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Procedures for the Design of Roads in Harmony with Wildlife

Cost-effective maintenance to support the ecological functions of roads

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Roughan O'Donovan Innovative Solutions (ROD-IS)

Bureau Waardenburg (BuWa)

Swedish National Road and Transport Research Institute (VTI)

MTA Centre for Ecological Research (MTA)

CEDR Call 2013: Roads and Wildlife – Cost efficient Road Management

Harmony
Procedures for the Design of Roads in Harmony with Wildlife

Cost-effective maintenance to support the ecological functions of roads

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Author of this deliverable:
Dennis Wansink & Anneloes Tukker, Bureau Waardenburg, the Netherlands
András Weiperth, Miklós Puky† & Blanka Gál, MTA Centre for Ecological Research (MTA), Hungary

PEB Project Manager: Vincent O'Malley

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Executive summary

Worldwide roads have significant impacts on wildlife, and this differs by species. Different measures are taken to prevent or diminish the impacts, from fences to prevent animal-vehicle-collisions to large green bridges to help animals cross roads safely. Also artificial breeding sites in the neighbourhood of roads or on bridges are offered and habitat in roadside verges and rest areas is created. To be effective in the long run these measures and habitat have to be maintained. In 2003 a European Handbook for the design and construction of these measures was published, but it lacked a chapter about maintenance. The objective of this research was to identify cost-effective maintenance practices to support the ecological functions of roads.

A desk study and a field study were conducted. Current road maintenance practices for mitigation measures and verges were analysed by reviewing literature and getting expert feedback. The expert feedback was obtained during interviews and a workshop with experts involved in road maintenance. In Hungary a field experiment was conducted that studied the effect of different maintenance regimes on fauna in verges. At the same time another CEDR-project, Saferoad, conducted similar research, but it was restricted to a desk study. For a complete overview about cost-effective maintenance practices, both reports should be read.

The desk study done for Harmony showed that it is not easy to create a low-cost inspection and maintenance regime that supports the ecological functions of roads. The fact that at the same time the safety of drivers has to be taken into account limits the possibilities. However the consultation with specialists and the literature review did reveal important insights and ideas. A lot of efficiency can be gained through smart design of mitigation measures and road components. Involving maintenance companies or personnel at the concept and design phase of a road project will cut costs in the operational phase. Secondly, the goals of the maintenance should clearly be stated in maintenance contracts to make verification and validation possible afterwards, especially when maintenance is outsourced. The PDCA (Plan-Do-Check-Act) circle of quality management should be applied more consistently in the road (maintenance) department of the Road Authority. It is also advised to develop an institutional memory at the Road Authority, e.g. a database with locations of the mitigation measures and experiences with maintenance techniques and methods.

Often reported complaints that legal obligations hinder efficient maintenance can be neutralised with a legally approved code of conduct. This will reduce delays and the administrative loads of the maintenance department/company.

Maintenance costs can be cut by combining the maintenance of verges and the natural part of overpasses with the maintenance of the surrounding landscape. This can be done by involving landowners or NGOs that own the land next to the road.

Concerning maintenance practices for road verges, a maintenance regime that creates and maintains a diversity in vegetation cover will result in high species richness. Sine mowing and grazing are the best to achieve this. Both, however, also have drawbacks that limit their application. In general, for creating and maintaining a diversity of habitats to support different species and fulfilling road safety regulations at the same time, large areas are needed. This implies that verges and overpasses must be broad to offer enough space.

Regular inspection of mitigation measures and road components is needed to verify if the ecological functions are still met. The inspection frequency and detail, as well as the

maintenance techniques and frequency depend on the target species, materials used, fertility of the soil, etc. Effective inspection and maintenance needs to continue in the long term. Sufficient budget should be set aside for a long period.

The field experiment showed differences in species composition of ground-dwelling fauna along roads in different landscapes. The maintenance regimes (mowing frequency) had different effects on the abundances of species groups in the different landscapes. Hence, to support biodiversity, the maintenance regime should not be the same everywhere but should be tailored to the local species composition. The field experiment showed that especially in agricultural landscapes, road verges can provide refuges for ground-dwelling fauna, including protected and endangered vertebrate species. When the mowing frequency is low, the higher vegetation offers shelter to animals, especially during hot summers. However, in the first metres adjacent to the carriageway, the vegetation should be low, because otherwise, animals may get too near to the carriageway, which increases the chances of animal-vehicle collisions.

