the analysis and assessment are 330 relevés, documenting the occurrence of complexes of plant communities, taken in the year 1994, and 52 relevés from the year 2006. The inventory was performed in a section of 210 km in a strip 1000 meters wide (500 m on both sides of the planned road). Borders of complexes of plant communities are shown in the map at the scale of 1:25000. The field relevés describes the surface layout of all plant communities (phytocoenoses) and the size of populations of selected plant species. For identification of plant communities, the studies by Matuszkiewicz (1981, 2005) and Brzeg & Wojterska (2001) were used. On this basis, types of natural habitats were identified, as specified in Appendix no. 1 to the Habitat Directive (HD 1992) as well as in the Regulation of the Minister of the Environment (RMEnv 16. 05. 2005). The following was accounted for in the selection of species: Appendixes nos. 2 and 4 to HD 1992, national and regional lists of endangered or vulnerable species (Zarzycki *et al.* 2006; Żukowski & Jackowiak 1995) and the Regulation of the Minister of the Environment on the species protection of plants (RMEnv 9. 07. 2004).

3.1.1. Participation of potential natural vegetation units in the 10 km wide strip

The studied section of A2 highway fragments 10 potential natural vegetation units ranked as communities (Table 2). Two of them, namely riparian ash-elm forest (*Ficario-Ulmetum minoris)* and oak-horn-beam forest (*Galio silvatici-Carpinetum betuli*) were specified in two forms. The identified units represent most types of the potential natural vegetation characteristic for the Northern European Lowlands. The largest area in the analysed strip is occupied by oak-hornbeam habitats (more than 40%). Almost the same total area is occupied by mixed coniferous forests and pine forests. A much smaller area is occupied by riparian ash-elm forest habitat. Other types of habitats can be treated as uniquely regional ones.

The information on the differentiation of potential natural vegetation and the role of its individual types is of paramount importance for further analysis for at least three reasons: (*i*) this vegetation can be a point of reference in the evaluation of the degree of naturalness of the existing real vegetation; (*ii*) surface share of individual types enables relativisation of the assessment of the degree of spreading of real vegetation units, and indirectly also of the species of plants related to them; (*iii*) this type of information can be used when designing compensation measures.

3.1.2. Classification and share of real complexes of plant communities in the assessed strip

In such diversified natural conditions, 34 basic types of real complexes of plant commun ties were identified, occurring with variable frequency in the 1000 meter-wide analysed strip (Table 3). They were classified into three groups differing in terms of the degree of anthropogenic transformation of habitats and vegetation.

The group of complexes of natural plant communities comprises nine basic types: two non-forest, six forest, and one mixed type. Their total share in the represented set of relevés is less than 21%. Our attention is drawn to lack of a complex of oak-hornbeam forest, although potentially habitats occupied by this type of phytocoenosis are largely predominating in the analysed area (compare with Table 2). The following three types of complexes are very rare: oak forests (oak woods), beech-oak forests, and beech forests (beech-woods).

The group of semi-natural complexes of plant communities contains seven basic types, and their total share is approximately 18%. The unique character in the analysed area has a complex of sward communities, and extremely rare are the complexes of mesophile scrub.

Table 2. Characteristics and participation of potential natural vegetation units in the 10 km wide and 210 km long strip, in which the A2 highway is localised (Świecko-Września section)

Potential natural vegetation unit*	Occurrence and habitat conditions	Area	
		km²	%
Salici-Populetum (R. Tx. 1931) Meijer Drees 1936	Riparian forest, poplar-willow, forming on sandy alluvia of larger lowland rivers, within the reach of high water levels and annual flooding.	7.32	0.33
Ficario-Ulmetum minoris Knapp 1942 em. J. Mat. 1976 *typicum*	Riparian forest, elm-ash, forming on wings of valleys of larger lowland rivers, in the zone of episodic flooding, resulting in accumulation of fine mineral sediments. Particularly eutrophic.	9.79	0.44
Ficario-Ulmetum Knapp 1942 em. J. Mat. 1976 *chrysosplenietosum*	Riparian forest, elm-ash, also forming outside valleys of large rivers – in valleys of smaller rivers and watercourses, in wide depressions on lake terraces and in rainwater discharge troughs. Particularly eutrophic.	147.25	6.67
Fraxino-Alnetum W. Mat. 1952	Riparian forest, ash-alder, forming on flat lowland areas, in valleys of slowly-flowing watercourses, in slightly boggy habitats.	178.24	8.08
Galio silvatici-Carpinetum betuli Oberd. 1957 poor form	Oak-hornbeam forest, forming on flat highland areas and high terraces of large rivers, in medium trophy and humidity of habitats. Climax community for the predominating part of the Northern European Lowlands.	401.05	18.18
Galio silvatici-Carpinetum betuli Oberd. 1957 fertile form	Oak-hornbeam forest, forming on flat highland areas and high terraces of large rivers, in fertile and humid habitats. Climax community for the predominating part of the Northern European Lowlands.	487.42	22.09
Melico-Fagetum Lohm. ap. Seibert 1954	Fertile lowland Pomeranian type beech forest, developing on hilly lowland areas, on habitats at least moderately fertile and humid.	31.01	1.41
Luzulo pilosae-Fagetum W. Mat. et A. Mat. 1973	Acidophilus beech forest developing on fawn or brown, leached and acidic soils.	24.4	1.11
Potentillo albae-Quercetum Libb. 1933	Oak forest (light oak woods) developing on hilly areas at the area of end moraine in moderately fertile habitats, relatively dry, sometimes distinctly acidified.	13.79	0.62
Fago-Quercetum petraeae R. Tx. 1955	Beech-oak forest (subatlantic mesotrophic 'acidic' oak woods of 'Pomeranian' type) developing on fresh or wet acidic sandy-clay and fine-sand soils, usually on slopes of moraine hills.	52.82	2.39
Pino-Quercetum	Forest with equal share in the forest stand of coniferous and deciduous species (mostly pine, oak, or beech), developing on moderately fertile, fresh, and wet soils.	391.95	17.76
Leucobryo-Pinetum Juraszek 1927	Suboceanic fresh pine forest developing on poor sandy podzolic soils with low level of underground water.	447.27	20.27
Water habitats (lakes)		14.12	0.64
Total:		2182.04	100.00

*Approach and names of units acc. to Wojterski *et al.* (1973) and Wojterski *et al.* (1982)

More than 61% of relevés document the occurrence of 18 types of complexes of non-natural plant communities. Such a high frequency and high internal variation of this group of distributions testifies to the considerable transformation of natural environment in the analysed area and draws our attention to the anthropogenic impact in the process of fragmentation of natural vegetation landscapes. The participation of three subgroups is quite balanced, namely: complexes of substitute forest communities (3.1), complexes of farmland weeds communities (3.2) and complexes of ruderal plants communities in urbanised habitats (3.4). Our attention should particularly be drawn to the first one, because despite the low degree of naturalness, management forests play an important environment generating role, increasing the environmental quality of the area.

3.1.3. Plant communities and natural habitats of particular ecological importance

Along the analysed section of the A2 highway, there were 297 plant communities, of which there were 191 ranged associations, 34 communities, and the remaining 72 were trunk phytocoenons and degenerative forms of associations. 42 syntaxonomic units, enabling definition of 18 types of habitats described in Appendix I of the Habitat Directive, including two types of priority habitats (five plant communities), requiring protection in the form of delimiting Natura 2000 sites (table 4). The frequency of complexes from HD ranges from one to 34. An exception are meadows – *Arrhenatheretum elatioris* (108 occurrences), usually developed in the form of narrow strips in roadsides.

The associations found represent all the vegetation formations of the Northern European Lowlands. More than 64% are of natural origin, of which 10.5% are communities limited to habitats not changed by humans (perdochoric). Semi-natural vegetation includes green utilised land and lawns (9.4%), whilst the synanthropic vegetation is made up from ruderal (14.7%) and segetal (6.3%) communities. Approximately 5.2% are xenospontaneous communities, made up from species of foreign origin, entering a habitat slightly changed by humans.

From among 191 communities as many as 97 (50.8%) are endangered in Wielkopolska, including eight in direct danger of extinction (E), 34 vulnerable to extinction (V), and 55 in indefinite danger (I).

3.1.4. Plant species of particular natural importance

In the environmental impact zone of the A2 highway, the occurrence of several dozen species of particular importance for the assessment of effect of this undertaking on plant cover and habitats was discovered (Table 5). Included here were three taxons from appendixes 2 and 4 HD, 53 species subject to legal protection in Poland (32 species of vascular plants and 21 cryptogamae species), nine species from the ‘Polish Red List of Vascular Plants’ and 40 endangered and vulnerable species in Wielkopolska.

Table 3. Classification and share of complexes of plant communities in the assessed strip of the impact of the designed A2 highway on the environment (Świecko-Września section)

Number and name of complex of plant communities	Number of relevés	%
1. Complexes of natural plant communities (functioning in conditions of very limited anthropogenic impact)	69	20.9
1.1. Complexes of non-forest communities	15	4.5
1.1.1. Complexes of water and water-edge communities	11	3.3
1.1.2. Complexes of peat-bog communities	4	1.2
1.2. Complexes of forest communities	45	13.6
1.2.1. Complex of fresh pine forest	21	6.4
1.2.2. Complex of oak forests (oak woods)	1	0.3
1.2.3. Complex of beech-oak forests (beech-oak woods)	3	0.9
1.2.4. Complex of beech forests (beech woods)	2	0,6
1.2.5. Complexes of riparian forests	7	2.1
1.2.6. Complexes developed in a mosaic of forest habitats	11	3.3
1.3. Water-peat-bog-forest complexes	9	2.7
2. Complexes of semi-natural plant communities developed as a result of moderate anthropogenic pressure	59	17.9
2.1. Complexes of rush communities (reed and sedge rushes)	12	3.6
2.2. Complexes of meadow communities	39	11.8
2.2.1. Complex of wet meadows	14	4.2
2.2.2. Fresh meadow complex	5	1.5
2.2.3. Complexes in a mosaic of meadow habitats	20	6.1
2.3. Complexes of sward communities	1	0.3
2.4. Complexes of scrub communities	7	2.1
2.4.1. Complexes of mesophile scrub	2	0.6
2.4.2. Complexes of hygrophilous scrub	5	1.5
3. Complexes of non-natural plant communities developed as a result of strong anthropogenic pressure	202	61.2
3.1. Complexes of substitute forest communities	50	15.2
3.2. Complexes of farmland weeds communities	75	22.7
3.2.1. Complexes of weeds communities on fertile farmlands	33	10.0
3.2.2. Complexes of weeds communities on moderately fertile farmlands	16	4.8
3.2.3. Complexes of weeds communities on poorly farmlands	15	4.5
3.2.4. Complexes in a mosaic of farmland habitats	2	0.6
3.3. Complexes of plant communities on post-farming fallow land	9	2.7
3.4. Complexes of ruderal plant communities on urbanised habitats	59	17.9
3.4.1. Complexes of ruderal communities in settlements with predominating farmbuildings	5	1.5
3.4.2. Complexes of ruderal communities in rural settlements with concentrated buildings	16	4.8
3.4.3. Complexes of ruderal communities in rural settlements with dispersed buildings	14	4.2
3.4.4. Complexes of ruderal communities in suburban settlements with concentrated garden-villa buildings	6	1.8
3.4.5. Complexes of ruderal communities in settlements with workshop-industrial and transportation buildings	8	2.4
3.4.6. Complexes of ruderal communities in settlements with predominating gardens and orchards (allotment parcels)	2	0.6
3.4.7. Complexes of ruderal communities in town settlements with flat row buildings	7	2.1
3.4.8. Complexes of ruderal communities in town settlements with block-of-flat buildings	1	0.3
3.5. Complexes of plant communities on special, currently used, habitats	6	1.8
3.6. Complexes of plant communities on special habitats, subject to renaturalisation	12	3.6
3.6.1. Complexes of water and rush communities	5	1.5
3.6.2. Complexes of sward communities	2	0.6
3.6.3. Complexes of scrub and forest communities	5	1.5
Total:	330	100.0

Table 4. A section of specification containing the characteristics of plant communities and natural habitats in the assessed strip of the impact of the designed A2 highway on the environment (Świecko Września section)

Code and habitat	Syntaxonomic unit	Form	Syn	End	Fr	Com
2330: Inland dunes with sand swards	*Cladonietum mitis*	PS	NAC	I	2	1
	Corniculario-Corynephoretum	PS	NAC		21	1
	Armerio-Festucetum	PS	SNC	I	20	2
	Filagini-Vulpietum	PS	SNC	E	1	2
3130: Banks or drained bottoms of water reservoirs	*Cypero fusci-Limoselletum aquaticae*	ST	NAC	I	1	1
	Juncetum bufonii	ST	NAC		19	1
3140: Hard water oligo- and mesotrophic reservoirs	*Charetum tomentosae*	W	NAC	I	2	1
3150: Old river courses and neutral eutrophic reservoirs	*Lemno-Hydrocharitetum morsus-ranae*	W	NAC	I	2	1
	Myriophylletum spicati	W	NAC	I	1	1
	Polygonetum natantis	W	NAC		5	1
	Potametum lucentis	W	NAC	I	1	1
	Potametum pectinati	W	NAC		1	1
	Nymphaeo albae-Nupharetum luteae	W	NPC	V	21	3
3270: Flooded muddy river banks	*Bidention*	ST			3	1
	Bidenti-Polygonetum hydropiperis	ST	NAC		26	1
	Chenopodietum rubri	ST	NAC	I	3	1
4030: Dry heath communities	*Pohlio-Callunetum*	HC	NAC		2	2
6210: Inland sand swards	*Tunico-Poetum compressae*	XS	NAC	I	4	1
6410: Variable humidity *Molinietum medioeuropaeum* meadows	*Galietum borealis*	HGL	SNC	E	4	2
6430: River-bank herbs	*Carduo crispi-Rubetum caesii*	NHC	NAC		12	2
	Convolvulo sepium-Cuscutetum europaeae	NHC	NAC	I	4	1
	Epilobio hirsuti-Convolvuletum	NHC	NAC		25	2
	Eupatorietum cannabini	NHC	NAC		28	2
	Fallopio-Humuletum	NHC	NAC		26	1
	Urtico-Convolvuletum sepium	NHC	NAC		26	2
	Convolvuletalia sepium	NHC			8	1
6510: Fresh meadows, extensively used	*Arrhenatheretum elatioris*	FGL	SNC	V	108	2
7140: Temporary peatbogs and swamps	*Calamagrostietum canescentis*	R	NAC	I	13	4
	Carici-Agrostietum caninae	PB	NAC	I	5	2
	Eleocharitetum pauciflorae	PB	NPC	E	12	4
	Scorpidio-Caricetum diandrae	PB	NPC	E	5	4
	Sphagno recurvi-Eriophoretum angustifolii	PB	NPC	V	1	4
9110: Acidic beech-grooves	*Deschampsio flexuosae-Fagetum*	AF	NPC	V	2	1
9130: Fertile beech-grooves	*Melico-Fagetum*	MF	NPC	V	3	1
9170: Oak-hornbeam forest	*Galio sylvatici-Carpinetum*	MF	NPC	V	10	1
91DO*: Swamp forests	*Vaccinio uliginosi-Pinetum*	C	NPC	E	1	4
91EO*: Willow, poplar, alder and ash riparian forests	*Carici elongatae-Alnetum*	HF	NAC	I	19	1
	Fraxino-Alnetum	HF	NAC	I	34	1
	Populetum albae	HF	NPC	E	2	1
	Salicetum albae	HF	NPC	V	8	1
91FO: Riparian oak-elm-ash forests	*Querco-Ulmetum minoris*	HF	NPC	V	16	1
91TO: Lichen pine forests	*Cladonio-Pinetum*	C	NAC	I	2	1

Notes on table 4: Form – plant formation: C – coniferous forests, AF – acidophilus forests, HF – hydrophilus forests, MF – mesophile forests, XS – xerothermic swards, PS – psammophilus swards, R – rush, ST – shore therophytes, PB – peatbogs, FGL – fresh green utility land, HGL – variable humidity green utility land, W – water plants, HC – heath communities, NHC – nitrophilus herb communities; **Syn – syngenesis** acc. to Faliński (1969) and Brzeg & Wojterska (2001), simplified: NAC – natural auksochoric communities, NPC – natural perdochoric communities, SNC – seminatural community, **End – endangered community in Wielkopolska** acc. to Brzeg & Wojterska (2001): E – in direct danger of extinction, V – vulnerable, I – in indefinite danger; **Fr – frequency** (number of relevés); **Com – the manner of compensating** (compare with Table 7)

Table 5. The occurrence of species of vascular plants of particular environmental importance in the impact zone of the A2 highway (Świecko-Września section) on the environment

Plant species group	Number of species
Species from Appendixes 2 and 4 to the Habitat Directive	3*
Species protected by law in Poland:	
full protection	18
partial protection	14
Total	**32**
Species endangered and vulnerable in Poland	
directly endangered [E]	3
vulnerable [V]	6
Total	**9**
Species endangered and vulnerable in Wielkopolska	
directly endangered [E]	2
vulnerable [V]	30
rare [R]	8
Total	**40**

*2 species of vascular plants – *Liparis loeselli*, *Luronium natans* and 1 species of moss – *Hamatocaulis vernicosus*

3.2. Valorisation

The assessment of environmental values was carried out at the level of complexes of plant communities, in accordance with the assumptions and criteria presented in Table 1. The analysis of their share in the assessment strip (1 km wide) and in the strip of immediate impact of the highway (100 metres) showed similar proportions between the individual categories (Table 6). Divisions of exceptional environmental value are quite numerous, but in total they occupy a small area (2.9 and 2.2% respectively). The lowest vale synanthropic complexes of simplified structure predominate – mainly communities of farmland weeds.

3.3. Conflicts

In the section of 210 km, 73 collisions of the designed A2 highway with the natural environment were found. Of these conflicts, in accordance with the prior division (compare with Table 1) which takes into account the probability of conflict stood out: (*i*) obvious conflicts (52), that is such when the planned highway dissects valuable natural objects, and (*ii*) possible and probable conflicts, then the road will run near areas of great environmental value (indirect danger) or the danger will only be present in case of potential emergency situations (21). In more than 82% of the assessed section of the future highway, there is no major conflict with the natural environment. Conflicts take place along the total length of approximately 47 km, including obvious conflicts in the section of 31.4 km.

Besides the ones listed on the route of the designed highway, there are conflicts of formal character, e.g. fragmenting the protected areas of various levels of importance.

Table 6. Differentiation of environmental values in the assessed strip of impact of the designed A2 highway on the environment

Environmental value	Definition	Assessment strip (1km)		Strip 100 m	
		Area in km^2	%	Area in km^2	%
Extraordinary	Natural forest or non-forest complexes, very rare at regional scale, with endangered or protected communities and species.	6.2	2.9	0.5	2.2
Very important	Natural forest or non-forest complexes, rare at regional scale or very rare semi-natural complexes, with endangered or protected communities and species.	11.0	5.2	1.0	4.6
Important	Widely spread regional natural forest or non-forest complexes, enclaves of forest substitute communities of high biocenotic importance, semi-natural complexes and relic complexes of synanthropic communities.	72.2	34.0	7.7	36.1
Average	Large-area forest substitute communities and well-developed complexes of synanthropic communities, found in mosaic layout.	37.5	17.7	3.9	18.2
Not significant	Synanthropic communities of simplified structure.	85.3	40.2	8.2	38.8

3.4. Minimisation and compensation for environmental loss

Assuming that the route of the road was conclusively delimited, in the case of probable conflicts the danger can be avoided using special technical solutions during construction and exploitation of the highway (minimisation).

The consequences of certain (unavoidable) conflicts will be mitigated first of all by various types of compensation measures. These make up more than 71% of all conflicts and take place on a total distance of more than 31 km.

When selecting the communities that require compensation measures, the following criteria were followed: (*i*) status of community as provided for in HD and RMEnv on habitat protection; (*ii*) status on the 'red list' of communities of Wielkopolska; (*iii*) regional uniqueness resulting from nature or being the effect of anthropogenic pressure; (*iv*) biocenotic importance, in particular the role in maintaining the populations of rare and endangered species of plants and animals; (*v*) representativeness expressed in accounting for communities from all formations of vegetation (compare with Table 4).

Four compensation measures were proposed. 70 communities present in the studied area were envisaged for it, of which 42 from HD, to whom the highest level was assigned (table 7). This number includes five communities from two priority types of habitats, and 37 from the 16 remaining types of habitats. The group of communities proposed for first compensation contains in total 29 endangered associations in Wielkopolska.

In addition, eight further protected and endangered plant communities were distinguished, not present in the strip of impact of the highway, but despite this recommended for compensation (compare with Table 7, point 4).

The largest surface share was envisaged for forest vegetation, in particular for communities which are potentially the broadest distributed and the poorest represented within the real vegetation. Various types of swards, herbs, and water communities also appear in great number.

Detailed examples of solutions in the field of compensation, realised on permanent research surfaces, should be started at the stage of the construction project.

Table 7. Methods of compensating for loss of communities and species of plants included in the Habitats Directive as well as endangered in Wielkopolska, related to the construction of the A2 highway

Methods of compensation	Community category				
	HD*	HD	E	V	I
1. Allowing for spontaneous succession of vegetation within the same type of habitat, with possible use of promoters accelerating this process.	4	22	1	5	12
2. Controlling the process of succession within the same type of habitat by using manipulations adequate for the type of compensated vegetation (e.g. mowing, cutting down).	0	10	2	1	2
3. Translocation of populations of species of supraregional importance and species crucial for the functioning of plant communities listed in the Habitat Directive, supported by the use of manipulations adequate for the type of compensated vegetation.	2	4	0	1	0
4. The replacement of impossible to restore habitat and phytocoenotic systems with types of plant habitats and communities listed in the Habitat Directive.	1	4	3	1	1

Explanations: 1-4 numbers in accordance with Table 5; HD – communities corresponding to habitats from Appendix I of the Habitat Directive; HD* – communities corresponding to priority habitats; communities directly endangered (E) vulnerable to extinction (V) and indeterminate (I) Wielkopolska.

Compensation is also possible through the use of other actions contributing to the protection of the natural environment, e.g. very environmentally valuable areas, so far not protected, were recommended for protection, and in case of some already protected areas, a higher protection status was suggested.

4. Conclusions

Methods of geobotanic studies, developed for several dozens of years now, can be successfully used in environmental impact assessments, in particular pertaining to areas of high environmental value. Their advantage is first of all the possibility to know and assess biodiversity at various levels of environmental organisation, from population to vegetation landscape. Therefore, as needed, they can be used at various levels of detail. These methods are particularly useful in protected areas, e.g. as part of international ecological networks, including Natura 2000.

On the other hand, EIAs using scientific geobotanic know-how to the full extent enrich knowledge of the diversity of plant cover of a region and its anthropogenic transformations. This was proved in research conducted within a study strip of 1 km width and 210 km length, crossing almost all of Wielkopolska. They show, among other things, that although on more than 82% of the route of the designed highway there are no significant conflicts with the natural environment, along the total length of more than 31 km, conflicts are significant. This corresponds to the occurrence of natural complexes of plant communities and divisions of the highest environmental value. Mainly in these areas, there are concentrated habitats of the "most valuable" species of plants and phytocoenons.

The highway is undoubtedly an investment with a negative impact on the natural environment. Nevertheless, the proper delimitation of its route and the use of appropriate technical solutions contribute to the mitigation of loss within the fragmented and adjacent biotopes. Properly designed and carried out compensating measures can to a certain degree mitigate the loss and even contribute to increasing the local value of environment. However, it is important that all the actions in this respect be monitored by specialised scientific bodies.

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of the Community, whose protection requires delimiting special protection areas; *Appendix 3* Criteria of selection of objects qualifying them to determination as objects subject of particular interest of the Community and delimiting them as special protection areas; *Appendix 4* Species of plants and animals which are subject of particular interest of the Community and which require strict protection.
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Assessment of the impact of highways on biotopes and landscape: is there an international methodological model?

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Abstract. The article describes the Polish and German experience in the assessment of the environmenta-limpact of highways (highway EIA). In the first part of the paper, a short analysis of experience of the two countries in this area will be presented. The second part will present the results of the assessment of environmental impact conducted based on the so-called German methodological model of EIA for biotopes and the landscape in the area near the designed A2 highway's intersection with Łagowski Landscape Park (ŁLP).

Key words: highway, Environmental Impact Assessment, landscape, biotop, research methods, landscape park

1. German and Polish experience in highway EIA

So far, EIA experience in Poland has lacked the appropriate scientific and methodological foundations pertaining to surveying the environment. Many changes in environmental legislation in recent years, related to the adapting of the Polish legal system to membership in the EU as well as the pressure to construct highways, resulted in EIA being treated as a major obstacle in the investment process, having no major effect on the conservation of the environment.

Table 1 presents the most important facts in the development of environmental impact assessments. Both in Germany and in Poland, the impulse to sanction EIA was the impact of highways – one of the most dangerous undertakings for the natural environment. According to the data of the European Environment Agency, in the years 1990-1998 in the European Union, more than 30,000 ha of area was taken over for highway construction (10 ha per day). Since the year 2000, the tempo of construction has decreased, but nevertheless, the length of the network of highways in Germany alone in the year 2005 was 12,200 km, the longest in Europe. In the year 1998, only 480 areas with a total area of 80,062 km2 were not subject to fragmentation by a linear undertaking (Gawlak 2001). In Poland in the same period, the length of highway network was 550 km, and in localisation procedures the problem of habitat fragmentation is treated harshly (for example, the positive decision of the Minister of the Environment for the realisation of the Augustów ringroad through the Rospuda Valley).

The first reports on the impact of highways on the environment in the two countries were drafted before the legal basis for their production came into being: in Germany in the mid 1980's and in Poland in early 1990's. The present legal basis for the EIA system in Poland is the Environmental Protection Law (UPOŚ) of 2001, and in Germany the Act on Environmental Impact Assessments (EIA Law) of 1990, as amended.

The EIA system in Germany is based on the broad experience of the German spatial and landscape planning school (Jessel & Tobias 2002) and experience with the abovementioned control of environmental intervention. The Germans have 70 years of experience in the field of highway construction, and the subject matter part of the research for the EIA reports is based on a verified and strengthened procedure, so-called good practice. Environmental consultants have at their disposal a number of standard materials and guidelines. Table 2 presents example methodological materials that can be used in highway EIA in Poland and in Germany.

Most Polish EIA handbooks refer to the problems of administration procedures but lack detailed methodological indications pertaining to research design in order to define the impact of highways on the environment, the selection of criteria, and methods of delimiting the area of research.

Table 1. The development of highways' environmental impact assessments in Poland and in Germany

	Germany	Poland
First EIA signals	Regulation on the principles of environmental impact assessment in public acts of law[1] of 1975. This used to be a tool for internal administration control and did not meet most of the requirements for EIA today.	Law of environmental protection of 1980 – for the first time in Polish law, the need for specifying the impact of an investment on the environment is mentioned.
Environmental impact assessment of highways	Beginnings of informal EIAs date back to 1980's, but the so-called Control of Environmental Interventions (*Eingriffsregelung*) was introduced as early as in 1976, pursuant to the Law on Environmental Protection[2].	First informal EIAs date back to the early 1990's.
The first primary act of law for EIA	The law on EIA of 1990.[3]	The law on toll highways of 1994, which introduced the obligation to carry out an EIA for planned highways The law on EIA of 2000[4].
Present legal basis	The law on EIA of 1990, last amended in 2006.	Law of environmental protection of 2001
The state of implementation of EU law	Directive 85/337/EWG, implemented in 1990. Directive 97/11/EC, implemented in 2002. Directive 2001/42/EC, implemented in 2005.	Directive 97/11/EC and 2001/42/EC, implemented in 2000.

[1] Grundsätze für die Prüfung der Umweltverträglichkeit öffentlicher Maßnahmen des Bundes vom 1975;
[2] Bundesnaturschutzgesetz 1976; [3]Umweltvertraeglichkeitsprüfungsgesetz – UVPG 1990; [4]Ustawa z dnia 9 listopada 2000 r. o dostępie do informacji o środowisku i jego ochronie oraz o ocenach oddziaływania na środowisko

2. Methodological model of highway EIA for biotopes and landscape

The goal of the research project was to analyse German and Polish experience in assessments of the environmental impact of highways. The outcome of the research was the development of the model of identification and valorisation of biotopes and landscapes, and assessment of the environmental impact of highways. The premise for taking up this subject was the attempt to develop a coherent Polish-German model of EIA for biotopes and for landscape.

The following assumptions were made in the project:

- the subjects of the highway impact assessment are biotopes and landscape,
- the developed methodological scheme is adjusted to the environmental conditions characteristic for western Poland and eastern Germany,
- the procedure must be universal and must be applicable to the conditions of Polish, German, and European EIA laws.

The application area was a 16-km-long fragment of the planned A2 highway – the crossing through Łagowski Landscape Park. The section is located in western Poland within the borders of the Lubuskie Voivodeship, approximately 40 km from the German border. This is an area of exceptional environmental and landscape value, and the planned highway is one of the major localisation conflicts for A2.

At the first stage of research, it was necessary to analyze the definition of biotope and landscape in terms of their use in EIA. These terms are not defined in Polish law, and landscape itself functions in many facets in the world of science, e.g. as a cultural, anthropogenic, natural, plant, urban, or rural landscape. Therefore, what landscape is referred to by the legislator in the Law on Environmental Protection, art. 52, point 5b? The landscape is the element which must be assessed in terms of impact of the undertaking, next to other elements of the environment such as wildlife, plants, water, air, soil, climate, material goods and historical ancient monuments. For this reason, approaching the notion of landscape in comprehensive terms should be ruled out (in Germany *Landschaft*). Therefore, in EIA we deal with so-called visual, aesthetical landscape (in Germany *Landschftsbild*), which reflects external elements of the natural-cultural environment, and thus vegetation cover, land relief, and cultural elements. Using the definition given by Bastian & Schreiber (1998), we can say that landscape is the part of the earth surface that creates spatial character in a given place, thanks to its formation, external vision, and process-oriented functional synergy, as well as internal and external relations.

Table 2. Practical experience in highway EIA in Germany and in Poland – examples of 'good practice'

	Germany	Poland
Presentation of highway EIA in graphic form	BMV 1995. Standard maps for environmental impact assessment in road construction.	None
Handbooks referring to EIA procedures	i.a. Gassner E. & Winkelbrant A. 2005. EIA – legal and methodological introduction to environmental impact assessments. Storm P.-C. & Bunge T. 2005. Environmental impact assessment handbook. Köppel J., Peters W. & Wende W. 2004. Control of environmental interventions, environmental impact assessment, assessment of impact on NATURA 2000 sites.	i.a. Tyszecki A. (ed.). 1999. Guidelines for the procedure and implementation of environmental impact assessments. Florkiewicz E. & Tyszecki A. 2003. Procedure in EIA in administrative decision-taking. Wiszniewska B. *et. al.* 2001. Procedure in environmental impact assessment of planned undertakings.
Natural environment in EIA methodology handbooks	i.a. Bastian O. & Schreiber K-F. 1998. Ecological analysis and valorisation of landscape. Knospe F. 2001. Argumentative assessment handbook, Gareis-Grahmann F. 1993. Visual landscape and environmental impact assessment – analysis, forecast, valorization of landscape according to the law on EIA. Jessel B. *et. al.* 2003. Developing compensation measures in landscape impact. Koch M. 1989. Undertaking's environmental impact assessment – roads.	Lenart W. 2003. Scope of environmental information for the needs of environmental impact assessments.
Handbooks related to environmental impact of roads and highways	i.a. MUVS. 2001. Information leaflet to the report on the environmental impact of undertakings as part of road planning[1]. Reck K. & Kaule G. 1993. Roads and habitats, identification and assessment of the impact of road on flora, fauna, and their habitats. Tischew *et. al.* 2004. Long-term effects of compensation measures in projects. Günnewig D. & Hoppenstedt A. 2001. Methodological development of environmental risk assessment in communication projects.	Tracz M. *et al.* 1999. Assessment of the impact of roads on the environment. Badora K. 2004. Highway – natural environment.

[1]the brochure was translated into Polish as part of the Polish-German Twinning project of evaluation of impact on the environment

Interpretation problems also appear when we look for the relation of the biotope and EIA. Based on the analysis of the definitions given in Polish and German sources, it has been assumed that biotope is the environment (habitat, place) of the biocenosis (species, organism). German sources add that this is an area of clearly marked borders, characterised by the occurrence of specific abiotic conditions.

As was already mentioned, the key elements of highway EIA are identification and classification of the environment, its valorization, and the assessment of the force of impact of the undertaking. Below, we present the analysis of these stages of environmental impact assessment:

2.1. Identification of the environment

This is a very important element of highway EIA, because its particularisation and reliability decides of the contents of the report. If at this early stage, mistakes are made and the environment is incorrectly identified and described, it will be impossible to correctly carry out further research for an EIA report, which will be disastrous for the entire procedure. At this stage, the working scales of from 1:10,000 (biotopes) and 1:25,000 (complexes of biotopes and the landscape) were assumed. Identification of the environment was carried out according to the following schedule:

Analysis of materials in terms of delimitation of the area of field tests. It has been assumed that further detailed analysis will cover the areas identified as valuable, on which the highway could exert direct or indirect impact. To do this, a research area of 1 km width was delimited on both sides of the designed highway for the biotopes, which was then divided into three impact zones. Next, the area was analysed for overall qualities of complexes of biotopes. For further land mapping, valuable areas that will be subject to considerable negative impact of the highway were indicated. More remotely located farmland and urban areas were excluded from mapping (Fig. 1).

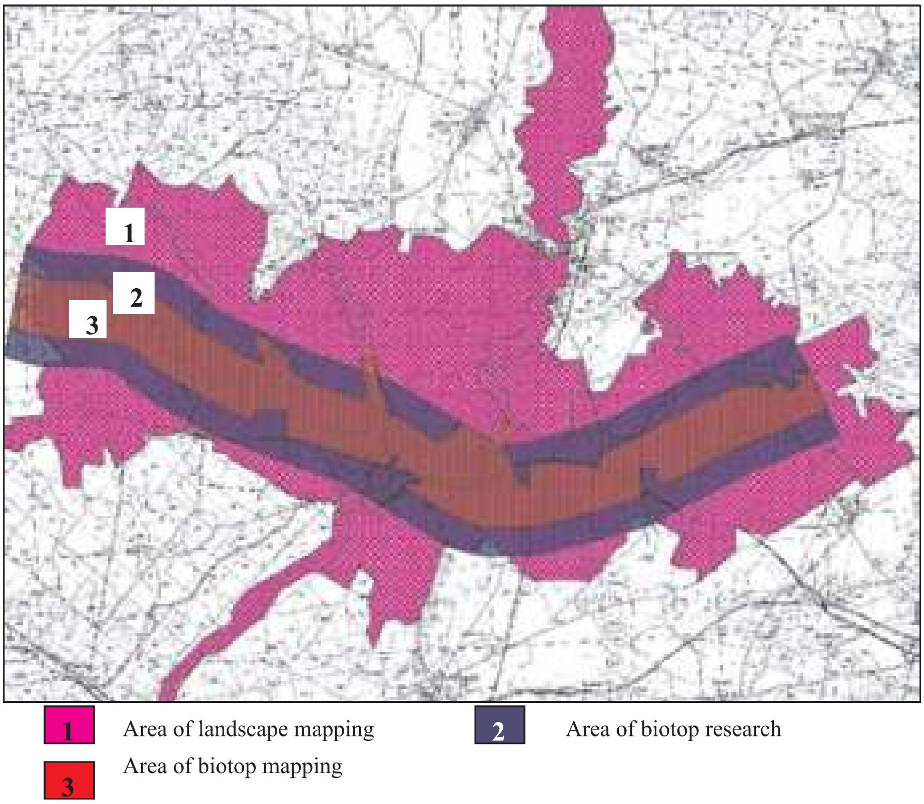

Fig. 1. Borders of the area of studying the biotopes and the landscape in EIA for the planned A2 highway – the crossing through Łagowski Landscape Park

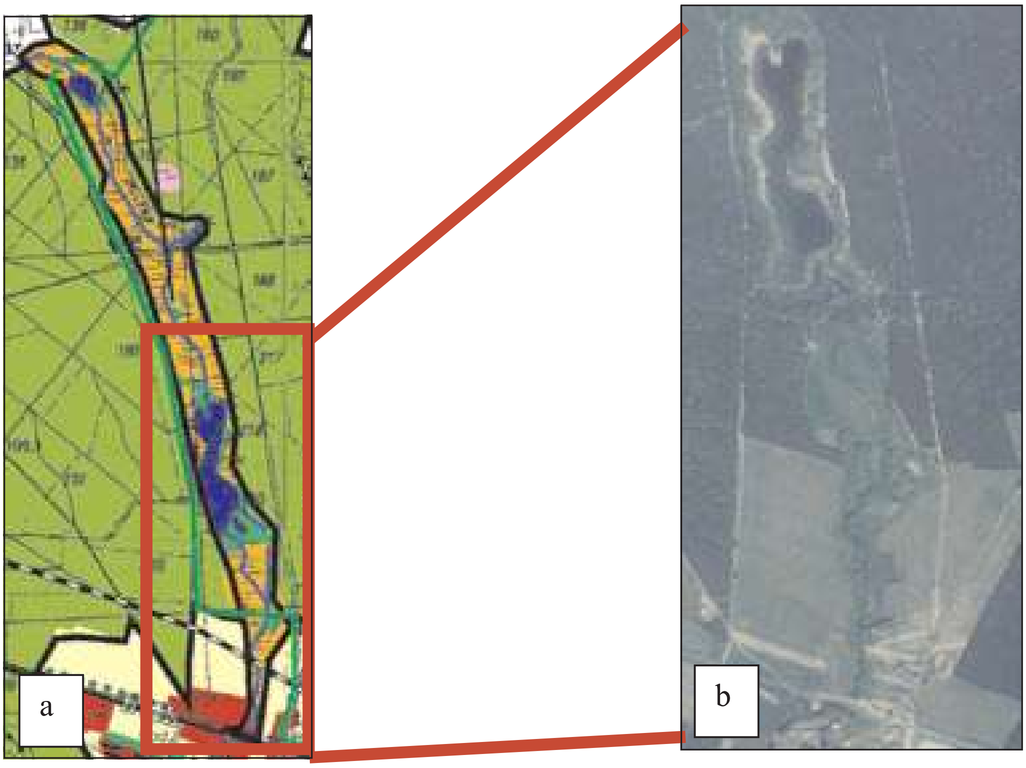

Fig. 2. A fragment of a landscape map (a) with a landscape unit: a river valley; and a fragment of an aerial photo (b) that was used for further analysis of complexes of biotopes

Fig. 3. Fragments of maps of biotope complexes (a) and biotope maps (b)

In the landscape identification, the methodology proposed by Jessel *et al.* (2003) was used, consisting in delimiting the landscape units using the vantage points method. This method consists in determining the impact of the highway within the reach of sight. The final limits of the research area for the biotope and landscape are presented in Picture 1. This research showed that due to the variety of impacts of the highway (visual, change of aquatic relations, barrier effects) it is optimal to delimit, individually for each element of the environment, the borders of the study area, taking into account the intensity of the research carried out. For example, where there is direct contact with the highway, one should introduce detailed stocktaking adjusted to the characteristic type of biotope (e.g. water, forest); at a distance of several hundred meters, mapping can be limited to identification of the biotope's characteristics and its basic parameters.

Field mapping, which was carried out based on the key for mapping the biotopes of Brandenburg land (LUA, 2003). The key was adjusted to the specific environmental conditions of the studied area (e.g. the predominating share of years-long fallow land in the surface structure of biotopes). Examples of biotopes: oak mixed forests of warm and dry habitats, fresh meadows, small water reservoirs, reed fields on secondary areas.

Analysis of thematic, topographic, hydrographic, soil, and forest maps, as well as publications about ŁLP.

Graphic presentation of results. The final result was the creation of a biotope use map at the scale of 1:10,000, as well as a landscape units map at the scale of 1:25,000.

The research was conducted on various spatial planes – from the overall landscape level (Fig. 2a) and aerial photo analysis (Fig. 2b), for delimiting a complex of biotopes, and then individual biotopes (Fig. 3a) and their analyses in terms of environmental parameters (e.g. the degree of hemoroby).

The condition for the smooth presentation of various levels of mapping is using the GIS (Arc View) platform for analysis of spatial analysis and presentation of results.

2.2. Environmental valorisation

Valorisation is a process which serves to assign quality to environmental objects (Bastian & Schreiber 1998). Kostrowicki (1992) is of the opinion that any assessment is subjective, but all conditions for objective assessment should be created. The goal of environmental valorisation in EIA in relation to biotopes is the assessment of the structure, the form of use, and the function of the element, taking into account the potential of the environment. Environmental valorisation requires the development of a set of specific partial grades and their logical presentation (e.g. on a 5-grade scale).

The following partial grades have been used in the valorisation of biotopes: hemeroby, age, biotope functions, uniqueness (basic grades) and degree of separation/connection of biotopes, species or micro-habitat Diversity (secondary grades).

The criteria of landscape assessment in Germany are set forth in the Law on Enviromental Protection of 2002[1]. The criteria are as follows: aesthetical impressions, uniqueness and variety.

The effect of this stage of research was the preparation of a 5-grade map of biotope qualities and landscape qualities.

2.3. Assessment of the intensity of impact

The assessment of impact is the final stage of research as part of an EIA report. It plays the key role, because it lets us not only identify and locate conflicts resulting from the realisation of the undertaking, but also determine their intensity. The results of the assessment have an effect on issuing a decision concerning the undertaking.

A 5-grade evaluation scale was adopted in the project. The assessment process ran based on the analysis of the following partial assessments: evironmental quality of a biotope, location of the biotope in relation to the highway (distance), biotope vulnerability (Basic grades) and the foreseen

[1] Bundesnaturschutgesetz vom 25 Maerz 2002.

intensity of the effect of highway on biotope, the so-far existing burdens on the environment (secondary grades).

Fragments of the environmental quality map as well as maps assessing the intensity of the conflict with the environment are presented in Fig. 4.

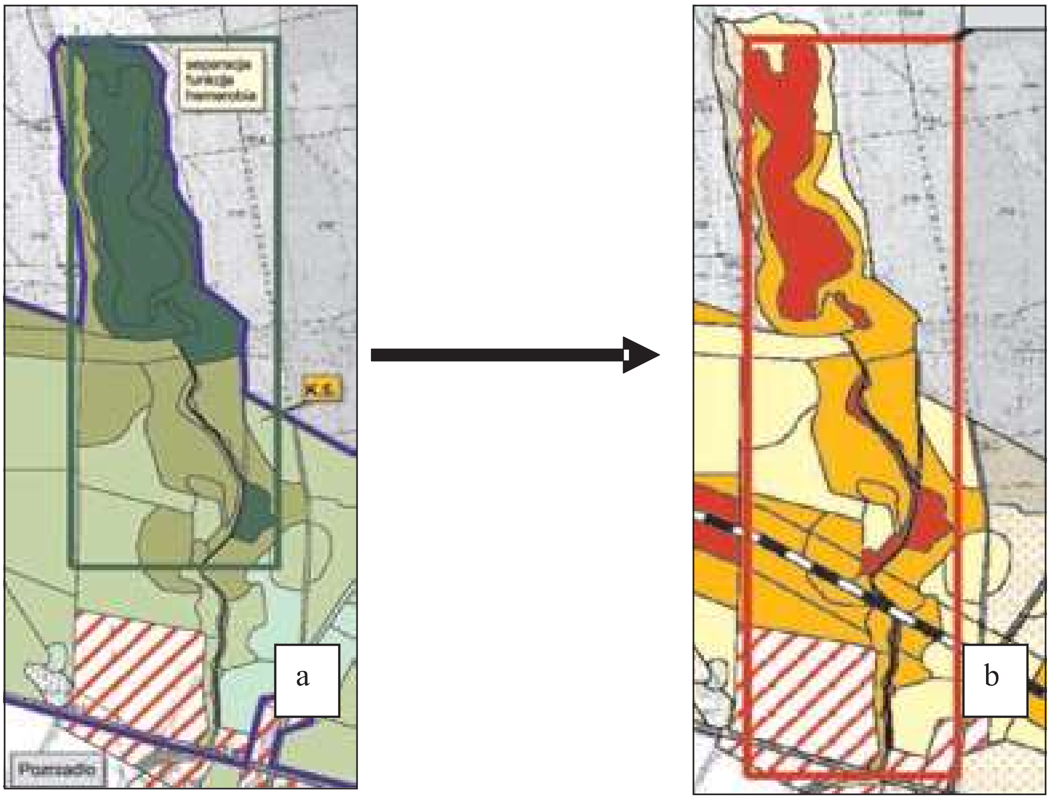

Fig. 4. A fragment of the environmental quality map (a) as well as the assessment of impact intensity (b)

Green (Fig. 4a) expresses the grade of the environmental quality (the darker the green, the higher the grade). Red (Fig. 4b) illustrates the forecast of the conflict with the environment caused by the construction of the highway. As can be seen from the maps, not every biotope of the highest environmental quality will be in the highest conflict with the highway. The decisive factor in intensity of impact is the quality of biotope, vulnerability, and the location in relation to the planned highway.

3. Recapitulation

The analysis of Polish and German experience in the field of environmental impact a sessment showed that methodological models for biotopes and landscape in EIA in these countries are universal in character. Their application only requires adjustment of the parameters to local environmental conditions. A very important difference between Poland and Germany is in the role of biotopes and landscape in making the EIA decision. These two elements of animate nature are treated marginally in Polish reports and during decision-making. In part, the fault for this is attributable to the lack of 'good practice' and the lack of formal definitions of these terms.

We should strive to develop a systematic model of taking into account biotopes and landscape in highway EIA in our country.

Another difference is related to the importance of graphic presentation of results in the form of maps. In most reports in Germany, three maps are created for each element of the environment

– presenting its stocktaking, valorization, and highway impact assessment. There are no such requirements in Poland. It is necessary to develop guidance in the scope of graphic presentation of data and legal alignment if this issue. The graphical side considerably increases the clarity of the report and makes it easier for the officials who make the decision as regards the assessment of EIA documentation.

So, is there an international methodical model of assessment of highway impact on biotopes and landscape? There is formally no such model, but its creation is the natural consequence of the growing importance of cooperation within the EU and the internationalisation of the environmental impact assessment system, as part of cross-border EIA procedure, for example.

The first step towards developing an international EIA model was establishing common legal framework through the EU directives. The second step was the European Commission's issuing EIA methodology handbooks on screening, scoping, and review of the report (EC 2001a, KE2001b, KE2001c). Another step should be supporting actions whose goal will be to develop methodological standards in EIA studies for individual undertakings. First of all, taking into account the extensive plans for construction of the road network in Poland, we should start from developing minimum methodology standards for studies of the impact of these dangerous linear undertakings on the environment in EIA procedure.

Acknowledgments

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Evaluation of de-fragmentation measures in the Netherlands: Report of an international workshop around implications of the Dutch MJPO

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Abstract. This paper report of a three-day international workshop, held in The Netherlands, to investigate the implications of the Dutch Long-Term De-fragmentation Program (MeerJaren Plan Ontsnippering – MJPO).

Key words: habitat fragmentation, fauna passages, evaluation, effectiveness

1. Exploration of the implications of the MJPO

Roads, railroads, and waterways heavily fragment nature areas in The Netherlands. This fragmentation causes barriers and the destruction of habitats for both animals and plants, and causes disturbance and road kills for animals. Fragmentation can therefore have strong negative effects on the sustainability of populations, with most visible effects on animal populations.

However, in the Agenda for a Living Countryside, from the Dutch Ministry of Agriculture, Nature, and Food Quality, is stated that '*migration and dispersal of animals and plants must no longer be impeded by the presence of roads, railroads and, waterways, in so far as such migration and dispersal is necessary to the sustainable survival of populations at provincial, national, and international levels*'.

In The Netherlands, a bottleneck analysis has been preformed and, based on this analysis; an inventory of needed de-fragmentation measures has been made. These de-fragmentation measures are listed in the Long-term De-fragmentation Program (with the Dutch acronym MJPO – MeerJaren Plan Ontsnippering). Dutch politics budgeted Mil. € 410 for these specific de-fragmentation measures, to reach the goals stated by the Agenda for a Living Countryside. A first evaluation of the MJPO will take place in 2008. The whole program will be completed in 2018, together with the completion of the Ecological Main Structure in The Netherlands.

To prepare for the evaluation in 2008, an international workshop of three days has been held in The Netherlands. During this workshop, several questions have been addressed, with a main focus on the questions how to evaluate, what is already known, and what research and monitoring will be needed. The workshop has provided numerous success stories about fauna infrastructures, and has led to an outline of a monitoring and research program, which will be discussed in this report. Prior to the workshop, and also afterwards, the CML has interviewed several experts on the subject of fragmentation and de-fragmentation.

The outcomes and insights obtained by the workshop and the interviews can be divided into four groups of interest: construction and maintenance of the fauna infrastructure, use of the fauna infrastructure, population and biodiversity effects, and political relevance. Throughout this report these four groups will be used to organize all insights.

2. Seeking a base for evaluation of de-fragmentation measures

2.1. Introduction

In The Netherlands, at this time, there is no need to argue the threats to biodiversity by habitat fragmentation, as already € 410 million has been allocated for habitat de-fragmentation projects in the next fourteen years.

Still, for reasons of accountability and responsible governance, insight in the effects of various de-fragmentation projects is indispensable. The infrastructural constructions designed for fauna mobility will have to be evaluated, both by monitoring its use and effectiveness, and, more fundamentally, by its contribution to the achievement of ecological goals. This is not trivial. It has been demonstrated that fragmentation of habitat leads to extinction of some populations, but that does not mean that increasing connectivity automatically leads to a revival of these populations. The argument just cannot be reversed. Moreover, the time span of ecological processes is far longer than that of politics and administrations. And worse, ecological processes are extremely hard to measure and even harder to predict. On the other hand, good governance demands that the spending of public money is closely monitored and evaluated. The Dutch parliament expressed the wish to have a first evaluation of the MJPO projects in 2008. A final evaluation can be expected in 2018.

The question is: how to prepare for these evaluations? What can be the foundation of these evaluations? Are the data and insights that will be needed already being collected and if not, what constructions are needed to collect these data and insights? In this paper, we explore four different approaches to build a foundation for the future evaluations.

2.2. Evaluating measures

In trying to construct a robust evaluation of the measures, two main questions present themselves. First, was the decision making procedure correct and consequent? This leads to a policy based answer. Second: are the measures effective? This leads to ecological answers, which can be further divided into argumentations based on landscape, populations or opportunities.

Of these, the policy-based evaluation proves to be the most easily constructed. The other approaches are far less easy. We start with the question of legitimacy.

2.3. Policy based evaluation

Was the decision to spend € 410 million reached in a legitimate way?

It can be shown that de-fragmentation policies can be derived from stated and accepted policy goals. The Netherlands are signatory to the Convention on Biological Diversity and as such are committed to pursue '*...the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources ...*' (Article 1).

In translation of this principal into Dutch nature policy, and inspired by meta-population theory, an important role has been assigned to the connectivity of habitats, to be implemented in the form of the EHS, the National Ecological Network. This coherent network of nature areas is to comprise 728,500 hectares of nature by 2018.

The goal has been restated in various papers and bills, among others in the Agenda for a Living Countryside (2004, p 56).

The Agenda for a Living Countryside is part of the *Nota Ruimte*, the bill on spatial planning, which defines the spatial planning in The Netherlands for the coming 20 years and came into force on January 17, 2006. As a consequence, concrete measures to mitigate habitat fragmentation by transport infrastructure are needed and these are listed in the MJPO.

The *Nota Ruimte* contains maps delineating the ecological links to be constructed and has a very strong policy status. The ecological network has a remarkably long and stable history in Dutch nature policy making. Clearly, the decision to spend € 410 million is correct, consequent and well founded on earlier parliamentary decisions.

2.4. Effectiveness

The question of effectiveness is far more complicated. Understanding the effect of de fragmentation measures is theoretically equal to understanding the spatial dynamics of metapopulations and metacommunities. Large progress has been made in the field (Holyoak *et al.* 2005), but the theory is still in a rather abstract phase. Consequently, the value of de fragmentation projects has often been derived from variables that are assumed to be an acceptable indicator. Various approaches have been attempted, as for instance economically by measuring willingness to pay for de-fragmentation scenarios (Van der Heide *et al.* 2005), spatially by modeling the permeability of connected area (Loehle *et al.* 2005) or calculating the infrastructural fragmentation index (Biondi *et al.* 2003), and genetically by showing that linking forest fragments increased the genetic diversity of the red squirrel in northern England (Hale *et al.* 2001).

One of the more sophisticated ecological models, developed and maintained by Alterra in The Netherlands, is LARCH, which stands for Landscape Assessment using Rules for Configuration of Habitat. As the name says, LARCH is a landscape assessment model, which assigns a measure of habitat suitability for a certain species to a certain landscape, based on vegetation, size and the needs of the species (Van der Grift *et al.* 2003).

It seems there are two main schools of thought in analyzing the effect of connecting fragmented habitats: landscape centered and population centered.

2.5. Landscape based evaluation

De-fragmentation measures can be seen as a way to mitigate and minimize the disturbing effects of transport infrastructure on landscape. In this case, the measure of success is the degree in which the landscape that existed before the disturbance is recreated. Landscape is also a potential habitat and landscape is far easier to measure and to govern than populations, so there are clear methodological advantages to this approach.

Assuming there is a clear understanding of the original state of the landscape, which is now fragmented by transport infrastructure, de-fragmentation measures can be interpreted as restoration work. The idea is easily associated with restoration of valuable art works and it seems to assign a value as lost natural capital to ecosystems that disappeared. By technical means the ecosystem is restored and the natural capital is retrieved. This approach is attractive to large groups of the Dutch population, as the explosion of transport infrastructure took place during their lifetimes and many people remember quieter and wider landscapes.

There are some complications to the landscape centered approach. First, there is no clear definition of the 'before', as it very much depends on the year one has in mind. Also, concentrating on the natural features of the former landscape may deny the multifunctionality of many former landscapes (Haines-Young *et al.* 2006). The main problem seems to be that restoring landscape only creates potential habitat. Survival or revival of populations will be dependent on many other factors. Still, an evaluation of the de-fragmentation projects in terms of hectares of landscape restored and connected has many advantages. It is relatively easy to do, can be checked by others, and has a relevance to biodiversity, though indirect.

2.6. Population based evaluation

To justify the de-fragmentation policies more directly to the biodiversity goals as agreed upon in the convention, a proof of direct effect on populations would be convincing. Political issues easily confuse this discussion. Large mammals are popular with the general public, and measures to protect these groups are politically attractive. These mammals are very vulnerable to road deaths and habitat fragmentation, so measures to decrease traffic accidents and to increase mobility have easily a positive effect on these species (and on road safety). Measures like ecoducts or other fauna passages have a high visibility. However, the policy goal should not be limited to large mammals only, but should cover biodiversity in all its complexity. De-fragmentation measures can have effects that are specific to species, or are possibly specific to trophic levels.

Rare species of plants and insects are often found in isolated places and Darwin himself already pointed out the logic of this. De-fragmentation of habitat is just another word for destruction of unnatural isolation and harmful scenarios are easy to construct. One can imagine the negative effect of newspaper headings like ‘Fauna passages open up rare bird habitat for foxes’ or ‘Bird flu travels by ecological network’.

Though an evaluation based on proof of the existence of sustainable populations seems to be closest to the original policy goal of protecting biodiversity, it seems also to involve most practical difficulties.

2.7. Development based evaluation

Finally, it might be worthwhile to explore a totally different approach. De-fragmentation measures can be seen as constructing new ecosystems, offering new potentials, and producing unexpected results that can by definition not be known beforehand. One can be certain that living organisms will make use of the spatial opportunities provided, but it is uncertain which species will do so, what ecosystem will evolve and what ecological processes will be started.

For the evaluation, this would mean that an analysis on the newly created ecosystems would have to be made. This is certainly feasible and it has the advantage that such an approach does not have to be limited to pre-assigned groups of species. On the other hand, Dutch nature policy has also a responsibility for specific endangered groups of species and it is doubtful if these can be disregarded without raising political unrest.

2.8. Conclusion

The four approaches probably result in very different methods of evaluation. It seems there does no objection to have more visions co-exist, but to be able to interpret a given evaluation, it is important to know upon which vision it is based.

Whatever perspective is chosen, habitat fragmentation by transport infrastructure and the ecological effect of de-fragmentation measures pose some impressive theoretical questions, with implication for policies on climate change-dependent habitat movement, and isolated populations of rare species. Both the theoretical and policy issues have a scale that far surpasses that of only the Dutch territory.

3. Justifying fauna infrastructures

During the workshop the focus has been both on validating the construction of fauna infrastructures, without restarting the discussion about the negative effects of habitat fragmentation, and on giving the outline of monitoring and research programs.

The validation for de-fragmentation measures varies from moral viewpoints about the implementation of fauna infrastructures, to success stories about the effectiveness of these infrastructures. These success stories about the effectiveness in particular can be used to defend the MJPO in a political arena, which can be useful if the first evaluation of the MJPO will take place in 2008. In explaining the need for a de-fragmentation policy, success stories play a crucial role; these can pertain both to the political level regarding the realization of the fauna infrastructure, and to the level of the effectiveness of the infrastructure. Well-founded success stories should be carefully collected, at an international level.

3.1. Construction and maintenance of the fauna infrastructures

It is relatively new to build structures for animals. 'The world' is watching and using the implementations (both in Banff – Canada, and in The Netherlands) as a model. Therefore these implementations should be right. At this moment, we are setting standards for design and maintenance. There is a lot of exchange of information between different countries, and what we do in The Netherlands and what have be done in Banff serve as an example.

3.2. Use of the fauna infrastructures

The acceptance of the fauna infrastructures is species-dependent, but overall can be said that the infrastructures are used. Ecoducts are used by (large) animals, even during, and short after construction. Signs of this use can be found on all ecoducts, in the form of tracks, prints and faeces. For culverts, fences, and badger-tunnels there is also strong evidence that these measures work (Fig. 1), because of tracks, the presence of faeces, and pictures (Fig. 2).

Fig. 1. Evidence for the presence of a badger (photo by Hans Bekker)

Fig. 2. Evidence for the use of a badger tunnel (photo by 'Stichting Das en Boom')

3.3. Effects on populations

Fences led to reduction of road kills (80% in Banff), and there has also been an increase in population-size with fences in place (Banff). This stresses the importance of combined measures (ecoduct/badger tunnel in combination with proper fences) and also shows that the fauna infrastructures can have a positive effect on populations.

In The Netherlands, a package of measures involving the badger has led to an increase in population size from 1200 individuals to approximately 4800 individuals. The fact that a whole set of measures has been used and that these measures have been connected properly, may be responsible for this success.

3.4. Political relevance

There is widespread acceptance and awareness, both local and governmental. Top-down initiated measures have led to bottom-up actions, and *vice versa*. An example of a local initiative is the building of the ecoduct Crailo in 'het Gooi' (between Bussum and Hilversum), where people wanted to contribute something themselves. The building of this ecoduct has now led to a higher prioritization of a governmental ecoduct nearby, to improve connectivity. The acceptance is even so widespread, that the rule 'for one kilometer road constructed, one kilometer road has to be removed' causes hardly any opposition.

On a provincial level there are a lot of initiatives as well. In the province Utrecht for example, seventeen parties joined in the project 'Heart of the Heuvelrug', to reconnect the northern and southern part of the Heuvelrug, by building ecoducts and providing other measures.

A complete other validation of the MJPO is that it is our moral duty to de-fragment. The last 50 years we have destroyed whole habitats, and fragmented our nature areas. Now we have the opportunity to restore (some of) the connectivity and create new areas, not only for the animals, but also for ourselves and future generations, to keep our country a nice place to live. The M€ 410 can be seen as an investment: past measures can be strengthened by new measures, and the connections themselves can become part of the protected area, which is needed in a small country. In this way a new asset is created.

4. Construction and maintenance of the fauna infrastructures

Although we think we know how to construct fauna infrastructures, there are still a lot of things that have to be taken into account when constructing these measures.

In the USA (California) has been shown that simply making the connection is not enough. An area has to meet the requirements of the target-species, before it is linked with another area, and a combination of measures is needed to get the best results. These combinations should always be custom-made, because they are dependent of the situation in a certain area. The success of defragmentation measures is furthermore dependent on the balance between the extent of isolation and the extent of links between the areas: the more links and the less isolation, the better a measure works.

We have established that ecoducts are used by different kinds of animals, but larger animals mainly use these overpasses. Overpasses are only effective for small animals as well, when the overpass provides the habitat they need, since their action-radius is much smaller.

There is also a strong need for maintenance of the infrastructure. Fauna infrastructures must be functional over their whole life span, and therefore robust measures should be chosen. Although the construction-costs are usually higher for robust measures, like ecoducts, the maintenance-costs of these measures are lower, making the robust measure more economical in the end.

Road-safety (both for animals and humans) is another issue that should be taken into account when constructing fauna infrastructures. Ecoducts and other measures work, but most important are the fences: they bring down the number of road kills, which is important for the survival of adults. Populations of longer-living animals are dependent of the survival of these adults for reproduction. Road kills should be regarded relative to the population size, and not in absolute numbers, to calculate the impact on a population. There are for example so many hedgehogs in The Netherlands, that road kill has hardly an effect on the population size, although according to the number of road kills, there appears to be a problem for the hedgehog.

Another issue that should be considered is, for example, how the interaction with the human environment is. Are the animals at risk of being poisoned? Are there side effects, like unforeseen use of the measures by humans? How are the physical conditions of the adjacent areas? During the preparation of the construction of a fauna infrastructure, these questions should be answered, and depending on the answers opportunities and solutions have to be selected.

There are also some more fundamental questions that need to be answered about the construction and maintenance of fauna infrastructures, to make them more effective in the future. We need to know, for example, how to design fauna infrastructures. It is true that this is known for ecoducts, but it is still unknown for corridors and small measures, like escape ramps. Another question is whether we should build single large or several small measures. Is it better to have 10 ecoducts connecting several areas, or will 1000 culverts do the trick? Monitoring and research should answer these questions.

5. Monitoring use, and researching effectiveness of fauna infrastructures

During the workshop, the main questions that should be asked during the evaluation of the fauna infrastructures have been discussed, and a general outline for a research program has been made.

5.1. Outline research program

First there has to be a description of the measures and of the objectives, to know what to monitor and what to evaluate. Without a clear goal, it is hard to establish whether the objectives are reached. A strategy can be, to choose a few important and easy-to-monitor species as target-species. By doing so, the effects of fauna infrastructures can be visualized, generally ensuring that, when there are positive effects, these effects can be shown.

Standard evaluation methods (in which common data is used) have to be designed. Monitoring the use of fauna infrastructures (which should be applied for all measures, to see if the maintenance is good), or performing presence/absence studies (there can be discussion whether this method should be applied on a smart selection or on as many measures as possible) can be applied.

Furthermore, specific evaluation methods have to be developed. These should be adapted to see whether the objectives are reached, like looking at population dynamics, and genetic studies. These methods should be applied on a smart selection of measures, for time-efficiency and economical reasons.

5.2 Main questions

Questions that should be addressed when evaluating the fauna infrastructures are:

- Are the fauna infrastructures built and maintained as planned and designed? This question should be answered for all measures.
- Is the design good, or can it be improved? There should be a control-phase before the beginning of the construction; projects should be looked at beforehand. There should be a sample of different types of measures; we should learn as much as possible, vary dimensions, use it as an experiment and monitor very closely.
- Is this specific type of infrastructure being used? Why/why not? This question should be answered for all fauna infrastructures, since the answer depends on type *and* placing.

These first three questions are looking at the preconditions: do the fauna infrastructures work, and are they being used. The answers to these questions implicate whether there could be larger, sustainable effects on the populations.

The three questions are of main interest for constructors and engineers, as they are responsible for construction and maintenance of the fauna infrastructures.

Since the goal of the total set of measures is that migration and dispersal of animals and plants must no longer be impeded by the presence of roads, railways, and waterways, in so far as such migration and dispersal is necessary to the sustainable survival of populations, it is not enough to establish that there *could* be sustainable effects on populations. The questions that should be asked next are: Are this measures enough to reach and restore connectivity, and does this contribute to the sustainable survival of populations?

- Are there population effects? Sites and species should be selected for research.
- Does the set of measures contribute to the National Ecological Network? (although monitoring should be broader than NEN).

These questions are of main interest for both scientists and policy makers: the scientists will be the ones to answer these questions, whether the policy makers will use the outcomes of the researches to validate their strategies.

Problems, successes and failures must be analyzed, for instance with the ‘badger success’ in The Netherlands: What has caused it? Are there general trends? Is the success a result of the decrease in mortality (less road kill), caused by an increase in connectivity between different areas, or a result of both factors? Or is the increase of the population related to a better quality of habitats?

5.3. Monitoring use

It is not enough to monitor the passage use, but it is still important. Included in the monitoring should be: where are the species and where are they going?

Routine monitoring must be focused on the functioning of the fauna infrastructure in place, but at the same time be put in the context of existing broad monitoring programs.

The advantage of monitoring at a certain location is that local factors can be included, since success and failure depend on the local problem. Measuring at location gives the opportunity to manage at location. In other words: to see in place what is right and/or wrong.

During a monitoring program, there should be looked at several species at the same time, and the whole package of measures should be monitored at the same time. In doing so, the effects of a whole set of fauna infrastructures can be evaluated. In such a monitoring program it is important that extreme years are included, to get a complete comprehension of the situation. Therefore, long-term studies should be preformed, so that changes might be observed.

As mentioned earlier, monitoring of the passage use is not enough, since the use of a crossing does not automatically lead to gene flow. Animals can cross to feed, but not to reproduce, or the animals that cross don't reproduce yet. Therefore, scientific research is needed.

5.4. Researching effects on populations and effects on biodiversity

For research programs also holds that there should be looked at several species at the same time, and that long-term studies should be performed, so that changes might be observed. The results will differ over time, and many things will change all over the place. In an ideal situation, the research should cover the full time period of the changes caused by the fauna infrastructure. Therefore it should take place during the whole lifespan of an infrastructure, which is approximately 80 years for an ecoduct.

In-depth research should be broader than the functioning of the fauna infrastructure itself; it should also take the surrounding landscape into account, including the different landscape elements with their attributes, and species composition.

Monitoring and research must focus on construction and maintenance, use, population effects, and policy relevance. Furthermore it should also pay attention to, for example, age distribution, sex, and spatial distribution of users, since willingness to travel is species-, age-, sex-, and population-dependent. Indicators might be chosen at the level of individual animals, populations, and/or genetic characteristics.

These studies should have started 'yesterday', since a comparison between the situation before and after the construction of the measure would be ideal, but there are still many sites in The Netherlands where such studies could take place. We also have a unique opportunity to analyze with controlled-impact (potentials of CI), and following from this, we should be able to do so called BACI studies (before-after-controlled-impact analysis), to analyze the total impact of fauna infrastructures.

A few things have to be taken into account when carrying out a research program.One of these things is that populations of animals always fluctuate. There is need for mitigation if population levels are low, but it is difficult to evaluate the effect of the measures. Different factors (like e.g. climate change or seasonality) may play a part as well. Furthermore, road density should be treated as an independent variable, since road density has no correlation with habitat types, but can still be a factor when analyzing the road kill. Finally, models are limiting, although they are nice to work with. They only work for larger mammals, because the conditions required by these animals are known. For smaller animals, further research is needed to make the models work.

Before a monitoring and research program starts, a few questions need to be answered first, like:

- What is the most effective way of monitoring? Satellite photos, tracks, radio-tagging?
- Which animals will use the infrastructure and how does that affect the program?
- Habitats will always change; how should we react to these changes in habitat, in relation to the measures?
- Do we need to calculate population viability (knowing that it is hard to monitor population dynamics), or should we look at genetic change?
- Both routine monitoring and in-depth research are needed; how can these be combined?
- What are we going to measure? Passage use, where the animals are, maybe only presence/absence, age structure, should we collect density data?

The present and future developments around fauna infrastructures should be regarded as a unique opportunity for science. The whole implementation of the MJPO can be considered as one large experiment. The results of monitoring and research programs should be communicated to the public, to create sympathy and interest, to support evaluation, and to contribute to the political validation of the measures.

6. Political relevance

The evaluation of de-fragmentation measures is necessary, but difficult. Monitoring and research may contribute to the validation of these measures, but policy makers themselves can make evaluating more effortless. First, the objectives of the de-fragmentation measures have to be stated, to know what goals will have to be reached.

6.1. Stating the objectives of habitat de-fragmentation

First there has to be a clear description of the measures and of the objectives, to know what to monitor and what to evaluate, and to know beforehand what success looks like. This means that there is a need to choose success indicators beforehand. These indicators of success have to be conceptual, as well as at the level of use and population characteristics of selected species. Too high targets, or targets based on the wrong (e.g. too endangered) species pose the threat of not reaching the goals. When selecting target species, too rare and too common species both pose their problems. Too rare species, like the otter in The Netherlands, are hard to monitor and study, whilst it is difficult for too common species (like the hedgehog) to see any correlative effects of the measures.

The policy might be considered a success when the objectives are reached, but there has to be an open eye for alternative successes as well. A fauna infrastructure might not have led to a noticeable increase in, for instance, population size of the target species. Therefore, the goal 'increase the population-size' has not been achieved. However, if there has been an increase in biodiversity as a whole, the de-fragmentation measure(s) might still be considered a success.

Policies should not be based on theoretical information alone. A problem could be posed by a model, but there is a need for clear data on collisions, mortality rate, use of fauna infrastructure, etc. as well. The problem should be explained in strong arguments, and success stories, even when based on anecdotal data, should be analyzed.

Questions that should be answered before stating the objectives and implementing a policy are: How to prioritize areas to protect and to connect, and how to measure success and failure?

6.2. Validate the choice to de-fragmentation

In the chapter 'Justifying fauna infrastructures' different approaches to rationalize the choice to de-fragment have already been discussed. However, more fundamental and political reasons to decrease fragmentation play a part too.

A political argument could be that since the European strategy is to (re) connect nature areas (Natura 2000), national policies should fit into this European plan. Although The Netherlands have been ahead of the European policy with their National Ecological Network, the national plans should still be contiguous with international policies.

Another justification of the MJPO is that the program follows logically from previous nature policies in The Netherlands. Successful new fauna infrastructures are a protection of the past nature investments, and are consistent with the accepted strategy.

A more fundamental reason to increase connectivity between nature areas is that small populations are endangered and need to be connected. By doing so, gene flow can be established and inbreeding can be prevented.

6.3. Varia

There is a political, economical, and social pressure to combine the use of fauna infr structures with human activities, like hiking. However, it is not sure what the effects of combined use will be. In the USA (California) has been shown that human use of fauna infrastructures disturbs passing animals. In areas with a high density of humans, animals tend to be shyer. Human use will therefore have a larger impact. Nevertheless, in The Netherlands has been shown that the population size of badgers could increase in an area with many dog-walkers. The effects of combined use should therefore be studied carefully. As a consequence of the pressure to combine, arguments not to combine should be very good.

At this moment, the political consistency of the de-fragmentation measures is good. In order to ensure the long-term efficiency of the fauna infrastructures however, future political consistency is needed as well to guarantee this efficiency. Finding a budget for measures and research has always been a problem, and probably will always be, but the necessity of measures and research should be stressed to politicians to come.

When it comes to justifying the choice to de-fragment, it is important not to have a defensive attitude. It is rather self-evident by now that de-fragmentation is important, and that policy objectives can be reached if the fauna infrastructures are implemented well.

One of the results of the workshop was a matrix (Table 1). This matrix can be seen as a way to think about the subject of habitat de-fragmentation. The following matrix is far from complete, but gives a design for future additions With (+) is noted how, and how much, certain monitoring, research, or communication is related to the four groups of interest. The amount of political relevance of monitoring, research, and communication as a whole is stated as well.

Table 1. The matrix of factors connected with the de-fragmentation of habitats

		Construction and maintenance	Use	Population effects	Political relevance
Monitoring	Control (by RWS)	+			
	Standard monitoring: - PGO - NGO		+		
	Adapted monitoring		+	+	
	In whole				-/+
Research	Presence/Absence study			+	
	Population structure: age, sex, etc.			+	
	Genetics		+	+	
	Vegetation structure	+	+	+	
	In whole				+
Communication	Architects	+			
	Classical lovers of nature	+		+	
	Active collectors and obse-rvers		+	+	
	Scientists	+	+	++	
	In whole				++

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Fragmentation effects on wildlife habitats of planned transport infrastructure in protected metropolitan greenspace. The case of Barcelona, Spain

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Abstract. Collserola Park is situated within the greater metropolitan area of Barcelona, close to the Mediterranean coastline. The park occupies some 8,500 ha of predominantly Aleppo pine (*Pinus halepensis*) and Holm oak (*Quercus ilex*) woodlands with a high diversity of wildlife habitats. Wildlife have been monitored here for over 15 years and detailed data are available on the habitat requirements of a variety of mammal species with large territorial requirements such as the common genet (*Genetta genetta*) and the wild boar (*Sus scrofa*).

In recent years there has been considerable urban expansion in the Barcelona metropolitan area. As a consequence, many wildlife habitats in Collserola park are now effectively isolated from those of other nearby natural areas by a ring of major transportation infrastructures and urbanised ground. Several roads, including a fenced motorway and a railway, also cross the park within its boundaries leading to internal habitat fragmentation and limiting wildlife movements. The recently published 'Transport Infrastructure Plan for Catalonia' envisages the development of major new roads and railways within and around Collserola in the coming years (2006-2026).

Consideration of available data regarding wildlife requirements, in combination with detailed GIS analyses of the future infrastructure scenario, permits interpretation of likely habitat fragmentation effects and other impacts on certain wildlife species in Collserola Park.

Urbanisation processes beyond the park's administrative boundaries, facilitated by infrastructure development, are already leading to significant habitat loss and alteration in remaining metropolitan greenspace, thus lowering critical threshold levels for sensitive species within the park. Our results indicate that these threshold limits are likely to be approached or surpassed in Collserola as a consequence of the development of this new infrastructure plan. As such, this plan could seriously jeopardise the long-term viability of wildlife populations in Collserola Park and undermine its overall ecological integrity.

Key words: wildlife habitat, fragmentation effects, metropolitan area, Barcelona, Collserola Park, GIS analyses

1. Introduction

The Barcelona Metropolitan Area (BMA) covers some 3,200 km^2 (Fig. 1) and has a population of approximately 4 million inhabitants. In such areas, periurban habitats currently represent an ever increasing scenarios for wildlife, while at the same time these same habitats are subject to important anthropic pressure and major territorial transformations, due largely to the development of infrastructure and the process of urban expansion. Urban areas and infrastructure cover almost a fifth of the BMA and increasing urban sprawl means that habitats are becoming more and more fragmented. In the last 25 years as much new urban areas have been constructed as had previously been occupied in the entire history of the region, without major increases in population size. As a consequence, Marull & Mallarach (2005) estimated that two thirds of the BMA has either low ecological connectivity or none at all due to the continued fragmentation of habitats and the barrier effect generated by transport infrastructure and artificial ground.

Fig. 1. Ortophoto view of the Barcelona Metropolitan Area (delimited by white line) covering some 3,200 km^2, with Collserola Park indicated at its centre. Note the greenery of the forested mountainous areas in contrast to the greyish urbanised ground along the coast and inland to the north of Barcelona

Collserola Park, with 8,500 ha of mostly Mediterranean woodland and scrub, is situated in the heart of the BMA, where the current territorial planning framework (the 'General Metropolitan Plan' *PGM* from 1976, and the recently updated 'Transport Infrastructure Plan for Catalonia 2006-2026' *PITC*) augers intensified fragmentation and loss of habitats in this important area for wildlife, recently included in the Catalan proposal for Natura 2000. In Collserola, the relationships between different species and the main problems that affect this type of territory have been studied for the last fifteen years (Llimona *et al.* 2005). The present study illustrates these problems and some of their effects on wildlife, using as examples several case studies undertaken in the Park in relation to mammals with large and medium territorial requirements, such as the common genet (*Genetta genetta*), the wild boar (*Sus scrofa*) and the red fox (*Vulpes vulpes*), including the use of radio tracking techniques (Camps & Llimona 2004; Cahill *et al.* 2003a). This information has allowed for examination of the problems which the accelerated transformation of territory has on periurban natural areas (see Llimona *et al.* 2005; Llimona *et al.* in prep.).

2. Methods

The study of territories and animal movements in relation to transport infrastructure allows for interpretation of possible barrier effects and problems of isolation. Observed displacements between known animal radiolocations in Collserola Park were compared with simulated displacements obtained by randomising the direction of movement and maintaining the same point of origin and length of displacement. Displacements were randomised for fox and wild boar using ArcView 3.2 and the *Alternate Animal Movement Routes* extension (version 2.1, Jenness 2005).

From the analysis of core area (interior habitat areas unaltered by edge effects) as a habitat fragmentation parameter, the current transport infrastructure scenario in Collserola Park was compared with a possible future scenario as envisaged under the planning framework for the BMA. Analysis of core area habitat was undertaken for the genet with Fragstats 3.3 (McGarigal & Marks 1995, and see explanations on its use in Collserola in Cahill *et al.* 2003b) and ArcView 3.2 Spatial Analyst extension using 4m x 4m pixel grids generated from habitat maps for this species in Collserola based on previous radiotracking studies (Camps & Llimona 2004).

The concept of core area attains special relevance in the study of impacts generated by habitat fragmentation. Edge effect buffers were estimated between different habitat classes and infrastructure types based on data available for the genet from Collserola (Camps & Llimona 2004), as well as from literature available on this subject (see for example Forman *et al.* 2003).

3. Results

3.1. Isolation and barrier effect: case studies of two generalist species in Collserola Park – the red fox and the wild boar

Figure 2 shows the radiolocations, home ranges (95% minimum convex polygon) and core areas (50% minimum convex polygon) for a male red fox and a female wild boar followed during eight and eleven months respectively in the western sector of Collserola Park. Both of these are species with relatively large territorial requirements in the context of Collserola, with home ranges of 880 ha and 417 ha respectively in these two particular cases. Both home ranges clearly show part of their boundary delimited by the presence of large motorways, on the periphery of the park by the A-7 motorway in the case of the red fox and internally by the E-9 motorway in the case of the wild boar. Simulation of trajectories between consecutive animal radiolocations in comparison with observed trajectories (Figs. 3 and 4) shows that although some crossings of motorways were expected both for the red fox and the wild boar, in reality not one crossing of such infrastructures were observed during radiotracking of these two individuals. In contrast, low traffic volume conventional roads within the park were crossed to varying degrees by these individuals, more often than expected in the case of the fox and less often in the case of the wild boar (Fig. 4).

Fig. 2. Radiolocations, home ranges (95% minimum convex polygons) and core areas (50% minimum convex polygons) for a male red fox and a female wild boar in Collserola Park (hatched area). Light grey areas are urban ground and heavy grey lines are main motorways in the study area. The city of Barcelona lies to the lower right of the image

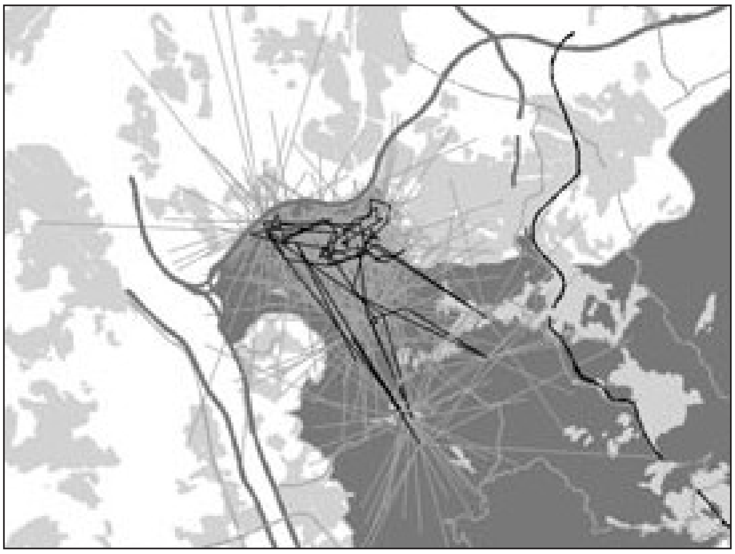


Fig. 3. Simulated (straight grey lines from ten random repetitions) and observed crossings (straight black lines) of roads and motorways by a radiotagged male fox in Collserola Park. Data from 94 linear displacement routes based on consecutive localisations. Light grey areas are urban ground and the city of Barcelona lies to the lower right of the image

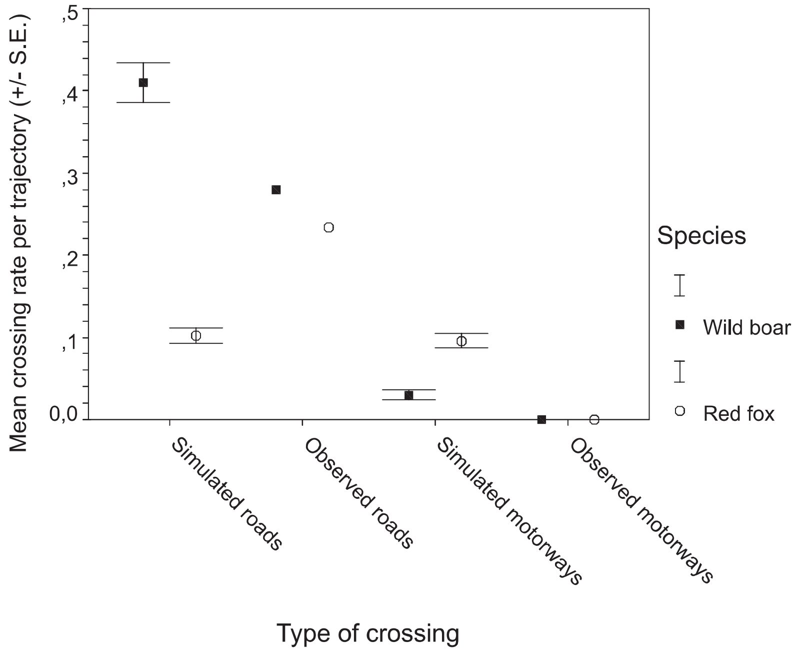
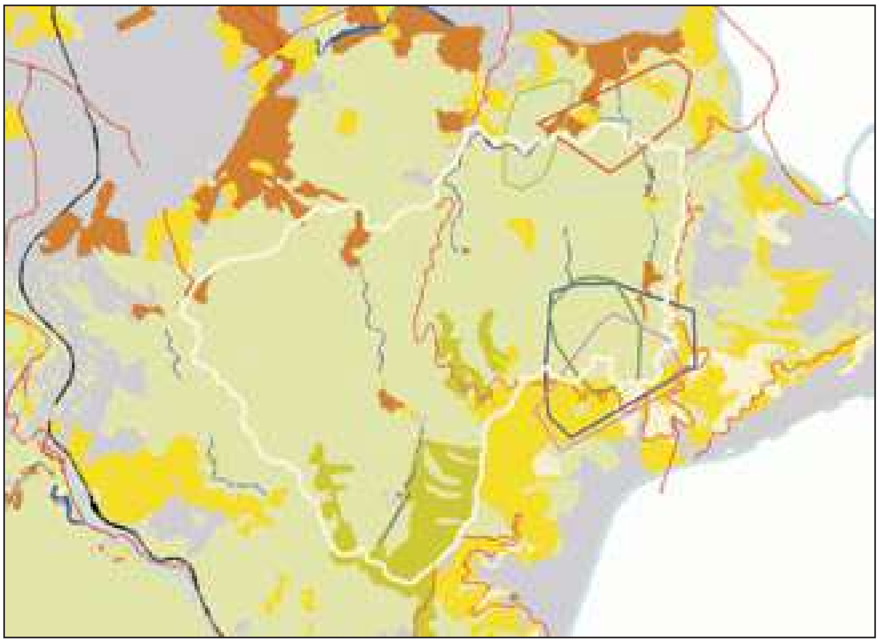


Fig. 4. Simulated (ten random repetitions) and observed crossings of roads and motorways by a radiotagged male fox and a female wild boar in Collserola Park. Data from 94 and 86 linear displacement routes based on consecutive radiolocalisations for fox and wild boar respectively

3.2. Edge effect and loss of core area habitat through fragmentation by infrastructure

The evaluation of the extent of edge effect emanating from linear infrastructure is complex and at local scales is almost an artisan task, but in general average ecological effects are considered to reach some 300 m away from roadsides, with effects on sensitive forest species attaining between approximately 300 m and 800 m (Forman & Deblinger 2000). From a foraging point of view, an optimal territory shape would approximate a circle, with a central key element from which to forage (refuge, lair, breeding area, etc.). In this sense, although even when habitat could be utilised right up to the immediate edge of a fenced road or railway, its barrier effect would impede location of an ideal circular territory centre at a distance of less than one radius length from the infrastructure. As such, key elements within this band attain suboptimal status. The mean home range size of male genets in Collserola is 113 ha (Camps & Llimona 2004). A circle with such a surface area has a 600 m radius, and this distance was considered here as the maximum extent of edge effect adjacent to fenced infrastructures such as motorways and railways susceptible to producing barrier effect on genets. For unfenced conventional roads, half a radius length, 300 m, was taken as an average effect distance. Such figures are in line with average effect distances as previously indicated by Forman & Deblinger (2000), and although applied here specifically on the genet, could probably be considered as applicable for average effects on forest systems in Collserola.



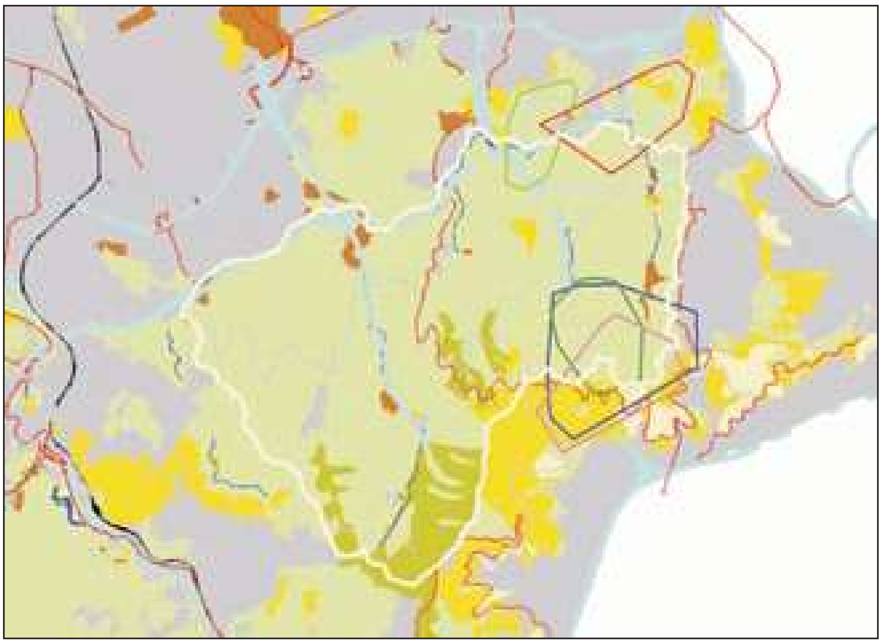


Fig. 5. Location of six genet territories (from Camps 2002) in the eastern sector of Collserola Park in relation to the current transportation network (above) and under the possible future scenario (below) as envisaged by territorial plans (PGM 1976 and PITC 2006-2026)

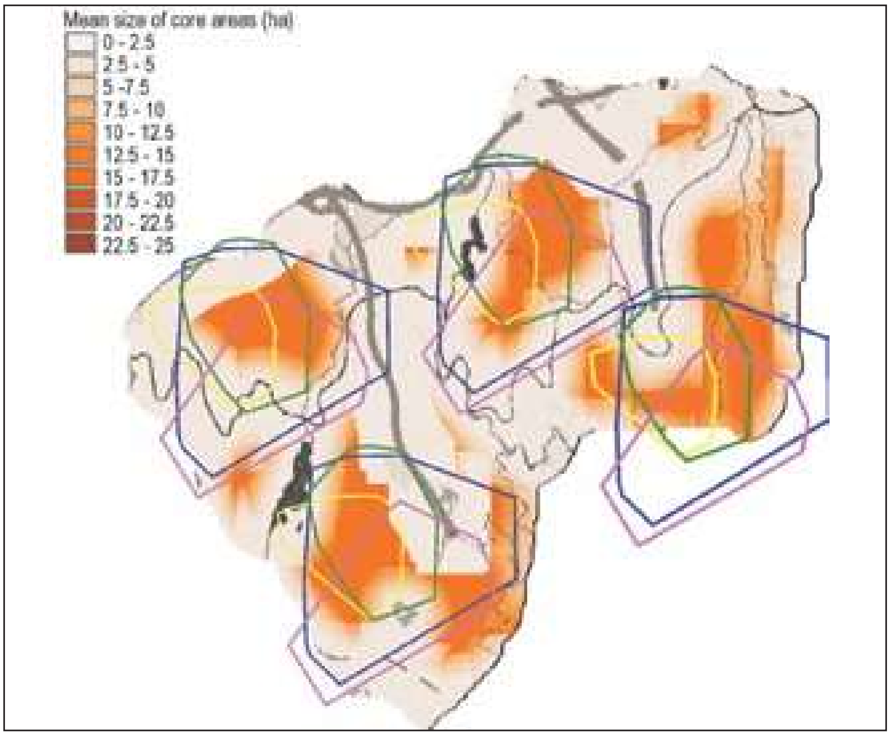


Fig. 6. Map of predicted core area habitat remaining under the possible future infrastructure scenario in Collserola in relation to size and locations of functional territorial groups (male, largest polygon, and three females) of the common genet. Functional group at bottom right is from known territories whilst the other three represent possible hypothetical locations for territories in the future scenario

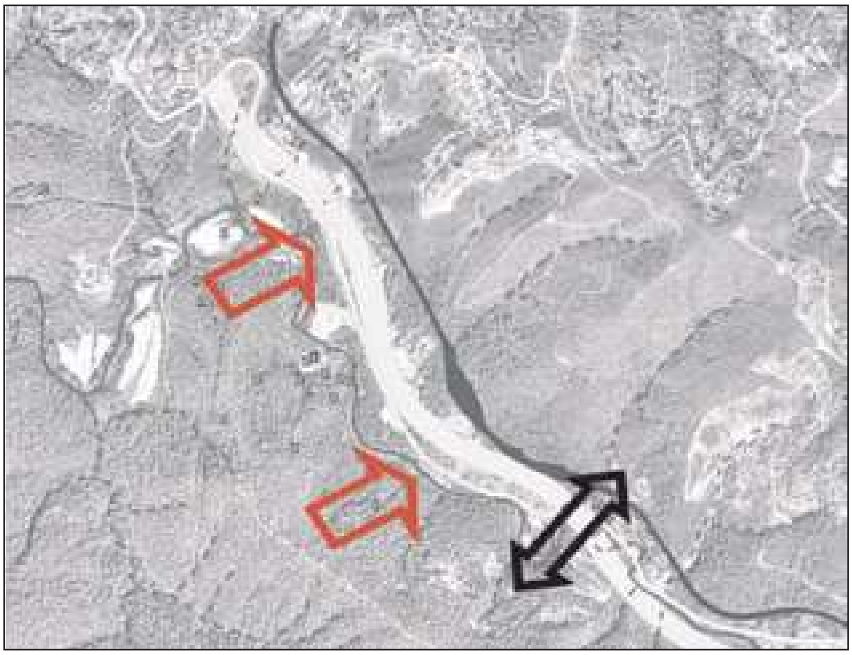


Fig. 7. Internal barrier in Collserola Park due to the juxtaposition of three transport infrastructures: the fenced E-9 motorway (wide grey), the BV-1462 road (thin grey) and the fenced FGC railway line (black). Grey dots are radiolocations of a wild boar, all located to the west of the transport axis. The double headed arrow indicates the site for the proposed construction of a wildlife fauna passage on the FGC railway line, coinciding with an existing viaduct on the motorway and the presence of the Vallvidrera stream

Figure 5 shows the current and possible future transport infrastructure network in the forested eastern sector of Collserola Park as envisaged under the present land planning framework for the Barcelona Region, based on the previsions of the 1976 General Metropolitan Plan (PGM) and the recently updated previsions for transport infrastructure contained in the Transport Infrastructure Plan for Catalonia 2006-2026, which largely coincide with those of the original 1976 PGM. There are essentially four main components of these plans with regard to Collserola Park: firstly, two new fenced infrastructures crossing through the Park approximately from north to south, either as motorway or railway (not yet clearly defined), with tunnels through the mountains close to the city of Barcelona (Fig. 5). The third component is a ring road to the north of the Park, between the towns of Sant Cugat and Cerdanyola, and finally a transversal high-capacity road running roughly west to east through the Park interior (Fig. 5). In the eastern sector of Collserola Park the coincidence and criss-crossing of these infrastructures would have especially negative fragmentation impacts on wildlife habitats. In this sector the territorial requirements of the common genet have been studied in detail (Camps & Llimona 2004), allowing for valid interpretations of probable fragmentation effects in this area. Figure 6 shows a map of the core area habitat which would remain if all envisaged infrastructures were finally to be developed, with the annual home ranges of four adult genets superimposed. In the case of the genet, functional territorial units (consisting of one male territory overlapping two or three female territories), in Collserola Park cover an average of 220 ha in size (Llimona *et al.* in prep.). As can be appreciated from Figure 6, although such units would approximately fit in the intervening habitat fragments remaining in the future infrastructure network, they would only partially encompass areas containing core area habitat.

4. Discussion

The case studies presented here on the red fox and the wild boar illustrate the barrier effect that exists in Collserola Park for species such as these with relatively large home ranges, leading to both internal fragmentation and also isolation from other natural areas in the metropolitan region. Wild boar and other ungulates are indeed known to use crossing structures on motorways less frequently than other vertebrates, but in contrast foxes often use them regularly (Mata *et al.* 2005). In this sense, it should be highlighted that the increasing degradation of natural habitat beyond the Park's limits in certain areas on the periphery of Collserola may also inhibit this species from crossing such structures.

Ironically, the formal establishment of the Natura 2000 network may indeed make it more and more difficult to conserve unprotected habitat beyond the sharply drawn limits of protected areas, and sadly certain areas of known value as ecological corridors in the Barcelona Metropolitan Region, as well as those identified recently by Forman (2004), have still received no real protection or incorporation within a true ecological network. In this sense, priority must be given in the case of Collserola to preventing new fragmentation on the internal level and also to *de-fragmentation,* in so far as is viable. To give an example, Figure 7 illustrates the barrier effect caused internally in Collserola Park by the juxtaposition of three parallel infrastructures: the fenced E-9 motorway, a heavy trafficked unfenced road (BV-1462), and the fenced FGC railway. As part of a study on the problem of collisions between trains and wild boar on this railway (Cahill *et al.* 2005), a proposal has been made for the construction of a large wildlife underpass on the FGC line at a site which coincides with the presence of a viaduct on the E-9 motorway (Figure 7), and where the Vallvidrera stream criss-crosses the BV-1462 road. This point represents the only viable option for restoring connectivity across all three infrastructures in this central area of Collserola. This particular case underlines the importance of *preventing* fragmentation, given the often very complex difficulties of de-fragmenting *a posteriori*.

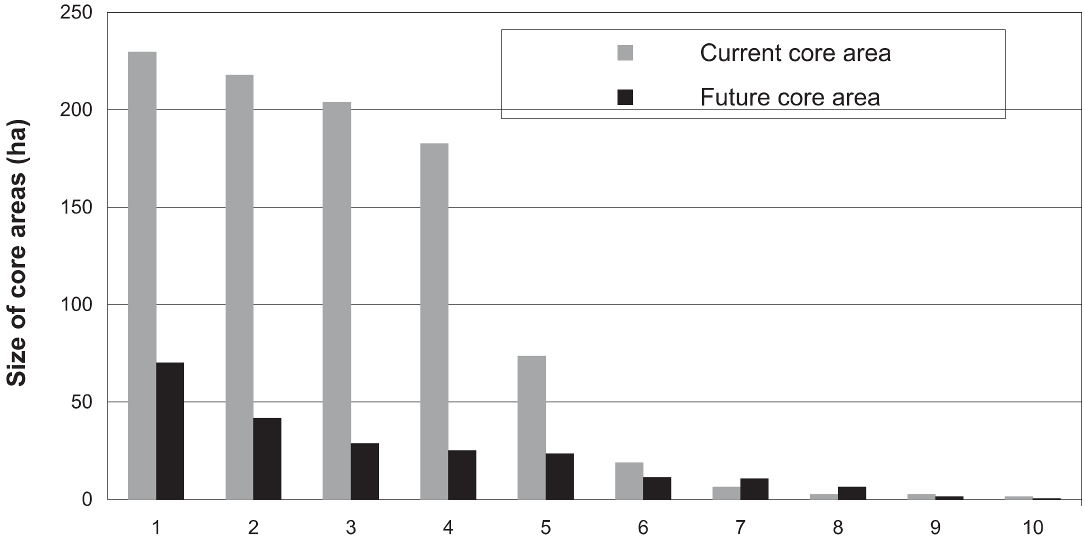


Fig. 8. Size of the ten largest patches of high quality core area habitat for the common genet in the eastern sector of Collserola Park under the current and possible future infrastructure scenarios (after Llimona *et al. in prep.*).

It is obvious that one of the goals of sustainable land planning must be to avoid surpassing critical thresholds in relation to ecosystem functioning. Nevertheless, little information is still available on what such limits are in Mediterranean ecosystems, and clearly they will often be species dependent. Medium and large sized mammals means that they can be useful as umbrella species whose conservation needs surpass those of a majority of other species occupying the same habitat. Jongman (1995) lists a range of minimum dimensions for size of habitat patches to be connected as part of a viable ecological network. Although the information is based on quite varied habitats from diverse countries and territorial plans, most minimum sizes are considered to be in the tens of hectares to the low hundreds (range 10 to 250 ha). Similarly, Marull & Mallarach (2005) established minimum sizes for 'ecologically functional areas' of between 50 and 200 ha for different habitat types in the BMA. In this context, the mean sizes of 'functional territorial units' for the common genet in Collserola, estimated as 220 ha for units of one adult male and two or three adult females, lies well in line with this concept of ecologically functional area, and can thus be taken as a minimum threshold size for unfragmented forested areas. Indeed, the minimum size established by Marull & Mallarach (2005) for dry wooded areas in general, resembling those occupied by the genet in Collserola Park, was 200 ha. At present in the eastern sector of the Park there still exist three fragments of core area habitat for the genet of more than 200 ha in size, whilst under the possible future scenario envisaged by land planning none would remain of this size, and the largest remaining fragment of core area habitat would measure only 70 ha (Figure 8), equivalent to a single female genet territory (Camps & Llimona 2004).

In summary, our results show quite clearly that the previsions regarding transport infrastructure contained in the current land plans for the BMA would surpass such thresholds in relation to core area habitat for wildlife in Collserola Park.

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Long-term monitoring of wildlife roadkills in Collserola Park, Barcelona. Results from the first 15 years

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Abstract. Collserola Park (Barcelona) is a protected nature area occupying 8,500 ha. The park is subject to intense human pressure and includes an extensive transportation network made up of surfaced roads, forest trails and even a motorway and a railway line which form a major transport axis that crosses the Park.

As part of a wider study concerning the impact of transportation infrastructure on wildlife, roadkill data gathered since 1991 were analysed. These data come from several sources, basically from Park technical staff, wardens and from occasional roadkill studies. Since 2004 a more specific monitoring has been carried out of roadkills on roads and forest tracks in the Park by means of pre-established transects in order to obtain quantitative indices. In total, 865 roadkill incidents have been incorporated in the Park's wildlife GIS database, of which 56% correspond to mammals, 20% to birds, 16% to reptiles and 8% to amphibians. This high percentage of incidents associated with mammals is related to the different detection rate of mammals in comparison to other groups. The mammals with the highest incidence of roadkills are wild boar *Sus scrofa* (21.4%), which have increased sharply in the last few years, hedgehogs, *Erinaceus europaeus* and *Atelerix algirus* (20.7%), squirrels *Sciurus vulgaris* (15.0%) and rabbits *Oryctolagus cuniculus* (14.4%).

Roadside habitats were characterised by means of 100 m wide buffers established around roads and overlapped with GIS land use maps of the Park. Also, other factors linked to the road itself were considered in analysis, such as the daily average density of traffic (DAD: vehicles/day) and velocity. Analysis of the incidents shows a positive relationship between the number of roadkills/km and DAD. On the other hand, there was also a seasonal trend to roadkills with a peak at the end of spring which coincides with the period population levels is maximal (presence of juveniles).

Incident black spots were identified, which differ according to species and which in the case of the wild boar, for example, coincide with connection zones between the two main forest areas of the Park.

Finally, it should be highlighted that roadkills are not necessarily the main impact of infrastructures, at least for most species concerned, but rather their effects are added to other impacts such as the barrier effect and habitat fragmentation which can have more damaging effects at the population level.

Key words: black spots, conservation, mammals, mortality, roadkills

1. Introduction

The study of roadkills is becoming more and more important in the management of natural spaces and especially in wildlife conservation (Trombulak *et al*. 2000; Malo 2004; Saeki 2004). Due to the continuous expansion of road infrastructures and the increase in traffic, as well as the problems derived from road safety, it is becoming a topic of major concern (Bennet 1991; Müller & Berthoud 1997; Forman 2003).

Roadkill data collected from 1991 in Collserola Park have been analysed as part of a wider project on the impacts of transportation infrastructures on wildlife. This project examines other impacts such as habitat fragmentation, barrier effect and connectivity. The main objective of this work is to measure the effect of roadkills on the Park's wildlife: the effect of road mortality on certain species and location of black spots. The aim of this study is to determine the characteristics of wildlife roadkills in Collserola park in relation to the main species affected, the phenology, the roadside habitat and traffic aspects.

2. Study area

Collserola Park occupies some 8,500 ha of protected land in the middle of the Barcelona metropolitan region, which is surrounded by more than three million inhabitants. The park is under great anthropic pressure, an obvious example of which is the extensive network of transportation infrastructures; 7.6 km of motorways, 70 km of conventional roads and 42 km of forest trails open to traffic. There is a central transportation axis crossing the park north to south formed by a motorway, a conventional road and a railway line than run parallel to each other and divide the park into two large forested areas.