The results of the desk study and field experiment are used to develop a strategy for a cost-efficient maintenance to support the ecological functions of roads.

1 Introduction

Worldwide roads have a significant impact on wildlife, and this differs by species (Polak *et al.,* 2014). Raptors, for example, were found to be more abundant near infrastructure, whereas other bird taxa tended to avoid it (Benitez-Lopez *et al*., 2010). Roads take is a major cause of natural habitat loss and pollution. In addition, they impose movement barriers to many animal species, which can isolate populations and lead to long-term population decline (Figure 1). The ability to move around a landscape is one of the key factors in species survival. So-called habitat fragmentation is recognised as one of the biggest threats to biological diversity. The only way to avoid the barrier effect, and to obtain an ecologically sustainable road infrastructure, is to make roads more permeable to wildlife. To achieve this, mitigating the effects of habitat fragmentation on wildlife is important (Iuell *et al.,* 2003). Options for mitigating the effects are numerous and are being increasingly implemented around the world (Van der Ree *et al.,* 2015).

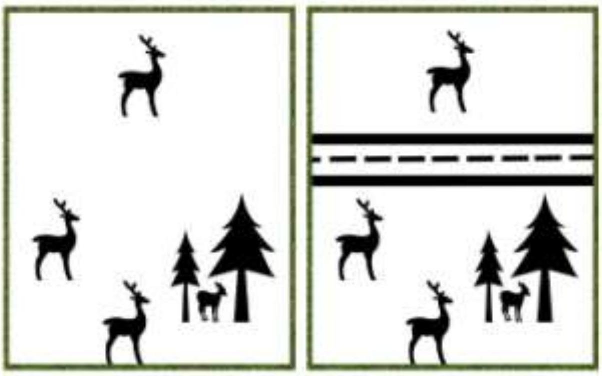


Figure 1 – Roads form barriers, which can isolate populations on both sides

Figure 2 – Example of a green bridge in the Netherlands (Photograph: Dennis Wansink).

Crossing structures (combined with fencing) as mitigation measures can increase permeability and habitat connectivity across roads without affecting traffic flow (Van der Grift *et al.,* 2011; Figure 2). Some existing road components (under- and overpasses), non-wildlife passages, support the crossing of animal species too. For example, non-wildlife passages in Spain are regularly used by foxes and wildcats (Rodriquez *et al.*, 1997).

Research has shown that many species benefit from mitigation measures (Bank *et al.,* 2002; Van der Grift *et al.,* 2003/2009; Lambrechts *et al.,* 2008; Clevenger, 2012), using them to safely cross roads. Even some bird species prefer to cross roads using these structures (Jones & Bond, 2010). The ecological functions of crossing structures are not only to offer routes for migration or dispersal. The crossing structures also appear to offer feeding, breeding, resting and hibernation sites (Wansink, 2016). Predators use crossing structures for hunting by using the structure as an ambush (Mata *et al*., 2015).

Among existing road components that have a function for wildlife, roadside verges are highly significant. Especially in highly modified landscapes, like intensive agricultural and urbanised areas, verges may be the only semi-natural habitat remaining (Hopwood, 2010). They provide a suitable habitat for a variety of species to feed, breed, nest, disperse and recolonize (Bennet, 1998). Many insects can benefit from the use of verge habitat (Noordijk *et al*., 2009; Nordbakken *et al*., 2010), including red listed grasshopper species like *Chortippus montanus* (Figure 3) and endangered butterflies (Munguira & Thomas, 1992). In the Netherlands, the verges are habitat for 50% (80 species) of Dutch butterfly species. Noordijk (2009) found that verges can be used by invertebrates to create ecological networks and that biotope edges in verges act as a guide for dispersing insects and are sometimes favoured as a mating site. Furthermore, Ruiz-Capillas *et al*. (2003) found that roadside verges are an important refuge for small mammals both in terms of greater abundance and population stability than areas farther away from a road. Taller vegetation in verges has been found to support small mammal species, in particular the Bank Vole and Field Vole, in Britain (Bellamy *et al.,* 2000).