The Collserola mountains are covered mainly by a forest of Aleppo pine (*Pinus halepensis*) and Holm oak (*Quercus ilex*). Notwithstanding the high level of anthropization, the park is of great natural interest, not just because of its metropolitan context, but in its own right due to the existence of elements of high ecological value (Raspall *et al.* 2004) for which it has recently been included in the Natura 2000 network.

As for vehicular traffic, a high number of vehicles driving through Collserola; data for the E-9 motorway in 2005 show a daily average density (DAD) of 33,561 vehicles per day. This trend has increased year after year since it was opened to traffic in 1991, as is occurring in the rest of Spain.

3. Methods

In order to conduct the current study we have used different data: (*i*) wildlife roadkill records; (*ii*) traffic data from the park's road network; (*iii*) GIS habitat map of Collserola park.

First of all, a roadkill database was available with information gathered since 1991 and introduced into the GIS of the park. Roadkill information comes from different reliable sources, mainly from technical staff of the park, wardens, other monitoring studies focused on specific fauna groups, as well as our own data. In all cases information related to location, date and species is obtained.

Secondly, from January 2004 on a specific monitoring was also been carried out of roadkills on roads and forest tracks in the park by means of pre-established transects in order to obtain quantitative indices of roadkill rates. Six transects were established along the road system of the park through different environments and with varying length, between 8.4 and 19 km. These were surveyed while driving at maximum speed of 40 km/h on roads and 20-30 km/h on forest trails. Repetitions of these gave a total of 219 transects were surveyed covering 3,199 km.

Thirdly, other factors linked to the road itself were considered in analysis, such as the DAD (vehicles/day) and velocity. Data referring to DAD and velocity for distinct individual stretches of the conventional road network in Collserola were provided by the road administration of Barcelona (Diputació de Barcelona, 2005). For analysis of roadkill data, the road network was also divided into different stretches based on those considered by the road administration for traffic monitoring. An index of roadkill rate (roadkills/km) was calculated on these road stretches, and its relationship with DAD was examined.

Finally, roadside habitats were characterised by means of 100 m wide buffers established around roads and overlapped with GIS land use maps of the Park using Arc View 3.2. Also, habitat around roadkill spots was characterisd for the four mammal species most affected by roadkills by establishing circular buffers of 100 m radius.

4. Results

A total of 865 records of vertebrate roadkills were registered in the GIS-fauna database of Collserola park (Fig. 1).

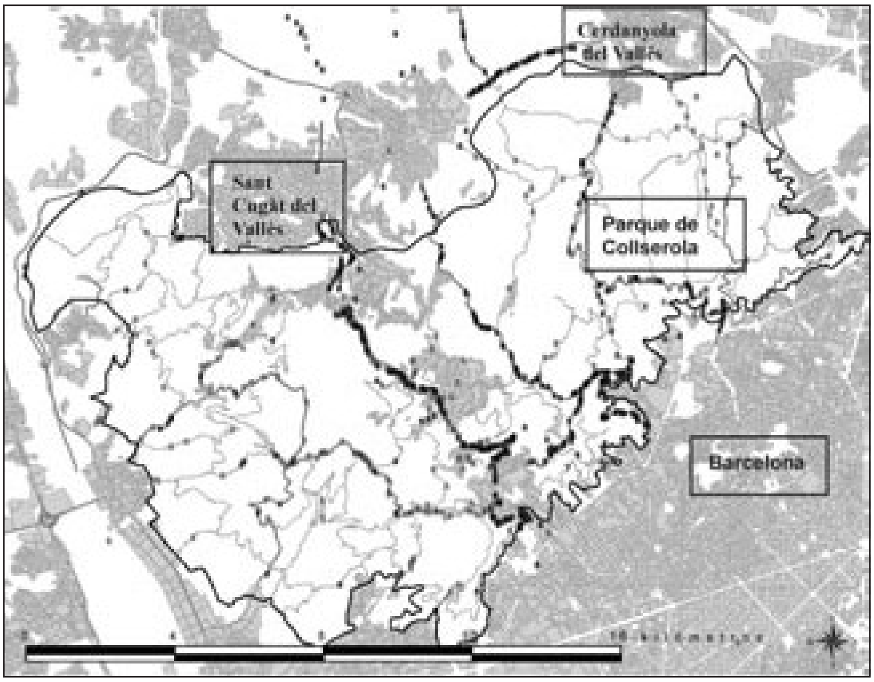

Fig. 1. View of roadkill registers in Collserola Park

Of these, 57% were mammals; 20% were birds, 16% were reptiles and 8% were amphibians. Seventeen different species of mammals were recorded which represent 81% of terrestrial mammals present in the park. The five most affected species account for 71% of all mammal records and correspond to wild boar *Sus scrofa* (21.4%), hedgehog – mostly *Erinaceus europaeus* (20.7%), squirrel *Sciurus vulgaris* (15%) and rabbit *Oryctolagus cuniculus* (14.4%) (Fig. 2). The North African hedgehog *Atelerix algirus* is also present at low density in the region, but generally in our case it was not practical to distinguish the two species in roadkills and as such they are considered here together generically as hedgehogs.

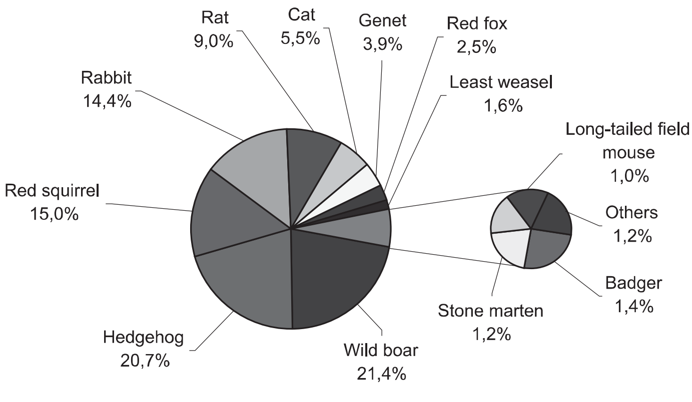

Fig. 2. Species distribution of roadkills in Collserola Park. Series 1991-2005 (n=487)

Between 2004 and 2005, a total of 157 records of mammal roadkills were registered in Collserola park (Fig. 3). Of these, only ten registers were obtained from specific monitoring of transects, underlining the importance of roadkill records obtained on a routine day to day basis in the park. As such, these data were all considered as highly useful in characterising wildlife roadkills given the important volume of information they represent. In this regard, mammals were considered the most useful group for describing roadkill traits given their high representation in the sample.

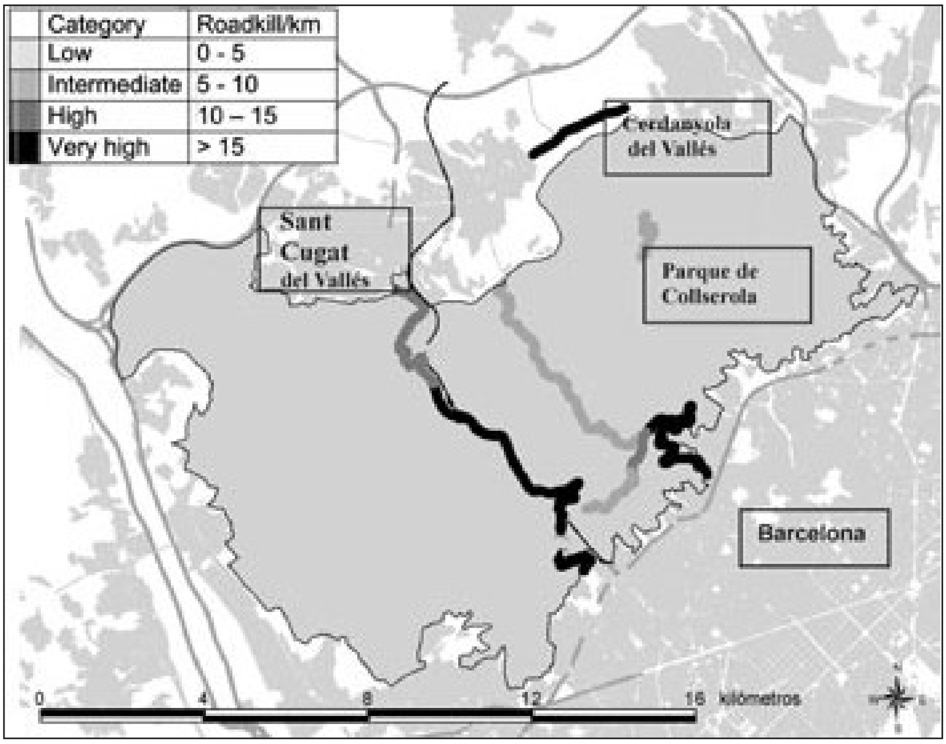

Fig. 3. Mammals roadkill kilometric index in the road sections of Collserola Park conventional roads

There was a seasonal trend to mammal roadkills, with a peak at the end of spring which coincides with the period of maximum population levels due to the presence of juveniles (Fig. 4).

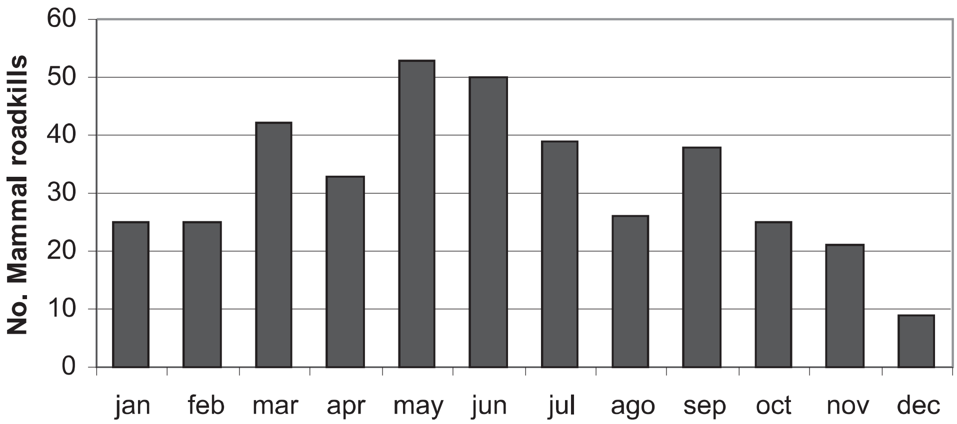

Fig. 4. Monthly distribution of mammal roadkills in Collserola Park (n=386)

With regard to the type of infrastructure, 86% of registers were from conventional roads, 6% from forest trails and only 5% of the data correspond to E-9 motorway, which is clearly underrepresented in the sample due to the practical difficulties of surveying this particular infrastructure. The remaining records (3%) correspond to roadkills in urban areas within the park. As such analysis of data for road mortality in Collserola was limited to registers from conventional roads. The roads considered in this analysis have DADs between 1,300 and 10,000 and average vehicle speeds of between 50 and 90 km/h, with very few stretches of over 90 km/h.

Mammal roadkill rate was highly variable among different road stretches in the park, ranging from 0.22 to 17.36 ind./km (Fig. 5) and was correlated with DAD (R^2= 0.82). The relationship between roadkill rate and DAD adjusts to an asymptotic logarithmic curve with a threshold of roadkills at DAD values of around 10,000 vehicles per day (Fig. 5). This result coincides with the theoretical model presented by Müller & Berthoud (1997), according to which, with increasing traffic, the number of roadkillls increases up to a point beyond which noise and vehicle movements repel more animals from attempting to cross the road.

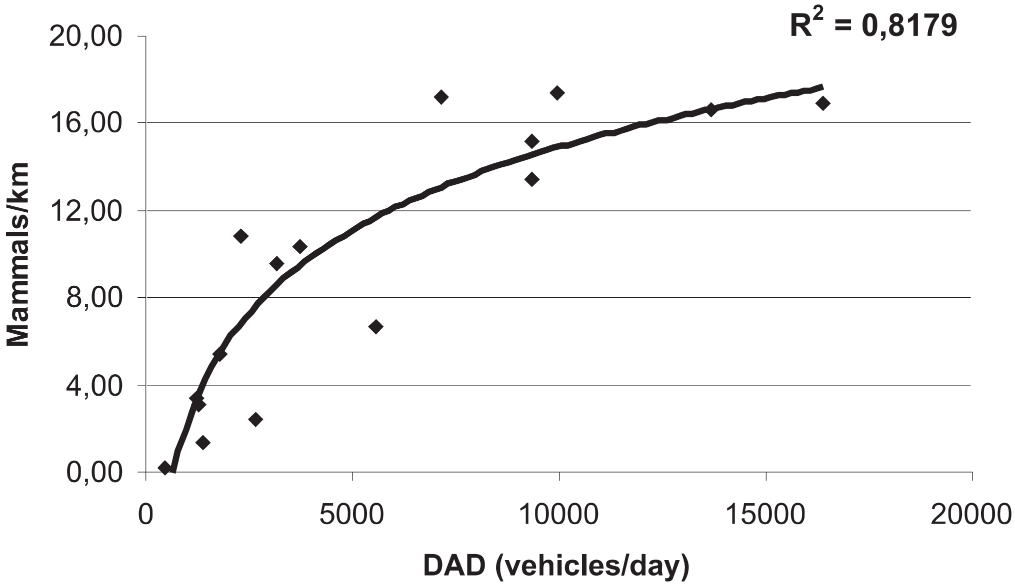

Fig. 5. Relationship between mammal roadkill rate and DAD (daily average density) on different road-stretches

Habitats around roadkill registers were characterised for the four species most affected by road mortality in the park; wild boar, hedgehog, rabbit and red squirrel (Fig. 6). The results show that roadkill spots for wild boar and red squirrel happen mostly in forested areas, on the other hand the hedgehog and the rabbit show a much higher percentage of open environments (crops, dry grass-lands…).

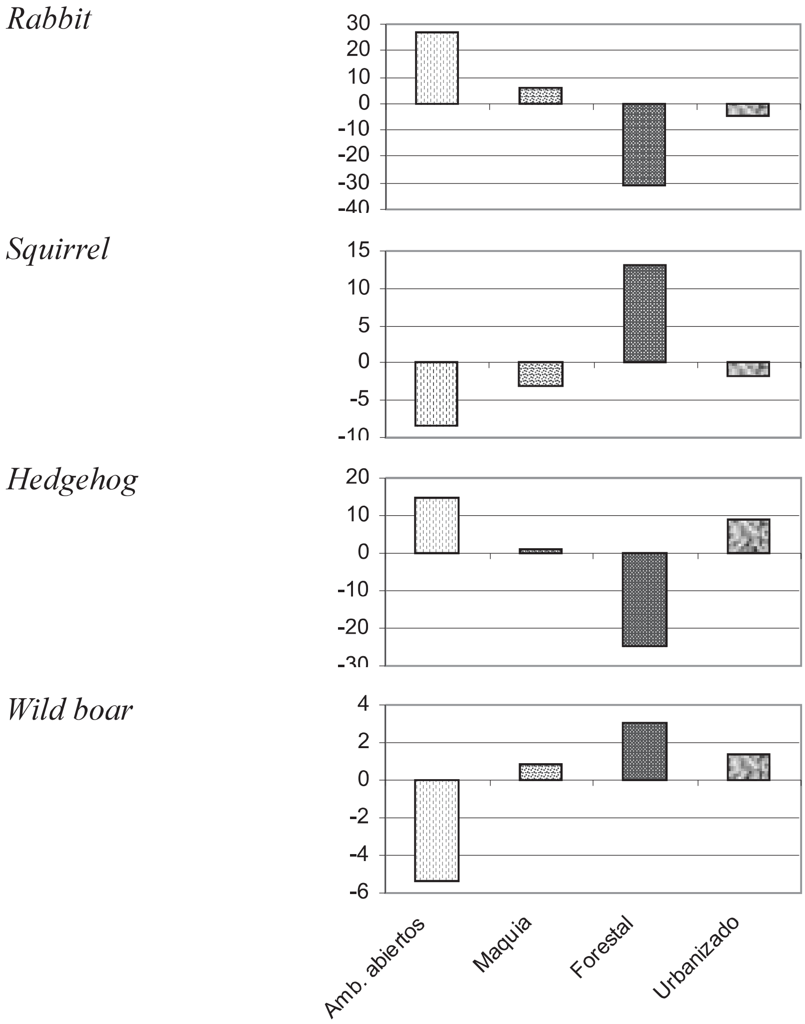

Fig. 6. Habitat selection around wildlife roadkill locations of the main species affected by this problem in Collserola (wild boar, hedgehog, rabbit, red squirrel)

5. Discussion

Collserola Park provides very interesting framework for the study of road mortality. Revision of 865 records of fauna roadkills gathered since 1991 in the Park, gives a first approach to the impact of wildlife road mortality in a periurban natural space.

Mammals rate of roadkills in our study is very high (56%) compared to results from other studies where it is around 33% (PMVC, 2003). Given the source of our information, medium sized mammals seem to be a very appropriate fauna group to carry out this type of monitoring. On the one hand they seem easier to detect, on the other hand the disappearance rate seems lower than other groups such as amphibians.

In relation to the seasonal trend of mammal roadkills, with a peak at the end of spring, according to bibliography it may be related the lack of experience of juveniles.

Although we couldn't study the effect at the population level, it is known that in some cases road mortality can be more important than mortality by natural causes as predation or illness (Forman & Alexander 1998) as it happens in Holand and Great Britain in the case of the badger (Van der Zee *et al*. 1992, Clarke *et al.* 1998). In our case, data show an effect that could be very strong on the badger population (Rafart-Plaza 2005) and it seems to appear some negative effect on hedgehog population, it should be monitorized in a close future.

Roadkills distribution on roads does not happen random but according to a cluster model (Clevenger *et al*. 2003). We found some stretches of the road where the roadkill rate is higher than average, this are known as black spots, or better, black stretches. These black stretches happen in different locations depending on the fauna species, and it seems to be related to factors linked to the road, to the roadside vegetation and biological characteristics of the species. As long as the vehicular traffic is concerned, there are several factors that ease accident rate such as traffic volume and velocity. In relation to the road design, curves or elements that reduce visibility can increase the risk of collision. Landscape features seem to be the most important factor, specially habitat quality; wildlife mortality risk increases if the road overlaps with a naturals passage of fauna such as a river, a trail etc… The existence of a big slope at one side of the road is also considered a risk factor (Malo 2004) Finally it has been observed that the existence of attraction elements in the roadside such as crops or roadside vegetation maintenance increase also the risk of collision.

In the orthophotomap a black stretch for wild boar is shown (Fig. 7). In this case, different factors explained before happen at the same time: (*i*) there is a U-turn with very little visibility, (*ii*) it is found between two straight stretches of the road where vehicles reach high speed, (*iii*) it is overlapping with a crick, which is a natural fauna passage very used by wildlife.

Fig. 7. Wild boar roadkills blackspot located in Rabassada road, Collserola Park

This work makes evident the difficulties of roadkill monitoring: driving at the right speed, visibility limitations and a high rate of corpse disappearance because of the traffic, carrion feeding or corpse removal by the road maintenance service (PMVC, 2003).

After this first approach to road mortality we consider very important to keep road transects monitoring in order to get our own standard information and still gather information from other sources. In that sense, a new link has been designed in the website of the park.

http://www.parccollserola.net/incidencies_fauna/atropellaments.htm

Finally, it should be highlighted that roadkills are not necessarily the main impact of infrastructures, at least for most species concerned, but rather their effects are added to other impacts such as the barrier effect and habitat fragmentation which can have more damaging effects at the population level.

6. Future perspectives

Our main aim in the long term is to reduce the impact of road mortality on wildlife in Collserola park. In this moment we are working in the design of first mitigation measures related to speed control and traffic reduction in conventional roads of the park. Also an agreement with train managers for first assessment has been reached in order to reduce the impact of the central axis of infrastructures.

Aknowledegements

To all the members of the staff and especially to the wardens of the park who have participated in data collection without which this work had never been possible. To Enric Morera from the Statistics Unit of Local Roads Administration and Joan Almirall from TABASA the company that manages the motorway, who provide us with information related to traffic. To the railway company members' of the staff that collected wild boar incidences in the railway line. And to Lluis Cabañeros for giving his support to the project.

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Habitat fragmentation and fauna mortality caused by traffic in the Czech Republic

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Abstract. An intensive research program connected with physical controls of all highway bridges over the whole Czech Republic was carried out between 1998-2003. A large number of sectors (70%), significant for roe deer migration, remain completely impassable. Many sectors of highways and motorways present an entirely impassable barrier for large animals such as red deer and moose. Seven sections on the highway network of the Czech Republic were identified as critical for big mammals.

Key words: highway network, fauna mortality, habitat fragmentation, fauna passages, Czech Republic

1. Introduction

Busy overland roads, especially highways and motorways, create barriers for migration of wild animals, causing fragmentation of their habitat and populations. Isolated populations are unstable and an increasing density of highway network is becoming the chief risk factor for the existence of some species. There are about 900 km of highways in the Czech Republic and their density will increase rapidly in near future.

A large study concerning the habitat fragmentation due to highway network was carried out during last 8 years. A new study on the fauna traffic mortality starts this year. Our research was focused on following questions:

- What is the permeability of existing highway network for different species?
- What are the minimum parameters for fauna passages for different species?
- What is the optimal density of fauna passages?
- Is it possible to identify ‚critical sections‘ on the existing highways?
- Which species can be endangered by traffic mortality?

2. Review of results

2.1. Permeability of existing highway network

An intensive research program connected with physical controls of all highway bridges over the whole Czech Republic was carried out between 1998-2003. 850 highway bridges were checked during this study, each bridge was sorted out into one of the following four categories:

- permeable for all species including red deer, moose and big carnivores
- permeable for small and medium size mammals like roe deer
- permeable only for small mammals (fox, badger, otter etc.)
- impermeable bridges.

The conclusions of this research indicate that the present highway and high-speed road network does not represent a significant barrier for animals of the size of fox, badger or otter. For animals of the size of roe deer the highway network is permeable in 40% of its total length. A large number of sectors, significant for roe deer migration, remain completely impassable. Many sectors of highways and motorways present an entirely impassable barrier for large animals such as red deer and moose. The total extent of impassable sectors for this category of animals represents about 70% of the entire length of these roads.

2.2. Parameters of fauna passages

The determination of minimum parameters of fauna passages was carried out on a sample of 100 bridges during the period 1999-2001: 93 underpasses 5-60 m wide, six overpasses 6-8 m wide and one overpass 70 m wide. Snow tracking and "sand bed" methods were used in this research. The observations confirmed that the best parameter for the expression of the suitability of underpasses was the *index i* (Table 1).

Table 1. Parameters of fauna passages

%	Description	Roe Deer		Wild Boar		Red Deer	
		i	example	i	example	i	example
80-100	Ideal stage	> 30	$\frac{60 \times 15}{30}$	> 30	$\frac{60 \times 15}{30}$	> 40	$\frac{80 \times 15}{30}$
60-80	Functional optimum	7-30	$\frac{30 \times 7}{30}$	7-30	$\frac{30 \times 7}{30}$	8-40	$\frac{30 \times 8}{30}$
40-60	Average	1.5-7	$\frac{15 \times 3}{30}$	2-7	$\frac{20 \times 3}{30}$	4-8	$\frac{30 \times 4}{30}$
20-40	Functional minimum	0.65-1,5	$\frac{6.6 \times 3}{30}$	1-2	$\frac{10 \times 3}{30}$	1.7-4	$\frac{10 \times 5}{30}$
0-20	Functionles	Up to 0.65		Up to 1		Up to 1.7	

index $i = \frac{\text{Width x Height}}{\text{Length}}$

% - Number of animals, which will use the passage (% of all animals coming to the passage)

A map of categorization of the territory of the Czech Republic was prepared to recommend the optimal density of fauna passages (Fig. 1). See also on the Table 2.

Table 2. Maximum recommended distances of passages for different mammal categories in different areas of importance

Categories of areas		Mammal category		
Category	Area	Red Deer	Roe Deer	Red Fox
I	Most important areas	3-5	1.5-2.5	1
II	High important areas	5-8	2-4	1
III	Important areas	8-15	3-5	1
IV	Less important areas	N	5	1
V	Areas without any importance	N	N	1-3

Remark: all data presented in km; N – no passages are needed

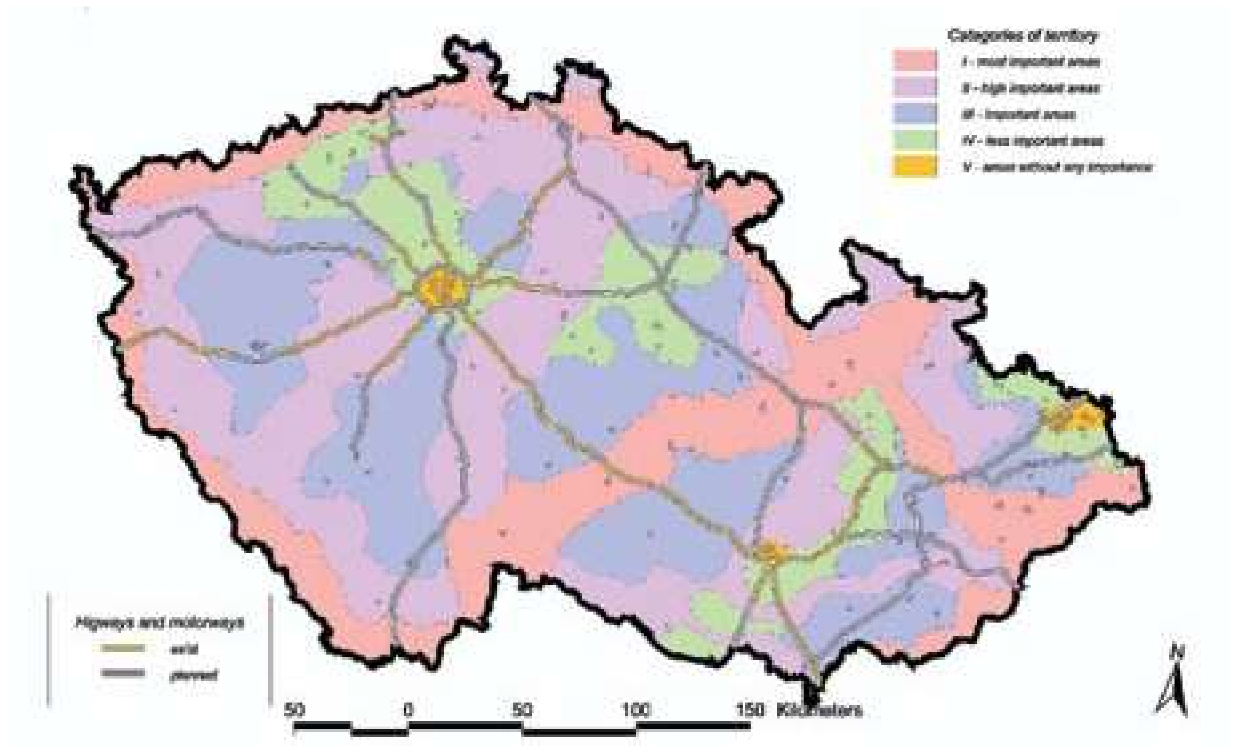

Fig. 1. Categorization of the territory of the Czech Republic according to the distribution and migration of big mammals

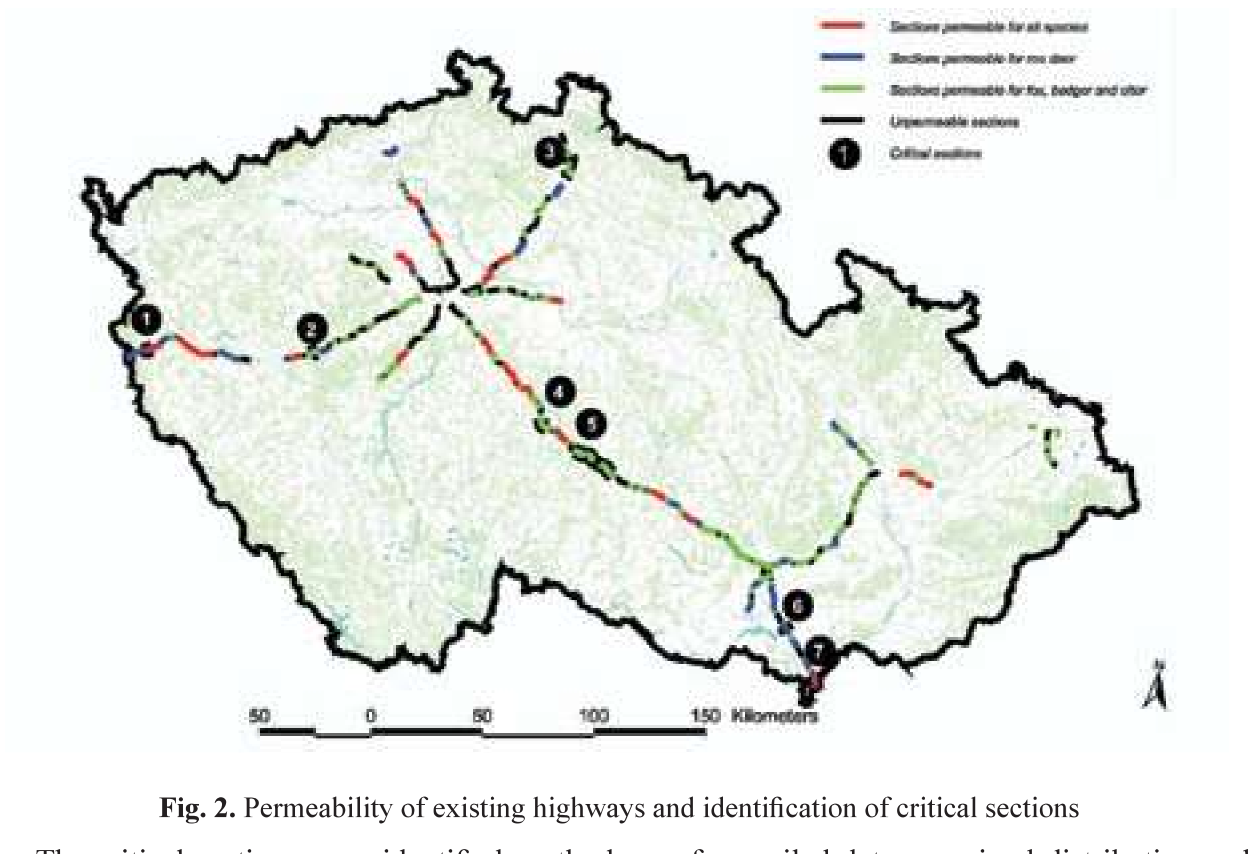

Fig. 2. Permeability of existing highways and identification of critical sections

The critical sections were identified on the base of compiled data on animal distribution and migration, fauna traffic mortality, traffic accidents caused by animals and the permeability of existing highway net (Fig. 2).

Seven sections on the highway network of the Czech Republic were identified as critical for big mammals. As the permeability of these sections is crucial for future existence of big mammals populations, a plan for restoration of permeability for all target species is being prepared at present.

A study concerning traffic mortality is being worked out at this time. This research started in April 2006 and is planned for next two years. Its aim is to estimate numbers of animal species which are killed by traffic in the Czech Republic per year. Chosen sections of different roads (highways, first class roads, local roads) in different types of the landscape are checked periodically and all dead vertebrates are recorded. The checks are made on foot walking along both sides of the road (that means, that each control is made by two people or by one patrolman going there and back).

The calculation of numbers of killed animals has a lot of methodical problems. It is important to estimate the percentage of cadavers which are possible to find on the road and roadsides of the number of all killed animals. (Many cadavers of small animals completely disappear just after the accident.) Another problem is how long the scraps of animals stay determinable on the road and roadsides. There are many factors, which can influence the results, like for example: size of the animals, the traffic density, the place (road or roadside), climatic conditions, influence of predators etc. During first five months 482.6 km of roads were checked and during this period 1054 of killed animals in 98 species of vertebrates were found (Table 3).

Table 3. The length of checked sections and numbers of killed animals found

	highway	motorway	1st class	2nd class	3rd class	total
The total lenght of roads in the CR (km)	564.4	322.3	5 831.4	14 667.5	34 124.1	55 509.8
Checked sections during April-June 2006 (km)	103.4	4.7	123.5	116.5	134.5	482.6
Numbers of killed animals (vertebrates)	326	32	281	238	177	1054

As most frequent mammal species were found hare (*Lepus europaeus*) – 140 cases, hedgehog (*Erinaceus europaeus* and *E. concolor*) – 54 cases and stone marten (*Martes foina*) – 28. The most frequent birds were blackbird (*Turdus merula*) – 25, finch (*Fringilla coelebs*) – 19 and yellowhammer (*Emberiza citrinella*) – 13. To rare species found during first three months belonged otter (*Lutra lutra*) – 2, barn owl (*Tyto alba*) – 1 or barred warbler (*Sylvia nisoria*) – 1.

The preliminary results are of course insufficient for making conclusions concerning total mortality of different species on the roads. But they show clearly, that the traffic mortality is a very important factor which can affect the development of populations of some species. Final results of this study will show important data for clarification of this problem

4. Conclusion

The real impact of habitat fragmentation and traffic mortality on different species has not been clarified well till now. As the density of traffic and the density of transportation infrastructures grow very fast, it is necessary to pay high attention to monitoring, to next research and to preparation of measures which will eliminate negative effects of traffic.

Via Egnatia case in Greece: an overview of the intervention

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Abstract. While economic growth in the modern world seems to be a one-way process, various threats for wildlife and the natural ecosystems are increasing. The development of intense road networks, cause habitat fragmentation and connectivity between important habitats and consequently influence the gene flow between sub-populations of large terrestrial animals. In, Greece the construction of the new cross country four line 600 km highway VIA EGNATIA is such an example. The highway connects the Ionian Sea harbor of Igumenitsa with the Greek-Turkish borders and passes through the provinces of northern Greece (Regions of Epirus, Macedonia, and Thrace). The construction cuts through important natural areas of Pindos Mountain massif, the main habitat of large carnivores like the brown bear (*Ursus arctos*) and the wolf (*Canis lupus*). ARCTUROS, an NGO based in Thessaloniki (established 1992), seriously intervened in the plans of highway construction since 1994 and achieved to change the initial route plan for a 34 km segment in the Prefecture of Grevena a critical corridor habitat for carnivores. The intervention lead to an increase of the total length of tunnels and bridges from an initially planned 7 to almost 17 km covering 50% of the total length of the road, whilst additional construction of green bridges and underpasses were planned so as to reduce further habitat fragmentation. Moreover a 6 year monitoring program was planned, to monitor the effect of the highway on animal populations, before and after construction.

Key words: highway, habitat fragmentation, green bridges, underpasses, Via Egnatia, Greece

1. Introduction

As the modern societies are developing rapidly, there is a growing construction of large scale technical structures, such as highways. The increased density of transport infrastructures, cause pressures on natural ecosystems world wide and intensify conflicts between humans and wildlife (Boitani *et all.* 1999; Fukeda 2005; Gibeau *et all.* 2001; Graham *et al.* 2005; Mattson *et al.* 1986; McCown *et al.* 2005; Naves *et al*. 2005; Schwab *et al.* 2005).

Via Egnatia is a new cross country four lane 600 km highway cutting through North Greece, connecting the harbor of Igumenitsa at the Ionian Sea with the Greek-Turkish borders and passing through the provinces Epirus, Macedonia, and Thrace (Fig. 1). The highway is part of the Trans European Network (TENT) and has links with the international roads and railroad network as well as maritime axons (Mertzanis *et al.* 2005). The construction is implemented by EGNATIA ODOS S.A. a company created by the Ministry of Environment, Physical Planning and Public Works which is the exclusive shareholder.

The planning of the appropriate wildlife passes for the larger mammals are necessary during the pre-construction phase, at Grevena-Panagia segment due to the fact that the highway is a closed – fenced highway. This means that in the case of inappropriate construction of the fauna passes, habitat fragmentation, the loss of the geographical continuity of the distribution of the large mammals will compromise their long scale survival (Beecham *et al.* 2006; Clevenger & Waltho 2000; Scheick & Jones 1998).

The absence of Strategic Environmental Assessment (SEA) in Greece (Directive 2001/42/EC) leads to separate and isolated measures and cases with no general study and relation on national level. The construction of high speed roads is expected to have a negative impact on the brown bear *Ursus arctos* and its habitat due to (Fig. 2):

- habitat loss
- disruption of habitat continuity, since artificial obstacles will limit the seasonal movements of the population as well as its expansion
- splitting of the home ranges
- genetic isolation which may lead to inbreeding therefore loss of genetic diversity
- increased the direct mortality due to traffic accidents
- behavioral changes since certain highway sections will be avoided due to disruption of continuity of the vegetation cover – «edge habitat effects»
- increased pressures due to land use changes and increased human presence at the areas adjacent to the highways.

For the minimization of the geographical and genetic isolation, it is needed to maintain and/or to create linkage zones between separate segments of the geographical distribution of an animal species. Therefore any construction must be planned with mitigation measures such as tunnels, bridges, green bridges to maintain the quality of the biotope in the neighboring areas and ensure the habitat continuity (Beecham *et al.* 2006; Clevenger & Waltho 2000; Scheick & Jones 1998). These cases could have an active and effective role as real passes.

For the correct planning of the tasks related with the large mammals there is a need of approaching at: (*i*) a larger scale for ensuring the geographical continuity of the national population of the species and avoid disruptions and (*ii*) a local scale for the most suitable design of the wildlife passes.

2. The rejection of the initial highway construction plan

The initial proposal by EGNATIA ODOS S.A. for the route of the highway, for the segment Panagia-Grevena, included cutting through the bear habitat without any special concern for the conservation of the species and its habitat.

The only one mitigation measure planned was related to the construction of few tunnels with 3.5 km total length for the safe crossing of the bear. From these, only two tunnels with total length of 1.1 km was in appropriate habitat location, while the rest were unsuitably designed mainly fitted to easy construction. This plan was unsuitable to secure the long term survival of the indigenous bear population, as the species use an extensive home range ranging 150-250 km^2 annually and is characterized by intense activity with large distance daily movements up of 15-20 km (ARCTUROS 2000).

On the other hand, with the construction of the highway there was a probable danger of isolation of the bear population in the mountain Hasia (220 km^2), inhibiting the expansion of the species to the east. Also with no gene exchange the small isolated population in mt. Hasia was severely threatened due to inbreeding.

Additionally the highway was planned to follow quite often the valley of Venetikos' river creating serious problems both to the landscape and the avifauna.

3. Results – the final alignment

After a series of judicial activities initiated by ARCTUROS and repeated discussions with the Ministry of Environment, Physical Planning and Public Works and Environmental NGOs many studies took place (Table 1). These studies were completed after the overlook of the initial environmental terms enforce by the Council of State (highest judicial level in the country) as there were not any alternative suggestions. These studies included one perimetrical route at the edge of the brown bear habitat (Fig. 2). They were rejected since they did not reduce or circumvent the important bear habitat. On the contrary the length of the road was increased by 28 km and the nature of the hilly landscape could not allow the creation of the necessary connecting corridors for the animals. If the perimetrical solution was selected a concrete obstacle for the brown bear would created, and the re-colonization of the new areas by the species as well as by other large mammals would never took place (Bousbouras *et al.* 2006).

Fig. 1. Brown bear (*Ursus arctos*) distribution in Greece (Pindos, Rhodope), Via Egnatia and its vertical axons

Fig. 2. Brown bear (*Ursus arctos*) distribution in Pindos Mountain and reappearance of the species. Via Egnatia is with red line while the alternative perimetrical proposal is with violet. Red points indicate the re-appearance of the brow bear in Greece

Table 1. Short history of the case of Via Egnatia and the intervention of ARCTUROS and the other environmental NGOs

Date	Activity
1994	ARCTUROS formulated the official objection to the Ministry of Environment, Physical Planning and Public Works related to the proposed design of the segment Panagia – Grevena of the Via Egnatia. The proposed changes are supported on the scientific data of the LIFE-Nature ARCTOS project (for the conservation of Brown bear in Greece) without their inclusion in the final design. in a special memorandum of ARCTUROS to the Ministry of Environment, Physical Planning and Public Works the solution of the perimetrical lining is proposed to be studied for the concrete segment. The data and the scientific documentation were completely ignored. In the same time European Commission is informed about the case.
1995, April	The Common Ministerial Decision of the improvement of the Environmental Terms for the segment Panagia-Grevena was signed by the Ministers of the Environment and Agriculture without any preventing measure or/and confrontation of the reverberation
1995, August	Appeal of ARCTUROS, WWF-Hellas and the Hellenic Society for the protection of Nature, to the Council of State for the cancelling of the Ministerial Decision.
1996, February	The subject challenged the activity of the European Commission. A special meeting took place with representatives of ARCTUROS, team of Ministry of Environment, Physical Planning and Public Works and the E.C. (DG XVI) with newly discussion of the problematic designed lining and the reverberation to the natural environment of the concrete area.
1997, July	The decision of the Council of State (reg. num. 2731/1997) justified the appeal of the NGOs and canceled the Ministry Decision for the concrete segment of the highway, while the same time proposed the investigation of the solution of perimetrical designed lining.
1998, June	As a continuance of the decision of the Council of state, EGNATIA ODOS S.A. implemented a new Environmental Impact Assessment (EIA) for the concrete segment. The Study proposed variants of the design with some more corrective measures. The new design is draw away from the Venetikos River. The same study investigated other two alternative solution one from which is the perimetrical design and finally rejected. The same period EGNATIA ODOS S.A. asked the beginning of a series of working meetings with ARCTUROS which newly documented the environmental impacts of the highway.
1998, July	ARCTUROS submitted to the EGNATIA ODOS S.A. and the European Commission relative memorandum, noted the reservation about the sufficiency of the corrective measures.
1999, December	The subject discussed at the Council of Europe in Strasburg.
2000, April-June	Tthe relative envelope opened by the European Commission (DG Environment) and warning letter to the Hellenic Government sent. On April 6th 2000 the co-relevant Ministries approved the Environmental Terms of the improved design (just before the National Election). The technical characteristics of the task included 13.2 km of tunnels and 3.7 km of bridges from a total length of 34 km of highway.
2000 October – 2001 November	Starting of new circle of discussion between EGNATIA ODOS S.A. and ARCTUROS with a design of the Special Monitoring Project as a result.
2002-2004	Implementation of the Special Monitoring Project funded by the EGNATIA ODOS S.A. the Ministry of Environment, Physical Planning and Public Works and the EC (DG REGIO).
2005, May	The results of the first phase of the project included proposals for small improvements of the technical characteristic of the highway with benefits for the fauna as well as subjects for land planning organization of the wider area.
2006	Installation of the constructor in the area and preparation for the second phase of the project.

At the sequential studies the EGNATIA ODOS S.A. and the Ministry of Environment, Physical Planning and Public Works undertook some additional measures:

- plan to construct the highway far from the rivers and fresh water sources
- increasing the length of the tunnels to facilitate bear movements

- construction of small animal underpasses
- hunting prohibition at a 2 km zone from both sides of the road.

The final plan included 13.2 km of 15 tunnels with length range 250-2.100 m and 3.7 km of 8 bridges with length range 250-500 m in a total of 34 km of highway stretch. These technical characteristic ensure the passes for the terrestrial fauna with coverage of 49.7% with the combination of special constructive needs.

One of the most important achievements for the environmental terms of the final improved solution was the implementation of the scientific project with title: 'project for the evaluation of the impacts of Via Egnatia at the forest ecosystem of the area with emphasis on large mammals and brown bear *Ursus arctos* in the segment Panagia – Grevena (seg. 4.1)'

The ongoing project continues for 6 years and includes three phases covering the periods before, during and after the construction of the highway. In the first phase (2003-2005) the project coordinated by ARCTUROS (as consultant and implementation body) in cooperation with the Aristotle University of Thessaloniki, the University of Thessaly and the Hellenic Ornithological Society (BirdLife partner in Greece). In this phase the project evaluated the status of the bear, wolf and ungulate population as well as the status of the important bird species in an area 10-20 km zone on both sides of the road.

The already implemented first phase of the project included surveys with different methods including bear monitoring with GPS collars, targeting on the precise movements and habitat use of the species. Based on these data at the end of the first phase special proposals for the improvements of the design were formulated as:

- changing of the position of existing fauna underpasses and creation of new as well increasing of the sizes of some of them
- planning of one green bridge for the crossing of the large mammals as ordered by the environmental terms decision
- construction of strong fence for averting bear traffic accidents
- creation of permanent wildlife reserve in a radius of 2 km on both sides of the highway
- seasonal closure of the secondary forestry road network
- land - planning regulations, which would keep the land use unaltered in the radius of 2 km on both sides of the highway
- prohibition of the construction of new forest road
- changing of the Forest management logging system from clear cutting to selective.

The technical characteristics of the highway construction works with the large length of the tunnels and bridges as well as the complementary constructions which proposed by the project ensured the communication between the large mammals population of the different sides of the highway (Mertzanis 2005). Similar construction improvements with large tunnels in other eastern position (segment Kozani-Veria) of *Via Egnatia*, ensured the movements of the brown bears across the highway.

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The effects of highway traffic on wild reindeer

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Abstract. In 2002 scientists from the Norwegian Institute of Nature Research (NINA) were engaged by the Norwegian Public Roads Administration (NPRA) in a 5-year study to undertake research on patterns of reindeer habitat use and movements in areas believed to be influenced by the road. The main purpose of the project was to find out to which degree the road and/or the traffic generated by the road constitute a barrier for the wild reindeer, and if it has a repelling effect on the animals.

The project equipped altogether 37 animals with GPS-transmitters providing detailed and accurate data on their habitat use and movements. The GPS units were programmed to register the position of each animal every 3rd hour, and the data were stored in the collar. Since the wild reindeer are living in herds up to some thousand animals, approximately 70-80 % of the total population was covered.

Maps of the distribution of different reindeer food resources (e.g. lichens) were produced by using field surveys and satellite images (LANDSAT 5). The winter grazing areas were found mainly in the eastern parts and along the Hw 7, while the summer areas were located in the south west and around the Hardangerjøkulen glacier.

The major findings of the project were that Hw 7 in fact has a repelling effect on the wild reindeer, as have other areas with human activity, e.g. the major hiking and skiing tracks between the tourist cottages. The GPS-data show that there is a significant reduction of the reindeer use of the areas close to the Hw 7, up to 8 kms from the road. This zone of avoidance also strengthens the barrier effect of the road such that the migration routes to and from the north are more or less cut off. The same effect can be found in the vegetation maps, but the correlation is not as strong as in the GPS-data. When the GPS-data were compared with the distribution of lichen resources, it appeared that animals do not use some of the areas richest in lichens. Hw 7 can be seen as a behavioral barrier, hindering the migration of reindeer between the central and the northern parts of Hardangervidda.

The project has also documented that the movements of the reindeer are heavily influenced by the direction of the wind, and, in wintertime, the snow conditions. During winters with a lot of snow the animals are found in the eastern parts; where there is usually less snow that in the western parts. The wild reindeer's use of the terrain is dependent on the population density and the available food resources. The possibility for the animals to have access to winter grazing grounds in the northern and eastern parts in years with much snow, can be crucial.

Key words: Wild reindeer, roads, barrier, fragmentation, disturbance, GPS

1. Introduction

More than 60% of Norway's land area is situated above the timber line, which is approximately 1.000 meters above sea level in southern Norway. These alpine and sub-arctic tundra areas in the southern parts of the country are a refuge for the remnant populations of European mountain reindeer (Reimers *et al.* 1980). The Norwegian topography is from nature's side fragmented by long and deep fjords, with narrow valleys surrounded by high and steep mountains. Norway is still called the green lung of Europe, and the density of roads is only 0.6 km/km^2 compared to the Netherlands at 3.8 km/km^2 (Trocmé *et al.* 2003). The densest developed areas are along the coast, and in the deep valleys.

The major road systems are relatively simple (Fig. 1), and they follow the topographic patterns that naturally fragment the country into a matrix of forested and mountainous habitats. The possible impacts of roads on Norwegian wildlife can be illustrated by their distribution and traffic levels. The total road network, including private roads and forestry roads, constitute a rather close and dense network covering larger parts of the landscape (Fig. 2).

Fig. 1. Main roads in Norway
(Source: Statens vegvesen)

Fig. 2. All roads in Norway
(Source: Statens vegvesen)

The traffic density on Norwegian roads is relatively low compared to most western European countries, and the average daily traffic (ADT) is highest in the south east part of the country and around the major cities (Fig. 3).

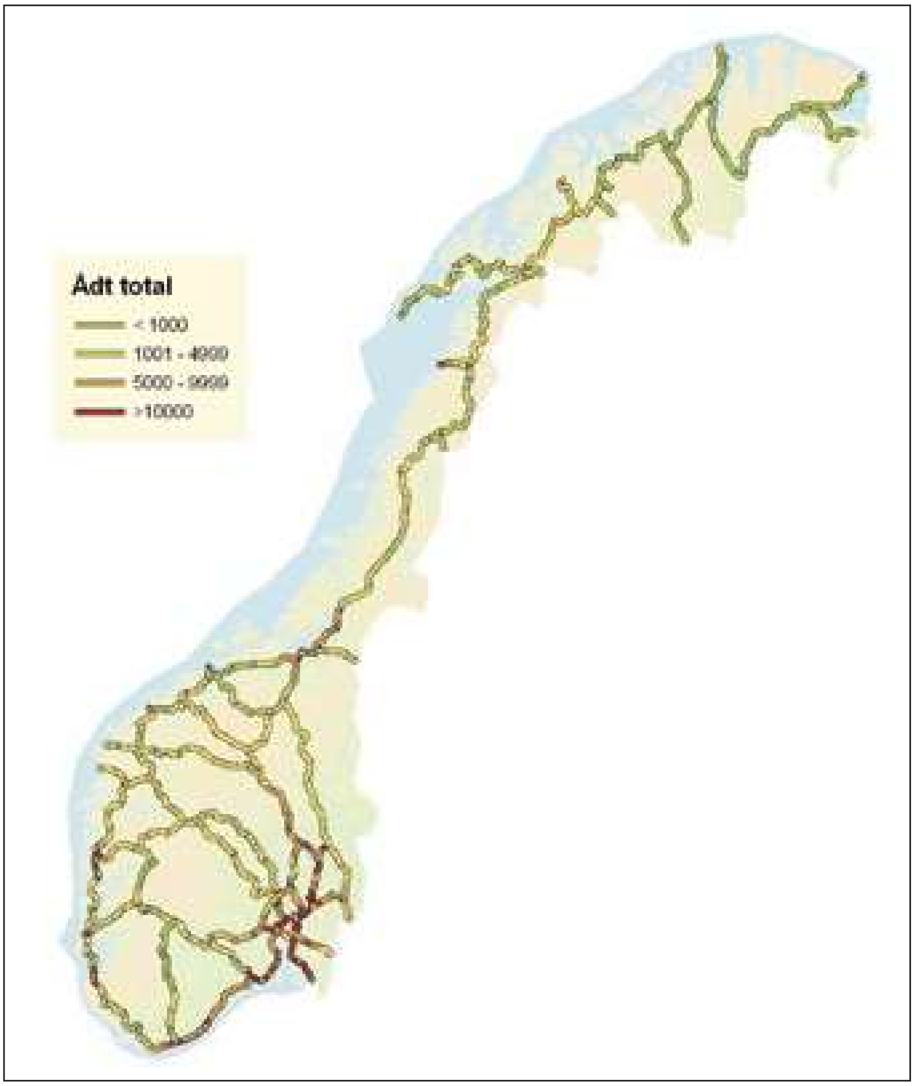

Fig. 3. Average daily traffic (ADT) on main roads in Norway (2004) (Source: Statens vegvesen)

The transportation network together with the network of power lines, dams and regulated water courses, leaves just a few spots of untouched nature left. This can be illustrated in maps classifying habitats into undisturbed and developed areas. Figure 4 shows that the distribution of 'wilderness areas' (areas more than 5 kilometers from larger technical installations, be it roads, railways, power lines, built-up areas or regulated water courses), has become greatly reduced since 1900. In fact more than 95% of the areas classified as 'wilderness' in Southern Norway have disappeared during the last century. The remaining wilderness areas are mainly protected areas above the timber line.

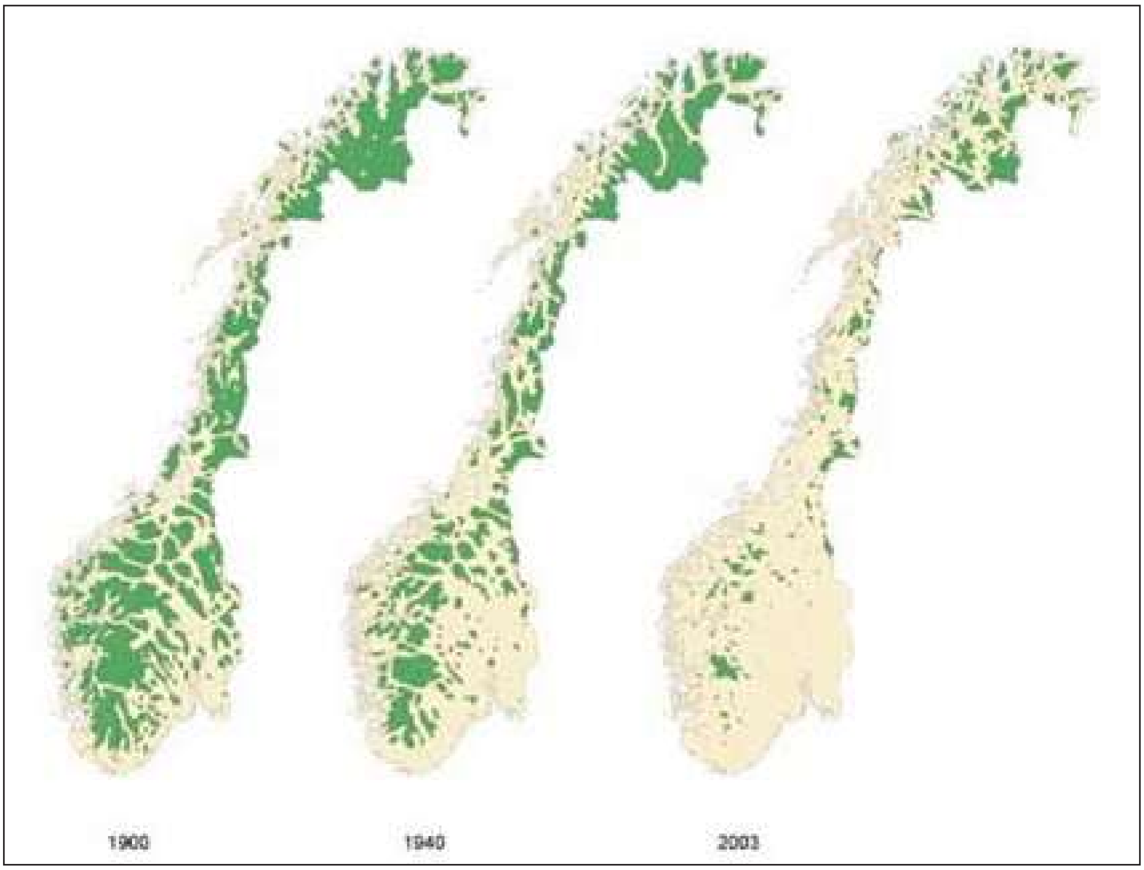

Fig. 4. Changes in the area of undisturbed land between 1988 and 2003 (Source: Statens kartverk/DN)

Wild reindeer

When the glaciers withdrew at the end of the last ice-age, some 10.000 years ago, reindeer migrated into these areas from at least two different directions. Some reindeer came from the south and central Europe, and inhabits today the southernmost areas in Norway. A second immigration came from the east, and descendants from this immigration are mainly found in the northern reindeer areas (DN 1995; Andersen & Hustad 2005). There is still a predominant and documented genetic difference between these two groups of reindeer.

Prior to the industrial development wild reindeer moved more or less freely in 2-3 defined areas in southern Norway, the major barriers being the deep valleys between the mountain plateaus. The present distribution of wild reindeer into 23 more or less isolated management units (Fig. 5) is thus a result of both natural factors, and effects of human activity and infrastructure (Reimers *et al.* 1980; Skogland & Mølmen 1980).

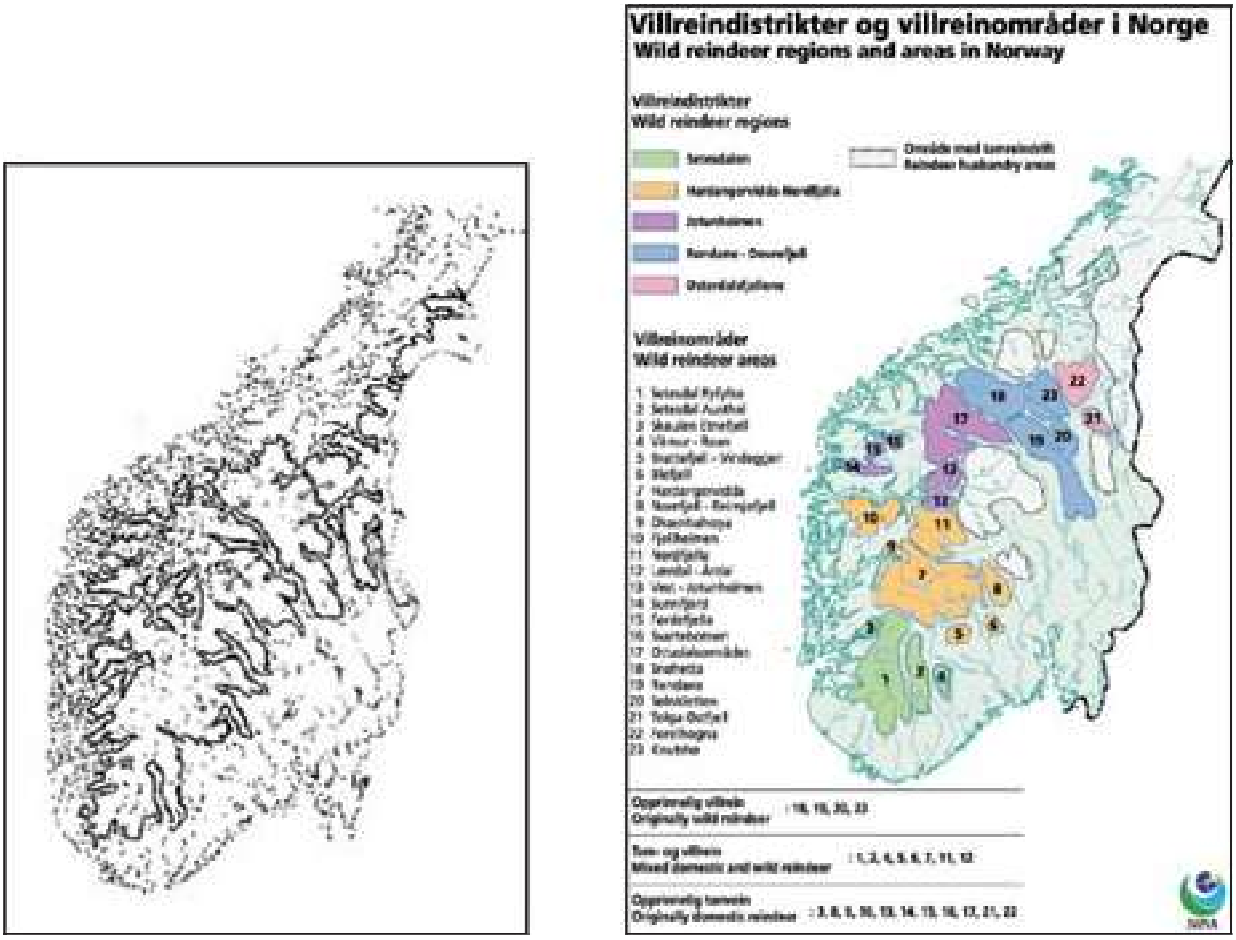

Fig. 5. Wild reindeer areas in South Norway before and now

Today the distribution of wild reindeer is limited to the southern parts of Norway, with approximately 30.000 animals left (Jordhøy *et al.* 1997). The hunting tradition is still strong, and the annual harvest varies between 3.000 and 10.000 animals, depending on the production and population levels. Hunting is strictly regulated by the means of annual population censuses and yearly adjusted hunting quotas.

Norwegian wild reindeer do not migrate over huge distances like caribou or reindeer populations found in large arctic tundra areas, but they do have nomadic and seasonal movements at a smaller scale between winter, summer and calving areas. Reindeer also lives in herds and aggregate in relatively large groups. In evolutionary terms this herding behavior is seen as an adaptation to co-existence with large predators (Skogland 1989). Today large predators are functionally extinct from the Norwegian wild reindeer areas, and hunting is the single most important factor limiting reindeer numbers and preventing populations from overgrazing their habitat (Skogland 1985). As a result of deep snow and limited access to other forage, reindeer in southern Norway utilize lichens as their main winter forage (Kojola, Helle *et al.* 1995; Gaare 1997). Unlike green plants, lichens keep all their biomass above ground (they have no roots), and have slow recovery rates (up to 20 -30 years) following periods with high grazing pressure (Helle & Särkelä 1993; Miller 2000). Management and conservation of wild reindeer is therefore directed both at population management through harvest, aiming to keep populations at reasonable levels in relation to available pastures, and to protect remaining habitats from further developments (DN 1995; Andersen & Hustad 2005).

Wild reindeer are known to be sensitive to disturbance caused by different kinds of human activity (Wolfe *et al.* 2000; Nellemann *et al.* 2003). Even at long distances reindeer responds to skiers, hikers, snow scooters and other vehicles. In the rather flat and open mountain areas reindeer are known to have a flight distance at several hundred meters, and sometimes escapes disturbances by several kilometres (Reimers *et al*. 2000; Nellemann *et al*. 2001; Vistnes & Nellemann 2001; Reimers *et al*. 2003). Known effects of human disturbances and infrastructure on reindeer behavior and habitat use can be summarized on two different levels. First, at an individual or a direct level, corresponding to changes in behavior or physiological state of single events where animals are disturbed by human activities. Second, effects of disturbances are demonstrated at the population level, where effects are documented through loss of important migration routes and grazing habitats (Wolfe *et al.* 2000). The latter studies are more easily related to management questions (since they are documenting effects at the population or landscape level), but are less interpretable with respect to their underlying mechanisms and effects of single disturbances.

2. Methods and materials

2.1. Study area

The Hardangervidda is the largest mountain plateau in Northern Europe (app. 8200 km^2) and can still be found as a rather large green spot in maps with classified wilderness areas in Norway (Fig. 4). Hardangervidda is also the home for the largest population of the remnant European wild reindeer. A larger part of the Hardangervidda is today protected as a National park (3422 km^2), and is still used for hunting, fishing and other out-door activities.

The Hw 7 is one of several roads between the two major cities Oslo (the capital) and Bergen, on the west coast, and crosses the northern parts of Hardangervidda. The Norwegian Directorate for Nature Management (DN) has suggested closing down the part that crosses Hardangervidda, a stretch of about 40 km, during the winter months. The aim is to restore reindeer habitat use in the northern parts of Hardangervidda. Even if the road has very low traffic in the winter months (300-400 ADT), the proposal has caused a lot of protest and discussion locally. Due to the local protests, the road is still open, except during periods of winter storms. The Norwegian Public Roads Administration (NPRA) therefore had to carry out a survey in 2001, including both the biological issues and the socio-economical effects of such a drastic measure. The survey lead to the establishment of a 5-year study of the wild reindeer's use of the area in wintertime, based on the use of GPS-collars attached to reindeer, and mapping of the grazing patterns of the wild reindeer. The project was financed by the NPRA, and was carried out by the Norwegian Institute for Nature Research (NINA), starting in 2002. The project was closed in 2006, and the results presented in this paper is taken from the final report of the project (Strand *et al.* 2005).

2.2. Data collection

In order to disentangle the effects of human disturbance on the habitat use of wild reindeer at Hardangervidda, the project adopted a two fold approach, focusing on both reindeer habitat use in relation to human disturbances, and the relationship between reindeer grazing and vegetation. In addition to studies based on GPS collared reindeer and the use of habitat maps the project also collected historical data including old pit fall systems and former reindeer migration routes.

Detailed data on reindeer habitat use (from GPS collars) were used together with habitat distribution maps in a GIS based analyses of reindeer habitat selection. The rationality behind these types of studies was to generate models for reindeer habitat selection including standard parameters such as seasonality, elevation, aspect and vegetation cover. Possible effects of human activities (and the road) have been tested as single elements in the models, and their ability to explain the residual variation in the models were used in order to test the hypothesis regarding disturbance effects on reindeer habitat use.

3. Results and discussion

During the last 50 years the density of reindeer at Hardangervidda has fluctuated more than five fold. During periods with high density (in the 1960's and the early 1980's) reindeer has found new and richer grazing areas in the outskirts of Hardangervidda and in neighboring areas (Fig. 6). Available historical data thus indicate that reindeer habitat use is a dynamical process where population density and food competition are important elements. Bearing this and the rather obvious limitations of the historical data in mind, it appears that the functional use of Hardangervidda has changed from a large scale rotation between complementary habitats and calving areas, to a more restricted occupation of central areas. The northern parts of Hardangervidda, including the glacier Hardangerjøkulen, appears to be functionally separated from surrounding areas to the south by Hw 7, and by the Oslo-Bergen railroad to the north.

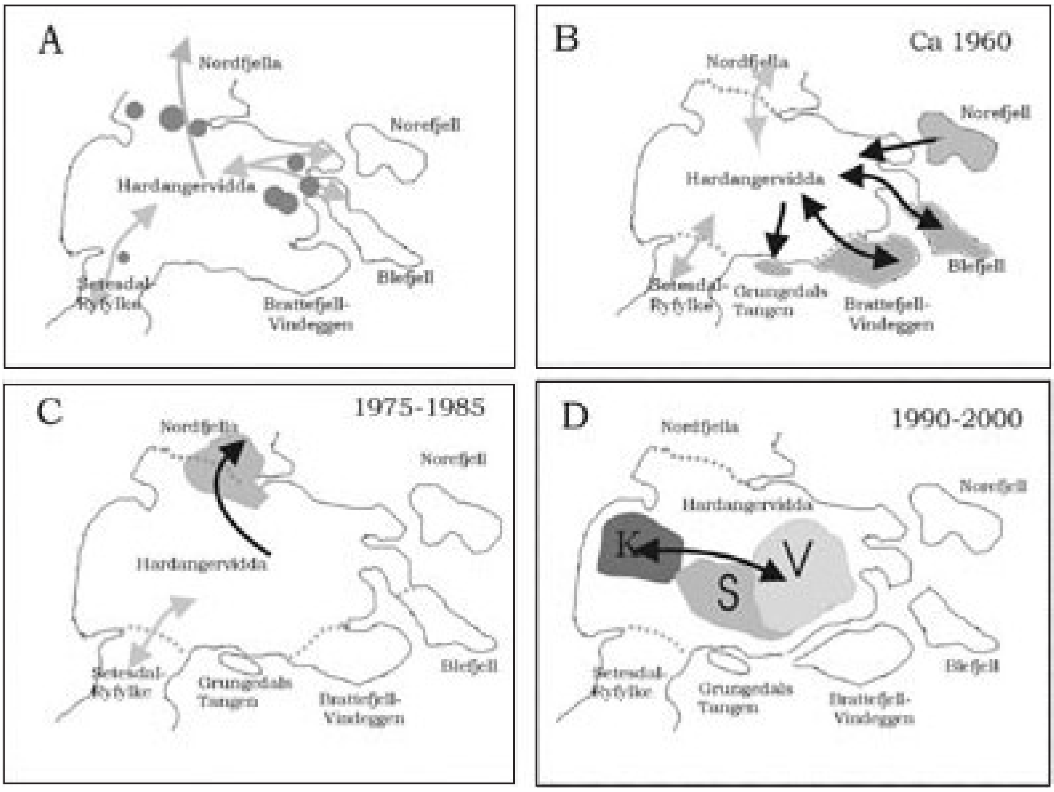

Fig. 6. The past and present use of the Hardangervidda. (K= calving areas, S= summer areas, V= winter areas)

3.1. Mapping of vegetation cover and reindeer pastures

Analyses of remotely sensed data shows that we have been able to map the vegetation cover on Hardangervidda with a reasonable accuracy for our purposes and that ca. 75% of the total satellite image are correctly classified. We had greatest success in classifying lichen heath communities where the classification accuracy is >90%. We had larger difficulties with classification of mires and snow-bed communities, however. Preliminary analyses of the data show relatively large regional differences in vegetation cover and distribution of reindeer summer and winter habitats. Areas with a large proportion of lichen heath communities, which are important to reindeer in winter, are more frequent in central and eastern regions, whereas snow-bed communities and rich summer pastures are more frequently found in southern and western areas (Fig 7). These analyses also confirm that the area north of Hw 7 contains potentially important pastures for reindeer, and that habitats close to the glacier should be regarded as potentially important areas for summer grazing.

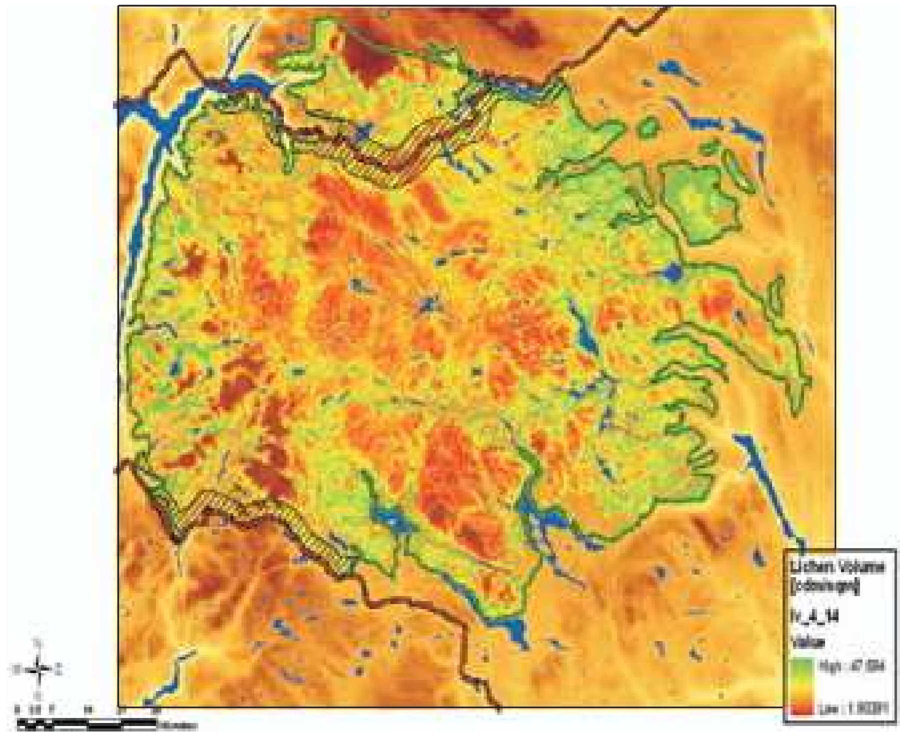

Fig. 7. Vegetation cover maps describing the spatial distribution of important habitats. Areas with a large proportion of lichen heath communities, which are important to reindeer in winter, are more frequent in central and eastern regions, whereas snow-bed communities (summer grazing) are more frequently found in southern and western areas

Our studies at Hardangervidda have documented rather pronounced and large scale regional differences in lichen biomass, suggesting a substantial increase in reindeer grazing pressure in central and undisturbed areas. Similar results was obtained in areas close to the road, and increasing levels of lichen biomass was observed in areas closer to the road (5-8 km), suggesting that there have been less reindeer grazing in these areas (Fig 8). The reduced biomass of lichens in remote areas further suggest that grazing has suppressed lichen biomass well below optimal levels in these areas, whereas lichens in the outskirts of the area probably has reached their un-grazed maximum biomass.

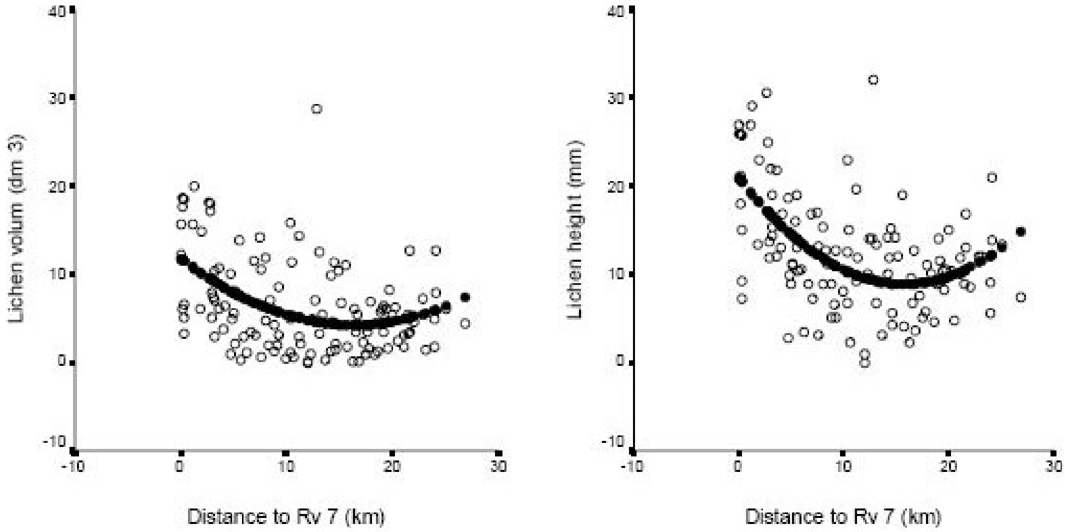

Fig. 8. Measurements of lichen height and volume indicate an increase in reindeer grazing pressure at greater distances (5-8 km) from the road

3.2. Using the Global Positioning System (GPS)

To be able to collect more detailed data of the movement of the wild reindeer, we initiated a GPS project, starting with 6 GPS transmitters in 2001, and adding 10 more in 2002 (Fig. 9).

Fig. 9. Wild reindeer with GPS-collar. (Photo: Bjørn Iuell)

The GPS collars were programmed to register the location of each animal every 3rd hour. The collar also sent out a VHF signal, so the animal could be tracked. The GPS system used on Hardangervidda also allows remote download of data, and was used to collect a data samples at the start of the project. Due to high field costs we later abandoned this routine, and in stead downloaded data when collars were retrieved from hunters or by removing collars by a remotely triggered 'drop-of' mechanism mounted on the collar.

Although we experienced some technical problems with some of the GPS collars most of them were working as scheduled. Late autumn 2004 we discovered that one out of a group of five similar collars had serious malfunctions. It was likely that all five collars had the same problems, and therefore 10 new reindeer were collared to collect the amount of data we needed. At the most we have had more than 20 GPS-collared reindeer females on Hardangervidda. During the project we have been able to collect data from 37 animals and altogether more than 100.000 data points with an average accuracy within 25 m.

Analyzes of the GPS data indicate that the collared animals had a rather uneven distribution, and that the central areas have been extensively used (Fig. 10). This effect seems to be especially strong in summertime (June, July and August) when animals have used less than 20% of the available area. During winter, reindeer seem to be more dispersed, and applications of Resource-Selection Function (RSF) models have confirmed a strong selection for lichen heath communities.

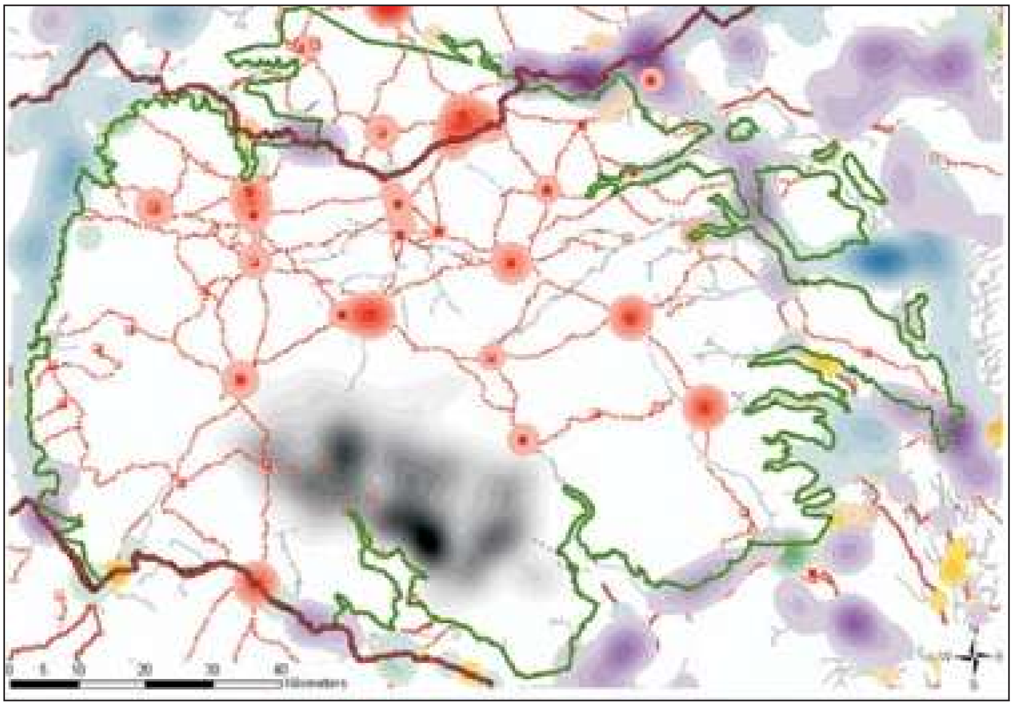

Fig. 10. Plots of the GPS-registrations of wild reindeer during mid-summer (June-August) show that the animals use a relatively limited part of the Hardangervidda. Dark color indicates high density of registrations. Green line: The boundary of the Hardangervidda reindeer area. Dark red line: Hw 7 in the north and E 134 in the south. Light red lines: main hiking tracks between mountain cottages (red circles, size of circle indicates number of beds). Blue and violet signature indicates areas of respectively all-year residences and holiday houses/tourist resorts.

Detailed studies of the GPS plots close to Hw 7 show a pattern of movement than can be described as the result of fear or avoidance (Fig. 11).

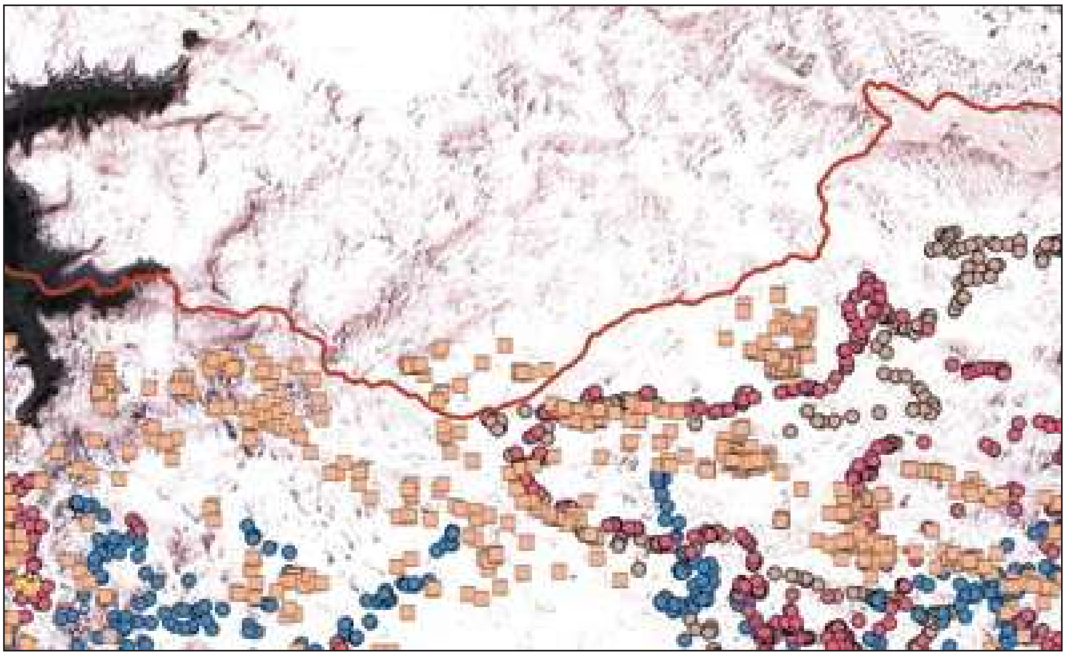

Fig. 11. Movements of wild reindeer according to GPS-registration of 4 different animals close to Hw7 (red line)

4. Conclusions

Maps of the distribution of different reindeer food resources (e.g. lichens) were produced by using field surveys and satellite images (LANDSAT 5). These estimates uncover significant gradients with respect to vegetation distribution and quality within the research area. For instance, winter pastures dominate in the eastern parts, while there is less winter vegetation in the southwest and larger areas of summer pastures. With regard to areas close to Hw7 in particular, mapping reveals that the areas around the Hardangerjøkulen glacier are particularly rich in snow beds, and therefore represents an important summer pasture resource. Along and south of Hw7, larger areas of winter pastures are located. Areas with possible impact from Hw7 therefore also include pastures important for the reindeer during the winter. The areas north of Hw7 are primarily summer pasture, however, it should be stressed that these areas also serve a function as travel routes for the reindeer, and 'relief' pastures during years where the snow conditions makes it difficult to find food.

The area use pattern found through the GPS-registrations, reveals that it is possible to subdivide the use of Hardangervidda into 12 different 'seasons', with differences in migration pattern and habitat use (Fig. 12). In interpreting these results, the calving, summer and winter seasons are particularly focused on. Analyses of the data indicate that predation and/or insect harassment, vegetation distribution, snow cover and access to pastures are all important factors in understanding the semi-nomadic use of the living areas of the wild reindeer.

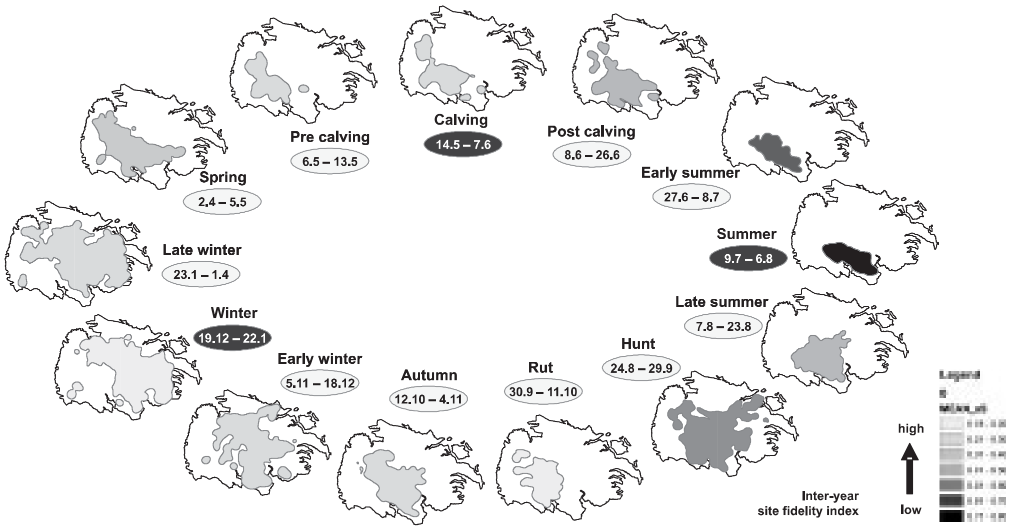

Fig. 12. The wild reindeer's use of Hardangervidda subdivided into 12 different 'seasons', with differences in migration pattern and habitat use. The darker the colour, the more is the same area used from year to year

During the summer the reindeer herds at Hardangervidda use a rather small part of the mountain plateau, and the data from this project indicate that the animals are using the same area over several years.

The use of the *calving grounds* is more variable between years; during the last few years calving has taken place in the southern and central areas while earlier it mainly took place in the western and north-western parts of the plateau.

The animals use the winter pastures more extensively, and they are using a significantly larger area compared to the summer situation. Possibly due to local snow cover and food access, the use of the winter pastures has a significant, inter-annual variation as well. During year one of the project the snow cover was quite insignificant in the western and northern parts, and during the period 2001-2003, these areas were frequently in use by the animals. During the last years of the project the snow cover was more 'normal', i.e. more snow in the west compared to the east, and the animals did to a greater extent use the eastern parts. GPS-registrations and snow cover maps indicate that the snow depth is an important factor in explaining how the reindeer use their winter habitat. It is quite evident that the animals, even at a low population density (5 000-6 000 animals), expand their pasture areas during periods with difficult snow conditions.

The GPS-data show that most of the reindeer population is using a rather small area in the central south of Hardangervidda during mid-summer, but also that even if they are not moving very far, their activity is high (Fig. 13). In the winter months the situation is quite the opposite; the activity is lower than in the summer, but the animals are still moving over long distances.

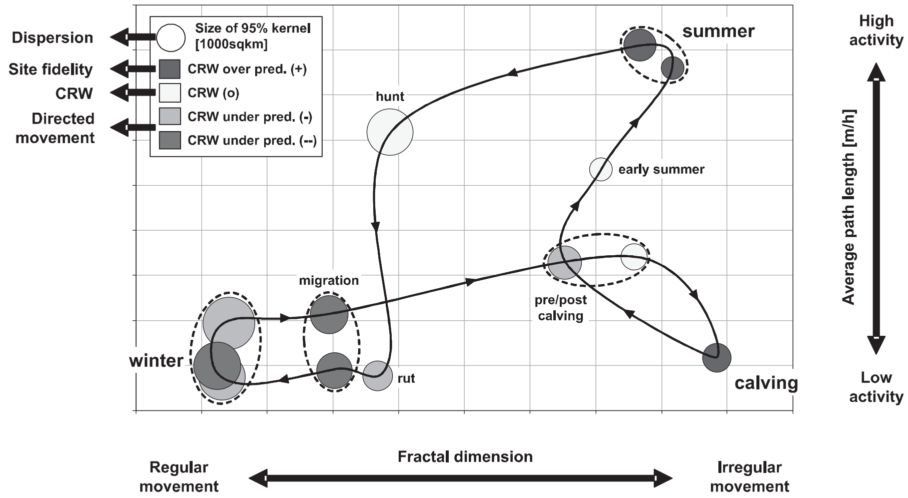

Fig. 13. Illustration of the activity levels and the movements of the wild reindeer throughout the 'reindeer-year' at Hardangervidda

The major findings of the project were that Hw 7 in fact has a repelling effect on the wild reindeer, as have other areas with human activity, e.g. the major hiking and skiing tracks between the tourist cottages. The GPS-data show that there is a significant reduction of the reindeer use of the areas close to the Hw 7, up to 8 km from the road (Figs. 14 and 15A). This zone of avoidance also strengthens the barrier effect of the road, leaving the migration routes to and from the north more or less cut off.

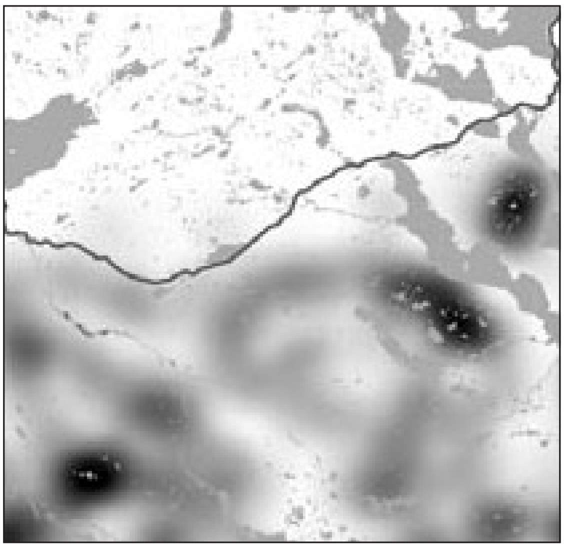

Fig. 14. Plots of the GPS-registrations of wild reindeer in the vicinity of Hw 7 (thick line). Dark color indicates high density of registrations

The same effect can be found by analysing the vegetation maps (Fig. 15B), but the correlation is not as strong as in the GPS-data. When the GPS-data were compared with the distribution of lichen resources, it appeared that animals do not use areas richest in lichens.

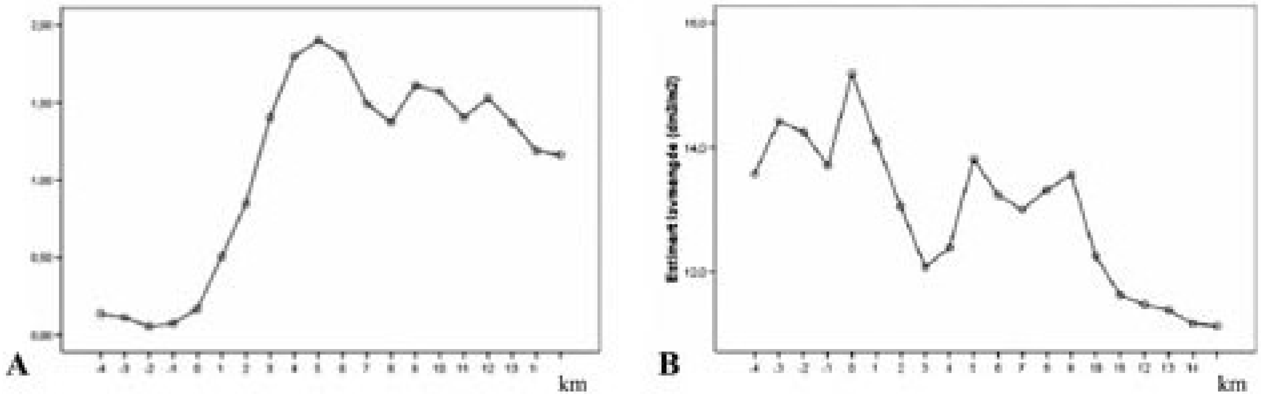

Fig. 15. A – Density of reindeer (GPS-registrations) and the distance to Hw 7 (km); B – Amount of lichens (dm^3/m^2) and the distance to Hw 7 (km).

Hw 7 can be seen as a behavioral barrier, hindering the migration of reindeer between the central and the northern parts of Hardangervidda.However, it is possible to see considerable local variation in this pattern. Among other things, topography seems to be important both for reindeer use of the area and lichen biomass on the ground. This is particularly evident for two areas where the animals approach the road much more closely compared to other areas. Archaeological remains of large trapping systems suggest that these areas coincide with migration routes traditionally used by this nomadic species. The GPS data from the project indicate that these routes are still of potential importance for migrating purposes.

Habitat-use analyses indicate that it is particularly during the winter period that the highway constitutes a problem for the wild reindeer. During this 5 year project reindeer with GPS-radio collars have been observed to cross Hw7 at only two occasions. One herd crossed the Hw7 early 2003, just to return a few days later. In recent years, summer use of areas proximate to Hw7 (and the areas close to the Hardangerjøkulen glacier) has been limited to summer pasturing by bucks.

The wild reindeer's use of the terrain is dependent on the population density and the available food resources. The possibility for the animals to have access to winter grazing grounds in the northern and eastern parts in years with much snow, can be crucial. During the period when this project took place, the reindeer population was relatively small (5.000 – 6.000 animals), but still the animals have used areas in the periphery. The management goal for the reindeer population at Hardangervidda is set to 10.000 – 12.000 animals. And as the population density increases, the winter grazing areas at the outskirts of the mountain plateau will become more and more important. How the reindeer then will react on barriers like Hw 7 is hard to predict, and further research is therefore needed.

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Dealing with bats: monitoring of the mitigation process and the effectiveness

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Abstract. The article draws the attention to the significance of monitoring for effectiveness of mitigating means used in case of natural habitats fragmentation caused by transport infrastructure. A problem was illustrated on the example of activities taken in Holland in connection with the construction of road N296 and N297, which threatened, among others, populations of 3 species of bats.

Key words: road, bats, mitigation, compensation, ecoduct, ecombiduct, monitoring, Netherlands

Since the seventies the Netherlands has taken several measures to counteract the fragmentation of habitats. In spite of the strict protection of bats (EU Habitat Directive) there has been only recently some serious attention for the effectiveness of infrastructure on bats. In the Province of Limburg some new infrastructural projects among them the building of the N296 and N297 (Fig. 1), are the first projects in the Netherlands in which mitigation and compensation measures for bats are implemented on a large and innovative scale.

The first step in the process of protection measures was a field research. This field research showed that in case of the N296 and the N297 the Daubenton's bat (*Myotis daubentoni*), the Common pipistrelle (*Pipistrellus pipistrellus*) and the Serotine (*Eptesicus serotinus*) use the habitat within the sphere of influence of these (new) roads (Figs. 2 and 3).

After the analyses of the flyways and hunting ways (there were no maternity places), the mitigation and compensation measures were determined.

Because of the construction of both roads, trees had to be cut, through which forage area of bats disappeared and flyways of bats were interrupted (Fig. 4). In the new situation flyways are being restored with the planting of trees. On the roads that lose their function after finishing the N296, the asphalt will be removed and trees will replace the asphalt (Fig. 5). As a result the living area of the bats will increase with about 12,000 m^2 after the road is realized.

With the project N297 a tree zone of 2.5 ha was planted as a compensation of the lost of ca. 4300m2 hunting/forage area. With the construction of the N297, a bridge was heightened in a way that flyways of Daubenton's bat will not be disturbed. On a other interrupted flyway trees of 6 metre high were planted to restore this flyway. An exceptional mitigation measure which is implemented is the construction of a so-called ecombiduct (Fig. 6). This ecombiduct is situated on a former flyway of bats which is interrupted by the new road (Fig. 7).

The ecombiduct is in fact a combination of a (in this case small) ecoduct and a badger tunnel (ø 40 centimetre). It's dimensions are 3 metres width and it reaches 42 metres. On this ecombiduct a 2.5 metres high hedgerow will be planted especially for the bats to restore the flyway. These hedges can also be used by other species like birds and insects as habitat and as orientation. The ecombiduct will also be useful for other wildlife, such as amphibians, reptiles and small mammals.

Also unique for this concept is the tunnel in the surface of the crossover. In this way animals have the choice to cross the road safely through the tunnel or over the ecombiduct. The tunnel can be very useful especially for animals that fear the traffic lights and the traffic noise. Two big pools on both sides of the ecombiduct have been realized intended to stimulate the use of the passage and to attract bats such as Daubenton's bat which hunt for the insects on and above the water.

The last step in the process is the monitoring. This monitoring already started during the constructing of the road. The results validated the forecasting that the flyways and huntingways of the bats were affected. Monitoring proves also the evidence of flyways and underlines the necessary of a license. Another advantage of monitoring during the construction phase is the possibility of fine-tuning of the recommendations of the researcher with the contractor. In this way ad hoc measures are possible. In this case for example the lighting of the construction site was adapted in a way that bats were not impeded by the light during their hunting.

Meanwhile some other new infrastructural projects have been prepared. The acquired experience with the N296 and N297 has now been applied in these projects and in some cases optimized. For example a new kind of street light has been introduced, because it has been proved that the standard street lights affect some bats. This new lamp limits the dispersing of light. At the same time these new kind of street lights supports the policy of reducing the light nuisance.

This year and next years the monitoring program will be continued to find out whether the mitigation measures for the bats and the other animals will be successful and were implemented in a correct way. The first results are anyway encouraging. At this moment foxes, stoats, mice, rabbits use the ecombiduct already and the pools have already attracted some Daubenton's bats. Also some Noctules (*Nyctalus noctula*) were located, a bat specie which was never found before in this area. After the hedgerow will be planted on the ecombiduct, the monitoring will focus on this section to verify if the former flyway of bats will be restored.

Monitoring appears to be an indispensable instrument to verify the function of compensation and mitigation measures. It can contribute to an optimization of the function and so in some cases to adaptations of these measures. In this way it can justify the choice of compensation and mitigation measures such as fauna passages. Last but not least it's therefore also important to communicate the results to insiders (scientists, officials and politicians) and to the people living in the neighbourhood.

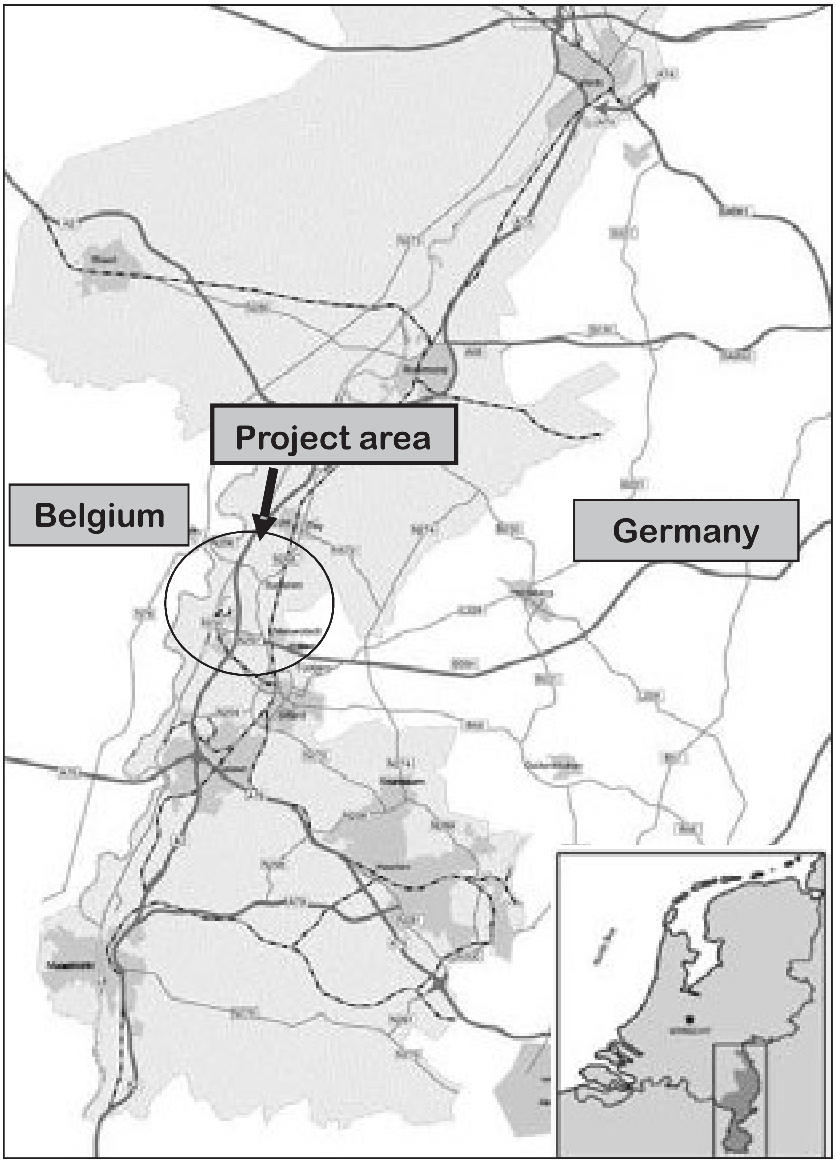

Fig. 1. Project area of the roads N296 and N297

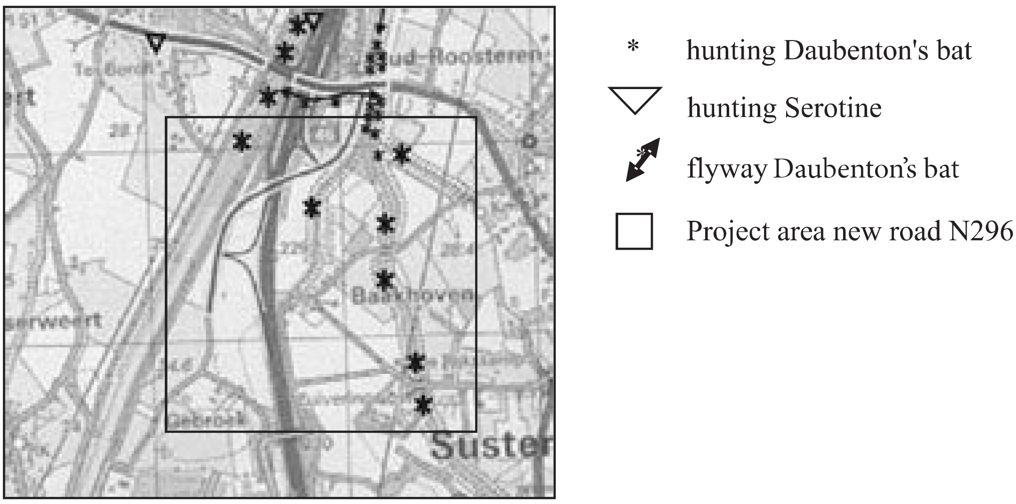

Fig. 2. One of the results of the field research in case of the N296

Fig. 3. Impression of the habitat and the flyway of bats near the planned N296

Fig. 4. Cutting of trees

Fig. 5. Planting on roads which lose their functions

Fig. 6. The ecombiduct is a combination of a (in this case small) ecoduct and a badger tunnel

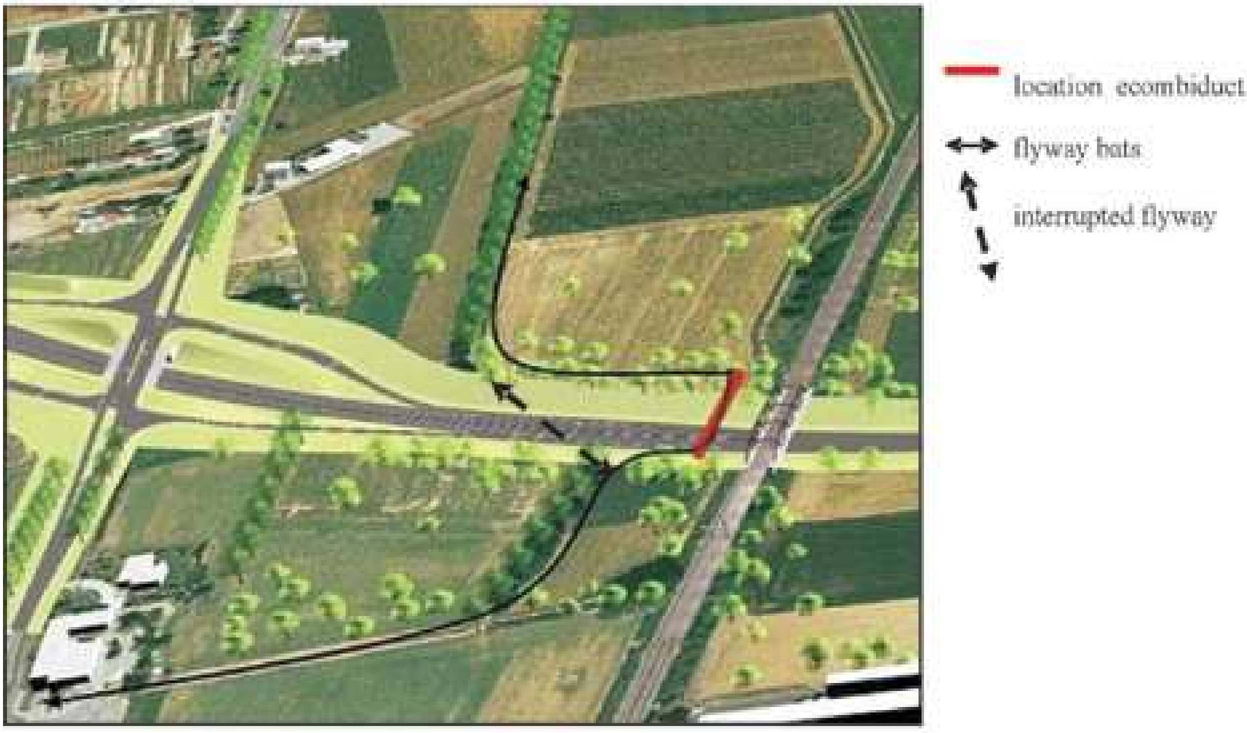

Fig. 7. The ecombiduct is situated on a former flyway of bats which is interrupted by the new road

Mitigation measures in Germany

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Abstract. Germany has made much effort to mitigate habitat fragmentation caused by transportation infrastructure. Examples are wildlife underpasses, overpasses, river crossings and tunnels at road and railway systems. More than 50 overpasses have been built during the last 20 years. Most of them mitigate fragmentation effects of new roads or highways, respectively. River passes have been upgraded with top soil and vegetation to connect biotopes. In order to prove the invested efforts, three large and several minor investigation projects have been carried out. The main results found their way into a German guideline: Construction of Fauna Passages at roads. It outlines not only the demands of red deer, roe deer, wild boar, badger, European otter and other animals with large and small habitats. But it distinguishes between passes for single species and those to connect habitats with all their inventory.