Figure 3 – Chortippus montanus is found in roadside verges (Photograph: Jurgen Fischer)

Figure 4 – Dutch highway, A12, with a flower-rich verge (Photograph: Paul Boddeke).

The effectiveness of mitigation measures depends on their maintenance. Van der Grift *et al*. (2004) showed that the construction of a new highway had no negative effect on the viability of a badger population in the south of the Netherlands if all mitigation measures (wildlife tunnels and fences) remained functional. However, if only half of the measures were effective, the badger population was likely to disappear. Proper maintenance of the measures (repair holes in fences immediately, remove vegetation overgrowth from tunnels entrances, etc.) appeared to be of decisive importance to the survival of the species in the region. Good guidelines on inspection and maintenance of road components and mitigation measures will help road authorities to increase the ecological value of roads and the effectiveness of mitigation measures.

The main objective of this research is to identify cost-effective maintenance practices to support the ecological functions of roads. Both a desk study and a field study were conducted. Current road maintenance practices for mitigation measures and verges were analysed by reviewing literature and expert feedback. In Hungary a field experiment was conducted that studied the effect of different maintenance regimes on fauna in verges.

This work was conducted by *Harmony*, a CEDR (Conference of European Directors of Roads) transnational research project. The Harmony consortium consisted of organisations from four countries: Ireland, Sweden, Hungary and the Netherlands. At the same time another CEDR-project, Saferoad, conducted similar research. Both projects collaborated in the interviews and at an IENE workshop in Malmö (see Section 2). In the analysis of the data an effort was made to distinguish between subjects to be treated, but some overlap could not be prevented. For a complete overview of the results and recommendations, both reports should be read.

2 Desk study

2.1 Introduction

The aim of the desk study was on the one hand to get insight into the current state-of-the-art of maintenance practices in Europe, and on the other hand to discover ways to improve the maintenance techniques, methods and organisation to support and preferably increase the ecological functions of roads in a cost-effective way. For this we used three data collection methods:

1. interviews with road maintenance experts;
2. a workshop about maintenance at the IENE 2014 Conference in Malmö and
3. a literature review.

As will become clear, scientific information about the effects of maintenance on the ecological functions of roads is very scarce. A lot of research has been done about the use of road components and mitigation measures by wildlife, but only the effect of mowing the grass cover in verges on wildlife has been the subject of scientific study. Nevertheless, both projects, Harmony and Saferoad, give advice about maintenance. Further research about the effects of maintenance practices on the ecological values of roads in terms of species richness or its contribution to species conservation, is still needed.

2.2 Methods

2.2.1 Interviews with road maintenance experts

In 2015, nineteen experts from ten European countries were interviewed (Table 1). The interviewees were professionals working as road managers or ecological advisors at national authorities, regional authorities or companies responsible for road maintenance (Figure 5).

Table 1 - Number of interviews per country

Country	Number of interviews
Austria (AT)	2
Belgium (BE)	1
Germany (DE)	1
Hungary (HU)	3
Ireland (IR)	4
Netherlands (NL)	1
Norway (NO)	2
Spain (ES)	1
Sweden (SE)	3
United Kingdom (UK)	1
Total	19