Key words: road infrastructure, mitigation measures, green bridge, underpasse, viaduct, Germany, handbook

In the process of road planning and construction an Environmental Impact Assessment [EIA] is necessary. Sequence of works for an Environmental Impact Study for a road construction project:

- Delimitation of survey area based on project and landscape/physiographic parameters
- Survey, description and assessment of the protected resources
- Depiction of area with different conflict densities with regard to protected resources
- Planning of route variants with reference to the areas where relatively few conflicts arise
- Determination and assessment of the impacts arising, and comparison of variants with reference to the individual protected resources
- Summary of the results and professional recommendations.

The EIA shows the main conflicts between the project and natural environment. Based on it an *Landscape conservation implementation plan* is worked out. This includes mitigation measures which are necessary to connect biotopes and individuals of affected animal populations.

There are different kinds of mitigation measures:

- 2 types of Green Bridges
  - Green Bridges for biotopes/landscape
  - Green Bridges or fauna overpasses for target species
- Large and high viaducts across deep valleys
- Green underpasses
- Ecological upgraded river crossings
- Underpasses for large and medium-sized animals
- Underpasses for small animals (incl. amphibians).

There is an uncounted number of underpasses for amphibians and other small animals in Germany. I estimate the number at several hundreds. They are wide-spread throughout the country.

Most of them are located at country- and district-roads, but on federal roads as well. This type was object of the first guideline about animal passes in the 1980ies, which was updated in 2000 (MAmS 2000 – Merkblatt für den Amphibienschutz an Straßen). This guideline says a lot about where and how to help Amphibians in the neighbourhood of roads, and determines exact dimensions for crossing tunnels in relation to their lengths. As well, lengths, height and quality of fences is determined. Last investigation projects pointed out, that only a minor number of animals heading to such a tunnel, is actual crossing it. Presently an investigation project tries to find out, why this is the case. In a presumption it might be the quality of the tunnels ground. We now test its acidity, humidity and microclimate conditions, which might contribute to a drying process of the crossing individuals.

There is evidence that other small animals like mice, snails, bugs etc. and even squirrels make use of these tunnels, but the pleasant effects on their populations have not been studied yet.

For all larger types of passages a new handbook has been written. It is called "Merkblatt zur Anlage von Querungshilfen für Tiere an Straßen" [Guideline for the construction of fauna passages at roads]. Its main characteristic is the differentiation whether a whole biotope or just a special target species gets help to overcome the road. It contains tables for dimensions of underpasses, river crossings and overpasses dependent on the structure of the biotope or the species, respectively (see for example table 1).

Table 1. A sample fragment of the handbook of „*Merkblatt zur Anlage von Querungshilfen für Tiere an Straßen*"

Minimum dimensions for a frame culvert (rectangular outline)	
length in meters	inside width and height in mm
< 20	1000/750
< 30	1500/1000
< 40	1750/1250
< 50	2000/1500
Minimum dimensions for a pipe culvert (circular outline)	
length in meters	width of bore in mm
< 20	1000
< 30	1400
< 40	1600
< 50	2000

Underpasses constructed just for Deers, wild boars and similar species don't need vegetation, but sandy ground, black coloured bottoms of walls and heavy stones at the entrances to avoid abuse by off-road vehicles. The need of sound-absorbing materials is plausible, but not yet proved. The number of this type of underpasses have not yet been counted. To make a rough estimate, it may be about 100.

For the purpose of getting more species underneath the road, especially those ones that need shelter by structure or vegetation, a wider type of underpass is necessary. If this one is not located at a valley and its purpose is just to connect biotopes, we call it "Green Underpass". It is of distinct height and wideness to allow growth of vegetation. The first one of this new type of underpass for habitats is constructed in Rheinland-Pfalz, western part of Germany.

Rather than achieving acceptance for Green Underpasses it is much easier to open river crossings not only for the highest water level, but for biological purposes as well. Based on a research project about these buildings, we determined the opening of at least 10 m plus waterbody in the case of runnels or creeks, and banks of at least 2½ times of the water body at each bank in case of rivers. This is for better growth of vegetation. The investigation showed the necessity of vegetation for smaller animals. In 2002 we started an inquiry in how many cases river crossings have been upgraded for ecological purposes. We got a large number of announcements and were very happy about progressiveness of the German road administration. But by proving those announcements we considered most of them as conventional river crossings, without any ecological attributes. This pointed out the shortfalls in understanding about what makes a crossing usable for animals. In particular, water is needed under the building and has to be supplied by various devices.

Large viaducts, especially if more than 15 m in height, give good conditions for the connection of biotopes. Top soil is needed to allow vegetation. Water from rainfalls and light are assumed to be sufficient. Sensitive areas have to be protected during construction for not being destroyed by construction site equipment. In many cases the vegetation of the valley can be continued under the building. Animals do not even notice that they are crossing an obstacle which they can't overcome at other places.

Green bridges are the best solutions for the connection of biotopes. As they are overpasses, microclimate conditions do not change as they do in case of underpasses. With them, nearly all aspects of the habitats beside the road can be connected. These are namely vegetation, i.e. soil, plant species and structure. With this, we hope to have the building equipped for the demands of the animal species which live in the fragmented biotopes. These are not only Wild Boars and Red Deers, but all the smaller species as well which live on or within the soil or the vegetation. These are species like mice, bugs, butterflies, birds or even bats.

We differentiate between green bridges built to connect the whole equipment of the fragmented biotopes and those bridges which work as wildlife overpasses for selected species. The former are at least 50 m wide, but should have a width of 130 m for natural or semi-natural old-growth forests. The width of the latter bridges might be only 30 m, which is sufficient for species like hare, wild boar and deer. Compared with underpasses for these species the "extra width" serves as shelter from the traffic.

In 2002, an inquiry showed that in Germany 36 Green Bridges were constructed, 8 were in construction and other 33 were planned. Without a new, current inquiry we can estimate, that there are at least 50, even more, constructed Green Bridges in Germany. I do not know any other country in the world that have a similar number. Most of these bridges are built in connection of the expansion of the road networks due to the openings and connections to eastern countries during the last decade.

Much has been done in construction and research, but many more is to do in future. A first conference focussing traffic routes and German habitat corridor network was held in March 2006 in Hannover. For connection of countries we do not only need connecting technical structures, but nature structures as well. The tasks are clear: avoidance of new barriers and removal of the old once.

Mitigation measures to reduce the effects of fragmentation of the natural habitats deriving from the infrastructure development

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Abstract. Referring to the current infrastructures modernization Italian programme, it appears necessary to write up norms to integrate the last addresses of UE relatively to the biodiversity conservation with the transport development and the infrastructures implementation policy.

Within a specific APAT initiative, the "Ecological Network and Territorial Defragmentation" work group has been engaged coordinating Public Administrations as the Environmental Protection Agencies System, the Ministry of Transport, the Ministry of Cultural Activities, "La Sapienza" University of Rome, Perugia University, the Italian Agency for the Ecology of the Landscape, companies dealing with the infrastructure networks, and NGO as WWF and LIPU.

The main project of such a multidisciplinary work group is to produce "Guidelines for the sustainable planning of mitigation interventions to reduce the effects of the natural habitats fragmentation due to the linear infrastructures".

Particular attention will be given to the management of ecological and functional hotspots connections as elements of the ecological network.

From the analysis of the collected data and from the study of the eventual critical points evidenced, the work group will define new criteria and lines of address in order to suggest to the planners and to the administrators methodologies and techniques to plan sustainable mitigation interventions in the respect of the Habitats Directive.

Key words: ecological network, transport infrastructure, habitat fragmentation, guidelines for the sustainable planning, mitigation measures

1. State of the arts

The Italian Agency for Environmental Protection and Technical Services is involved in nationwide technical and scientific efforts for protection of the environment and the water supply. It operates under the political jurisdiction of the Ministry of the Enviroment and offers counselling services to other government departments.

Within the agency, the Nature Preservation Department focuses on the protection of nature, biodiversity and ecological networks; the measurement of the environmental impact of human activities on species and ecosystems; and landscape restoration.

At present, the Department is studying the relationship between linear infrastructure and habitat fragmentation. These activities are aimed at producing projects to preserve habitat and biodiversity and the promotion of safer and more fauna-consistent infrastructures.

As a matter of fact, the loss of biodiversity due to the rising volume of transporation represents a serious problem for our planet today.

Animals being killed on roads by cars, and the pressure of the infrastructures over habitat and biodiversity (housing, farming, heavy industry, light, sound and atmosphere pollution) are such many species are at risk of extinction.

An helpful contribution to this situation is provided by the planning of ecological networks together with infrastructure networks, so that the industrial building activities, meet the need to maintain the "connectivity" which is one of the first ecological values according to the Habitats Directive.

The concept of making the infrastructural, meet the ecological needs is not yet popular enough in Italy, despite the 'General Plan of Transport', approved in 2001, has fixed some basic enviromental quality targets involving the infrastructural network, the national ecological network and landscape. This latter aspect became more important as a consequence of the recent approvation of the European Landscape Convention by Italy.

The 'permeability' of infrastructures for fauna represents one of the important issues to be considered when infrastructures are planned. Another important issue is the negative impact of altering the bio-geochemical fluxes.

The guidelines issued by 'Road Ecology' stress an integrated approach wherein all environmental problems are considered simultaneously in the design process. Furthermore, the design process must allow for developments that arise and discoveries that are made during the initial inspection of a new contstruction site.

Modern improvements of rural lands, as well as cities, requires a high level of committment from everyone in the design process. When the interests of diverse stakeholders cannot be politically unified, conflict will arise as we recently witnessed in Italy.

Thus, an important component of progress in our kind of environmental management will be the development of methods for identifying and unifying all stakeholders for a given project.

Indeed, at present, our agency is preparing a report that will provide these kinds of comprehensive guidelines for eco-compatible planning and design of linear infrastructures including both road systems and electric power distribution systems.

With the intention of gathering the best planning experiences where safety, technical skills, eco-compatibility and respect for the landscape are concerned, APAT has involved several Institution such as the Ministry of Transport, the Ministry of Cultural Activities, "La Sapienza" University of Rome, Perugia University, the Italian Agency for the Ecology of the Landscape, companies dealing with the infrastructure networks, and ONG WWF and LIPU.

The purpose of the document is to promote correct planning and monitoring methods for the mitigation of habitat fragmentation and other impacts on fauna for all who are involved in the planning, design and administration of the environment.

These guidelines, which are now being completed, have been devised to "find a solution" to two basic issues: the correct placement of infrastructures in the enviroment and the best techniques for making roads "permeable" to biodiversity.

As to the planning of large areas, some methods (based upon the Geographic Information System) will be available to understand the fauna permeability at this scale and to find solutions that are less damaging to the ecosystem connectivity.

The fragmentation of habitat signals represent in helpful to monitor the present trend and to understand the future one as far as the planning of the ecological network, and more specifically the design of linear infrastructures, are concerned.

Planning huge infrastructures demands instruments that give synthetic information about a wide range of aspects.

The second part of the document focuses on smaller scale planning and It shows ways to control the enviroment and the basic techniques of defragmentation consistent with fauna.

Data is organized in synthetic reports. Each report covers a specific design target: road barriers, underpasses and overpasses, warning signs and the likes.

2. Publications of the Italian System of Enviromental Agencies relative to the infrastructures, ecosystems and fauna, and ecological networks

- Criticità ambientali e paesistiche indotte dalle linee elettriche - Metodologia di analisi
  ARPA Piemonte. S. Tosatto, P. Debernardi
  http://www.arpa.piemonte.it/index.php?module=ContentExpress&func=display&btitle=E&mid=-1&ceid=662
- Fauna selvatica ed infrastrutture lineari
  ARPA Piemonte. E. Fila-Mauro, A. Maffiotti, L. Pompilio, E. Rivella, D. Vietti - 2005
  http://www.arpa.piemonte.it/index.php?module=ContentExpress&func=display&btitle=CE&mid=-1&ceid=609
- Gestione delle aree di collegamento ecologico funzionale
  APAT/INU - Manuali e linee guida 26/2003
  http://www.apat.gov.it/site/it- IT/APAT/Pubblicazioni/Manuali_e_linee_guida/Documento/manuali_lineeguida_2003_26.html
- Fasce verdi polifunzionali delle autostrade una proposta multicriteriale per la realizzazione di interventi di mitigazione - ARPA Piemonte. P. Debernardi, L. Graziano - 2002.
  http://www.arpa.piemonte.it/index.php?module=ContentExpress&func=display&btitle=CE&mid=&ceid=292

Assessment of the impact of the modernization of railway lines on the Natura 2000 network – the Polish experience

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Abstract. This work presents the most important conclusions from the assessment of a modernized railways impact on the Nature 2000 areas in Poland. The studies were conducted in 2005, in 8 sectors with a total length of ca 850 km, in several regions of the country. As a result, 10 direct impact effects of modernized railway lines on natural environment and a number of distant, indirect and accumulative influences were identified. At least some of the negative environmental effects could be minimized by employing the mitigating means proposed in the work.

Key words: railway lines, modernization, Natura 2000 network, accumulated influence, mitigation measures

1. Introduction

In 2005, we conducted for PKP Polskie Linie Kolejowe S.A. an evaluation of the impact of the modernization of the railway lines E-65 from Warszawa to Gdynia, E-59 from Wrocław to Poznań, the Warszawa-Łódź line, E-20 from Siedlce to Terespol, E-20 Poznański Junction, E-30 from Węgliniec to Zgorzelec, from Węgliniec to Bielawa Dolna, and E-30 from Węgliniec to Legnica on Nature 2000 territory (Fig. 1). The analysis covered altogether about 850 km of the modernized railway lines. This article presents experience from the conducted evaluation.

2. Aspects of the impact of railway line modernisation requiring consideration in the context of their impact on the objects protected by Nature 2000

Analysing the potential impact of the planned undertaking on the condition of the components of the natural environment, considering the possible kinds of impact on the protection targets (species and natural habitats) in Nature 2000 areas, involves analysing all the possible interactions between the undertaking and the Nature 2000 network's protection targets. Such interactions may arise at the stage of construction, exploitation, or liquidation.

Below, there is a characteristic of most important, recognized influences.

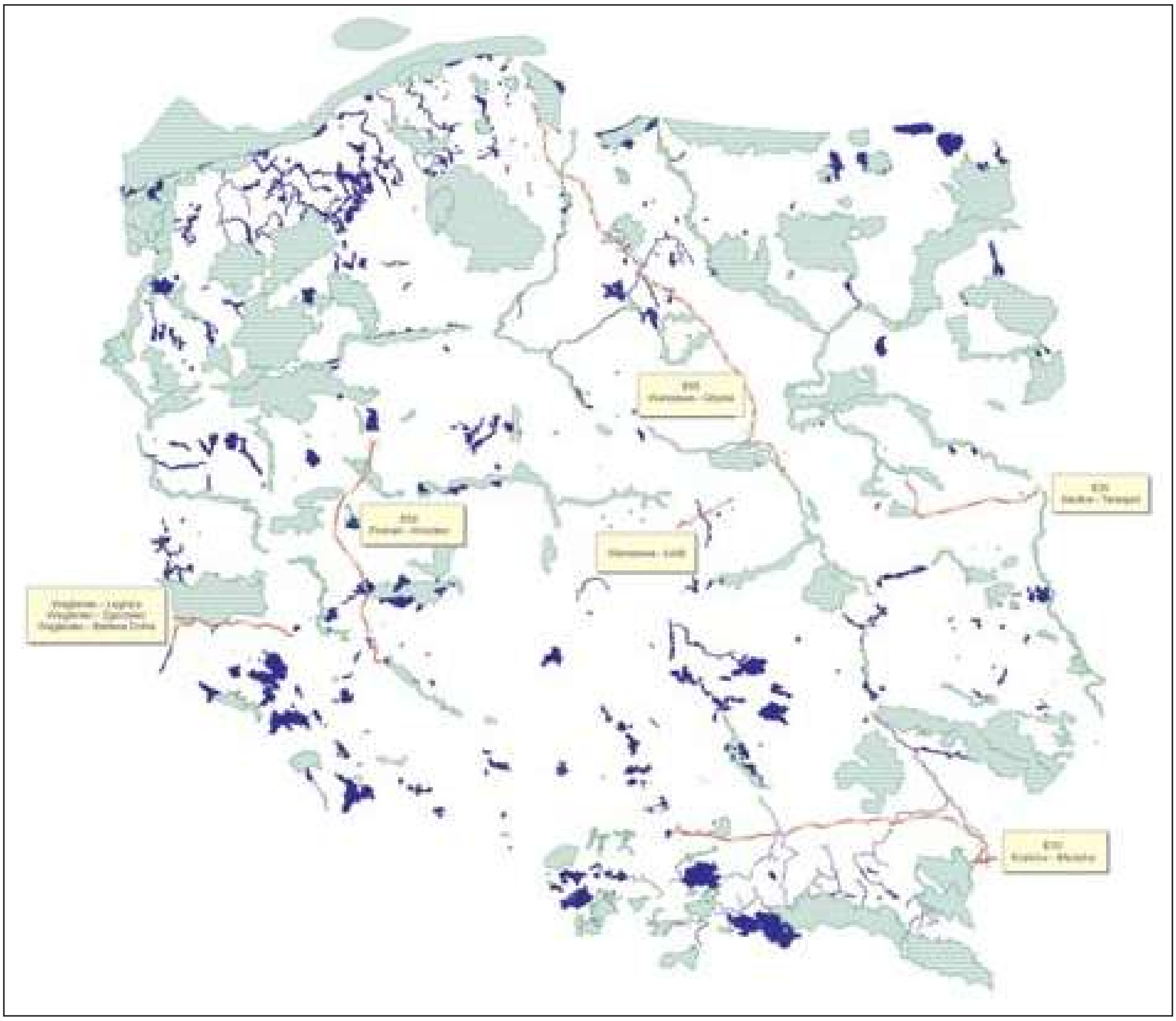

Fig. 1. Modernised railway lines in the context of the Nature 2000 network

2.1. Land occupation

The permament occupation of land is connected with local adjustments of the geometry of railway tracks, particularly the correction of curves, and with building of access roads due to the planned closing-down of the railway crossings as well as organisation of a construction site, including a storage area. Temporary occupation of land is connected with the excavation for fibre optic cable construction. If land occupation concerned natural habitats or habitats of species listed in the Appendices to the Habitats Directive or the Bird Directive, it would cause irreversible devastation of the relevant fragment of the habitat, which requires evaluating whether this impact is important at the scale of the Nature 2000 area.

In the case of modernisation of existing railway lines, the scale of permanent occupation of land was usually insignificant; however, it may be a significant problem if the line is adjacent to small but very valuable patches of natural habitats or if the sites of the protected species are present on the existing embankment or in the close vicinity of the line (on the embankment one might find, for example, Pasque flower (*Pulsatilla patens*); in the immediate vicinity of the line there were small water reservoirs important for the Great Crested Newt (*Triturus cristatus*) and the Fire-bellied toad (*Bombina bombina*).

A major problem was the temporary occupation of land due to construction works; e.g. for storing materials, stock of machines, etc. Most often they are located in "unusable" areas which in fact can be precious natural habitats (sandy swards, valuable meadows). In the current tradition of evaluating impact on the environment, such impact was treated as temporary; however, from the point of view of Natura 2000, a habitat once destroyed cannot be quickly restored. Despite the temporary character of the impact, its effects are long term.

The problem of this effect usually can be solved by designing the line appropriately and first of all by planning the construction works appropriately (saving patches of precious habitats and species).

2.2. Cutting trees or shrubs

Such logging may have an impact on Natura 2000 protection targets if it involves trees which are habitats for insects listed in Appendix II to the Habitat Directive (e.g. oaks being habitat to the Longicorn Beetle (*Cerambyx cerdo*) or the Hermit Beetle (*Osmoderma eremita*) as well as trees or shrubs which are essential elements of the structure of birds biotop, e.g. blackthorn thickets in places of occurrence of a Red-backed Shrike (*Lanius collurio*) and the like.

In the case of modernization of the existing railway lines, the impact scale was usually relatively insignificant, but major conflict situations were encountered locally, e.g. blackthorn shrubs on the slope of an embankment destined for modernization, being an important biotope for birds; and clusters of maple (*Acer campestre*) near the line, species from a regional Red List. Usually cutting down bushes and trees could not be avoided, but this particular kind of impact can be compensated for relatively easily by planting new shrubs of appropriate species.

2.3. Noise and disturbance connected with construction works and exploitation of the line

Noise resulting from the construction of the line as well as the disturbance introduced by the permanent presence of human beings may impact the behaviour of animals listed in the Appendices to the Habitat Directive or the Bird Directive, especially of mammals and birds. In the case of some birds, this may cause relocation of breeding places and avoidance of the close neighbourhood of the line. When it comes to mammals, the line might function more strongly as an ecological barrier during construction. The impact is proportional to the intensity and duration of the construction works.

Although difficult to measure, the noise-impact was one of the most significant and important problems. What is more, it is very difficult to mitigate it effectively. This is because the stress factor for animals is not the measurable noise level (which can be reduced) but rather the very presence of human beings and the frequency of disturbing stimuli (which cannot be excluded if construction works are to be carried out). A particularly important problem arose when the modernized line cuts across refuge sites of strongly antropophobous species (wood grouse, black grouse, black stork).

The noise connected with train traffic is surprisingly a far lesser problem for functioning of natural systems than one might think. It is a repeated factor that animals are able to get used to. Moreover, modernization of a line usually results in its ‘silencing’, although increase of train traffic frequency is assumed.

2.4. Impact on surface and ground waters at the stage of construction

The danger of change to water relations is caused by works connected with drainage of the track-way, excavations, pile-driving during construction, and reconstruction of viaducts, bridges, culverts, etc. The risk of negative impact arising is especially high in places where the line crosses hydrogenic habitats, e.g. boggy forests. The existing conflict is in such a case irresolvable, because due to technological reasons, the substructure of the track has to be well drained, whilst the adjacent ecosystems, in order to maintain a proper state of protection, need to maintain their marshy character.

Moreover, we need to bear in mind that some technical solutions serving to drain the line (e.g. so-called 'Krakowskie open channels') can be a major ecological barrier and the cause of mortality of small animals (see below).

In places of intersection of the railway line with water courses, there is the danger that mo ernisation works (e.g. repair or redevelopment of bridges or culverts) could change the ecological character of the water course. Works carried out in a river stream, e.g. near bridge piers, as well as all works transforming a river bed near bridge structures (including local reinforcement of banks and local restoration of river control) sometimes cause damage to local but important fauna biotopes and aquatic plants, including in particular direct damage to water-crowfoots (habitat 3260) and fish biotopes, including their spawning-grounds. The problem is easy to resolve by designing the works in a way that eliminates technical intrusion in the water course bed.

Works conducted at the 'intersections' of the railway line with water courses that are biotopes of protected fish, carried out during the spawning period or fish migration period, can locally disturb the functioning of their populations. This requires planning such works in non-conflict periods according to the needs of fish.

The danger of pollution permeating to waters pertains in particular to works carried out near bridge objects and culverts, but also remote surface flow from the area of earthworks. In most cases, the danger of pollution with chemicals and crude oil derivatives is noticed, but the danger of temporary disturbance of water is disregarded (polluting with suspended matter). In the case of earthworks, temporary clouding of water in small water-courses nearby the building site is particularly dangerous. Despite the temporary character of this phenomenon and the fact that it does not cause major and lasting deterioration of water quality as understood in the regulations in force, it can exert considerable impact on the populations of some species of fish from Appendix II of the Habitats Directive and on vegetation. Even the temporary presence of larger amounts of suspended matter in water can destroy water-crowfoot vegetation in the water course stream and lead to fish leaving the biotope. This problem can usually be solved using technical means.

2.5. Impact of pollution generated at the exploitation stage

Exploitation of a railway line is connected with creation of various pollutions, among whichpredominate: (*i*) bulk and liquid materials dispersed/spilled in transport (e.g. crude oil derivatives, chemicals, fertilizers, crops, etc); (*ii*) crude oil derivatives from rolling stock (if using the older rolling stock type); and (*iii*) utility sewerage dumped from railway rolling stock. Exploitation of a railway line is also connected with the risk of occurrence of considerable pollution as a result of breakdowns or accident. These pollutions can have a serious effect on natural habitats protected as part of Natura 2000 sites and on populations of fish and amphibians and as a consequence on populations of birds and mammals that feed on fish and amphibians (e.g. otter, kingfisher). The risk becomes serious at points where the line intersects with environmentally valuable water courses. Technical solutions need to be applied, making the flow of water from the railway line to such a water course impossible.

The use of herbicides as part of maintenance of the railway line has a major effect on the railway line vegetation. They have (as assumed) a considerable impact first of all on the vegetation of the track-way which may modify the occurrence and the distribution of 'railway neophytes' but also through damaging their habitats and opening ecological niches for specialised and more durable species. Moreover, the use of herbicides poses a danger to amphibians. Herbicides are very dangerous for their sensitive skin and can cause deformation of animals, especially the young. They have also negative impact on the biology of a species, e.g. on breeding. The problem becomes even more serious when the railway line crosses local migration routes of amphibians or nears important amphibian refuge sites. The use of herbicides in such sections has to be discontinued.

2.6. Accidental killing of animals

On a building site or access roads to a building site, the fauna mortality rate can increase, in particular for amphibians – including species listed in Appendix II to the Habitat Directive – related to their accidental killing by building equipment. The impact is proportional to the intensity and length of the construction works. The problem can be usually alleviated or avoided through proper spatial and time organisation of work.

2.7. Bringing and spreading of alien species

The breaking of ground surface, as well as redevelopment of track-way, can create ecological niches susceptible to inhabitance by expansive species of plants of geographically foreign origin. This will, however, result in the destruction of their populations that currently exists on the track-way. Therefore, either stimulating or limiting effect of the works on the populations of 'railway neophytes' is possible. The construction work related to breaking ground surface can also create niches which make it easier for foreign expansive species to spread along the railway line, entering natural habitats. Publications include descriptions of such phenomenon in relation to *Impatiens parviflora*. This phenomenon is, however, very difficult to model and forecast; moreover, there are no practical ways to limit the related risks.

2.8. Barrier effect for wildlife

This is one of the most serious effects of railway lines on the nature. A railway line is for various species of wildlife a barrier of various degrees of 'permeability' (Fig.2). The barrier effect of a railway line, related to a larger extent to its physical features (scarps of embankments and excavations, scarps of drainage facilities, sometimes concrete 'Krakow-type open channels', a wide strip of foreign environment, ecologically alien substrate on the track-way) than to the movement of trains along the line (even the maximum density of train traffic corresponds to a low-density local vehicle road).

For large mammals (lynx, wolf, as well as ungulates which are their food) a railway line which has existed for a long time is a foreign element, but it has to considerable extent 'melted into' the landscape and for fauna crossing it is not very stressful – so long as nobody tries to fence the line along longer sections, trying to avoid another danger – the collision of animals with trains. A serious barrier can occur in places in which a road also runs along the railway line.

For animals linked to aquatic environment (otter and beaver), the places of crossing the railway line are first of all culverts on water courses. Therefore, the barrier effect of a line depends on the design of culverts, and here in particular on their diameter and size. Pipe culverts that are generally used, as well as all kinds of culverts whose bottom is fully filled with water, often regarded as 'fauna passages', in fact do not function this way at all.

For amphibians, most existing railway lines are now serious barriers. Modernisation often assumes construction of drainage ditches along certain sections of a line, so-called Krakow-type open channels, which are completely impassable for amphibians and, in addition, they become traps in which amphibians and other small fauna die. The barrier effect of a railway line causes the fragmentation and isolation of populations and makes the migration of fauna impossible or difficult. Moreover, the track itself – rails and a strip of stony, dry, and in many cases polluted ground (herbicides) – is an impassable barrier for amphibians. The problem occurs locally, in places where the railway line cuts off e.g. habitats or areas of winter stay and breeding of a local population. Such places may become the sites of mass mortality of amphibians during local seasonal migrations. This can even lead to the extinction of the population. In such places, appropriate passages for amphibians need to be constructed.

The barrier effect of the line itself can be augmented by the barrier effect of roads running parallel to the railway line. The permeability of the linear element of fauna infrastructure depends, among other things, on the width of the strip of the foreign environment and the number of structures foreign to animals in this strip. Therefore, planned modifications of the road system, including the construction of access roads to crossings parallel to railway line (due to the liquidation of some of single-level crossings) need to be considered in this respect too.

Important for the functioning of the Natura 2000 network is the barrier effect of not only the sections of the line that cross Natura 2000 sites, but also those sections which dissect ecological corridors connecting the sites or create edge barriers that make dispersal of animals from the sites or their migration to the sites more difficult.

Despite the possibility of using technical mitigation solutions (various systems of fauna passages), the barrier effect of the line cannot be reduced to zero.

Fig. 2. The line E65 fragments the ecological corridor of the River Mławka and after modernisation could be a major ecological barrier. In its present form, it already poses a threat of isolation

2.9. Wildlife mortality as a result of collision with trains

Train traffic on the line causes collisions with animals and their death (Figs.3,4). This risk pertains to practically all the species of animals crossing the railway line; however, the most frequently registered are collisions of wild boar and roe deer with trains. The increased risk of collision pertains to all birds (e.g. ravens and kites) that feed on carcasses (e.g. a roe deer killed by a train). The cases of collision of species protected as part of the Natura 2000 network with trains are relatively rare, but due to low numbers of their population, even the slightest risk might be regarded as considerable. Predator birds and owls (also Venus Flytrap and shrikes) use the traction poles as lookouts in many places, because nearby are the most attractive hunting places for these species. They eat carcasses found on the track-way. Such behaviour elevates the risk of their collision with trains. Besides mortality on the track-way, mortality as a result of collision on roads parallel to the railway line can also be important. Therefore, the planned modifications of the road system, including the construction of access roads to crossings parallel to the railway line (due to the liquidation of some of single-level crossings) need to be considered in this respect too.

The fencing of long sections of a railway line, sometimes done in order to make passage of fauna impossible, is not a good solution – although it can reduce mortality, it increases the barrier effect of the line, which in most cases is much more dangerous. A promising method of mitigating the death risk without a corresponding increase of the ecological barrier effect are acoustic deterring devices, currently at the stage of tests in practice. However, there is no way this effect could be reduced to zero.

Fig. 3. Amphibians are often killed in collisions with trains. The track-way is an impassable barrier for them

Fig. 4. So-called Krakow-type open channels, serving to drain the railway line embankment, are a barrier for amphibians and other animals

2.10. Birds crashing into railway line infrastructure

Flying birds can crash into barriers, e.g. elements of bridge structures or the traction network. This risk is considerable in the case of bridge structures in river valleys which are migration routes for birds. A considerable number of birds migrate at night, which increases the risk of collision with structures which are not lit. Lighting the structure of a bridge can reduce the risk, although it does not reduce it entirely.

3. Remote and indirect impacts

Remote and indirect impacts are of equal importance, and sometimes even more important than the direct ones. Although their inclusion in EIAs is not simple, they must not be disregarded!

3.1. Change of impact of alternative communication channels

The condition of the railway line and its exploitation parameters (throughput, train speed and the resultant time of run) obviously have an effect on the attractiveness of the railway line as compared to alternative transport channels (road and air). Because infrastructure elements exist related to these alternative channels and the resultant environmental impacts (including the effect on the Natura 2000 network), the subject matter undertaking needs to be considered in this context, too.

3.2. The effect on urbanisation processes

In many countries, including in Poland, one can observe the relation of urbanisation processes with communication routes. Such a relationship can also theoretically pertain to railway lines. Good availability of passenger transport can stimulate housing developments, and the availability of cargo transport, industrial developments. In Poland, however, this effect seems to be disregarded, as compared to the urbanisation effect of the road network. It is not observed that the availability of passenger railway transport and the quality of this communication (time of travel) has currently had any influence on the prices of real property or the decisions related to spatial development. In the same way, industrial, service (including sales and logistics) investments localisation decisions are these days made rather on the basis of the quality of communication services on roads and not railway lines. However, such an effect can take place in the longer term. Similarly, in the longer term there could be the pressure to locate industrial investments where there is good communication services provided by railway transport ensured.

3.3. Changes in the model of area penetration in connection with changes in road system

Modification of the layout of roads, as well as the network of forest roads, related to the liquidation of some railway crossings, as well as the construction of temporary access roads to building sites, can result in a change in the way the area is penetrated, including ‘opening and making available’ places so far hard to penetrate or in which to carry out economic activity. We have observed this phenomenon in particular in Bory Dolnośląskie, where minor modernisations of forest roads made in order to improve access to a building site improved the accessibility to the area for forest management (they won positive opinions of forest managers), but this meant ‘opening’ the so far inaccessible area and a very negative effect on refuges of anthropophobic birds.

3.4. Difficulties in the protection of Natura 2000 sites

The liquidation of crossings at the track-way level, related to the modernisation of the railway line, can to a certain degree impact the accessibility of farming land, thus exerting an effect on their use. Because meadow habitats (e.g. 6150, 7230) are material objects of protection as part of Natura 2000 sites, whose protection consists in their mowing in the proper rhythm and at the proper time, limiting access to individual patches of habitats can make the performance of protection tasks more difficult. Such an effect should also be included in the assessment.

4. Accumulated effects – a major problem in impact assessment

The instances of potential possibilities of the effects of modernisation of railway line accumulating with the effects of other undertakings are related first of all to the case of a railway line and a road running parallel, in particular to bridge crossings that are parallel and located close to one another (Fig. 5). In such a case, integrated solutions need to be applied (jointly designed), but the procedures provided for in Polish law make it very difficult.

Fig. 5. Accumulated impacts – a railway line and a road (E 65 near Zakole Rzeki Wel Natura 2000 site)

5. Examples of mitigation measures

5.1. Systems of amphibian passages

A well-designed system of passages for amphibians should be preceded by a reliable field stock-taking, specifying the directions and the types of migration of amphibians and a preliminary assessment of the degree to which the system of passages can reduce mortality of amphibians and preserve the functionality of the local migration corridor. In typical conditions, migration activity of amphibians has several stages:

- Breeding migrations – adult individuals migrate from hibernation places to breeding places and then, after mating, to feeding grounds (spring);
- Trophic migrations – 1-year old or older individuals that are not yet old enough to mate migrate from winter stay places to feeding grounds (spring); adult animals and 1-year olds or older individuals that are not yet old enough to mate migrate from one feeding habitat to another (summer); juvenile animals (after metamorphosis) migrate from their lair to feeding habitats (summer, early autumn);
- Migrations to winter places – adults and juvenile animals migrate in search of proper places of hibernation (autumn).

Optimum amphibian passages should consist of a system of tunnels and guiding fences. A fence is an indispensable element placed along the embankment, which leads the amphibians to the tunnel and which prevents the animals from entering the track-way. This element has to be installed between the tunnels. The shape of fences should be designed so as to eliminate the possibility of the amphibians' climbing, as well as to protect the fence from dumping and overgrowth.

The dimensions and shape of tunnels should be in line with ecological requirements for wildlife, providing contact with natural ground during migration. The best and the most durable are concrete elements. Their dimensions should be appropriate (minimum width 100 cm and minimum height 60 cm), which should guarantee that the animals enter the tunnel. ZIEGER prefabricates are a good example of tunnels that meet wildlife ecological requirements (Figs. 6,7).

Fig. 6. Tunnels and ZIEGER type guiding fences for amphibians. Maintaining the natural soil and placing a guiding board in the tunnel is significant.

Such tunnels fulfil the function of a safe passage not only for amphibians. Experience shows that not only amphibians use the passages, but also small shrew-type mammals, arvicolinae, muridae, and sometimes mustelidae, as well as badgers.

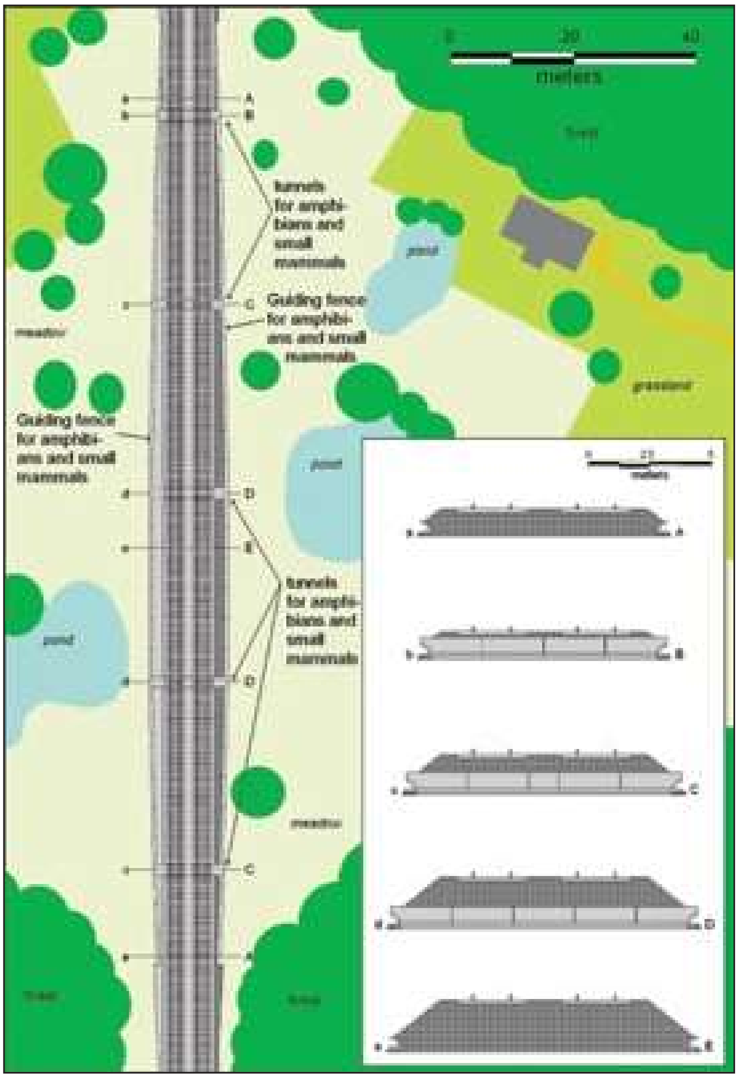

Fig. 7. Scheme of the designed system of underpasses for amphibians under the railway

5.2. Minimizing the barrier effect of the railway line on animals – UOZ 1 disperser and reconstruction of bridges

In order to maintain the patency of ecological corridors, solutions are pursued that would enable fauna to freely cross the railway line at places where they migrate or live. On railway sections which cross ecological corridors, we proposed the experimental use of acoustic dispersers, UOZ-1 devices, prepared by the Forestry Research Institute – Department of Natural Forestry, which are sign stimuli dummies, triggering an instinctive flight reaction in wild mammals (Fig. 8). This promising solution might prove effective and much less expensive than other risk minimisation measures.

Fig. 8. UOZ-1 acoustic dispersers

A properly modernised railway bridge can become the most valuable facilitation of migration of animals, as the main passage for otters, beavers, wolves, lynx and other forest animals (deer, wild boar, small predators), species which in their migrations and penetration of home range are willing to use the semi-natural river banks. In order to keep the river course clear throughout the year, we recommended building additional spans on dry land along the river bed, if land relief allows it. Such a solution was proposed, among others, at the crossing of the E65 railway line with the River Drwęca Valley Natura 2000 site.

6. Recapitulation

Taking into account the effect of the railway investment on Natura 2000 sites and the integrity of the Natura 2000 network results from the current regulations of EU and national law. In line with the same regulations, not the place of origin but the place of effect is decisive in starting the procedure of assessment of impact on Natura 2000 sites. Therefore, the procedures should consider not only the areas crossing with railway investments, but also remote areas, in which there is the risk of effect. The most important effects of modernisation of the railway line on Natura 2000 sites which we identified are: (1) cutting trees or bushes, (2) noise and disturbance related to the exploitation of the line, (3) the effect on surface and underground waters during construction, (4) fauna mortality as a result of collision with trains, (5) the barrier effect of the railway line on animals, (6) the spreading and distribution of alien species and other, described in the present study. In order to minimise the negative effects, we proposed the use of various mitigation measures, such as: (1) appropriate passages for wildlife, (2) preservation of valuable habitat patches, (3) redevelopment of bridges and (4) installation of experimental acoustic dispersers.

Protection of wildlife and migration corridors along the arterial railway line: example of actions taken for the E20 line in Poland (Rzepin – state border section)

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Abstract. The work deals with the problem of wild animals living in the vicinity of the E20 railway line, in the area of the Rzepińska Forest (western Poland). The E20 railway line is part of the 2nd Pan-European transport corridor (relation: Moscow-Warsaw-Berlin-Paris) and is the most important railway connection between Eastern and Western Europe. An impact of modernization of 15 km section of this line on the local landscape and fauna has been evaluated. Moreover, the appropriate means mitigating its influence on the area resident and migrating animals, such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), fox (*Vulpes vulpes*), Raccoon dog (*Nyctereutes procyionoides*), badger (*Meles meles*), mink (*Mustela vision*), pine marten (*Martes martes*) and hare (*Lepus europeaus*), were offered. As a part of taken activities locations and technical parameters of 3 passages for large forest mammals and 7 for the medium and small ones were proposed as well as a construction of the protective wire fence for the whole forested section of the line.

Key words: arterial railway line, mammals, migration corridors, barrier efect, mitigation measures, fauna passages, protective fencings

1. Introduction

Modern communication infrastructure – fast train routes and arterial railway lines – have a multilateral effect on the environment of the adjacent areas. The intensity, scale, and ecological importance of such an effect result directly from the location of such an investment, structural solutions, and density of traffic. The negative impact of railway lines covers first of all fragmentation of migration (ecological) corridors, making the movement of wildlife across railway line impossible or difficult, and wildlife mortality as a result of collision with trains.

The most serious ecological effects of the development of railway infrastructure include making the unconstrained movement of animals impossible, that is, the barrier effect.

In the case of railway infrastructure, the barrier effect is conditioned first of all by:

- superficial modifications of land morphology (laying track-way on embankments and in excavations)
- introduction of protective fencing
- the presence of infrastructure objects of anthropogenic origin (track-way, power traction, control devices)
- removal of vegetation from the track-way zone and replacing the (sub)soil
- noise and light emission.

The currently applied methods of protection of wildlife within the impact of railway lines are similar as in the case of roads; they can be divided into three main types: (*i*) preventing conflicts between the course of a new line and the location of habitats and migration corridors by appropriately planning the course; (*ii*) minimisation of the effects of fragmentation of habitats and the effects of ecological barriers by building wildlife passages; (*iii*) reducing mortality on roads and railway lines by building protective fences, using active and passive dispersers.

2. Study area

The E20 railway line is part of the 2nd Pan-European transport corridor (relation: Moscow-Berlin-Paris) and is the most important railway connection between Eastern and Western Europe. The Polish section of the E20 line was for the most part modernised with the adjustment to the traffic of fast passenger trains. The subject of the analysis was a 15 km-long section of this line running almost entirely through the compact forest complex of the Rzepińska Forest, between the localities of Rzepin and Kunowice (a border crossing with Germany) (Fig. 1).

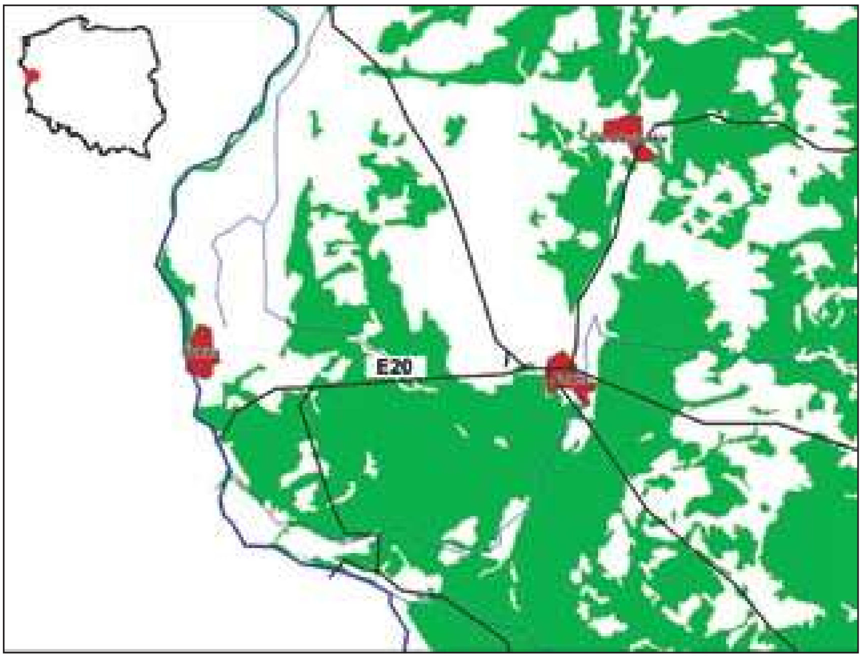

Fig. 1. Localisation of the study area

3. Investigative methods

Environmental analyses were conducted in two principal stages: (*i*) valorisation of the landscape in terms of usefulness for the needs of wildlife migration; (*ii*) localisation of conflict areas along the route of the railway line.

3.1. Valorisation of the landscape

Inventorying and valorisation of the area adjacent to the railway line was done in a strip 1 km wide in terms of the usefulness for the wildlife migration. The area was divided into 100x100 meter-plots, specifying the following features:

- presence of forest vegetation > 75%
- degree of density of tree cover > 60%
- multi-leyer forest stand
- multi-species forest stand

- no clearings > 100 m
- no urban developments
- no public roads
- no infrastructure related to railway line maintenance
- no above-standard light and noise emissions (sources beyond railway traffic)
- presence of natural water courses and water reservoirs
- presence of water courses of a length exceeding 500 meters
- presence of land depressions of a length > 500 m, not related directly to water courses
- hilly terrain of considerable elevation differences.

Using the 0-1 method, each plot was assigned a point for the presence of a given feature. The maximum number of points is 13 and theminimum is 0. Areas with the highest number of points were regarded as possessing landscape qualities superior for performing wildlife migration functions in the analysed area.

3.2. Localisation of conflict areas along the route of the railway line

The areas with the best landscape features were subject to further verification in order to precisely localise conflict areas. The following data was used in the verification:

- course of wildlife migration corridors of higher than local importance (regional, national, international)
- course of local wildlife migration routes
- the constitution of species and distribution of fauna in the analysed area
- topography of the area adjacent to the track-way (in particular embankments higher than 6 m and excavations deeper than 4 m)
- identified areas of collision with animals.

Verification and assessment were performed qualitatively, using multi-criteria analysis and expert appraisal, with the result of selecting areas with the most advantageous features.

4. Results

4.1. Fauna – species constitution and distribution of fauna

The following types of mammals are present in the studied area: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), fox (*Vulpes vulpes*), Raccoon dog (*Nyctereutes procyionoides*), badger (*Meles meles*), mink (*Mustela vision*), pine marten (*Martes martes*), hare (*Lepus europeaus*).

The highest density of the ungulate population is in areas located north of the railway line and decreases considerably when approaching the infrastructure, reaching its minimum on the southern side of the track-way.

4.2. Migration corridors

Rzepińska Forest has been included in ECONET, the Polish ecological network concept, having the status of a junction area of national importance (Liro 1998).

The analysed fragment of the Repińska Forest has been included in the network of ecological corridors of the Natura 2000 network (Jędrzejewski *et al.* 2005). It has the status of a corridor of national importance and plays a key role in the regional connectivity of the network, in particular for the following areas, designed as refuge networks: the mouth of the Warta River, Łęgi Słubickie, the mouth of the Ilanka River, the Pliszka River Valley.

The ecological corridor, whose fragment is Rzepińska Forest, also plays an important role for the connectivity of the Natura 2000 network on an international scale – it complements the main corridor connecting the refuges of southern Poland with the forests of Brandenburg.

4.3. Effect of E20 railway line on populations of wild animals living in Rzepińska Forest

The negative effects of railway line include:

- breaking the continuity a the migration corridor of national importance in the section: the railway crossing in the locality of Gajec to the railway station in Kunowice; particularly threatened species: red deer, wild boar
- breaking the continuity of local migration routes for large and medium-sized forest mammals in three sections; particularly threatened species: wild boar, red deer, roe deer, badger, fox
- mortality rate amounting with some species to more than 10% of the total local population; particularly threatened species: wild boar, red deer, roe deer, badger, fox.

The expected long-term ecological effects of the functioning of the E20 railway line in the analysed section (in conditions of maintaining or increasing the current level of train traffic) in the present form:

- genetic isolation of the ungulate population living on the northern and southern sides of railway track-way;
- seriously reducing long-range migration possibilities, in particular of rare and protected species – wolf, elk;
- gradual decrease in population of red deer and wild boar in a 500 m strip on the northern and southern sides of the track-way;
- gradual decrease in population of red deer in the entire fragment of the forest complex on the southern side of the track-way;
- dramatic increase of mortality of red deer and wild boar in late autumn and spring, and of red deer, wild boar, roe deer, fox in winters with deep snow cover.

4.4. Actions aiming at minimising the negative effect of E20 railway line on the populations of wild fauna

The optimum actions that minimise the negative impact of the E20 railway line in the Rzepin-Kunowice section are:

- construction of three passages meeting the requirements of large forest mammals: two overpasses in the form of green bridges and one underpass in the form of a viaduct in the embankment
- construction of seven passages meeting the requirements of medium-sized and small mammals, realised as modified protective fences in selected sections (passages on track-way)
- building protective fencing from metal mesh in the entire forested section of the railway line.

4.4.1. Location of structures

The location of structures was determined as the optimum resultant of two groups of factors:

- environmental valorisation of habitat areas fragmented by the railway line and the course of wildlife migration corridors of international, national, regional, and local importance
- degree of collision with the existing infrastructure – in particular with traction network and traffic control devices.

The simultaneous consideration of all the above-mentioned factors led to the determination of locations that optimally fulfilled the ecological needs and characterised by the lowest possible level of collision with the existing infrastructure. There is no way that collisions could be avoided entirely, because most of the collision-generating objects are linear and run along the entire length of the analysed railway line section.

Fauna passages should located as follows (Figs. 2, 3 and 4):

- overpass (green bridge I) – 466.778 km
- overpass (green bridge II) – 470.199 km
- underpass (viaduct in embankment) – 467.241 km.

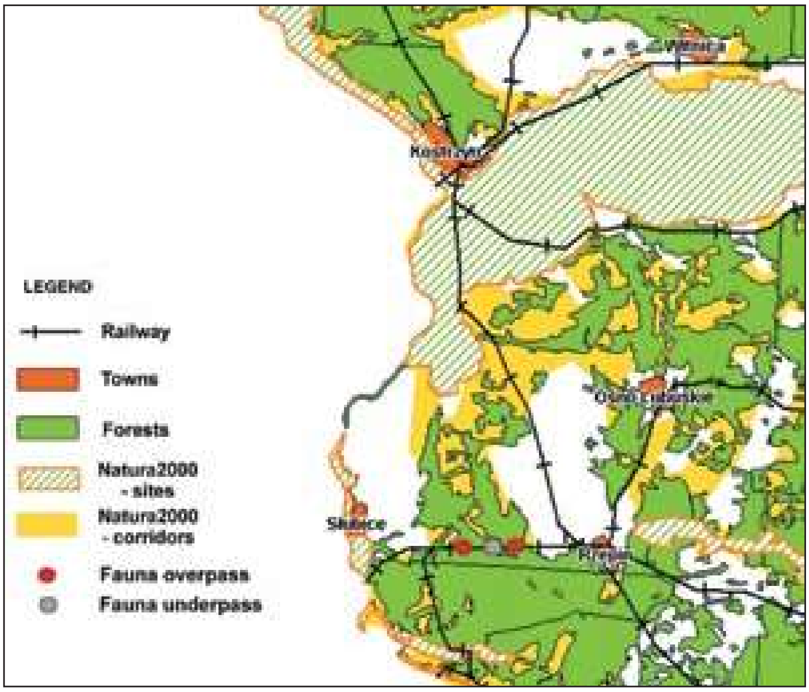

Fig. 2. Location of the planned fauna passages and distribution of Natura 2000 sites

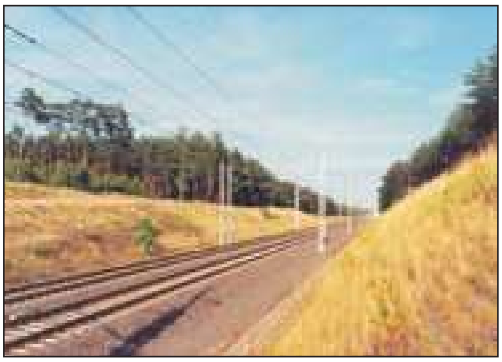

Fig. 3. Location of the overpass on the 466.778 km. Photo R. Kurek

Fig. 4. Location of the overpass on the 470.199 km. Photo R. Kurek

4.4.2. Technical parameters and structural features of the structures

Overpasses (Fig. 5):

- passage in the form of a viaduct over the railway line, located between traction poles, over the main power supply line
- the effective width of the passage at the narrowest point – 40 m
- the passage surface widening smoothly towards the passage approach area
- maximum inclination of the passage surface and the inclination of the surface in approach area – 10%
- restoration of the natural vegetation of the passage surface and on approaches to the passage – minimum 80 cm layer of soil, of which 50 cm of humus
- formation of grassy vegetation cover on the surface of the passage with clusters of bushes and higher-growing perennial vegetation, allowing the natural expansion of species
- using protection fences on the outer edges of the passage – fences connected to the whole fencing system
- using acoustic and anti-glare screens in the form of a light wooden structure.

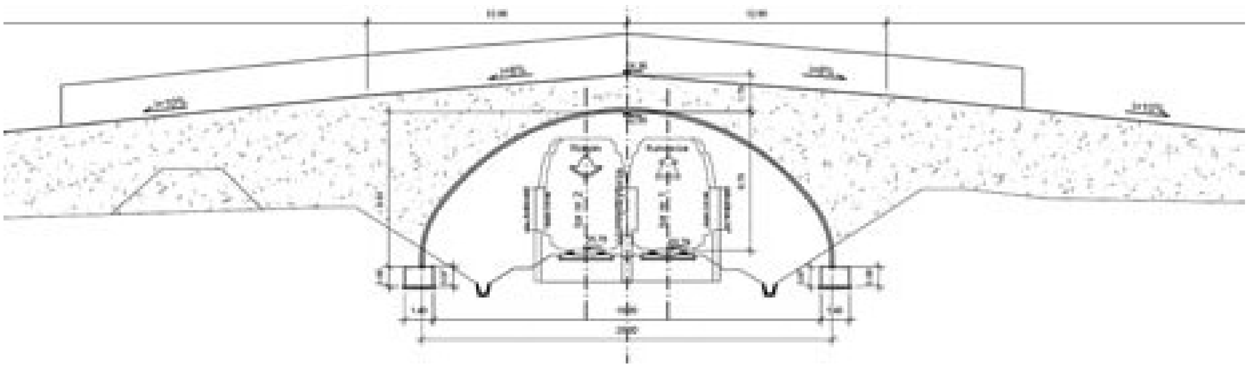

Fig. 5. Cross-section (along the structure's axis) of the planned overpasses

Underpasses:

- a passage in the form of a viaduct under the track-way within the embankment
- effective height of the passage: 5 meters
- effective width of the passage: 20 m
- single-span structure
- keeping a water course (stream) in an unchanged course and the unchanged physiognomy of the bed under the surface and near the passage
- maintenance or restoration of the natural vegetation of the land under the passage – minimum 80 cm layer of soil, of which 50 cm of humus
- formation of grassy vegetation cover under the surface of the passage with single bushes and higher-growing perennial vegetation, allowing the natural expansion of species
- connecting the entrances with a system of protective fencings.

4.4.3. Protective fencings

The designed protective fencings have the following features and parameters (Fig. 6):

- nominal height – 240 cm
- the mesh must have various sizes of holes – getting smaller toward the bottom
- the mesh needs to be dug underground to the depth of 30 cm
- a solid foundation of the piles, enabling strong tension of the mesh and ensuring vertical stability of the structure; it is recommended that the allowed deflection from the pi-meson does not exceed 1 cm

- the distance between piles should not exceed 300 cm
- the fencing should be built in straight lines or with slight curves with a radius not exceeding 15º.

Due to the migration needs of medium-sized and small mammals (mainly rodents and hare-like), amphibians, reptiles, and invertebrates, which will not be fully satisfied by the construction of viaducts for large mammals, modification of the principal (above-described) type protective fencings in the selected sections of the line is proposed (Fig. 6). These modifications will perform the function of passages under the track-way surface.

These modifications ensure that the above-mentioned groups of animals can cross fences in a fairly unconstrained manner. Due to their small body size, these animals are no threat to the safety of railway traffic in the event of collision. Mortality of these animals in the conditions of the expected train traffic density should be very low.

The major differences in parameters of fences modified in relation to the principal type:

- bottom edge of the mesh laying on the ground level – without burying it underground
- larger loops of the mesh in the lower part of the fence.

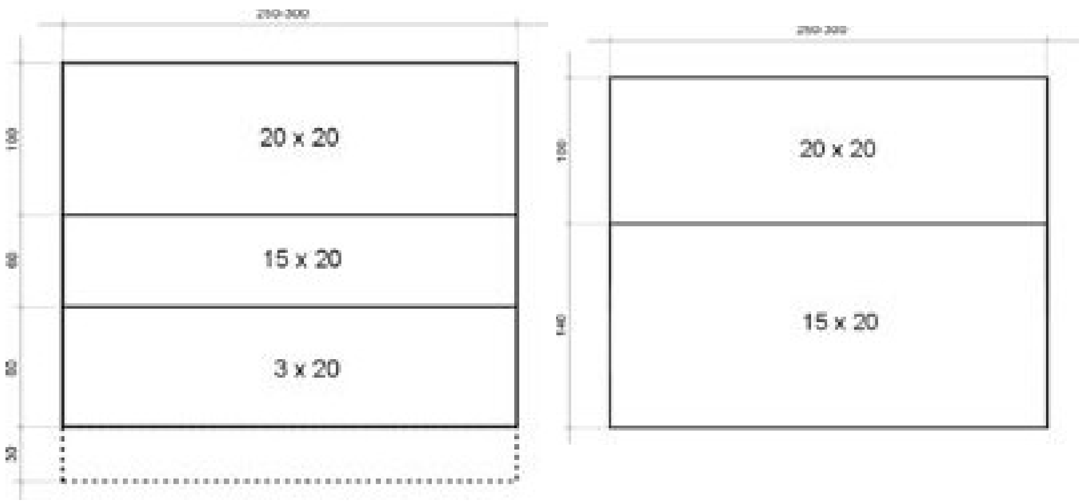

Fig. 6. Fencing modules diagram: principal and modified for the needs of migration of small mammals

4.5. Collisions with the existing infrastructure

The construction of fauna passages near railway lines in the form of overpasses is tied to a number of collisions with the existing infrastructure related to railway traffic maintenance. These collisions considerably impact the selection of materials and structural features of the planned passages. These collisions pertain in particular to:

- traction network – the distance between the traction piles necessitates a limited maximum width of overpasses; the height of suspending the power lines and bearing lines necessitates adjusting the terminals of overpasses, which is related to the considerable height of overpasses and high elevation over the surrounding terrain;
- train traffic – building the passages usually takes place without stopping the planned train traffic, which necessitates appropriate non-colliding performance of assembly works and the choice of such a design solution which will be possible to install from the terrain neighbouring the track-way;
- linear drainage of track-way – the span of the designed overpasses has to be increased so as to provide for passage over the drainage ditches.

An additional problem in designing the fauna passages is the necessity to keep a safe distance from the individual constituents of railway infrastructure, which is regulated by detailed provisions of law on the conditions for terminals by railway lines.

When fauna passages along the discussed section of E20 line were designed, environmental and building analyses were conducted for various types of passage structures, taking into account ecological, technical, and financial conditions. Analyses showed that the optimum solution will be building overpasses ('green bridges') of the minimum width 40 m, with a steel structure, made of high-profile steel sheets. The assembly of the structure will take place in conditions of continued train traffic (switching off power and introducing motor traction) by sliding subsequent layers of steel sheath from the area located outside the track-way.

Building fauna underpasses in railway embankments is free of the above-described collisions and therefore is the best constructional solution for lines which are newly-built or subject to overhaul. It is important to start the realisation of such passages at an early enough stage, when embankments and track-way zone are reconstructed, before the stage of assembly of railway traffic infrastructure. When planning underpasses by existing railway lines which are not redeveloped and on which train traffic will be continued, considerable difficulties should be expected, which will require additional technological activities and a considerable increase in the costs of realisation of objects. The construction of the underpass by the E20 railway line would require the complete demolition of the embankment where the structure is located, disassembly of traction network and other traffic control installations, complete stoppage of train traffic on both tracks for a period of more than ten weeks, or directing train traffic to one track using proper, complicated protections. The estimated total cost of the construction of such a passage, together with the costs of removal of collisions resulted in this type of structure being regarded as currently unfeasible.

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The principles of operation of the sign stimuli dummy applied in the device UOZ-1 for deterring animals from high-speed train traffic

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Abstract. The article presents ethological basis for functioning of prototype device for deterring wild animals which are inclined to cross express railway lines. A role of vision, touch, hearing and smell senses has been emphasized and an instinctive animal behavior discussed. The main objective of the device is an 'advanced warning', i.e. stimulation of animals to leave the given site several dozen seconds before a real threat occurs. The warning consists of at least one minute sequence of natural alarming and information sound signals borrowed from the nature and supplemented with a few 'supernormal' stimuli.

Key words: animals, railwy lines, instinctive behaviour, sign stimuli, deterring device, dummy

1. Introduction

For several years now, extensive modernisation of main national railway routes has been carried out. Poland leads European countries in terms of the richness of flora and fauna. There are many areas that will be intersected by trains well exceeding the speed of one hundred kilometres per hour that are national and landscape parks, nature reserves, or areas included in the NATURA 2000 network. In line with the requirements of the European Union, any investment planned needs to take the good of the natural environment into account. In this particular case, the point is to reduce the risk of collision of wildlife with trains, while making their fairly normal functioning in the environment possible. In view of the above, the plans for modernisation of subsequent railway line sections envisage a series of railway underpasses for small animals and spacious culverts for larger mammals. By the force of events, mainly due to the considerable cost of completion and technical problems, the passages will be located at large distances one from another. Therefore, in the sections of the line that are strategic for animals, in particular in wooded areas and areas under legal environmental protection, as well as in places where culverts are not feasible, other solutions should be applied.

Protecting an animal that has entered the tracks from colliding with a train is easier than protecting it from colliding with a road vehicle: (*i*) trains arrive at a given point at a specific point in time; and (*ii*) in between these moments the tracks are free and can be safely crossed. It is enough to motivate an animal, using appropriate stimuli, to refrain from entering the railway line embankment for the period of just a few moments prior to the arrival of the speeding train.

However, to effectively control the behaviour of animals, one needs to have the appropriate knowledge in the field of zoopsychology. If the concepts of 'dispersers' are conceived in the heads of laymen or ecologists who are not specialists in ethology (animal psychology), and if, in addition, the investor wants to cut down on some of the costs, the outcome will be easy to foresee – the devices designed and constructed this way will be practically useless. Let us take as an example round pieces of aluminium foil that reflect the lights of the coming train, installed with the naive faith that the animals, strongly convinced that these are the eyes of predators, will be scared to death and run away.

The Department of Natural Forests of the Research Institute of Forestry [DNF RIF] in Białowieża developed an original concept of stimulating the desired behaviour of animals, fully grounded in the latest achievements of zoopsychology. The principles of the sign stimuli dummy were: (*i*) high effectiveness of signals transmitted at a specific time and place; (*ii*) preventing the animals' becoming dulled to the transmitted stimuli; (*iii*) eliminating the need for erecting fences along the railway line, that is, creating ecological barriers and fragmenting the habitats of mammals.

In order to explain the principle of the apparatus's operation, basic information of the behaviour of wild animals needs to be provided. This information is always the outcome of the nervous system's processing of the whole spectrum of visual, aural, olfactory, tactual, and many other types of stimuli simultaneously coming in from various directions.

2. Etological basis of the operation of disperser for wild animals deterring

2.1. Sense organs

Sense of hearing is an analyser of acoustic energy. From the whole range of incoming sounds, it selects the components to which it is evolutionarily sensitive. The localisation of the source of sound and the distance is in general less precise than when done using the sight organ; however, mammals locate a source of sound at least twice as precisely as humans. The range (low and high tones) and the sensitivity to sound waves are, on the other hand, many times higher than with humans.

Sense of vision. Mammals' ability to perceive still objects, the speed of moving objects, as well as to judge distance and the derived ability to build a three-dimensional picture of the surroundings, to great extent depends on the ability to see (in the broad range of light), whilst one of the principles is stereoscope vision obtained thanks to a pair of eyes and head motility. The determination of distance by means of other sense organs is of lesser importance (except for species which use echolocation for this end, for example).

Sense of touch is located on the soft tips of hoofs or paws that are rich in nerves, among other places and senses the vibration of the ground generated not only by the movements of the earth's crust, but also by movement of other animals or vehicles.

Sense of smell is extraordinarily effective with most mammals. However, because in the process of developing the theoretical foundations for the sign stimuli emitter, this sense was regarded as secondary, it needs no discussion, as with the whole range of senses that animals have.

2.2. Instinctive behaviour

Innate (instinctive) and genetically passed-on forms of animal behaviour came into being as a result of evolutionary anatomical-physiological-psychological changes, as a response of living creatures to signals coming from the surroundings. The entire, unimaginably complex set of innate (fixed) behaviours of individual species and animals is controlled by three basic instincts: self-preservation, feeding, and breeding instincts.

The study of theoretical foundations of the 'sign stimuli' dummy was based on the strongest of instincts. This was the imperative to run for life. Contrary to reason (originating from the rational assessment of situation and from experience), this self-preservation instinct forces an animal, with amazing and blind power, to do everything to save its life in most situations. The compulsion to save oneself is evident in its simplest form through the motor reflex to run away, triggered by an appropriate stimulus (a signal from the surroundings). In an unconstrained environment, this means in most cases running away from another animal (friend, predator, human being) and intensive abiotic phenomena (an earthquake, rock and snow avalanches, a storm, flood wave, fire, etc.).

The adaptability of the responsiveness of senses and motor activity, consisting in such a connection of the receptor (organ of sense) and defensive reaction (flight, seeking shelter and, as a last resort, attacking the enemy), in order to increase the chances for the preservation of life, is primarily based on the organisation of the central nervous system, created in the course of evolution. This is an axiom which cannot be disregarded when making any attempt to control the instinctive behaviour of untamed animals.

2.2.1. Fixed action mechanisms sign stimuli

Knowledge of the potential of sense organs, obtained in laboratory experiments based in principle on training (the process of learning or acquiring conditioned reflexes), consisting in coupling any chosen stimulus with prize or punishment, answers the question as to whether the nervous system of a given animal receives the tested signals at all. However, a positive response does not suffice to automatically interpolate the results onto the behaviour of wild animals. Without the knowledge of functioning of a given species in its natural environment, as a highly conditioned component of the specific biocenosis, with a number of evolutionary interrelations, with its biotic and abiotic elements, it cannot be assumed that analogous stimuli will trigger any reaction in the animals. Animals will not react to the predominating part of signals that come from the natural environment. They are neutral to them: they do not worsen nor improve their ecological situation. This is the basic characteristic of behaviour of all animals (including man).

The key element of visual stimuli is detecting the movement of the observed object and a sessing the distance to the object. This is primarily aimed at preliminary assessment of a threat. The shape of the object, its size, and sometimes the colour are of secondary importance. On the other hand, reaction to sound may be completely independent of the associated image/vision. For example, an alarm sound triggers the flight reflex, despite the simultaneous reception of visual stimuli evidencing the complete absence of any threat. This is because the feature of instinctive behaviour is its conditioning upon one or at most a few sign stimuli picked out from among the neutral stimuli incoming simultaneously in much greater numbers – the neutral stimuli are not related to the threat signal (e.g. no connection of the moving shadow cast by a tree and the sound of the river with the incoming scent of a lurking predator).

Conditioning the reaction of an animal to a precisely specified signal or a set of signals (sign stimuli) coming from the outer world results from the existence of a special nervous-sensory mechanism. In zoopsychology this is referred to as a 'fixed action pattern'. The dependence of instinctive actions on sign stimuli enables triggering reactions of animals that are desirable for men through presenting an appropriate dummy. In the case of stimuli triggering reflexive locomotory activity, knowledge of the ecological system of oppressor/ oppressed that functions in the habitat of the given species is indispensable.

The natural sensory stimuli that inform about threats trigger a 'chain reaction'. These are increased watchfulness, wariness, fear, and flight. Many apparently very simple behaviours (flight among them) in fact consist of a chain of separate reactions, of which each depends on a specific set of sign stimuli. Of paramount importance is their configuration, compatible in terms of quality, intensity, and duration with the string of psychophysical reactions of an animal. This means that the stimuli to which an animal reacts are not simple measurable units. With their proper configuration comes new quality and only then – like a key fitting in a lock – the configuration chain reaction is triggered. In such a situation, we talk about 'the comprehensive stimuli situation activating the motivation'. This is related to a considerable extent to all stimuli, not only those related to preservation of life.

Usually, the first indicator of the chain character of response is the sudden break of its circle. In natural conditions, if the response took place as a result of a mistake, the animal stops reacting to the still-incoming stimuli, e.g. first drops of rain scare off the fish floating just under the water's surface, but after a few minutes of continued rain, the fish become indifferent and return to their normal actions. This is because only one signal is repeated over and over again (monotonous), which means that there is no consistent sequence in the chain of sign stimuli that would generate instinctive flight: stimulus A – reaction A (increased watchfulness, alertness), stimulus B – reaction B (physiological readiness to flight) stimulus C – reaction C (flight at a safe distance), stimulus D or fading off of stimuli – reaction D (interrupting the flight and atrophy of emotions). In other words, the change of location is a spontaneous behaviour triggered by a sequence of events matching a specific pattern of concrete organisational features internally arranged into a logical flow.

2.2.2. Social and inter-species triggers

The overall stimuli situation not only triggers the reaction, but also gives it a direction, depending on the characteristics of the surroundings. In open air, this means moving away from the source of the signals, and in the case of forest animals, leaving the open air and trying to hide in canopy. An important role is played here by the phenomenon of widely understood 'mnemotaxy' – moving away for any reason from a place previously remembered as dangerous, towards known and safe shelters. As time goes on (recurring situations), a partly memory-induced reflex of elevated readiness to flight may appear when the animal enters a certain area or even with the first stimulus from the chain of reaction triggers.

This readiness, signalled with warning behaviour (certain posture, movement, expressions, or voice), can be passed on to their kindred. This is a so-called social trigger – the reaction of animals at an appropriate distance from one another – takes place as a result of receiving information, that is, a warning from another animal and not a stimulus coming from the environment (ethology knows instances of such distance reaching tens of kilometres). Information exchange, mimicry, and learning through mimicry are a widespread phenomenon, in particular with animals at higher level of organisation (birds and mammals). Many innate fear reactions are triggered by warning stimuli sent by more experienced (parents), most vigilant, or most sensitive individuals. The animal stimulated with a warning signal instinctively reacts with relevant behaviour or produces an alarm cry. The positive result of revealing the presence of the enemy, which means preserving the life of all members of the group or reducing the loss to a minimum, depends on how fast the most vigilant individuals react.

Ethology has recorded many instances of purposeful or involuntary cooperation of animals for protection against an enemy at inter-species level (birds-birds, mammals-mammals, birds-mammals). These are most often alternating watching and emission of information-alarming signals (inter-species triggers). Many animals produce two different alarm cries: one at the sight of a predator that is not yet attacking but is a potential threat, and another cry in the case of a sudden attack. The group reaction to the first type of cry is elevated watchfulness, and the reaction to the second type is all animals' quickly moving away from the source of danger or seeking a safe refuge.

To sum up: a signal (social or inter-species trigger) provided by the most vigilant animal triggers the reaction of other animals of the same or another species.

2.2.3. 'Supernormal' sign stimuli

When we test the triggering values borne by any sensory stimuli, we deal with variable threshold values. The variable threshold value of constant force stimuli is revealed in increasing or decreasing the internal motivation of an animal to exhibit the targeted activity. For example, hunting behaviour of a predator at the sight of potential prey is stimulated by the degree of hunger or estrous behaviour (the level of sex hormones).

The only instinctive behaviour that does not have a variable threshold value as a result of internal factors (in the animal organism) is life-preservation. On the condition, however, that the stimuli denotes such imminent danger that the effect of habituation ('immunisation', 'insensibilisation') cannot take place. Some examples of an animal's 'immunisation' to the stimulus initially triggering the flight reflex are a scarecrow on which birds brood, the sight of roe deer grazing on train tracks when the train is moving through, or the already-mentioned behaviour of fish during a rain.

Experimental research conducted on various species of birds and mammals indicated a possibility of constructing stimuli of supernormal force that trigger instinctive reactions in the tested individuals. This was confirmed by observations of wild animals living in a natural environment. This group of stimuli covers certain physical features of animals (lures and dispersers) as well as elements of hunting and parasite behaviour. Supernormal stimuli prove more effective than typical signals, which are not always optimal, thanks to which predators achieve hunting success and obtain food.

2.2.4. Reaction time, flight distance, attack distance

The time that elapses between the first signal from the chain of sign stimuli and the reaction of the animal is specific for the given species, particular animal, and external situation. In the case of life-saving behaviour, the speed of counteracting of the potential prey is closely evolutionarily related to the aggressor behaviour and the speed reached by the set of antagonist species living in the given climatic zone. This ranges from hundredths of a second (falcons' attack on birds) to tens of seconds (large carnivores hunting herbivores). The time the predator needs to travel a certain distance to the prey is known to the prey instinctively (and experientially); therefore, the prey adjusts its locomotory activity – the moment of starting and the speed of flight – to the particular situation.

With the speed of a non-natural aggressor (a plane, a car, or a train), the animal standing on the road seems to be reacting with considerable delay – because the set of instinctive behaviour of all animals is equipped with the so-called flight distance. This is a relatively small distance from the aggressor, only after which life is in danger (it is possible to catch up to and attack the animal). This is amazingly pragmatic behaviour, because escaping too early is a totally unnecessary waste of energy, whilst escaping too late means death. The manifestation of a fixed action chain – noticing, curiosity changing into fear, physiological mobilisation to move and then insensibilisation in the end – if the object was classified as 'not dangerous', or conversely – recognising the enemy and flight - often requires more time than the vehicle needs to travel the distance to the 'victim'. In addition, the delay of the moment of starting flight in the proper direction (to the side of the line along which the vehicle travels) is impacted by the type of stimuli – they do not belong to the group of instinctive triggers of life-saving action. Moreover, the vehicle motion itself is in principle different from that of natural terrestrial enemies. It approaches with steady and high speed, whilst predators traverse the large distance from potential prey in steps – at first this is marching, then gradual, with stops, approaching using natural cover, and only then, after reducing the distance to the minimum (the attack distance is characteristic for a given predator species), reaching maximum speed. The potential prey, which noticed the aggressor early enough, has time for observation, making the decision to flee at the optimum moment – before the aggressor reaches its full speed. In short – at the same distance, the danger from of another animal increases much more slowly than in the case of a high-speed mechanised vehicle. This is the main cause of collision of animals with high-speed cars and trains but never with cyclists, horse-carts, or even farming tractors. In other words: a vehicle travels a considerable distance in such a short time that the nervous system of the 'victimised' animal does not keep up with giving subsequent orders: 'it's far away: observe', 'recognise', 'run away!'. In such a situation, the last instinctive attempt at saving its own life can be made (the classic behaviour of 'a rat in the corner'): when there is not time for anything else, the 'victim' takes the challenge and is determined to defend its life: the bison or the moose attacks the approaching locomotive or car head on.

2.3. The principle of operation of the dummy triggering animals' flight reflex

After taking into consideration the above-described behaviour of wild animals, the original prototype of the 'sign stimuli chain' dummy was developed in DNF RIF and recorded on a CD. Its sole task is a 'prevenient warning', that is, motivating herbivorous animals and predators to leave their current location a few tens of seconds earlier, before the real danger comes.

Three slightly differing variants of the 'sign stimuli chain' were developed. Each variant is composed of a string, at least one minute long, of natural warning-alarming-informing sound signals taken from the natural world, enriched with several 'supernormal' stimuli. Their configuration in terms of type, duration, and internal logic is in line with the sequence of warning sounds accompanying the growing danger, acts of intra-species aggression, hunting action of predators, as well as the death of animals of various species. The duration of each sequence is compatible with the time of occurrence of subsequent psychophysical reactions of the scared individuals. When developing the dummy, we did not at any time purposefully provoke, torment, or kill any animal.

The knowledge of the acoustic stimuli used in the dummy is fixed in the genetic base of birds and mammals (deer, wild boar, hares, as well as small and large carnivores). Its effective operation does not require the process of superficial sensibilisation (training) of the animals, which would be impossible anyway. The acoustic stimuli provoke the production of warning cries by 'real' animals, which makes the dummy even more believable.

The sequence of warning signals is produced directly following the broadcast of the dummy sounds and comes directly from the environment: ever-growing earth vibrations, sounds, and the sight of the approaching train. This is the tangible validation of the authenticity of threat – the proof of the existence of the 'enemy'. The enemy always comes shortly after the animal receives the sequence of warning signs. As the final verification of the appropriateness of the animals' psychophysical reactions, it rules out the possibility of decreased internal motivation to leave the track, that is, insensibilisation to 'artificial' sound stimuli.

The relatively short time of scaring the animals away, always concluding with the departure of the oppressor, that is the quickly departing train, and then the many times longer period of peace, should quickly lead to the creation of a ritual based on a conditioned reflex. The first earth vibrations sensed by "experienced" individuals and still faraway sounds of the locomotive can become further stimuli that trigger the flight reflex. At that time, we will at the same time deal with 'mnemotaxy' – moving away for any reason from a place previously remembered as dangerous and the so-called transferred stimulus: an ethologically neutral signal will take on sign stimulus qualities. This ritual, as the "social trigger" transferred to offspring and migrants, with time will become the local tradition of the animals that live near the high-speed train track.

During the time between the runs of trains, animals are not disturbed by the stimulation to run away. Thanks to this, animals can freely move all day and night all over their home acreage on both sides of the railway line.

The dummies are located only near the track-way. Wild animals can precisely locate the places permanently dangerous to them, but stationary. By keeping a certain distance from the source of warning signals (the flight distance and the attack distance) they can go about their lives without disturbance.

Thanks to the use of dummies and the rather densely located, spacious wildlife underpasses, located in natural land depressions and in river valleys, the particularly detrimental fencing of track-ways with impassable fences will no longer be necessary. The permanent fragmentation of home acreage and cutting off the migration routes of animals drastically limit their habitats and make the exchange of genetic material impossible, which in aggregate leads to the gradual disappearance of isolated populations and even of the entire species.

UOZ-1 animal deterrent for railway lines with high-speed train traffic

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Abstract. The article demonstrates the principles of functioning, structure and basic technical parameters of a device for deterring animals migrating across express railway lines. The novel device UOZ-1 is a result of cooperation of animal ethologists and designers of sophisticated electrical and electronic equipment. The presented device has been already tested in the field conditions and first conclusions are very encouraging.

Key words: rail way lines, animmals mortality, animal deterrent, acoustic signals

1. Introduction

The problem of wildlife being killed by quickly moving trains has existed since the beginnings of railway transport. This problem has recently escalated along with the improvements in the substructure of the track and the application of advanced solutions in the construction of runway subassemblies of cars and locomotives. All this has led to such a significant reduction of noise and vibrations produced by increasingly fast trains, that on modernised railway line sections, the train is first seen, and when and if it is heard, it already very close. However, it is not the lower noise level that is the source of danger. The problem here is the ever-increasing speed of trains.

Leveraging years of experience in constructing microchip automatic devices for PKP (Polish State Railways) as well as the outcome of discussions, consulting, and direct cooperation with representatives of nature conservation bodies, PKP, and scientists and practicing experts involved with wildlife behaviourism, the Implementation-Production Enterprise (Przedsiębiorstwo Wdrożeniowo-Produkcyjne) 'NEEL' Sp. z o. o. in Warsaw developed the UOZ-1 animal-dispersing apparatus, an innovative solution that is unique on the global scale. Experts from the Forestry Research Institute in Warsaw, the CBPBBK 'Kolprojekt' in Warsaw, and Bombardier Transportation (ZWUS) Polska Sp. z o. o. in Katowice participated in the work.

These devices are designed to prevent the migration of large mammals across railway lines just before the run of a train, minimising losses in the population of these animals caused by collision, while at the same time ensuring that they are not limited in their migrations into their pastures and calving areas. Acoustic signals were used for deterring, prepared by Prof. Dr. hab. Simona Kossak, the Head of the Department of Natural Forests in the Forestry Research Institute, a renowned specialist in zoopsychology.

2. Scope of application

The scope of application of UOZ-1 devices is for the protection of railway lines in permanent wildlife migration places. This can be point type protection, covering a section of several hundred meters long, or continuous (e.g. on the borders of nature reserves), operating in an area determined by the size of the border region.

3. System structure

3.1. Overview

The complete animal deterring system consists of UOZ-1 devices (dispersers) installed by the track-way at the place of fixed migration routes of wildlife, as well as of the communicating EZG-2102 diagnostic modules with modified software, installed in linear self-blocking SHL-12 containers manufactured by Bombardier Transportation (ZWUS) Polska Sp. z o.o. (they are their factory equipment) (Fig. 1).

Fig. 1. Depicts a UOZ-1 device installed by the track-way and the linear self-blocking container next to it

Each UOZ-1 device is an autonomous unit, equipped with an electric terminal strip, an electronics control unit, as well as a head with electro-acoustic transformers. The device is mounted to a solid concrete foundation in the substructure of the track (in line with traction poles) alternately, on both sides of the track-way. It is cylindrical in shape, approx. 110 cm in height, and approx. 30 cm in diameter. There are visible holes in the upper part of the device through which deterring sounds are broadcasted. The casing is grey and is made of weather-resistant, high impact-resistant epoxy-fibreglass composites.

The power to the devices is supplied through a cable from the linear self-blocking container with UPS emergency power for a minimum of 8 hours. All UOZ-1 devices, which are powered from one linear self-blocking container (SBL), are connected with one another and with the SBL container by an information bus based on wire communication. It enables the operation of devices to be synchronised, as well as for full auto-diagnostics with the option to control their work in the Service

Centre of the Local Railway Traffic Control Centre. Moreover, each UOZ-1 device is equipped with a set of sensors that react to theft and vandalism attempts (in such a case, all the UOZ devices from a given region broadcast an alarm sound and transmit information about the theft attempt to LCS).

Up to 32 UOZ-1 devices can work with each SHL-12 type linear self-blocking container (which guarantees full protection of the route along the entire length of the isolated section (length of up to 2300 meters) and can be used for protection of railway lines running through large forest areas or a nature reserve) (Fig. 2).

Fig. 2. UOZ-1 devices installed along the length of an area of more than 2 km bordering the nature reserve

If it is necessary to protect smaller areas, the number of dispersers can be adjusted to their size (e.g. four UOZ-1 devices allow for protection of a railway line section approx. 250-300 m in length). The assumed effective scope of impact of a single UOZ-1 device is more than 70 meters. The same (approx. 70 meters) distance is counted along the track-way axis between the subsequent dispersers. Installing UOZ-1 devices in this way makes it possible to maintain the continuity of the deterrence zone, without any acoustic ‘holes’, with maximum equalisation of the intensity of the acoustic field transmitted by dispersers.

3.2. Technical parameters

The UOZ-1 device is designed for operation in a moderate climate in open air in an ambient temperature ranging from -35^{0}C to +55^{0}C. Other technical parameteres are presented by the table 1.

Table 1. Technical parameters of the UOZ-1 device

Characteristic feature	Value
Weight of UOZ-1 device	~29 kg (290N) (composite casing)
Weight of foundation foot	~128 kg (1.28kN)
Protection degree	IP 65 (control electronics unit)
Power supply	230V 50Hz (separated voltage)
Test voltage	4000 V RMS
Maximum power input	80VA, cosφ>0.9
Protection	C class overcurrent installation switch
Maximum output power of amplifier	Pmax=50W
Standard transfer of digital data	RS-485
Transfer speed	300 Bd

3.3. Design of UOZ-1 device

The UOZ-1 device is made of the following components: casing, head with acoustic transformers, electronics control unit, temperature control system and anti-overvoltage and anti-disturbance protection elements.

The casing was made in the form of a covering tube, narrowing in the upper part, with an external diameter of approx. 30 cm, fitted to a concrete foundation foot and sticking out of it to the height of approx. 110 cm. Inside the protective tube, there is inner casing, containing a terminal strip to which power and data transmission cables are connected. Over the strip, a complete electronics control unit that controls the operation of the device, enclosed in a hermetic casing, was fastened. The upper part of the body was closed with a round head containing acoustic transformers.

The head with acoustic transformers is an integral part of the inner body. A set of two dynamic transformers has been used, together covering the acoustic range from 300 to 20,000Hz, with an effectiveness above 90dB and characterised by surround-sound transmission.

The electronics control unit is responsible for the logic of operation of the UOZ-1 device and is built based on a single-unit microprocessor of very low power consumption and high processing power.

Samples of deterring signals stored in the specialised memory system are the source of the acoustic signal controlling the power amplifier. The module moreover consists of:

- A feeder operating on 230V 50Hz voltage provides power for digital systems and a power supply to the heater and the acoustic power amplifier.
- The data transmission module was built using specialised RS-485 series transmission systems, providing proper voltage separation.
- The power amplifier module, built using a monolithic integrated circuit, has output power of 30-50 W, whilst maintaining full resistance to thermal stress and surge charge.

The temperature control system has to maintain the temperature of operation of electronic devices in the moisture condensation safe range during the winter exploitation period of the system.

Anti-overvoltage and anti-disturbance protection elements protect the operation of UOZ-1 devices from power energy and radioelectrical disturbances and overvoltage that occur in power supply and data transmission networks.

The terminal strip makes connecting the power supply and data transmission cables possible. Moreover, on the strip there is an installation overcurrent switch, an anti-overvoltage protector, and an anti-disturbance filter for data transmission lines.

3.4. Description of mechanical design

The UOZ-1 device is made of materials fully resistant to corrosion. The appearance of the UOZ-1 device is shown in Fig. 3. The device consists of an inner body (hot galvanised steel or epoxy-fibreglass composite) as well as a cylindrical outer shell (epoxy-fibreglass composite). The inner body and outer casing are tubular in shape. The outer casing is fastened to the body with special (anti-theft) bolts. The lower part of the body has a base plate with assembly holes and staffing boxes, whilst at the top there is a head with electroacoustic transformers. On the side of the inner body there are two rectangular inspection holes, making access to the apparatus installed inside possible. The openings are covered with covers fitted with rubber gaskets.

Fig. 3. The appearance of the UOZ-1 device

On the rim of the outer casing of the UOZ-1, there are a number of holes that make u hindered broadcasting of warning sounds from the electroacoustic transformer possible. The space between the outer casing and inner body creates an area of thermal circulation of air, effectively protecting the electronics unit inside the body from overheating. The material from which the casing was made guarantees its durability for a period of 20 years.

3.5. System autodiagnostics

Each UOZ-1 device was fitted with an autodiagnostics system, enabling remote detection and localisation of all malfunctions (meaning from the level of the Local Control Center and linear self-blocking container). The preciseness of localisation of malfunctions from the level of LCS is limited to determining the localisation of the container and the general type of defect. Detailed information of the place and type of damage is shown on an LCD display of the diagnostics module in the linear self-blocking container.

3.6. Anti-theft protection

The UOZ-1 device is fitted with an anti-theft protection system, reacting to attempts to disassemble or destroy the casing. The protection activates shortly after assembling and closing the outer casing. If a theft or break-in attempt is detected, all the devices belonging to one deterring point emit a very loud acoustic alarm signal (police sirens, etc.) for 90 seconds and a report of the break-in is immediately sent via the communication system to the container and further along to the Local Railway Traffic Control Center.

3.7. UOZ-1 communication system

UOZ-1 devices belonging to one deterring point are linked with a wire communication system with one another and with the cooperating linear self-blocking SHL-12container. A two-channel two-directional system of series transmission was adopted, a 'master-slaves' type based on the standard RS-485. An EZG-2102 diagnostics module was selected as the master, being the standard equipment of the SBL container, equipped with an LCD display unit, RS-485 transmission output, and linking with linear self-blocking automatics. ‘Slave’ functions are played by controllers of UOZ devices.

Modified software of the diagnostics module enables the execution of all its existing functions as well as functions controlling a UOZ system in a given area. The planned transmission speed in the communication network is relatively low and amounts to 300 Bd. Such a slow transmission made it possible to achieve very high resistance to frequently-occurring electromagnetic and radio-electric disturbance.

4. Principle of operation

UOZ-1 devices are automatically started shortly before the run of a train, based on signals received from linear self-blocking automatics circuits. In practice, the principle is that all the UOZ devices connected to the given container are sent information about trains freeing or occupying the subsequent isolated sections. This enables maps of the area of the railway line where changes in the current movement of trains are tracked to be created in the memory of computers controlling the operation of UOZ-1 devices. For calculation of the time of arrival of a train to the area of the dispersers, an intelligent algorithm that takes the topology of the line section and the analysis of the speed of trains into account was utilised. For each train, the time until the arrival of the train is calculated, and based on this the procedure of deterring is started at the appropriate time in individual UOZ-1 devices. The complete deterring sequence lasts from 50 to 180 seconds and its duration is adjusted to the traffic situation on the railway line (the train slows down, speeds up, or stops at a station).

The initiation of the deterring procedure consists in all of the UOZ-1 device stations belonging to one point emitting acoustic signals. Moreover, it is assumed that during the deterring procedure, which lasts from 1 to 3 minutes, the duration of individual signals making up the complete sequence will change in order to eliminate the effect of animals’ insensibilisation to warning signals of one type that are repeated and come from the same area. Moreover, several different sequences are utilised. The decision to start and select a sequence is made by all UOZ-1 devices located in a given group of stations. One of them will do it the fastest and it imposes its decision on the others. The changes are synchronised in real time, using the previously described communication system. The selection of the sequence can also be controlled by a calendar or a timer. The use of certain sequences can be limited to a particular time of day or season of the year.

The deterring procedure ends after playing through completely. There might be cases in which the deterring sequence does not end directly before the arrival of a train and its final part is played during the run of the train through the area of deterrence. In accordance with the assumptions made, this is correct operation.

5. Conclusions

As compared to the limitation of access to railway line track-way of increased or high-train speeds generally used in western Europe, through their fencing with a tall fence as well as the construction of engineering structures in the form of wildlife under- and overpasses, the proposed form of wildlife protection has two crucial advantages. The first one is the complete lack of limitation of the free migration of animals in their pastures and calving areas; the second, the incomparably lower cost of the investment. The cost of building one wildlife overpass corresponds to the cost of protecting a railway line section of from 200 to 500 km in length using UOZ-1 devices. Such a large discrepancy in the length of railway lines results from the varying density of forest and forest-meadow areas. The proposed solution meets the requirements of the European Union in the scope of environmental effect of transportation investments.

6. Recapitulation

The first lot of UOZ-1 devices was installed on the railway line section E20 between Mińsk Mazowiecki and Siedlce, where in the conditions of real exploitation, the technical solutions as well as method of emission and the arsenal of deterring stimuli were verified. A total of 62 UOZ-1 devices were installed there, of which 32 were located at eight points of wildlife migration and the other 30 limit the access of animals to the railway line at its 2 km long section bordering the "Stawy Broszkowskie" nature reserve near Siedlce. Photo 4 shows UOZ-1 devices installed at the Woźbin deterring point near the Mrozy railway station. Four UOZ-1 devices provide protection there of the railway line along a length of approx. 300 meters.

Fig. 4. UOZ-1 devices installed at the Woźbin deterring point near the Mrozy railway station on the railway line section E20 between Mińsk Mazowiecki and Siedlce bordering the 'Stawy Broszkowskie' nature reserve near Siedlce

More than two years of exploitation of the devices has shown their high reliability and resistance to theft and damage. The composite design of the casing has proven very resistant to attempts to devastate, not yielding to such actions as an attempt to pull it off using a chain tied to a car or a tractor. A key role was undoubtedly played here by the effective anti-theft system, in which a very loud alarm signal emitted at the same time from the whole group of devices was very discouraging to the perpetrators, and the report of the break-in sent to the Local Control Centre made the immediate intervention of the maintenance service staff or officers of the Railway Security Service possible.

The cycle of testing the effectiveness of UOZ-1 devices was realised by the Forestry Research Institute in the winter of 2004/2005, when based on observations of traces of animals on snow, we could reliably determine their reaction to the stimuli applied. The final report showed that both wild herbivores(red deer, roe deer, wild boar, and hare), as well as carnivores (foxes) and birds (jays) correctly read the meaning of the applied deterring signals and while not giving up staying near the railway line section with UOZ-1 devices installed.

Management, maintenance and monitoring of wildlife passages in France

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Abstract. This work presents results of over 40-years experience in functioning of animal passages in France. Several types of basic monitoring equipment, permitting to track usage of passages, were characterized and some examples illustrating their effectiveness discussed. The prerequisite condition of efficient functioning of the whole system aimed at the protection of biodiversity is the proper management of passages and monitoring equipment.

Key words: highway, motorway, wildlife passages, camera trapping, video surveillance, management, France

1. Introduction

Wild fauna passages, overpasses as underpasses, would they be dedicated to big or small animals, do exist in France since almost forty years. Their efficiency is usually controlled with the help of various footprint recording systems (sand beds, etc.). These devices give indications about the level of use by various animals, gut do not deliver any information about fauna's behaviour while approaching the passage or while crossing the road using the passage. This is why systems as photographic infra red filming or video monitoring offer interesting abilities for studying such behaviours.

This paper shows results obtained with different techniques and materials (cameras equipped with light amplifying devices, thermic cameras) and shortly describe the various photo or video monitoring systems, infra red or radar activated, in use in etc. It will then explain and comment some of the acquired knowledge with the help of these instruments. It will then explain and comment some of the acquired knowledge with the help of these instruments.

2. Camera trapping and video surveillance

A camera trap is a system in which the pressure exerted by an animal on a switch (generally a wooden board hidden under vegetation) triggers a camera (which may be disposable). The camera may also be triggered when an animal takes bait.

Infrared and radar photo-surveillance systems may be made using equipment available from photographers or alarm specialists, or may be purchased in complete kit form (Jama Electronique, Trail Master 1500). A radar system may be used instead of the infrared barrier. Infrared and radar photo-surveillance systems may be used for photographing small subjects (amphibians and micro-mammals) or other creatures such as lynx and bats.

Current digital cameras offer a number of advantages – they are silent, can store up to 100 images (3 times as many as conventional cameras) and may be left for 5 to 6 days (the limiting factor being the battery). The use of radio waves eliminates the need for cables running between the sensor and the camera.

The cost of a Trail Master system in a metal case with a radar detector, electronic counter and auto-focus camera with built-in flash is approx. €800, excl. VAT. Installation time is 2 hours.

'Light' video surveillance: a simple, compact system requiring no triggering sensor may be put together using a video-surveillance camera with original watertight case combined with a 12 V battery, a VCR recording 12 hours on a three-hour VHS cassette and an infrared lamp. The continual operation of this system means that the operator must view the entire cassette even if no animals have used the passage. This disadvantage is counterbalanced by the easy installation and high degree of reliability. The system ensures that all events are filmed.

The cost of such a system, comprising an infrared lamp mounted under a camera on a tripod, with a battery and VCR in a watertight container on the ground is approx. €5,000, excl. VAT. The system can operate for 12 hours.

'Heavy' video surveillance: Figure 1 shows the arrangement for a system comprising a video-surveillance camera, one or two infrared lamps (200W to 450W), one or more infrared barriers, a VCR (VHS), 4 standard batteries + a timer, a detection counter, etc. This system, which may be set up using standard equipment, costs some €12,000, excl. VAT.

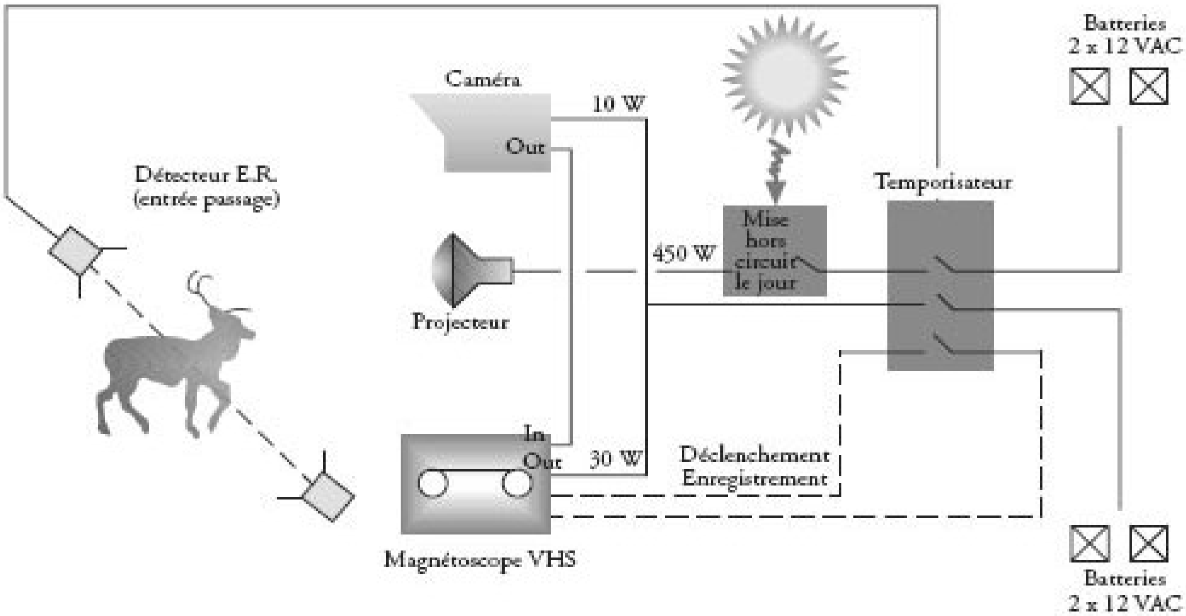


Fig. 1. Arrangement for video-surveillance system (Source: J. Carsignol/Sétra; CETE de l'Est; 1988)

Laser cameras: in the future, this type of equipment could render video surveillance simpler by eliminating the need for the infrared lamp (energy savings, lower cost and fewer connections). The civilian market offers laser cameras whose performance could be enhanced through the provision of additional light.

Thermal cameras: while this type of equipment provides images of exceptional quality, it is still prohibitively expensive (€30,500, excl. VAT), despite a 50% drop in prices over the past few years. Thermal cameras are much less bulky than they were, and now feature built-in batteries (2 kg for a high-resolution portable camera). Images may be recorded using PAL video outputs. Despite their remarkable performance – such systems are capable of detecting a roe-deer a kilometre away with a wide-field lens covering a large expanse of terrain – the cost factor means that they are not yet a viable alternative to the conventional infrared systems.

Photography and video surveillance may be used for different applications depending on the studies to be carried out and on the information to be gathered (Table 1).

Table 1. Applications of photography and video surveillance

Types of use	Information
Experimentation	• Test various types and sizes of passage, passage components (parapet and light well), floor and wall coating, etc. • Analyse the effectiveness of reflective systems, attractants, etc. • Evaluate the influence of vegetation at the entry or on the platform: does the density of the vegetation discourage use of the passage (implications in terms of management)?
Behavioural studies	• Observe moving animals discreetly: analysis of the approach and crossing conditions, study of the exploratory behaviour of certain species or individuals, and study of habituation
Pedagogical documents and promotion of know-how	• Release details of successful experiments, and transmit information and know-how.
EP, APS and APA/DP operational studies	• Determine the precise locations of passages during studies, • Listing of species on identified runs.
Effectiveness monitoring	• Know levels of use by wild fauna and other users. • Check (mixed or non-specialist) passages where track traps cannot be set up (coated or hydraulic passages). • Analyse the reasons why animals refuse to use the passage although using the vicinity regularly.
Counting and identification	• Estimate the biological significance of the use of passages and runs. • Evaluate competition within and between species (e.g. role of dominant male).