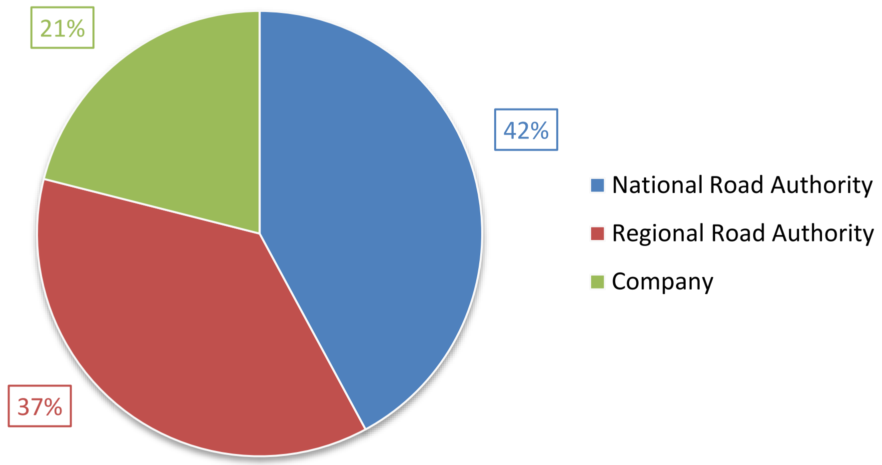


Figure 5 – Organisations the interviewees worked for

A list of 29 predetermined questions was used for the interviews (Appendix A). The interviews were grouped into five categories:

1. General information (existence of guidelines, handbooks and databases; road kill management).
2. Maintenance practice and organisation (wildlife habitat improvement; inspection regime for wildlife mitigation measures; maintenance consideration in design of measures; maintenance organisation; training of field teams; specifications related to wildlife in road maintenance contracts; other conflicts related to wildlife).
3. Costs and effectiveness of maintenance (cost of mitigation measures, maintenance and other wildlife topics; monitoring and evaluation of cost-effectiveness).
4. Status and improvement (proposals for reducing costs and increasing the effectiveness of road maintenance practices in regard to wildlife).
5. Additional information (documents and images provided by the interviewee).

Interviews were conducted face-to-face, by telephone or via online meetings.

The findings of the interviews have been quantified into numerical data for analysis in SPSS (Statistics Package for Social Scientists), version 20. Logistic regression has been used to determine if there is a relationship between two categorical variables. Questions that were not answered by interviewees were excluded from all the analysis. All tests carried out were weighted by the number of experts in each country, in this report referred to as weight by country. These tests produced a visual representation of calculated frequencies and the strength of association between variables.

2.2.2 IENE workshop 2014

During the 2014 Conference of the Infra Eco Network Europe (IENE) in Malmö, Sweden, participants were invited to take part in a workshop about the maintenance of road components and mitigation measures. The goal of this workshop was to explore maintenance practices as perceived by experts from different countries and to discuss how this may contribute to the development of guidelines for Best Maintenance Practices (BMPs). In particular, the following questions were addressed:

- How can we optimize the maintenance of **verges and medians**? The focus was placed on the influence of verge vegetation maintenance on the occurrence of wildlife casualties and on the creation of new wildlife habitats. Both cost and benefits could be highlighted.

- Which are the key maintenance practices for ensuring long-term functionality of **wildlife passages**?
- Which maintenance practices can be applied to **bridges and drainage structures** to enhance their function as safe passages for wildlife?
- How can maintenance practices help **improving fencing** in order to reduce road casualties and to guide the animals to the fauna passages? And how can we help to reduce wildlife mortality caused by other elements such as bird collisions with screens?

A total of 25 people from 12 countries (Austria, Czech Republic, Denmark, France, Germany, Ireland, the Netherlands, Poland, Russia, Spain, Sweden and Switzerland) participated in the workshop.

2.2.3 Review of literature

To find literature related to the maintenance of road components and mitigation measures, database searches were carried out between December 2015 and February 2016. Search terms included 'mitigation, measures, fauna, wildlife, road and maintenance' in combination with 'barriers, ecology, biodiversity, connectivity, effectiveness, fragmentation, verge, culvert, tunnel, overpasses and underpasses'. The reference lists of the relevant articles were reviewed in detail to find additional articles. Articles were excluded when irrelevant to Europe, missed key-information on design, costs or maintenance, or if they were opinion pieces. Most of the articles reviewed were written in English. Online searches in other European languages were conducted too, but revealed only a few articles that added something new to the English literature.

Finally, thirty-seven articles were included in the review, covering studies on overpasses, underpasses, fences and verges (Figure 6).