3. Results and lessons

3.1. Examples

Example of passage at St Alban d'Hurtières (specific lower passage, Vallée de la Maurienne)

Located on A43/SFTRF (Vallée de la Maurienne): fauna dedicated lower passage (20 m wide with a single span). This passage, which is on a regional deer route, is also used by small local fauna from the mountain and the Vallée de l'Arc (Table 2).

Table 2. Use pattern for passage at St Alban d'Hurtières since 1997

Animals	%
marten species	6
roe-deer	34
stag	6
wild boar	24
fox	18
badger	12

(Source: Fédération Départementale des chasseurs de Savoie, 2002)

Example of passage at La Rougellerie (specific (fauna dedicated) lower passage, Sologne)

Located on A71/COFIROUTE (Sologne): passage at La Rougellerie; 6 m long and 3 m high. (Source: M. Galet; COFIROUTE).

Photographic monitoring of the passage at La Rougellerie on the A 71 recorded 175 events over a 16-month period (i.e. one event every three to four days), thus demonstrating the usefulness of the lower passages for small fauna as a whole (Table 3).

Table 3. A71/COFIROUTE (Loir-et-Cher): animals crossing the La Rougellerie passage

Species concerned	Crossings recorded
stone marten	58
pheasant	37
roe-deer	30
hedgehog	18
fox	15
wood pigeon	4
wild cat	4
hare	2
coypu	3
red squirrel	2
+ walkers, hunters and hunting dogs	1

Source: V. Vignon and P. Orabi/OGE/COFIROUTE (2000)

Example of the E 44 (Trèves-Luxembourg, two specific upper passages)

In Luxembourg, on the E 44 motorway (Trèves, Luxembourg), camera-trap monitoring of fauna at two upper passages (12 m wide) recorded 575 events concerning 9 species of mammals (Table 4).

Table 4. E44 motorway (Treves – Luxembourg): breakdown of the species using two green eco-bridges between 23 September 2003 and 9 March 2004 (Source: Public Works Ministry, Grand Duchy of Luxembourg 2004)

Species	%
wild boar	55.8
roe-deer	24.9
polecat	0.2
marten cat	0.2
hare	2.6
badger	0.3
wild cat	1.2
cat	5.7
fox	9.1

3.2. Lessons

Infrared video-surveillance studies conducted in Switzerland (Sempach ornithological station) on the use of 22 fauna passages between 8 m and 200 m in width provided new insights into passage construction requirements.

The regression curve obtained using data concerning use by various species (roe-deer, boar, deer, fox, hare, badger, marten and stone marten) is asymptotic (see Fig. 2).

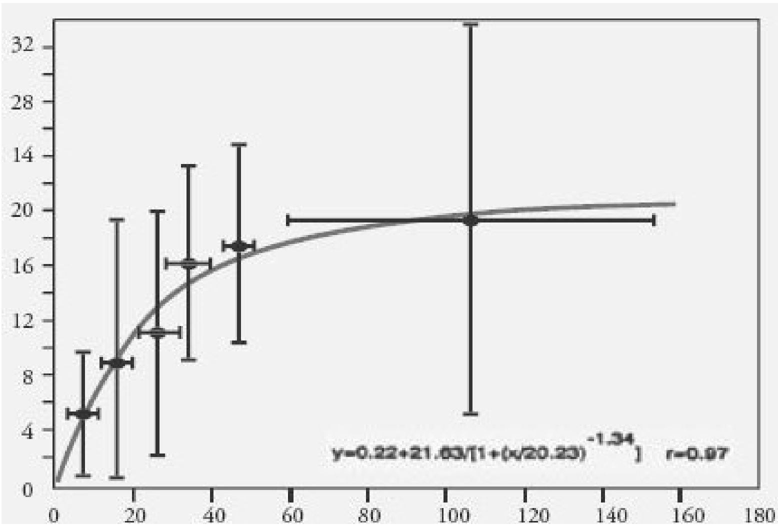
This illustration shows that:

- up to 20 m in width, the curve is characterised by strong linear growth, corresponding to a reduction and considerable variance in the cost-effectiveness ratio;
- between 20 m and 50 m in width, slowing growth corresponds to the stabilisation of the cost-effectiveness ratio;
- beyond 50 m in width, the curve flattens out gradually as far as 100 m, approx.: the additional width over and above 50 m makes only a very slight contribution to effectiveness, while the cost-effectiveness ratio rises considerably.

The results of this study show that:

- passages of less than 20 m in width would be of limited effectiveness, and are deemed undersized by the observers at the Swiss ornithological station. Fauna generally rush through (or even avoid) such passages, whereas they find the wider versions less stressful, and even spend time in them;
- passages of between 20 m and 50 m in width prove sufficiently effective for hoofed animals;
- beyond 50 m in length, the curve rises more slowly, the number of additional crossings becomes smaller and the additional effectiveness gained is due to use by particularly demanding species;
- the optimal observation frequency (i.e. the number of animals encountered per night, which is an indicator of the exchange rate) occurs between 80 m and 100 m. This large widths recreate multifunctional links between population nuclei.

Number of wild animals per night



Width in metres

Fig. 2. Average number of animals observed by class and width of passage. (Source: Pfister *et al.* 1997)

More detailed observations using video surveillance cast light on animal behaviour in the vicinity of passages and in/on passages, and on the factors responsible for such behaviour or reactions.

4. Managing passages and other facilities

4.1. Principles

Management, which is a vital component, is often neglected, despite the fact that feedback has taught us that creating a facility is not enough. Facilities must be monitored to ensure that they are used only for the intended purposes, and must be maintained regularly if they are to remain effective.

Facilities for small fauna – and particularly for amphibians – are often managed by voluntary workers, which means uncertainty over the long term. Certain installations encountering special difficulties due to their location or to climatic conditions require regular, sometimes-heavy maintenance (use of mechanical equipment to clear entries, high-pressure hosing to clear conduits and installation of deflectors) to keep the passages from being obstructed by earth. Highly-motivated local naturalists may provide project owners with advice, but will not always be able to manage the facilities subsequently, even if paid.

There are various ways of enhancing the effectiveness of facilities:

- Management issues need to be taken on board in the initial phases of a project, and addressing such issues successfully is one of the keys to ensuring the effectiveness of small-fauna facilities. Decisions taken at the works phase can have a profound effect on the operation of facilities. Sites should be visited on a weekly basis during the implementation phase, and site workers should, ideally, be made aware of the issues.
- Wherever possible, construction work should be conducted without damage to vegetation. Measures (acquisition or management agreements) should be taken to ensure that the land is used appropriately and that fauna can move freely.
- Later, during the operations phase, it is essential to conduct weekly visits during the first year, and one or two visits per month subsequently. Overall coherence must be ensured.
- The effectiveness of the facilities also depends on: (*i*) regular surveillance of the facilities and their vicinity in order to detect any environmental modifications; (*ii*) maintenance of the facilities and their vicinity; (*iii*) monitoring of activity regulation and of land use near the passage.
- Management agreements (see below) must be arranged.

4.2. Management agreements

Although they are becoming more common for large-fauna passages, management agreements are not often initiated in respect of passages built for small fauna. Such agreements – which serve to optimise surveillance, maintenance and inspection – name a manager and define the roles of the various partners. They should be initiated very early on, since it is difficult to appoint a manager once a facility has been completed.

The management agreement must be signed by the infrastructure operator (State, Department or Concessionary), who maintains responsibility for the facilities. That party either contributes to management costs or provides the appointed manager with the requisite resources.

A management agreement specifies:

- the purpose of the facility, and the use to which it is to be put;
- the technical characteristics of the facility and the components planned for the vicinity (drainage, dedicated approach area, vegetation and track traps);
- the special protective measures: game reserve, nature reserve or listed wooded area (such regulatory constraints and easements make for better protection of the vicinity, and facilitate the work of the managers);
- the written agreements between the project owner, the manager and the adjacent owners; such agreements may, in effect, constitute easements (free or paid waiving of hunting rights to facilitate the manager's work; commitments regarding fencing and use of the land for agriculture or forestry, etc.);
- the conditions governing acceptance of the facilities, it being clearly stated that said conditions concern only the management of the land and of the components in the vicinity of the passage (the passage itself remaining the property of the project owner, who is responsible for its maintenance);
- the conditions governing effectiveness monitoring (one visit weekly the first year, and two visits monthly subsequently). Concerning surveillance, two or three visits annually suffice to enable maintenance or police operations to be triggered where necessary (visit reports should be produced);
- the nature of the maintenance;
- the cost of management.

4.3. Potential managers

In France, the main potential managers are:

- Municipalities;
- The national hunting and wildlife office or ONCFS (Office national de la chasse et de la faune sauvage) and the fisheries council or CSP (Conseil supérieur de la pêche);
- Nature-conservation associations and organisations;
- Département hunters' federations, and fisheries and fish-farming federations.

5. Conclusion

To conclude briefly, management, maintenance and monitoring of wild fauna passages remain the key to obtain new data and to improve our knowledge in this field, and management and maintenance actions are necessary to guarantee the basic functioning of such facilities, which are one of the main keys for maintaining biodiversity.

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Use of wildlife crossing structures by medium sized and large mammals

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Abstract. The use of 20 wildlife overpasses (green bridges) and 23 underpasses (10 viaducts, 6 river crossings or culverts, 7 wildlife underpasses) by medium sized and large mammals as well as about two dozens of small mammal underpasses and several non-wildlife passages have been studied during winter and spring 2004 and 2005. The study was carried out at three motorways, three highways and three state main roads in southern Germany (Baden-Württemberg) and at one motorway in northern Germany (Mecklenburg-Vorpommern). Amongst the observed animals were red deer, fallow deer, roe deer, wild boar, European hare, red fox, racoon dog, badger, beech marten (as well as pine marten and polecat) and otter. The results document that green bridges and larger viaducts were used most intensively (by about 85% of all animals recorded). The use of the smaller river crossings, culverts and small mammal underpasses was, with only 15% of all recorded animals, low. Fox, hare and roe deer accounted for about 72% (videos) and 89% (tracks) of passage crossings by animals. Using different multiple regression analyses eight of some 28 independent variables proved to be of significant influence in some cases on the use of green bridges by the species investigated: width showed a positive, length and age of the bridges as well as the amount of wooded area on the bridges, noise, human activities, number of roads leading to the bridges and buildings in their nearby neighbourhood a negative relation. The barrier effect of the roads studied seems to be mitigated sufficiently by the crossing structures although crossing rates are substantially lower than before road construction.

Key words: motorways, highways, mammals, use of wildlife passages, Baden-Württemberg, Mecklenburg-Vorpommern

1. Introduction

Over the last two to three decades, in Europe most governmental nature conservation and traffic agencies as well as NGO's have become increasingly aware of the effects that roads have on wildlife (Bright 1993; Bennet 1997; Trombulak & Fissel 2000; Forman *et al.* 2002; Trocmé *et al.* 2003). Significant advances in understanding the impacts and developing solutions have led to a large amount of handbooks in order to mitigate the effects (SETRA 1993; Hlavač & Andel 2002; Iuell *et al.* 2003; Carsignol *et al.* 2005; Iuell 2005; FGSV in prep., etc.).

Meanwhile most European countries have realized crossing structures for wildlife at least with larger motor or high ways. But there are only a view studies assessing the effectiveness of the different types of these wildlife passages (Clevenger & Waltho 2005; Hardy *et al.* 2003) or the results are spurious because of their failure to address masking effects of confounding variables (site, size, design, age, activity, traffic noise, habituation of animals etc.). Furthermore most studies focused only on specific over- or underpasses than to compare different types of crossing structures.

During the last three years an investigation was carried out in Germany to evaluate the use of different types of wildlife and non-wildlife over- and underpasses by medium sized and large mammals (three additional studies occupied badger, dormice and bats; Herrmann 2006; Müller-Stieß 2006; Bach & Müller-Stieß 2006; for the complete report see Georgii *et al.* 2006). The study was financed by the Federal Ministry of Transport, Building and Urban Affairs as well as the transport agencies of some regional governments. The results show, that only green bridges and viaducts were used intensively. In the case of green bridges the influence of some variables (e.g. noise, human activity, vegetation structure) proved to be of statistical significance.

2. Study area and methods

One part of the study was carried out in Baden-Württemberg (southern Germany) at three motor ways (A8, A96, A98), three high ways (B31neu, B33neu, B464) and three state main roads (L113neu, L1100, L1207). The other study area was a section of the A20 motor way in Mecklenburg-Vorpommern (northern Germany). Both study areas differ in landscape (Fig. 1), the former showing mainly hilly terrain with a small scale mixture of meadows, fields and forests the latter mainly consisting of large scale farm land with only scarce forests. Main medium-sized to large mammals in both parts are roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), European hare (*Lepus europaeus*), red fox (*Vulpes vulpes*), badger (*Meles meles*), especially beech marten (*Martes foina*) but also pine marten (*Martes martes*) and polecat (*Mustela putorius*), racoon dog (*Nyctereutes procyonoides*), in the A20 area also red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and the otter (*Lutra lutra*). Otter, polecat and pine marten are threatened species (according to the red data books of Germany or the FFH-categories).

The mean road density in Baden-Württemberg is nearly twice as high (0.78 km/km^2) than in Mecklenburg-Vorpommern (0.43 km/km^2). The traffic volume of the ten roads varies from only about 1.700 to more than 63.000 vehicles per 24h-day. All motor and high ways are fenced, but not the state main roads. The study involved 20 green bridges, 10 viaducts, 7 wildlife underpasses for large animals, some 20 underpasses for small mammals, 6 river crossings and culverts (Fig. 2 and Table 1) as well as non-wildlife over- and underpasses (for use by farmers, foresters or public traffic, n=38). Their age ranges from three to sixteen years according to the age of the roads. Vegetation on the green bridges or below the viaducts varies from nearly pure meadow, open parts mixed with shrubs to completely wooded. Most crossing structures involve gravel (in some cases also paved) roads which were used by humans.

Fig. 1. Air photos showing typical landscape examples from Baden-Württemberg (above) and Mecklenburg-Vorpommern (below). Google Earth

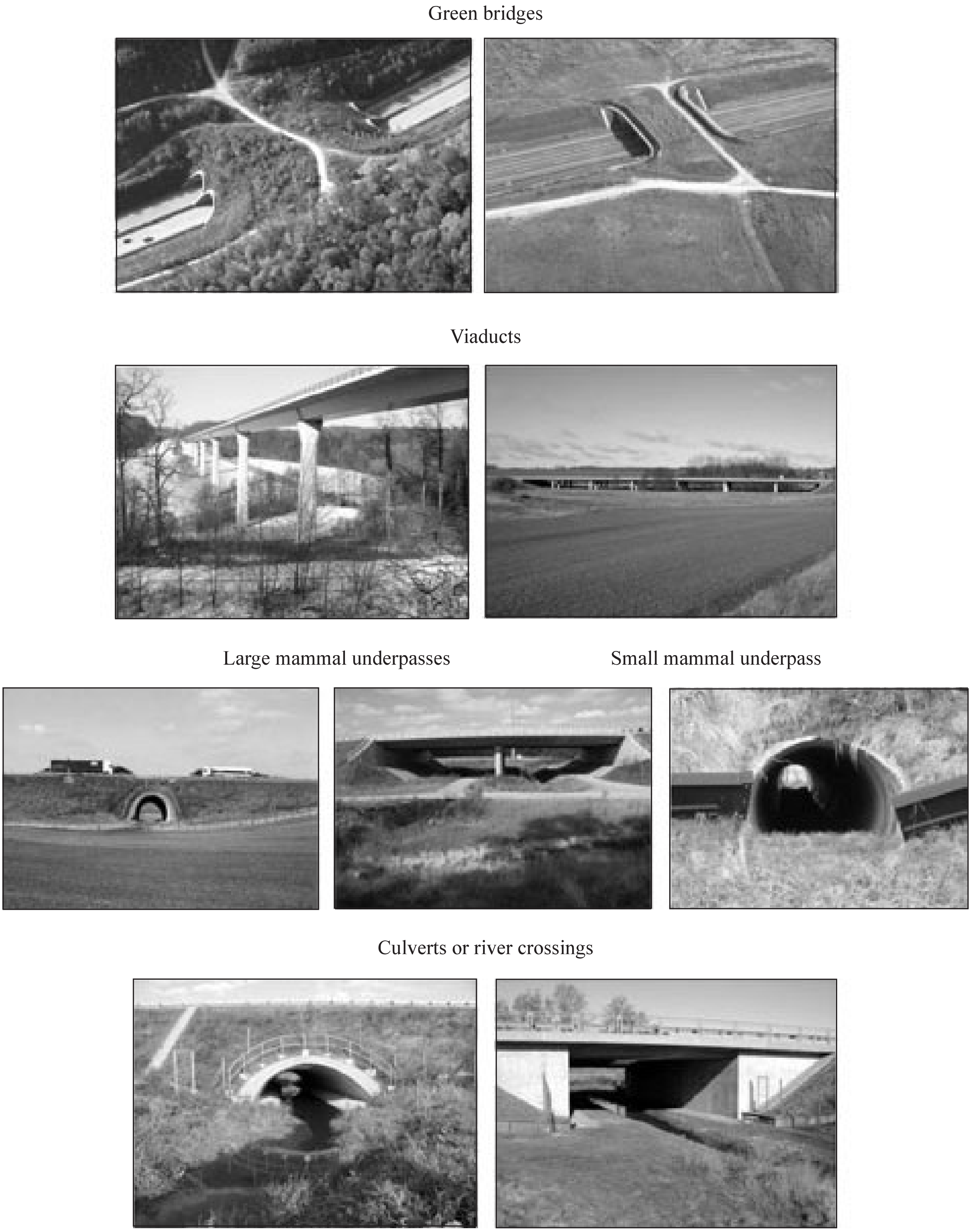

Fig. 2. Examples of the different crossing structures investigated

Table 1. The main wildlife passages involved in the study; further crossing structures were non-wildlife passages for use by farmers, foresters, recreationists or even public traffic (joint-use passages); parantheses show abbreviations used in figures

crossing structures	quantity	width[1] (meters)	height (meters)	length (meters)	vegetation
green bridges (gb)	20	23-201	-	23-120	pure meadow, totally wood, mixed
viaducts (vd)	10	58-440	5.5-55	*	pure ground, mainly meadow, partially wood
large mammal underpasses (lu)	7	6-44	2.4-8	45-95	pure ground, partially meadow
culverts[2] (cu)	6	3.2-15	1.8-4.3	35-68	mainly pure ground
small mammal underpasses[2] (su)	20	0.8-2,0	0.8-2.0	35-55	pure ground

Explanations: [1]from the perspective of the animals (between fences or walls); [2]circular and box shaped; *equal to road with

We monitored the passage of animals using infrared video cameras recording at least four nights during March or April 2004 and 2005 (on green bridges and at wildlife underpasses) and track counts during at least five days from December to February in the same years (at all crossing structures). In some cases also sand beds and digital trail cameras (Cuddeback® , DeerCam®) were installed. We defined the intensity of passage use as the number of animals from each species seen on the videos per night or the amount of tracks in snow per 24h-day. Data on the observed species in the neighbourhood of the roads there sampled by interviewing hunters, foresters or other people experienced with the local situation, because field estimation of population densities would have been to time consuming and not financeable. Intensity of road side use by the species was recorded by monitoring tracks along transects (distance to road verge or fences about ten meters).

Using multiple regression analysis (Zar 1999) we investigated the influence of 28 (roe deer: 29) independent variables on the species' use of the 20 green bridges (variables shown in Table 1 and 2 and additionally e.g. location of passages, distance to canopy etc.). For the other crossing structures their number were too small or the use by animals too less for statistical treatment. We used models including the whole group of mammals as well as models regarding only roe deer, fox and hare (the three most frequent species). Differences between mean values were tested by simple or paired t-test (Zar 1999), aspects of use of vegetation structure by compositional analysis (Aebischer *et al.* 1993). In some cases the regression results explain differences in the intensity of species' passage with relatively high R2-values (0.56 to 0.86).

Data were collected in 2004 and 2005, for some green bridges there are also data available from 1994 and 1995.

3. Results

3.1. Species

Summarizing the 117 video nights and 43 tracking days we recorded a total of 1441 and 2126 animals, respectively, crossing the different types of passages. As Figure 3 shows, hare, fox and roe deer accounted for 72% (videos) and 89% (tracks) of the recorded animals. Next frequent species were badger, martens (pine and beech marten, species not distinguished) and wild boar. Red deer, fallow deer, otter and racoon dog made up only 2-3% of all species recorded. The category 'others' comprises mainly domestic cats.

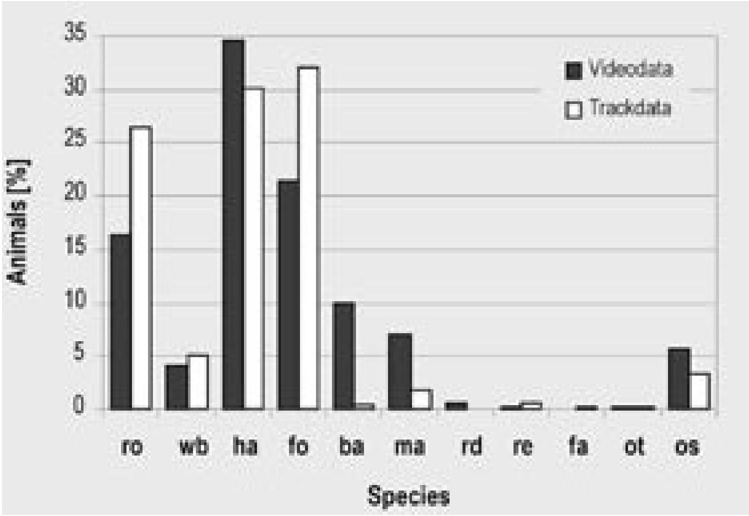

Fig. 3. Roe deer (ro), wild boar (wb), hares (ha), fox (fo), badger (ba), martens (ma), racoon dog (rd), red deer (re), fallow deer (fa), otter (ot) and other mammals (os) as percentage of all animals observed (re, fa, ot live only in the A20 area)

3.2. Use of different crossing structures

When analysing the video data and the track data, both reveal green bridges and viaducts as the crossing structures most intensively used by the species studied (Fig. 4), despite the fact that viaducts are build for other purposes. Unexpected was the only moderate use of large mammal underpasses by ungulates although they have been build especially for these species. On the other hand use of all underpasses showed that predators (fox, badger, martens, otters) and in some cases also hares had no problems to use even the smaller ones. Whereas the ungulates used the green bridges mainly for crossing the road, hare or badger and fox use them as feeding habitat also or have been observed leaving scent or urine marks.

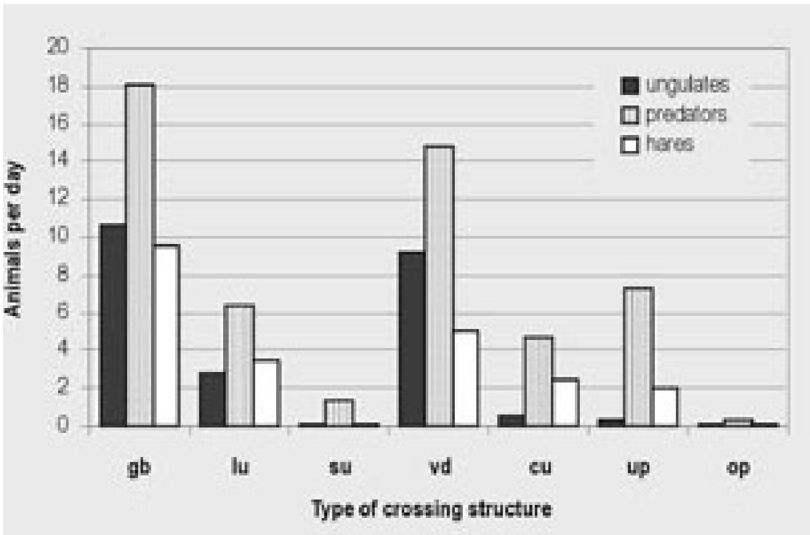

Fig. 4. Use of the seven types of crossing structures by the species investigated; species grouped into ungulates, predators and hares; gb – green bridges, lu – large mammal underpasses, su – small mammal underpasses, vd – viaducts, cu – culverts, up – non-wildlife underpasses, op – non-wildlife overpasses

3.3. Influence of constructional and environmental attributes of green bridges on their use by mammals

In the case of green bridges the sample was large enough for treatment with statistical methods. Of the 28 independent variables tested eight proved to be of influence on the use of this kind of overpass in some cases (Table 2).

3.3.1. Age

With the video data the multiple regression revealed age of the green bridge to be a significant factor explaining green bridge use by all observed mammal species ($p=0.016$): the younger the buildings the less intensive was the frequentation by the animals. This was confirmed by the fox data alone also ($p=0.004$). On the other hand there exists a strong correlation between the age and the amount of wooded area on the green bridges ($r=0.802$): the older the bridges the more of the surface is covered with wood. The regression analysis showed, that this is of influence on the age-dependend use of the overpasses because a higher amount of wooded area results in less animals crossing the green bridges ($p<0.001$).

This can dampen the effect of age so far that there is no difference recognizable between younger and older performance data. This became obvious when we compared the actual data with those from 1994/95 of the same seven green bridges (Fig. 5). Notwithstanding the ten year difference in the vegetation development there is a highly significant correlation between the number of species' passages in 1994/95 and 2004/05 ($r=0.905$, $p<0.005$).

Table 2. Eight out of some 28 independent variables which proved to be significant factors explaining the green bridge use by medium-sized and larger mammals (using multiple regression analysis); all other variables failed or nearly failed to be of significance. Rank is based on sum of squares (relative importance) of this variable

Attribute	**Video data**			
	Beta	SE	P-value	Rank
all species	$R^2 = 0.56$			
gb_age[1]	-0.552	0.063	0.000	1
gb_wood[2]	-0.042	0.007	0.000	2
anth_use[3]	-0.579	0.233	0.038	3
roe deer	$R^2 = 0.76$			
road_numb[3]	-0.722	0.235	0.013	1
gb_length[4]	-0.040	0.014	0.020	2
build_envir[5]	-0.149	0.074	0.074	3
red fox	$R^2 = 0.65$			
gb_age[1]	-0.203	0.054	0.004	1
anth_use[3]	-0.804	0.301	0.023	2
Attribute	Track data			
	Beta	SE	P-value	Rank
all species	$R^2 = 0.86$			
build_envir[5]	-0.086	0.027	0.009	1
road_numb[6]	-0.449	0.147	0.012	2
gb_width[7]	0.007	0.002	0.015	3
gb_noise	-0.041	0.017	0.040	4

[1]date when build (1989, 1990, …); [2]amount of wooded area on green bridges (percent of whole surface); [3]number of people or cars per 24h-day in three categories (1, 2, 3); [4]from entrance to entrance; [5]number of buildings in the nearer environment of green bridges; [6]number of paved or unpaved roads on green bridges; [7]in meters between the fences; [8]dB(A) in the middle of green bridges

3.3.2. Vegetation and other structural features

Another influence of vegetation as well as other structures became apparent when we compared the use of the different structural features on the green bridges like wooded areas, meadows (or open parts, respectively), roads and the earth mounts at the outer edges. So, for example, the animals used the open parts of the green bridges more and the wooded areas less intensive than it would be expected from the percentage of area of this structures. Especially hares, badgers and foxes preferred to walk on the gravel roads. Compositional analysis to these data showed a clear ranking for the preference of the different structures (p=0.0073): open parts > gravel roads > wooded parts > earth mounts.

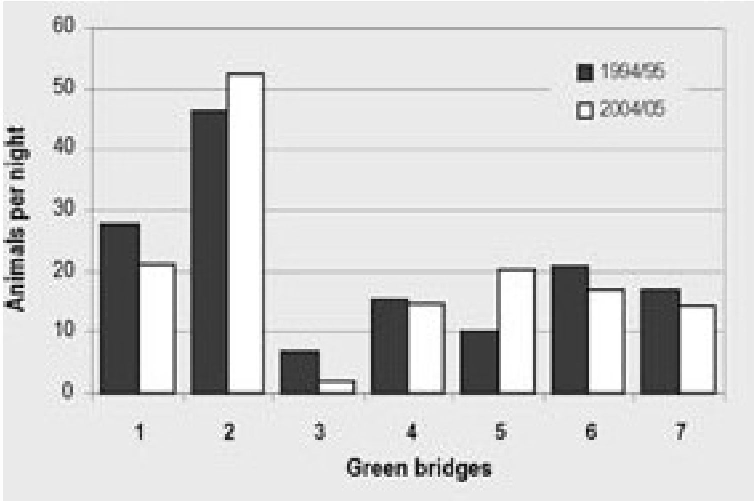

Fig. 5. Species' use of seven green bridges comparing video data recorded in 1994/95 and in 2004/05

3.3.3. Width

Pfister *et al.* (1997, 1999) were the first who showed that the intensity of use of green bridges by medium-sized and larger mammals increases according to the width of the buildings. In the actual investigation this could be confirmed with the multiple regression analysis using the track data for all species (p=0.015; but not with the video data). When using only the track data of roe deer it was interesting to see, that this species showed a significant negative reaction to the length of the green bridges as well (p=0.020).

For all other crossing structures there seems to be a relation between use intensity and width as well, but without statistical significance.

3.3.4. Traffic noise

Since long traffic noise is considered to be a factor making habitats near roads to be avoided by birds as well as mammals (Trocmé *et al.* 2003). But studies measuring this effect are scarce. In the present investigation we measured noise on the green bridges and at the road verges near by using hand-held noise meters (Integrating Impulse Sound Level Meter, Type 2226, Brüel & Kjaer, Denmark) with special emphasis on irregular noise bursts (e.g. extra noisy high-speed vehicles, trucks). Because of the noise lowering effect of earth walls or screens on the overpasses these traffic noise peaks were about 17 to 39 dB(A) lesser than at the road side (73-78 dB).

Applying multiple regression analysis to the track data of all species studied showed that less noisy green bridges were used significantly more intensively than more noisy ones (p=0.040). With the video data this relation was only nearly significant (p=0.070).

3.3.5. Human presence

Most of the investigated crossing structures (even the green bridges) are joint-use passages mainly with gravel but in some cases with smaller traffic roads also. Furthermore, in the nearby surroundings of most over- and underpasses there were additional roads as well as buildings like e.g. farm houses or barns. This enhances the presence of people at the crossing structures.

In the case of green bridges the multiple regression analysis with the video data of all species revealed that the recorded human activities on the bridges has a significant negative influence on their frequentation by wild animals (p=0.038). The same was true for the fox (p=0.023). On the over hand, when regarding the track data, the more indirect indices showed the same effect: The higher the number of roads leading to the green bridges or of buildings in their nearby neighbourhood the less was the use of the bridges by roe deer (p=0.013 and p=0.074, respectively) as well as by all species (p=0.012 and p=0.009).

3.4. Mitigation of the roads barrier effect by combinations of crossing structures

Estimating the mitigation effect of crossing structures is rather difficult especially because of the lack of quantitative crossing data without the road or without wildlife passages. In one case of our study there were such data. This was the B31neu, a three lane high way near the lake Constance in Baden-Württemberg (Southern Germany). Data were collected there when the road was just under construction (Jenny *et al.* 1993) using track counts in its earth bed. Since completed and opened for traffic there were six green bridges on only ten kilometres of the B31neu (with distances between 1000 and 2500 meters and some 15 additional small mammal underpasses as well as non-wildlife over- and underpasses).

Whereas the mean total of daily crossings in 1993 was 680 animals (the same species like in the actual study) the number of crossing animals in 2004/05 amounts to only some 125. Data from an additional investigation of the badger in the surroundings of the B31neu (Herrmann *et al.* 1997; Hermann 2005) confirmed these results. Despite of the high number of over- and underpasses the crossing rate of this species declined from 4.6 animals per kilometre in 1993/94 to only 1.7 in 2004/05.

But one should not look at crossing rates only. The data from the A20 suggest that there is an important other effect of combining different crossing structures: it widens the permeability of a road for the spectrum of species to cross safely. So e.g. otters were never recorded on green bridges but in the adjacent culverts.

4. Discussion

The findings from this study show that a sufficient size of over- and underpasses is one of the most important factors to meet the demands of medium-sized and large mammals as was shown already by Pfister *et al.* (1999) and for culverts by Clevenger *et al.* (2001, 2005). For the group of species investigated this seems to be more important than the design. We draw this assumption from the result, that there was no obvious effect of the ten year vegetation development on green bridges when comparing frequentation data from 1994/95 and 2004/05. The increase in species' passages with age of green bridges probably is more due to learned behaviour passed on by individual animals. But there can be no doubt that for small vertebrates or invertebrates convenient habitats on or under/in passages are essential (Pfister *et al.* 1997). Thus design should be orientated towards the demands of the latter species much more than to those of larger mammals.

Together with the width of green bridges human activities and associated factors like roads on or near the passages as well as buildings in their nearby surroundings and traffic noise seem to be important attributes to influence the frequentation of crossing structures by animals also. Whereas human disturbance is well known to influence behaviour of wild animals (e.g. Bowles 1997; Herrmann 2001; Knight & Cole 1991), up to now literature gives only little evidence of these factors influencing crossing structure use by mammals (Clevenger *et al.* 2001, 2005).

In the present study all other tested variables failed to show significant effects on species' use of the different crossing structures. Possibly this was due to the varying features of the surrounding habitats, differences in the density of the populations present, specific behavioural traits of individual species or other, unknown, factors. On the same reason it is difficult to predict how a special type of crossing structure will work in a special situation. In some cases the low species' use especially of wildlife underpasses was obviously due to design problems as e.g. fences at the entrances, flooding during wet periods or missing vegetation cover nearby. Moreover some animal species, like e.g. red deer, are reluctant to use confining structures (Reed *et al.* 1975; Ward 1982). And last but not least the sample periods of only four nights (videos) or five days (tracks) are very short to give an complete picture of what is going on at the passages (Malo *et al.* 2005).

We are aware that the present study does not say anything about the real effectiveness of the over- and underpasses investigated. But just this undoubtedly is the most important but only seldom answered question when regarding the success of mitigation measures (effects on long-term conservation of fragmented populations, genetic exchange across the road, re-colonization success etc.). To investigate these aspects is most urgent task in the future because the most effective measures should be applied predominantly in order to use resources efficiently.

Acknowledgements

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Reducing the negative effect of communication (road and railway) investments on free migration of wildlife

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Abstract. In this paper a general information about the harmful effect of transportation investments connected with free migration of the animals will be presented. A classification of typical passages for animals together with descriptions, both on roads and railroads will be included. Also general rules for designing those passages for animals are published. All these are illustrated with examples of above-mentioned constructions, both traditional and modern. On the base of extensive research carried out at the Research Institute of Roads and Bridges in Żmigród advantages of different types of passages for animals are published. The paper are finished with concluding remarks about the future design of construction of passages for animal.

Key words: fauna migration, transport infrastructure, barrier effect, technical solution, wildlife passages

1. Introduction

According to the principle of sustainable development, or in other words, ecological development, the relations between human activities and the functioning of ecosystems remain in homeostasis. The close interrelation and equivalence of economic development, the natural environment, and social development are the conditions for maintaining the stability of ecological processes and systems, including the protection of genetic diversity. This fact is of paramount importance from the point of view of fauna.

The present paper aims at to discuss and present technical solutions applied in the process of completion of communication investments, which according to the aforementioned principle, would reduce the negative effect of such investments on the possibility of free migration of wildlife. Nature protection does not entail giving up the investment. By applying the appropriate technical solutions that let the animals migrate freely, we remain in agreement with the development of roads and railways.

2. Origin of the problem

The basis for stable and lasting functioning of wildlife populations is the possibility of unconstrained movement of animals (Jędrzejewski *et al.* 2006). Dispersion and migration impact the spatial distribution of animals and the genetic structure of their population. Moreover, they constitute an important mechanism for maintaining the biodiversity of particular areas.

The construction of a communication route increases the fragmentation of habitats through the barrier effect, which leads to the reduction of wildlife habitats and to the interruption of their migration routes. This can even lead to such a decrease in the ecological value of the area that the area will not be able to provide sustenance to the populations that were separated (Katalog, 2002).

The infrastructure of communication routes such as roads and railway lines hinders and even in some cases makes impossible the genetic diversification which is necessary for the survival of a healthy population. Problems with finding partners for mating and problems with creating social structures typical for the species result in a lowered breeding rate. Mating closely genetically related individuals may result in genetic deformations. Isolation leads to reduction of a population's genetic diversity, thus reducing immunity to disease and the ability to adjust to environmental changes. This results in a decrease in the viability of a population (Jędrzejewski *et al.* 2006).

Besides the above-mentioned barrier effect, a serious consequence of the development of transport infrastructure is the increased traffic mortality of wildlife. It depends on the traffic density and the velocity of vehicles, the width of the communication route, and the area through which the route runs. Many studies analysing the effect of traffic on the number of collisions and roadkills show that the places of such accidents (so-called 'hot spots') are not accidental at all (Michelle & Page 2006; Evink 2001; Donaldson 2006). Most frequent on Polish roads are the deaths of amphibians, medium-sized forest and field-forest mammals, and large mammals. The highest mortality rates on West European (Jędrzejewski *et al.* 2006) roads and railway lines are recorded for roe deer, hare, foxes, badgers, and wild boars. This results first of all from high numbers of the populations of these wild species.

Summing up, the most serious consequences of the realisation of communication (road and railway) investments in relation to free migration of wildlife include (Jędrzejewski *et al.* 2006):

- making the displacement of many species of animals (barrier effect) impossible or limiting it
- traffic mortality on roads and railway lines as well as (which was not mentioned before)
- destruction of habitats within the reach/along the communication route, and
- expansion of foreign and synanthrope species.

3. Classification of wildlife passages and remarks on the economic justification for their construction

The effective solution to the above-presented problem is wildlife passages. They provide connectivity between two patches of environment, fragmented by the communication route, allowing the animals to migrate freely as well as ensuring stable and undisturbed functioning within the population.

Figure 1 presents the classification of wildlife passages. Below, they are briefly outlined based on Jędrzejewski *et al.* (2006) and Katalog (2002).

Small underpasses – the type of passage designed in general for amphibians, referred to as a 'frog passage', consists of a channel with a round or rectangular profile, laid out across a road, with openings fitted to the lengthwise fencing of the road at its ends. The dimensions of such an underpass are more than 2 meters in width, and more than 1.5 meters in height.

Designated use: amphibians and reptiles, mainly frogs, but it can also be used by other species of small animals like badgers, foxes, martens, weasels, ermines, otters, polecats, hedgehogs, as well as rodents.

Medium-size underpasses – objects of this type are constructed in the form of tunnels with a round or rectangular profile of inner dimensions enabling sufficient visibility of light and vegetation from the other side of the passage, that is a width of more than 6 meters and a height of more than 2.5 meters.

Designated use: mostly medium-sized mammals: roe deer, wild boars, foxes. When appropriately managed, they can also be used by lynx, wolves, and even red deer.

Large underpasses – this is a passage in the form of a tunnel under the road, with a rectangular or arched profile, built of concrete or metal elements, incorporated into the surroundings through the appropriate plantings of vegetation as similar as possible to the natural/local vegetation. Minimum parameters: width 15 meters, height 3.5 meters.

Designated use: large mammals such as moose, bear, red deer, wolf, lynx, bison.

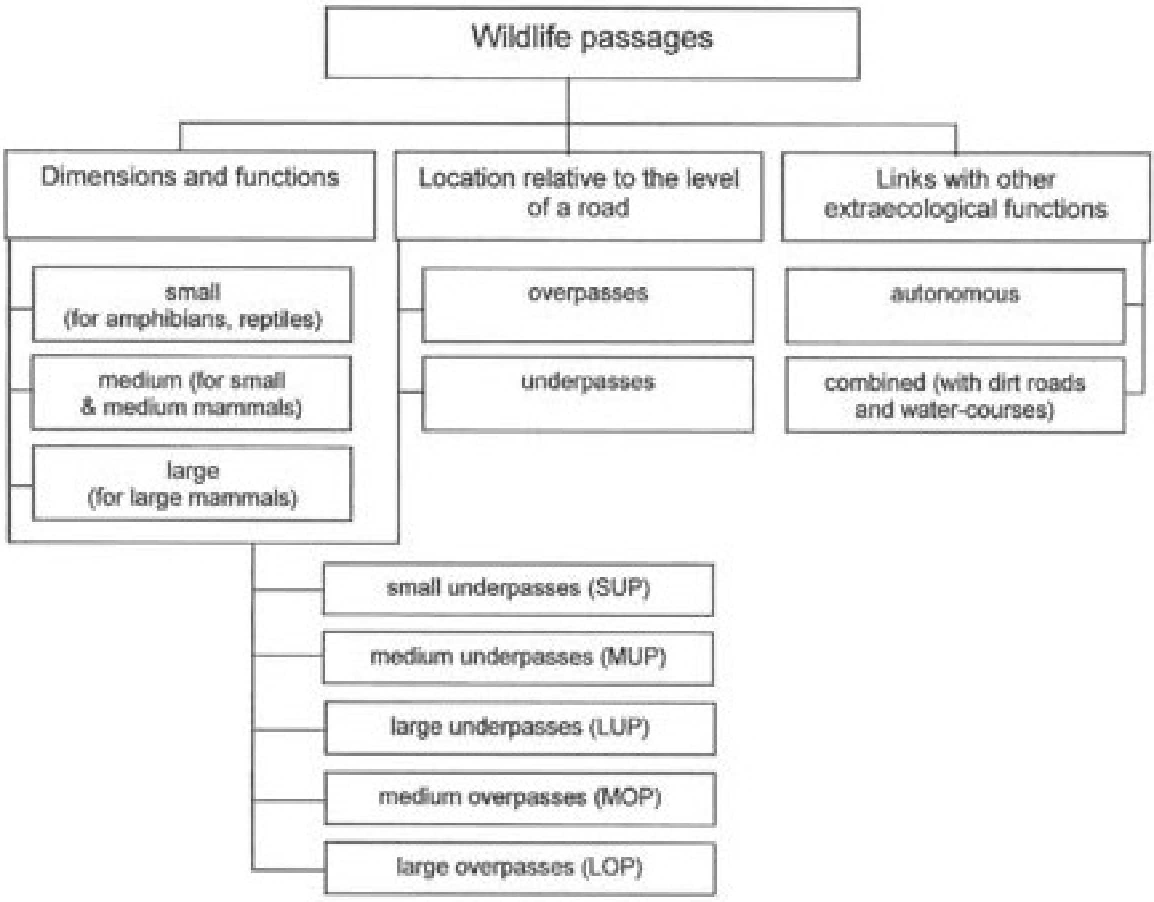

Fig. 1. The classification of wildlife passages [Source: Own research based on Katalog (2002)]

Medium-size and large overpasses – passages of this type are constructed in particular whenthe road runs through an excavation and the upper surface of the passage will be at the level of the surrounding land. These can be tunnels leading across a road or a viaduct above a road. The shape, the dimensions, and the manner of managing the passage should provide the best possible visibility of vegetation at the other side of the road. The outermost strips should be covered with natural vegetation, behind which non-transparent screens of a height from 1.5 meters to 2.5 meters should be installed, blocking out noise and road lights. The height of the screens depends on the species of animals using the passage. The screens could be extended by fencing erected along the road and appropriate bush vegetation directing the animals to the passage. An important element the management of the passage is a 30-70 cm layer of humus, on which grass and vegetation attracting animals should grow.

Designated use: medium-sized overpasses for small and medium-sized mammals; they can also be used by reptiles and amphibians, as well as by large mammals. Large overpasses for large mammals, and in particular ungulates; they can also be used by reptiles and amphibians, as well as by small and medium-sized mammals – therefore they are all-purpose.

Dirt roads for farmers, forestry, or technological roads can lead through the passes. In such situations, combined-use passages (multifunctional) are created, which besides their utility function, also have ecological functions.

In order to maintain or restore the natural environment on both sides of the road, a passage in the form of a biological or ecological bridge needs to be built – a green bridge, a landscape bridge. This type of passage is used when crossing the migration corridor of ungulates of regional importance is inevitable.

Various types of materials and technologies are used for building wildlife passes: concrete, steel, and plastics. The choice of material is often related to the size of the pass (small, medium-sized, large). The types of technologies and materials utilised were described in such works as: Janusz *et al*. (2003); Janusz & Bednarek (2005); Janusz *et al.* (2006a); Janusz *et al.* (2006b); Janusz (2006). In the USA, an algorithm was prepared enabling an economic analysis of the effects of wildlife road-kill prevention measures [Michelle & Page 2006]. Based on the record of costs of road accidents, a table was prepared, which enables financial assessment of the probable collisions and comparing them with the costs of preventive actions (including the construction of wildlife passes). Using the above-mentioned algorithm, we can look for threshold values of investment outlays for which the planned ecological investment is financially justified. The algorithm is described in works: Michelle & Page (2006); Janusz (2006); Janusz i in. (2006a).

Based on American research from Virginia (Donaldson 2006), the financial benefits generated as a result of construction of wildlife underpasses were assessed. The analysis of Figure 2 confirms that with the reduction of the potential number of deer-vehicle collisions (DVC) in a year, the savings in expenses caused by the collisions rise.

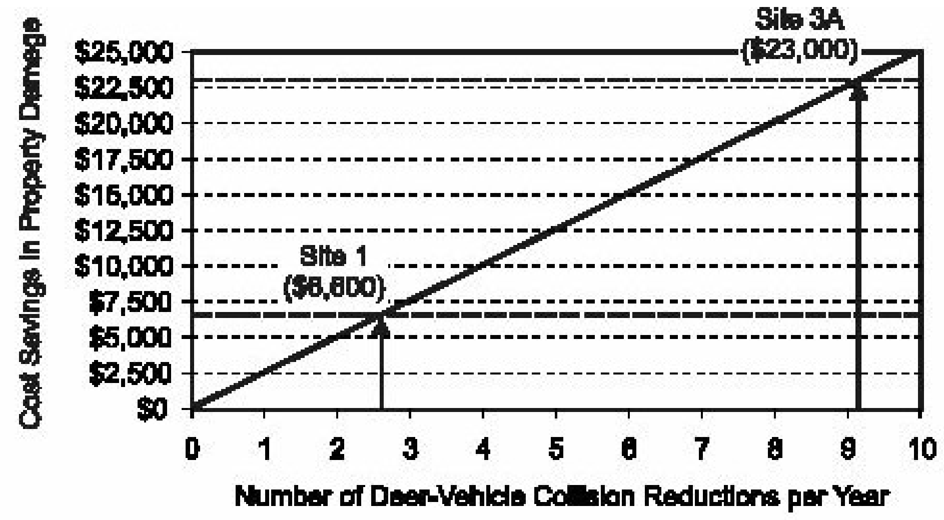

Fig. 2. Reduction of costs resulting from limiting the number of road collisions with red deer (Donaldson 2006)

4. An example of the use of corrugated steel plates in the construction of wildlife overpass over the A2 highway

In 2006, two wildlife overpasses over the A2 highway were commissioned, made in flexible structure technology. Each of the objects consisted of two structures made of corrugated steel plates of arch profile and of two structures of closed arch-round profile (Figs. 3 and 4).

Arched structures have a span of 17.67 meters and a height 5.50 meters and are founded on ferroconcrete supports. The structures were reinforced with fins made of corrugated plates. The main plate and the fins were made of 380×140×7 mm corrugated profiles. The length of steel structures at the point of support is approx. 59 meters. Closed profile structures have a span of 9.36 meters and a height 8.13 meters. They were made of plates of 200×55×7 mm corrugated profile. Their length is approx. 76 meters. Closed profile structures were founded on aggregate foundation.

All the steel structures were made of plates protected with a layer of zinc according to PN–EN ISO 1461:2000, and their internal surface was additionally coated with epoxy paint of a thickness of at least 200 µm. After assembly, the structure's surfaces that come into contact with the soil will be coated with bituminous emulsion. Structures made of corrugated steel plates are covered with a gravel-sand mix, compacted to the compaction ratio of 97% according to the standard Proctor's test. The height of the fill over the CP structures is approx. 2.2 meters. Over the structures, protective insulation was spread, protecting the inside of the structure from rain water permeation.

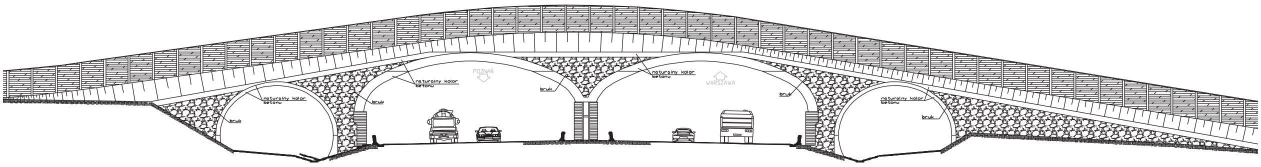

Fig. 3. Side view of the planned wildlife passage over highway A2

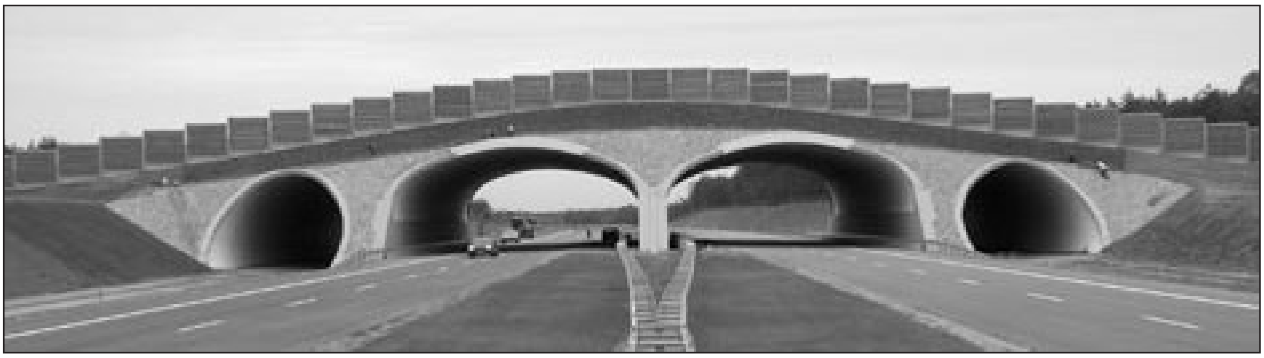

Fig. 4. The view of the completed ecological bridge

The minimum usable width of each of the passes is approx. 36 meters, and at the ends and at the foot reaches 75 meters. The planes of entrance and exit of the passage are slated in accordance with the inclination of 1:1.5 of the escarpment. The entrance and exit were reinforced with a ferroconcrete ring and escarpments reinforced with boulders and turf (Fig. 5). The objects were equipped with screening greenery and at the edges of the passage antiglare screens are planned. A fence was planned along the highway, reaching the screens, thanks to which the danger of animals entering this lane is reduced.

Fig. 5. The ends of the structure

The structures constructed over the A2 highway are the largest wildlife overpass in the world made with corrugated plates technology. The effective assembly time of four structures making one overpass is eight weeks, using one crane and a 12-person crew. The assembly was finished in the second week of September 2005. The organisation of the assembly process allowed works related to the construction of the highway under the structures to be carried out without any problems. After the completion of the structure, traces of animals which used it to walk to the other side of the highway were noticed (Fig. 6).

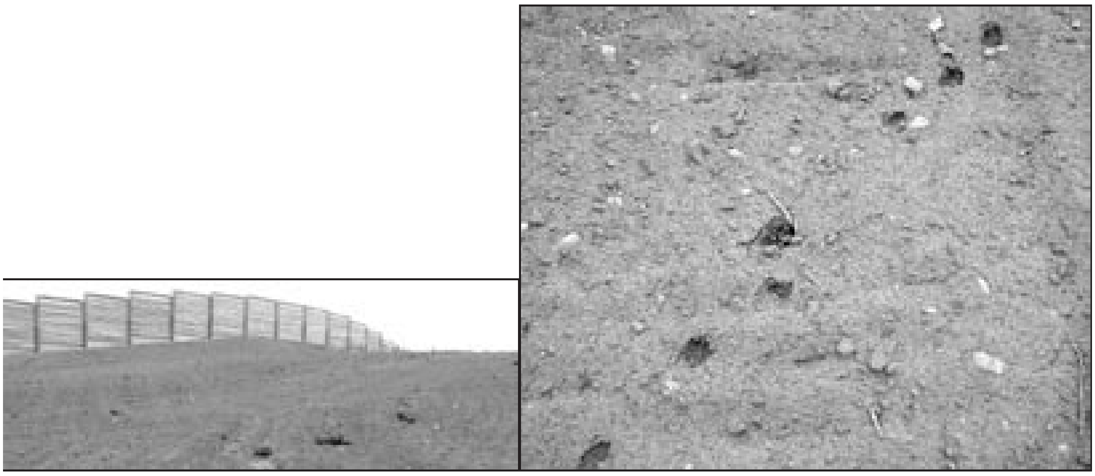

Fig. 6. Animal prints on the ecological overpass over highway A2

5. Additional examples of the use of ground-cover structures for building wildlife passes

Figures 7-9 present examples of passes for small and medium-sized animals. The above presented structures illustrate the structures which are presently most often completed on roads and railway lines in Poland.

Fig. 7. An example a pass for amphibians and small mammals under highway A2

Fig. 8. Openings providing additional lighting under the road in the road-dividing strip

Fig. 9. An example of a wildlife overpass under a highway in Canada

6. Research into modern ecological structures of wildlife passes at the Research Institute of Roads and Bridges [RIRaB] in Żmigród

Due to the advancement of the presented solutions for wildlife passes, a series of research tests of this type structures built out of various materials was realised in RSRaB, as ordered by the companies. This research was conducted in the last few years, mainly upon the orders of Viacon. The main tests completed included:

- tests of the oval structure of the Multi Plate closed profile,
- tests of the Box Culvert open profile structures of the Multi Plate system,
- tests of the Helcor steel grated structure with round profile of the diameter of 1 meter,
- test of corrugated structure of round profile made of PEHD plastics.

All these tests were performed at a natural scale on the test bridge stand in Żmigród. This research was described in several reports: Duszyński (1998), Wysokowski *et al*. (1999a) and Wysokowski *et al.* (1999b). The tests of the structures, all of which can be wildlife passes, were performed under static, dynamic, and selected ones even under extended load.

Due to the fact that the discussed structures are of the ground-cover type, the contact with the ground is very important in the tests. Therefore, the external forces in the construction of coats and the tensions in the ground were analysed. These tests showed the high rigidity and durability of these structures, due to the high cooperation of soil in the transport of tensions, among other things. The results of all the tests can be found in the respective reports and publications:Vaslestad & Wysokowski (1998), Vaslestad *et al*. (1999), Vaslestadt & Wysokowski (1999), Wysokowski (1999), Wysokowski (2001, 2002), Wysokowski and Vaslestadt (2002).

7. Recapitualtion

When summing up the present specification, it can be stated that the structures presented in the study are fully suitable for use as wildlife passage building structures. It has to be mentioned that these structures, due to their mass, do not transfer vibrations, which is important from the point of view of their use by the wildlife migrating across them. Also of importance is their high durability.

The problem presented here of building wildlife passages from the point of view of the negative effect of road and railway traffic resulting from communication investments confirms the need to abide by the principles of sustainable development of humans. The examples given show that besides ecological aspects, technical, economic, and social aspects can and should be taken into account. The skillful combination of the aforementioned aspects makes it possible to maintain sustainable development. The presented example of building a wildlife passage over the A2 highway in Poland can be a model for similar solutions in the road and railway industry.

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Habitats fragmented by transportation infrastructure connected again by green bridges and culverts: examples of wildlife passages in Austria, Belgium, France, Germany, Switzerland and Poland

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Abstract. Against the background of well projected ecological passages in Europe, the work presents a critical assessment of 5 passages built specifically for wild animals over the A-4 highway in the Opolskie province. The structures, put into use in the year 2000, do not comply with the requirements because they are too narrow and not appropriately incorporated into the landscape. The lack of planted trees and shrubs discourages animals (like e.g. deer) from taking advantage of them and crossing the highway.

Key words: A-4 highway, Poland, fauna passages, using

1. Introduction

Poland is a country in which in general the natural landscape, forests, meadows, pastures, and marshy and peat-bog areas have been preserved. Proof of this is, among other things, the richness of birds and other wildlife. We currently have approx. 40 thousand pairs of storks. Every third stork of the world census lives in Poland. According to the Central Statistical Office census from 2005, the number of wild animals as of March 31,2005 was: 13,115 fallow deer; 3,896 elk; 1,684 mouflon; 140,700 red deer; 691,600 roe deer; 173,500 wild boar; 201,200 fox; 475,400 hare. We therefore have a lot to protect. Wildlife is the natural wealth of nature and, as men do, animals have the right to live; therefore, we need to do all we can to preserve this wealth for generations to come.

However, roads, fast train lines, and in particular highways – due to the fact that there is very dense traffic there and that they are fenced – are an impassable barrier for wild animals.

Fauna have traveled hundreds of kilometers for years on well-known migration routes located in ecological corridors. Cutting these migration routes with highways and motor ways, as well as with fast train lines makes the migration of wildlife that cannot live normally in a too-small area impossible (Fig. 1).

Due to fragmentation of the landscape and contact being broken between remote and unrelated populations, animals are forced to exist on isolated patches of land and cannot migrate. Mating between genetically unrelated populations is impossible, and the lack of a broad gene pool results in their gradual degeneration, weakening their inborn resistance to diseases, which in the end leads to populations' gradual extinction.

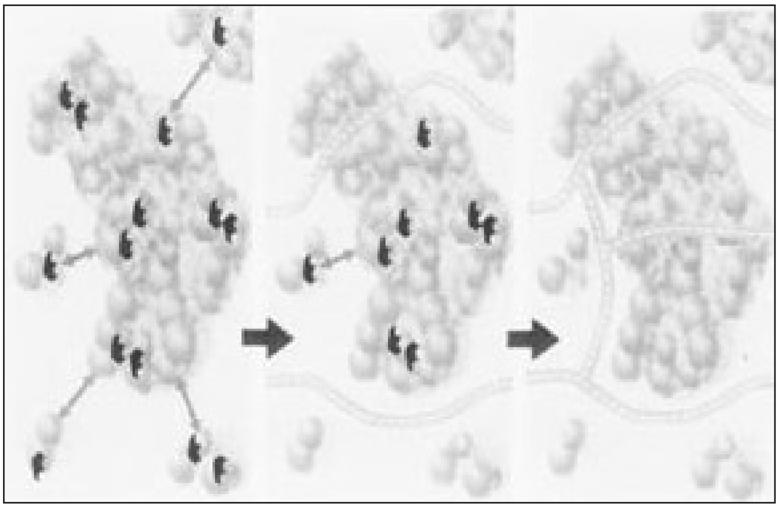

Fig. 1. Fragmentation of the landscape with roads and highways of dense traffic eliminates wildlife that cannot live in a too-small area from the environment (IENE, 2000)

2. The existing and planned network of highways in Poland

Currently in Poland we have fragments (sections) of highway of the total length of 398 km. The latest projects from the year 2002 provide that by 2010 we will have built 1,586 km of highways and we will have in total approx. 2,000 km. This is the necessary minimum. The network of motor ways (express roads) will also be modernised and extended.

Highways, due to their high technical requirements, brutally cut through the environment and are usually fenced; they are, therefore, an impassable barrier for wild fauna. The planned network of highways and modernised motor ways will fragment the migration routes of wild animals. The most seriously endangered by habitat fragmentation will be elks, which move from the rich habitats of the northeast regions of Poland towards the western border of the country, from where, across the River Odra, they go to Germany and south to Czech and to Slovakia. These routes are also traveled by deer and wolves, and these migrations take place in both directions.

3. The condition of wildlife overpasses over the A-4 highway in the Opole region

The A-4 highway on the segment in the Opolskie Voivodeship runs for 89 km, 32 km of which run across forest areas rich in wildlife: red deer, fallow deer, roe deer, wild boar, hare, and fox. Periodically, elks traverse these areas. On this section, five bridges were constructed, designed especially for wildlife.

The designs of the bridges were prepared by TRANSPROJEKT from Kraków. The bridges are too narrow (10-12 meters) and their surfaces, even of those serving exclusively for animals, were to be cobbled. As ordered by ATMOTERM Sp. z o.o. under the supervision of the author, an evaluation of the bridge designs was performed in the Agricultural University of Kraków. Due to the richness of wildlife and their migration, also including elks, the University proposed bridges 70 meters wide, but due to the cost, the designs were not modified but accepted, changing only the concrete bricks which were to be on the surface to soil and grass, as well as trees and bushes.

Seeing during the discussion that the designers and road planners lacked understanding, the author wrote to *Łowca Polski* an alarming article entitled "*Autostrady i zwierzyna. – Czy tylko au-*

tostrada opolska będzie zabójcza dla zwierząt?" ['*Highways and wildlife – Will only the Opolska highway be deadly to animals?'*] (Curzydło 1998).

In order to make clearer the problems related to the design, construction, and functioning of green bridges and culverts, as well as to submit the outcome of research in this area in Poland, the author, from 7th to 10th September 1999, organised the International Seminar in the Agricultural University's Congress Centre in Kraków (Curzydło 1999). The seminar was attended, among others, by: V. Keller (Switzerland), B. Georgil, U. Tegothof and M. Kilka (Germany), A.A.G. Piepers (The Netherlands), and F. H. Voelk (Austria). They gave very interesting lectures and presented films from video cameras installed on the bridges and culverts. All the lectures were printed out in 450 copies and distributed to the participants of the Seminar.

The first day was designed for learning about the bridges and their location in field. The specialists from abroad were critical about the width of the bridges and the concrete containers. Trees and bushes need to be planted directly in the appropriate soil laid on the surface of the bridges. The bridges, in order to be effective in particular for larger mammals (red deer, elk) should be at least 50 meters wide. At the beginning of the 1980's in Western Europe, narrow bridges were built (8-15 meters), but now, based on experience gained, they are no longer that narrow.

Wild animals are claustrophobic and do not enter narrow and fenced bridges. The surface of bridges, as well as the so-called 'funnels', need to be planted with guiding trees and bushes that encourage the animals to cross the bridge.

[It should be noted that as a result of the organisation of the International Seminar in Kraków in 1999, Vägverket – Swedish National Road Administration, in agreement with the General Directorate of National Roads and Highways, and in connection with experience in the field of fragmentation of habitats and infrastructure development, Józef Curzydło was appointed to the position of the National Coordinator for Poland and Joanna Zaifryd was appointed to the position of Sub-Coordinator (Vägverket nomination of March 8, 2000)].

When driving on A-4 from Wrocław toward Gliwice, we encounter in the Opolskie Voivodeship five bridges built especially for wild fauna. Visually, from the road they look excellent. The first bridge with open-work fence is at km 217.7 (Fig. 2). Unfortunately, this beautiful and structurally solid bridge is not accepted by wildlife, the proof of which is the complete lack of traces of migration of fauna (Fig. 3). Animals emerging from the forest (Fig. 4) do not see any trees on the other side of the bridge, only some building structures that limit their free flight, and due to the fact that they are claustrophobic, they do not use these 'green' bridges. The situation could change if the so-called "funnels" and the surface of the bridges are planted with vegetation guiding strips, which the author has called for for many years (Curzydło 2002; Curzydło J. & Curzydło M. 2002).

When we travel from Wrocław to Gliwice, we can see the third fenced bridge at km 230.3. A fragment of the bridge surface is presented in picture, which was taken in spring 2000 (Fig. 5). As the author predicted, junipers withered and the bushes of broom will wither 'later'. Now, only weeds grow there, as can be seen in picture (Fig. 6).

Fig. 2. A bridge with an open-work fence at km 217.7, situated amidst forests. 'Funnels' are not planted with trees or bushes

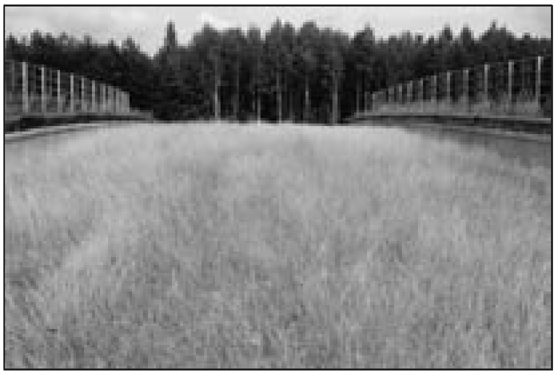

Fig. 3. Wild fauna does not use this bridge

Fig 4. The bridge at km 228.5. Animals do not use this bridge

Fig. 5. A fragment of surface of the bridge with containers and withered junipers. The broom will need more time to wither

Fig 6. The same fragment of the bridge surface presented in Fig. 5. In order to precisely weigh the soil and the lower layer of fine filtering stones, the contents of container 1 were taken out and weighed

As can be seen in photographs (Fig. 2-6), as well as the ones presented in the study done in the year 2004 as ordered by the General Directorate of State Forests (Curzydło i in. 2006), and in publication in *Magazyn Autostrady* (Curzydło i in. 2001), it is indeed very difficult to comprehend why TRANSPROJEKT from Kraków thought up such a strange management of the "greenery" of the surface of the bridges and the access paths to them, the so-called "funnels." At the edges of the bridges, heavy concrete containers were designed, 2x1 m in size and 1 m high. They were filled with soil, and juniper and broom were planted inside. As foreseen in 1999, the juniper and broom withered and now only weeds grow there. There are no guiding paths to the so-called ‘funnels’. The designs also envisaged paving the surface of the bridges with concrete bricks – even on bridges in forests, designed exclusively for wildlife. The only critical remarks of the author that was accepted was that concrete bricks be replaced with a layer of soil and grass.

As is presented in photography (Fig. 6), soil with small stones was taken out from one of the containers and weighed. The weight was 2.6 tonnes x 44 containers = 104 tonnes. Under the soil, at the bottom of the container, there is a layer of approx. 15-20 cm of small stones. Their weight is 0.848 ton x 44 containers = 37 tonnes, which means that the total load of only soil and filtering stones = 141 tonnes. This is a tremendous load for the bridge, to which we should also add the weight of the empty concrete containers, which, considering the fact that it is heavily reinforced concrete, must weigh twice as much as the soil and small stones. Instead of these unfortunate containers (which in addition narrow the surface of the bridge), a thicker layer of soil should be laid, which the author has long petitioned for (Curzydło 2002; Curzydło J. & Curzydło M. 2002). In the authoring study ‘Design and preparatory works for the modernisation of the wildlife overpass over the A-4 highway near Prószków Forest Inspectorate’ (Curzydło i in. 2006), it was proposed that fragments of these ineffective containers be cut off and removed together with their contents, and in their place a layer of 60-70 cm acidic soil from the surrounding forest should be laid down, and in this soil forest trees should be planted (the same species as in the surrounding forest). The modernisation pertains not only to the bridge at km 230.32, but to the other four bridges within the Opolskie Voivodeship as well.

The conclusion of the description of the functioning of wildlife bridges over the A-4 highway should also include positive facts. The two most recently built bridges in the Gliwice region (within the Silesian Voivodeship) are 32 meters wide, without these unfortunate concrete containers and with smoother and elongated funnels. The layer of soil laid on the bridge surface is approximately 40 cm thick and on it grow noble grasses, shamrock, and clover. These tasty plants attract animals, who use these bridges, as when they come out of the forest as a result of smoother funnels, they see tops of trees at the other side of the bridge and are thus encouraged to cross. The planting on the surface of bridges and funnels is, however, poor (crooked, weak). They were planted with forest trees, i.a. spruce, pine, linden, birch, berberis, and euonymus.

When we discuss wildlife bridges in the Wielkopolskie Voivodeship, at the Konin- Września section of the A-2, they are 32 meters wide, but again with these unfortunate (although lower) containers. Unfortunately, they have not been planted with trees or bushes.

There is a relatively good bridge, 33 meters wide, in the Poznań region in the Wielkopolski National Park over road no. 5 Leszno-Poznań. Funnels are smooth, planted with trees, as is the surface of the bridge. Animals use this bridge (Figs. 7 and 8).

Fig. 7. A bridge in the Wielkopolski National Park over road no. 5 (photo by J. Konopka)

Fig. 8. Both the surface of the bridge and the so-called 'funnels' have been planted with spruce and pine (photo by J. Konopka)

Fig 9. Belgium. A bridge over the highway between Brussels and Luxemburg in a forested region. It is only 8 meters wide, but very well managed. The bridge surface is leveled with the surrounding forest. Roe deer use this bridge

Fig 10. Germany. Road B31. One of several wildlife bridges, 33 meters wide. The road surface near the bridge was lowered

Fig. 11. Switzerland. One of the new bridges over highway N7. It is 200 meters wide. This is a super-comfortable bridge in a flat area, but the roadways of the highway were lowered. The level of the bridge is similar to the level of the surrounding forest

4. Wildlife bridges and culverts in some European countries

Wildlife bridges and culverts I have described in detail together with photographic documentation in some publications (e.g. Curzydło 2002; Curzydło J. & Curzydło M. 2002; Curzydło & Polak 2004; Curzydło i in. 2006). Moreover, the detailed description of wildlife passages together with photos was presented in the report on the results of research for Scientific Research Committee (the authoring project No. 6PO4G06715). In this article We present just a few examples (Figs. 9, 10 and 11).

5. Conclusions

The five bridges constructed and commissioned in the year 2000, built especially for wild fauna in the Opolskie Voivodeship over the A-4 highway do not perform the functions designed for them. The bridges are too narrow, but their most serious fault is the complete lack of management of planting of trees and bushes, which encourage and guide animals to cross the passage. Animals, including red deer, wander along the fence and stop in the lower parts of the so-called funnels, but because they are claustrophobic they fear to enter the bridge, because they see some barriers (palings, a fence), and because they see no trees or free space on the other side of the bridge, they do not enter the bridge. An exception is the bridge at km 230.3, near Prószków. The access to the bridge, the so-called ‘funnels’, are more elongated and smoother; therefore, animals coming out of the forest see tree tops on the other side of the bridge and are slowly starting to cross the bridge.

It is indeed hard to understand the origin of the idea of heavy concrete containers by the designers from TRANSPROJEKT in Kraków. Despite fierce criticism from the author in 1998 (Curzydło 1998) and from specialists during the International Seminar from 7th to 10th September 1999, neither designers nor road builders participating in this seminar accepted any of the critical remarks or proposals.

It should be regretted that following the construction of these ‘white elephants’, neither the contractor nor the road builders took any interest in what happened to the junipers or brooms planted in containers, or in the shrubs and trees planted on the so-called ‘funnels’. They just withered.

The question is where the contractors deposited the surface layer of valuable humus stripped from a 30 km forest section of the highway. Both the containers and the so-called ‘funnels’ were filled with poor alkaline chalky clay soil, in which tree vegetation will not grow.

There is an urgent need for repeated management of vegetation of both the so-called ‘funnels’ and the surface of bridges. Heavy concrete containers need to be removed and in their place good soil should be placed – acidic humus from the surrounding forest and trees should be planted there, as is envisaged in the project submitted on November 15, 2004, prepared by AR (Agricultural University) of Kraków for the General Directorate of State Forests.

When we drive on the A-4 highway towards Wrocław, we encounter two good wildlife bridges, 32 meters wide and without these unfortunate containers and with ‘better soil’, a mix of good grasses with papilionaceious plants, as well as trees and bushes planted directly in the ground. It is still surprising that the road builders spent millions on the construction of the bridge but planted sickly and already partially withering trees. Why did they not spend just a few thousand zlotys on planting trees?

Our country is at last starting more intensively the delayed construction of highways as well as wildlife bridges. Road planners should cooperate with foresters, environmentalists, and hunters.

There are numerous dissertations supported by the results of research, conducted in Western Europe (among other places) under the supervision of the Swiss Ornitology Institute SEMPY (the renowned specialist Dr. Verena Keller, Hans Peter Pfister, and others: A.A. Piepers, Udo Tegothof, Bertram Georgii, Friedrich H. Voelk, and others).

Since 1990, there have been many research papers prepared regarding conflicts between wildlife and roads (including ‘Environnement Faune construction de routes et trafic’. Copyright: SBF 1995). Recently, two volumes of results of research were published in COST Action 341 and COST 341 (2003). The results of this research were presented at the International Conference ‘Influence of transportat infrastructure on the nature’ in Poznań (2006).

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Amphibians crossing under motorways: solutions for migration or dispersion?

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Abstract. Since 1975, the Ministry of Transport, Public Works and Water Management in the Netherlands has been building fauna passageways crossing under or over motorways and has also adapted viaducts, bridges and culverts for joint use by fauna. Most fauna passageways are realised over and under 4-lane highways with intensive traffic and concern badger pipes, fauna strips under bridges and in culverts and stub walls alongside the road crossings under viaducts. All are constructed primarily aiming for a save passage of mammalian species. Surveys have been carried out, using different methods, to evaluate the use of fauna passageways by target species. Amphibians use a significant number of fauna passageways as well, including badger pipes longer than 40 meters. Detailed information of amphibian use was obtained from footprints and tracks on paper using an 'ink bed' or on sand beds on the passageway. These methods work well to distinguish prints of the species groups 'frog', 'toad' and 'newt'. These methods are not suitable to distinguish individual amphibian species. For the most frequently used passages the number of passages is 1 amphibian in 3 to 4 days, which equals 20 or more animals in the research period. Toads use fauna passageways more frequently than frogs and newts. Newts were not recorded in fauna pipes. The frequency of amphibian use for passages under motorways is considerably lower than expected for seasonal migration. On the other hand for 'occasional use' the requirements of a fauna passageway seem less strict, compared with passages for seasonal migration. The results indicate that different types of fauna passageways play a role in mitigating the barrier effect of motorways by facilitating potential dispersion of amphibians. For choosing the best solution for a fauna passageway the requirements for amphibians next to mammalian target species are important. Fauna passageways should be located near suitable habitat.

Key words: fauna passageway, amphibians, The Netherlands

1. Introduction

In the Netherlands many fauna passageways are constructed crossing under or over motorways. This includes new passages as ecoducts and fauna pipes as well as the adaptation of existing viaducts, bridges and culverts for joint use by fauna. The Road and Hydraulic Engineering Institute of the Dutch Ministry of Transport, Public Works and Water Management commissioned several systematic studies to evaluate the use and effectiveness of the fauna passageways. The results are used to improve layout, design and maintenance of existing and planned passageways.

In this paper we discuss the effectiveness for amphibians of fauna passageways costructed under 4-lane motorways with intensive traffic. These motorways are considered to be effective and absolute barriers for terrestrial animals resulting in complete isolation of populations at both sides of the motorway (Fig. 1).

Fig. 1. Motorways are efficient barriers for terrestrial fauna

Fauna pipe

A fauna strip (wood beam) in a culvert

Stubwall under viaduct

Fig. 2. The fauna passageways

The fauna passageways include fauna (badger) pipes, fauna strips under bridges and in culverts, and stubwalls alongside road crossings under viaducts (Fig. 2). The lengths of all fauna passageways vary from 40 up to 80 meters. The fauna pipes have a diameter of 30 up to 100 cm. Pipes with a diameter of 40 cm are most commonly applied. The fauna strips along waterway crossings vary from 25 cm wide wooden strips to extended banks under bridges with a width of several meters.

Most passageways are constructed primarily aiming for a save passage of mammalian target species. Field studies carried out to assess the use by target species revealed the use by unexpected species, for example Eurasian red squirrel and pine marten in fauna pipes. The first field studies also revealed that toads, frogs and newts visit the passageways under motorways (Brandjes *et al*. 2000). Though the locations for the fauna passageways were not selected for the presence of amphibian habitat, amphibian visits were common.

We will compile the results of different studies and discuss the implications for selecting solutions for amphibian target species. Field studies have been carried out in 1997, 1998 and 2000, 2001 and 2002. A total of 120 passages (64 underpasses under bridges and culverts, 50 badger pipes, 3 stubwalls, 3 non adapted tunnels) were investigated.

2. Methods

All passageways are surveyed for tracks using sand beds (Fig. 3A-B) or track boards with ink and paper (Fig. 3C-D) (Brandjes *et al*. 1999). Amphibian footprints are identified as 'toad', 'frog' or 'newt' (Fig. 3E). The method does not allow for identification at species level. All field studies are carried out in the autumn period for 6 to 8 weeks. In a study of 50 fauna pipes spring was included in the survey period and the results of both periods were compared (Veenbaas *et al*. 2003).

Each location is visited weekly. At each visit the tracks on sand beds were directly identified, registered and erased to prepare the sand bed for recording new tracks. Track boards were supplied with fresh ink and paper. Each track board had two paper sheets, one on either side of the ink zone. The paper was marked with location, date and a direction key (arrow in or arrow out). This way at each visit paper could be collected when tracks were identified later in terms of numbers of animals moving in or out the passage way. Usually only one track board was placed at a passageway. The difference in number of tracks in and out a passageway is considered as the minimum number of animals to have crossed the complete passageway.

Results of different studies can be indexed and compared using the number of recorded passages per week. Brandjes *et al*. (2002) use the following index: animal use is considered *occasional* if 1 or 2 passages were recorded in the survey period (<0.3 passages/week); animal use is considered *regular* with a maximum 1 recorded passage per week (0.3-1 passages/week); animal use is considered *frequent* with an average of more than 1 recorded passage per week (>1 passages/week).

3. Results

In a systematic study of 45 fauna strips under culverts and bridges (Brandjes *et al*. 2000; Brandjes *et al*. 2001), for 70% of the passageways visits of amphibians were recorded in 1998. This included 27 wood beams and 5 extended banks. Toads are the most frequent users of locations with wood beams (48% of all tracks) followed by newts (29%) and frogs (23%). For most locations the visits were occasional (50%). Frequent visits of wood beams were recorded at a few locations. At 6 locations toad tracks were recorded more than once a week. The maximum frequency was 1.6 animals per week. At 3 locations newt tracks were recorded more than once a week. The frequency varied from 1.6 up to 2.0 animals per week. Frequent visits of frogs were only recorded for 1 location (1.2 per week). In 2000 a selection of locations was optimised for animal passages in general by adding shelter material or broadening the wood beams. For amphibians these measures did not show significant effect on the use of the passageways, though positive effects were recorded for mammals (Brandjes *et al*. 2001).

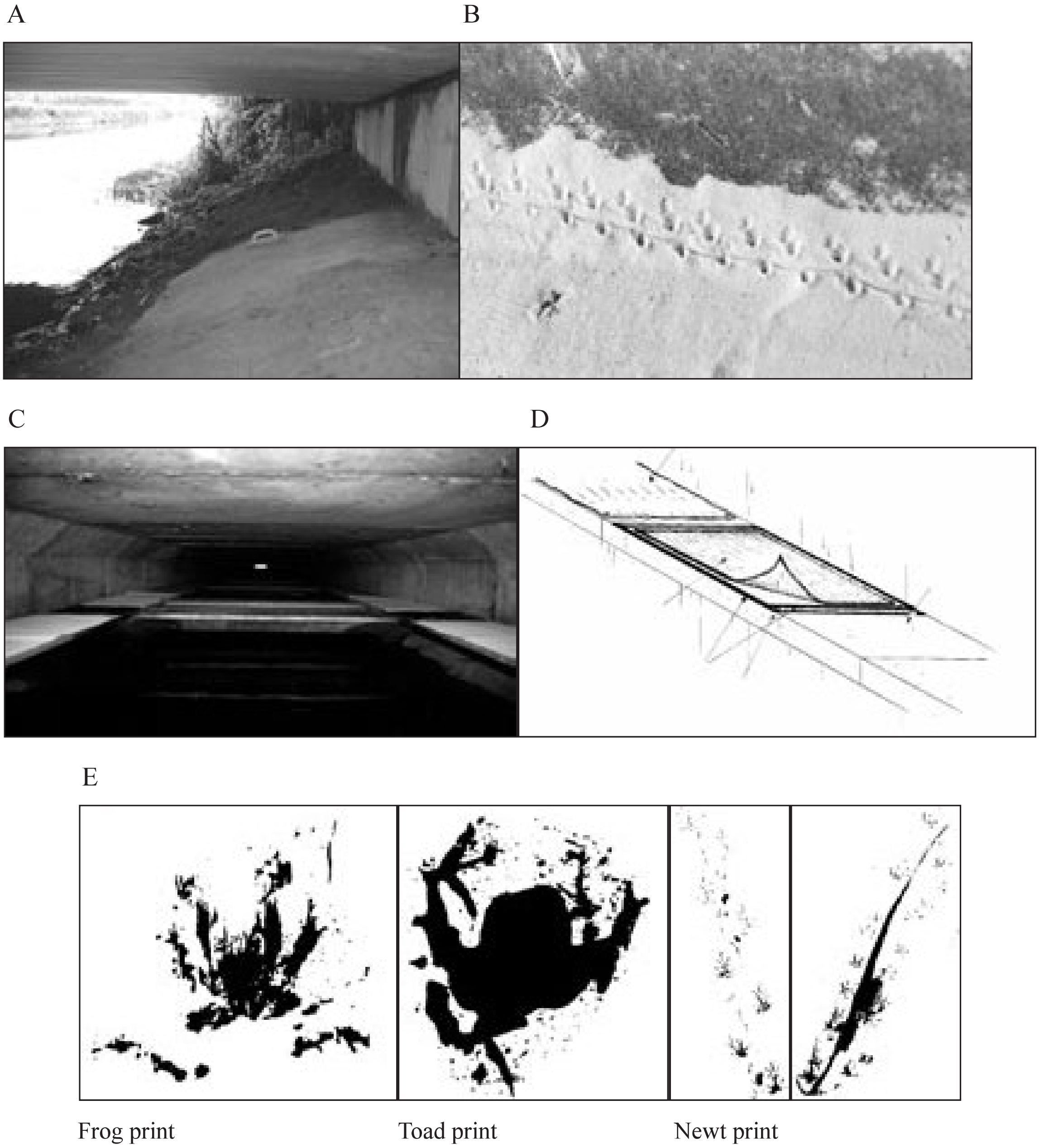

Fig. 3. Research methods of using to amphibian passages

In a systematic study of 50 fauna pipes amphibian passages were recorded at 12 locations. Toads were recorded at 9 locations and frogs at 10 locations. No newt tracks were recorded in fauna pipes but did occur at reference track boards in the direct surroundings (Brandjes *et al*. 2002). The use varied from occasional to frequent. The maximum toad frequency was 1.9 visits per week. For frogs the maximum frequency was 2.0 visits per week. The frequency of toad and frog visits was highest in pipes with high humidity. At each location the numbers of 'tracks in' and 'tracks out' were different which indicates real passages. The study included some pipes under regional roads of less than 40 meter length. The average frequency of visits in these pipes was higher than in the longer pipes. Spring was included in the study period, but the results did not show any difference in amphibian use between spring and autumn.

Several other studies are carried out to assess the use of individual fauna passageways. One study includes 3 locations with stubwalls under viaducts (Ottburg & Smit 2000). All amphibian groups frequently visited the stubwalls. At one location the number of newt visits was with 4.0 per week remarkably high. Both other locations had only occasional visits for newts. The maximum number of visits for toads and frogs was also recorded at this location and was 2.3 visits per week. The stubwall at this location was extended to a pond near the verge of the motorway, thus fitting optimal in the landscape.

Some studies are concerned with non-adapted situations. The results of one study show that amphibians use tunnels for local traffic in a nature area (Van Eekelen & Smit 2000). The intensity of traffic is expected to be very low, a few vehicles per day. At 3 studied locations toads, frogs and salamander visit the tunnels regular to frequent. The maximum number of visits is registered at one crossing. Newts, toads and frogs are recorded with 3.0 visits per week and 1.3 and 1.0 visits respectively. Also mammals where recorded frequently. Probably due to the low traffic intensity combined with the relatively high dimensions the tunnels function as fauna passageways.

4. Discussion

Toads, frogs and newts use a wide variety of fauna passageways under motorways. The numbers of visits vary from once in a study period of several weeks up to several visits a week. There are no known passageways under motorways with large numbers of recorded amphibian passages. Large numbers of amphibian crossings are known in The Netherlands from local roads, especially in spring time when hundreds of toads migrate within a short period to their spawning site. In autumn, with a maximum of 4 individual visits, most fauna passageways under motorways are used by only a small group of individuals. Only one study included the spring period. This frequency of visits of fauna pipes was relatively low in spring as well as in autumn.

Taking into account the relatively low numbers of toad, frog and newt visits and the average low density of fauna passageways under motorways (less than 1 per kilometre) there is no indication that fauna passageways under motorways play a role in seasonal migration of amphibians between hibernation site and spawning sites.

The use of fauna pipes in these studies by frogs and toads is remarkable. The dimension of the studied pipes (average 40 cm) is significantly smaller than recommended for amphibian tunnels under motorways. For amphibian tunnels Vos & Chardon (1994) recommend a diameter of 100 cm. Tunnels with this diameter are effective to facilitate seasonal migration under local roads (Glandt *et al*. 2003).

The results discussed in this paper show that toads, frogs and newts, use fauna passag ways under motorways that are primarily designed for mammals. Amphibian tracks are also registered in non-adapted tunnels with occasional traffic. The relatively low number of registered passages indicates that the passageways have a potential role in the dispersion of amphibians rather than in seasonal migration. We assume that the acceptance of the studied fauna pipes by toads and frogs follows from dispersing animals. The requirements of fauna passageways are expected to be lower for dispersing individuals than in case of migration.

Several studies emphasize the role of roads in fragmenting amphibian habitat. Vos and Chardon (1998) showed that the barrier effect of roads could explain the local distribution pattern of the moor frog in The Netherlands. The high mortality of amphibians crossing roads is considered as the main factor in habitat fragmentation. In this respect motorways can be considered as highly effective barriers. However where a fauna passageway is present the barrier effect is mitigated to the level of potential dispersion. Exchange of individuals between populations on either side of the passageway is possible.

For dispersion of animals in general the motorway will be a bottleneck. The end of the fauna passageway can be considered as a local starting point for dispersing animals on the other side of the road. Given the low density of fauna passageways under motorways the effect is expected to be local. The effectiveness will depend from the distance to the nearest population and the resistance of the habitat in between. In general it can be expected that the closer a passageway is located to a population site, as a pond or other reproduction site, the more it will be used by amphibians. The relative high frequency of newt visits of a stubwall next to a pond supports this.

The results of the different field studies, with amphibians as an example, show the importance of carefully defining the targets before choosing the best solution. For species with limited mobility as amphibians, fauna passageways under large barriers as motorways can facilitate dispersion. In choosing the best solution, the location of a passageway near suitable habitat (in case of amphibians a reproduction site) can be more important than the type of passageway. The following practical recommendations can be given: (*i*) choose target species with comparable habitat requirements; (*ii*) define for each species a dispersion either migration target; (*iii*) choose the best possible design for the local situation; (*iv*) make sure suitable habitat is easy accessible – it can be available or created in the direct surroundings of the passageway.

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The problem of the massacre of amphibians in Poland based on the example of road no. 780 Kraków-Libiąż in the village of Poręba-Żegoty

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Abstract. The work shows an example of drastic decrease in the size of amphibian population in the town of Poręba-Żegota, situated by the busy 780 road Cracow-Oświęcim. It is a result of the area draining and, until recently, massacre of the animals, mostly in the section of the road running along post-manor ponds and an old park. In this region grey toads and grass frogs used to occur in large numbers. A rescue action, initiated in 1999, starts to give positive results. It originally involved setting up road signs “Beware of amphibians” and subsequently, the construction of plastic fences of 300 m length, guiding animals to the special baskets. Three times a day frogs were transferred to the containers and carried to the other side of the road. Moreover, the article directs attention to the conditions which special passages for amphibians should meet in the Polish climate.

Key words: roads, fauna mortality, mitigation measures, amphibians passages

1. Introduction

Amphibians (*Amphibia*) are a group of heterothermic terrestial-aquatic vertebrates. Among the many species of amphibians, still commonly found in Poland are the common toad, common frog, pool frog, moor frog, and common newt. Our society can still enjoy the melodious concerts so romantically described by Adam Mickiewicz in ‘*Pan Tadeusz’*.

Unfortunately, there are less and less amphibians every year; they have disappeared from, among other places, the suburbs of Krakow (Borek Fałęcki and Wola Justowska). Let me just mention that as late as in the spring of 2006, I heard a frog concert in the Bieszczady Mountains, where there also are many storks, which is evidence of the unpolluted environment there.

Amphibians are beginning to disappear from other regions of Poland too, and it is high time to rescue them. I presented my position in the 1999 in *Aura* no. 7-8/99 (Curzydło 1999a) and in a paper at the International Seminar (Curzydło 1999b). Unfortunately, amphibians are still being massacred by dynamically developing road transport.

2. Massacre of amphibians in the village Poręba-Żegoty

The presented results of my observations were gathered in the years 1998-2006. By the densely-trafficked road no. 780 Kraków-Oświęcim in the village of Poręba Żegoty, there is a region with post-manor ponds and an old park, as well as arable fields and meadows. In the surrounding area, there are, or rather used to be, great numbers of amphibians, in particular common toads and common frogs, which migrate from the park and the fields to the nearby ponds on the other side of the road every year in the early spring during the mating season; they were massacred by cars on the road.

In the year 1999, thanks to the efforts of environmentalists and the Town Office of Alwernia, an “Uwaga na płazy” [‘Amphibians – slow down’] road sign was erected (Fig. 1).

In early spring 1999, as was the case in previous years, thousands of amphibians died under the wheels of cars during the mating season (Figs. 2 and 3).

In the year 2000, a considerable number of amphibians were rescued at the end of March (Ropuchy w siatce, 2000). Thanks to the financial support of the Department of Environmental Protection of the Małopolskie Voivodship Office in Kraków (director – Jerzy Wertz), and to the efforts of the Alwernia Town Office (Marta Siemek) and the involvement of the Environmental Protection Society (Jarosław Snopek), the situation for amphibians in Poręba-Żegoty, as well as in other regions of southern Poland, improved noticeably.

Mr. Aleksander Ziemba from Poręby-Żegoty built, from materials (foil) supplied by the Department of Environmental Protection of the Małopolska Voivodeship Office in Kraków, a fence approx. 300 meters in length and buried a few buckets. As a result of these actions, amphibians are forced to walk along this provisional fence, searching for a passage to get to the other side of the road to the ponds. Frogs, moving along the foil fence, fall into the buckets buried at ground level. From there, several times a day (usually in the early morning, at noon, and in the evening), Mrs. Krystyna Ziemba transfers them to another bucket (Fig. 4), in which she transports them to the other side of the road and dumps them out at the edge (Fig. 5), from where they can safely walk to the nearby ponds.

The author came across special culverts for amphibians in 1997 in Switzerland. Along Lake Neufchatel on the section of road between Yverdon and Yvonand, the road runs through an area rich in amphibians and aquatic birds. Each spring, this road was “crossed” by frogs heading to the lake. At that time, 90% of the amphibians were killed by cars. During the migration of amphibians, the road used to be closed, but this was troublesome. Therefore, in cooperation with biologists and road engineers, 14 culverts for amphibians were built along 1.5 km on migration routes in 1984, with special concrete open channels guiding the amphibians to the culverts, as presented in photos (Figs. 6 and 7). Through such culverts, the frogs have no problem, directed by their instinct, with no obstacles, reaching the nearby lake, laying spawn and returning through reversely built culverts to their permanent home.

Due to the fact that in Poland, winter conditions are more severe and the ground freezes deeper than in Switzerland, culverts built at the level of the road surface are more advantageous (Fig. 8), because then during migrations the surface of the road is not cooled and because of the heat produced by cars, culverts under the roads can be placed slightly deeper (20-30 cm) (Pfister 1995; Infra 2000).

Of course, these types of culverts (pipes) need to be cleaned after the migration in summer and before migration of amphibians begins in the early spring.

I would like to point out that for several years now, frogs have been carried across the road in Kraków-Wola Justowska. Amphibians from Lasek Wolski (Wolski Forest) and from fields head to nearby ponds in Mydlniki every spring. In order to get to the ponds, amphibians must cross the very crowded Kasztanowa and Królowej Jadwigi streets, where they are massacred in the spring. For several years, amphibians have been carried across the roads in buckets by the scientific assistant of our Department, Artur Szymacha. A similar situation with carrying frogs takes place in Rytra and in Ojcowski Park.

Fig. 1. Drivers do not pay much attention to road signs like this one

Fig. 2. Toads massacred by vehicles on road 780

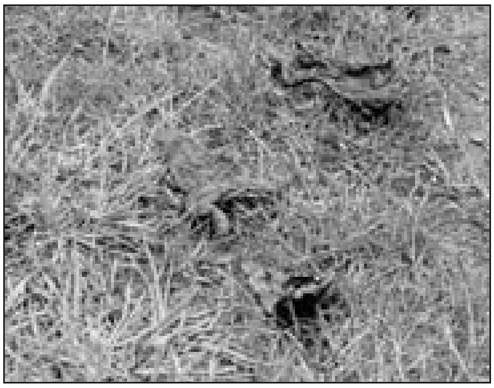

Fig. 3. Sides of the road covered with dead frogs

This commendable way of transporting amphibians proves temporarily effective in the early spring, when amphibians start their mass mating migration on a few warm and usually rainy days, but the problem with protecting amphibians starts upon their return, which is not concentrated and is extended in time. At that time, the animals are massacred again.

The special passages for amphibians and reptiles, however, work “both ways,” so that the returning amphibians safely reach their permanent home. I hope that in our region, such passages for amphibians will finally be built, which, in contrast with green bridges built over highways for large mammals, are not expensive.

Fig. 4. Transferring the frogs from buried buckets (in the ground just by the foil fence) to buckets in which the amphibians are carried across the road and 'dumped' at the edge of the pond (Fig. 5), from where they safely walk to the water in order to lay spawn

Fig. 5. 'Dumping' the frogs at the edge of the pond

Fig. 6. In early spring each year, frogs are guided by their breeding instinct from forests and arable land and head to the other side of the road to lay spawn in Neu Lake

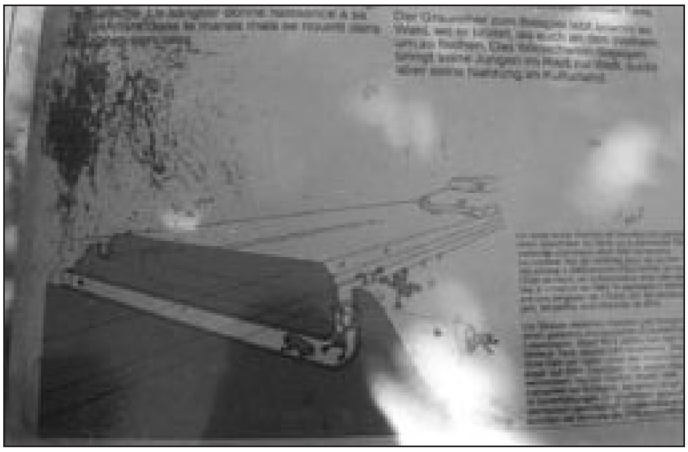

Fig. 7. Diagram of a two-sided safe tunnel for amphibians under a busy road

Fig. 8. Culvert on one of the roads in Belgium, built even with the road surface

3. Conclusions

The village of Poręba-Żegoty is classic evidence that there were two reasons for the dramatic reduction of the population of amphibians in this region: (*i*) no working two-ways or guiding culverts, which should be built at the same level as road surface or slightly lower; (*ii*) drying up of part of ponds in front of Podworski Park. Amphibians have no place to deposit their spawn, and the scarcity of offspring along with their massacre on the road gradually eliminate them from the environment.

Concrete culverts for amphibians, built deeper under the road surface (Fig. 7) have the effect that in the early spring, when amphibians in the mating season start their migration, can have a too-low bodily temperature during their passage under the road and stop, waiting until they warm up. Therefore, culverts built more recently are located at the same level as the road or in a small indentation.

Special culverts for amphibians need to be constructed in the regions where their habitats are, which means wherever there are water reservoirs (ponds, lakes) located across a road from the place of their permanent inhabitation.

When building culverts for amphibians, as in the case of green bridges for large mammals, the example and the rich experience of Western European countries should be utilised.

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Some remarks concerning International Scientific Technical Conference 'Influence of Transport Infrastructure on Nature', September 13-15, 2006, Poznań, Poland

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1. Putting transport infrastructure into a broader frame of sustainability

Railways and roads are two most important types of transport infrastructure on land. These two modes of transportation often complement each other but in many cases may be substitutive and/or compete with each other. Railway transportation is recognised as more environmentally friendly due to lower levels of gas emissions (Facanha & Horvath 2006). Studies explicitly contrasting environmental effects of two main modes of land transportation at regional scale are rather uncommon (e.g. Wacker & Schmid 2002). It is highly desirable that also the influence of railway versus road infrastructure and traffic on nature i.e. species, communities and ecosystems will be addressed by future studies. It would provide decision-makers with additional dimension in assessment of different scenarios of regional development.

2. Call for a more rigorous research addressing effects of transport infrastructure on nature

Research examining the effects of transport infrastructure on nature is a potential source of very important information for decision-makers, planners and environmental consultancy. Therefore, it is highly desirable that quality of this applied research correspond well with international standards set by modern science. In studies assessing the environmental impacts the scientific scrutiny often demands application of advanced methods to account for the complexity of studied systems (Mapstone 1995). The papers presented at the conference ranged from cases with anecdotal observations through descriptive studies to more advanced research examining predictive models. Overall impressions from the conference is that standards for making research addressing the effects of transport infrastructure on nature are set rather low in comparison with investigations dealing with other environmental impacts of anthropogenic origin (e.g. deforestation). In particular, the assessment of different mitigation and compensation measures needs well-designed and repeatable studies that may provide us knowledge regarding good solutions for different regional or local settings. Here, for instance, stringent behavioural studies on affected species would be very desirable. We have to make decisions on evidence-based research and not on common beliefs!

3. Effects of transport infrastructure in international perspective

The European continent encompasses large number of relatively small countries. Therefore, many environmental initiatives and activities are of pan-European character to account for the spatial extent of natural and antropogenic processes (e.g. Tillman 2005). Several papers presented on the conference dealt with impact of highways on large carnivores. In several instances, the isolation of the problem to just one country appeared to be insufficient since both the international highways and population processes of the studied species covered entire regions. In these cases, a more suitable approach would include trans-boundary analyses with several neighbouring countries. This would allow for integrated, regional management of environmental issues and facilitate international exchange and mutual learning.

4. Towards optimal and robust decisions

Our quest for ecological sustainability demands that its different components are balanced to achieve the most desirable result. In biodiversity conservation, several methods have been developed to deal with complexity of this issue (e.g. Pressey & Taffs 2001). The successful mitigation and compensation measures counteracting the negative effects of transport infrastructure on ecological sustainability are usually very expensive, Therefore, it is important to perform rigorous cost-benefit analyses that allow us to select the optimal or near-optimal solutions both from ecological and economical perspective. These analyses should include the uncertainty assessment in order to secure the most robust decisions.

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Environmental impact assessments in the light of discussions on the influence of transport infrastructure on nature

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1. The International Scientific-Technical Conference in Poznań (Poland), entitled 'Influence of Transport Infrastructure on Nature' has provided yet another opportunity to ponder over the definition of EIAs, and their place in social life, economy and science. From the oral presentations and the following discussions it can be concluded that the EIA procedure has become a permanent component of the international legal system and is gaining increasing importance in the environmental policy of EU countries. EIA can be effective only if it has a reliable scientific basis, particularly in terms of the methods and achievements of natural sciences (mainly environmental sciences), economy (e.g. localization theory), engineering and technology (chiefly in respect of construction industry). To ensure a maximum objectivity of the EIA procedure, the guidelines and principles formulated on the basis of the assessment theory should be widely utilized.
2. It has been emphasized many times that EIA should be holistic, so it should take into account all the crucial components of the natural environment, as well as interactions between them. An analysis of the EIAs made so far shows that the dominant approach has been reductionist, focused on details, and considered the individual components of the natural environment asymmetrically. In the context of the subject of the conference, focused on biotic elements of the natural environment, it is noticeable that so far, assessments of the impact of economic enterprises on wildlife have developed more quickly than assessments of their impact on flora and vegetation. In the case of wildlife, some 'model species' can already be distinguished, as they are nearly always used in EIAs in many parts of the world.
3. The examples of EIAs presented during this conference showed many similarities in respect of the successive steps taken, general methodological assumptions, and even the applied research methods. This suggests that it is more and more likely to develop in the near future a universal methodological model that could be applied in various geographical, environmental and technical conditions. This would be an important step towards EIA reinforcement not only in practice, but also in science.
4. The EIA procedure usually includes the following steps: (*i*) identification of the major components of the natural environment, (*ii*) environmental valorization; (*iii*) assessment of the influence of the enterprise on the natural environment and its components; (*iv*) indication of mitigation measures that would minimize the negative effects of the construction works and the later operation of the enterprise; (*v*) monitoring of the effectiveness of the applied meas-

ures. During the discussion, it was emphasized repeatedly that EIA effectiveness depends on the proper implementation of each of those steps. Special attention was drawn to the need for basing the whole procedure on a professionally performed inventory, and to the role of subsequent monitoring.

5. The essence of EIA is to preserve a balance between socioeconomic development and the natural values of the environment. This goal can be reached on condition that international specialists (from various branches of scientific research, economy, and administration) exchange information and cooperate with one another. During the discussion on the costs of habitat defragmentation programmes in West Europe, an appeal was made to representatives of the countries that are still rich in natural landscapes: 'Learn from our errors'. In this appeal, both environmental and economical reasons were taken into account. It has turned out that the costs of defragmentation of the already fragmented natural habitats are much higher than the costs of planned enterprises taking into account the need to preserve the continuity of natural habitats.
6. Conference participants were pleased with the fast development of EIAs and their increasing importance in many European countries, and emphasized the need to improve EIA quality continuously. Progress in this field will depend on the development of education of EIA specialists. Thus it is necessary not only to organize systematic training, but also to publish new handbooks, and add to academic curricula a more detailed introduction to EIA.