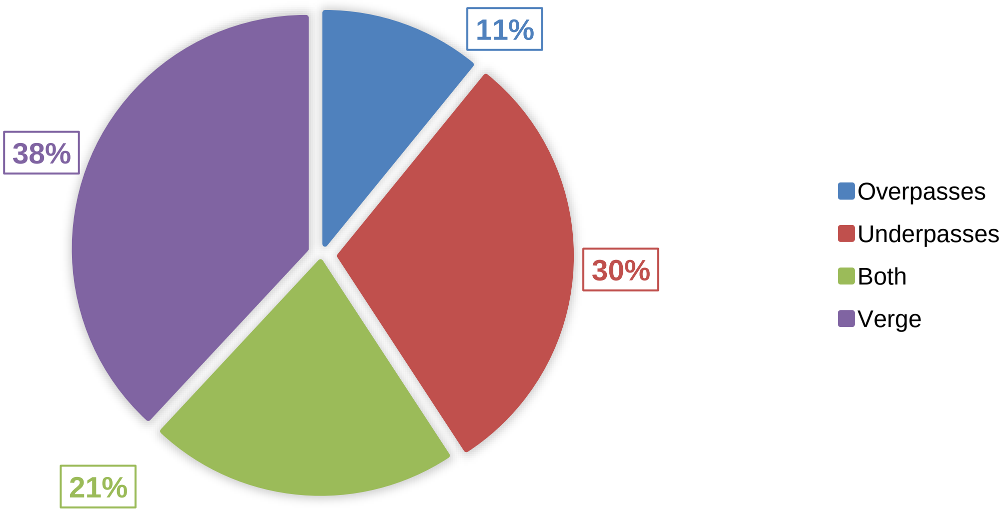


Figure 6 – Division of literature reviewed concerning road components.

A total of 1028 animal species were observed during these studies, belonging to five taxonomic groups (Figure 7). Most studies cover invertebrates, but these were only studies about verges (Table 2). Studies about underpasses mainly covered mammals and studies about overpasses covered in general birds and reptiles.

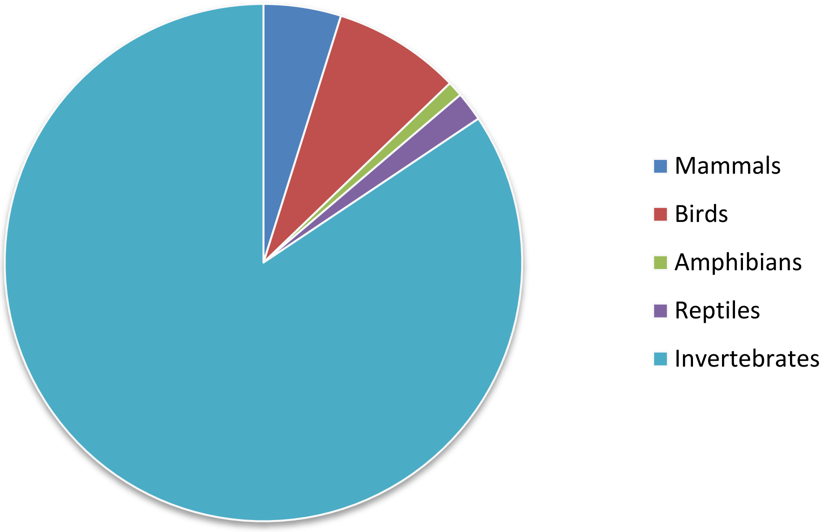


Figure 7 – Division of species over taxonomic groups covered in the literature reviewed

Table 2 - Number of animal species covered in the literature reviewed per road component.

Road component	Mammals	Birds	Amphibians	Reptiles	Invertebrates
Overpasses	2	16	4	14	0
Underpasses	38	0	6	5	0
Verges	9	66	0	0	868
Totals	49	82	10	19	868

The species in the studied literature using mitigation measures have a low conservation status (Figure 8). Most are categorized as being of least concern, according to the IUCN Red List. Some reptile species are not evaluated, but the species that are evaluated are categorised as of least concern. Only two mammalian species were listed as near threatened, namely the European badger (*Meles meles*) and the European rabbit (*Oryctolagus cuniculus*), as well as two amphibians, namely the Fire salamander (*Salamandra salamandra*) and the Perez's frog (*Pelophylax perezi*).

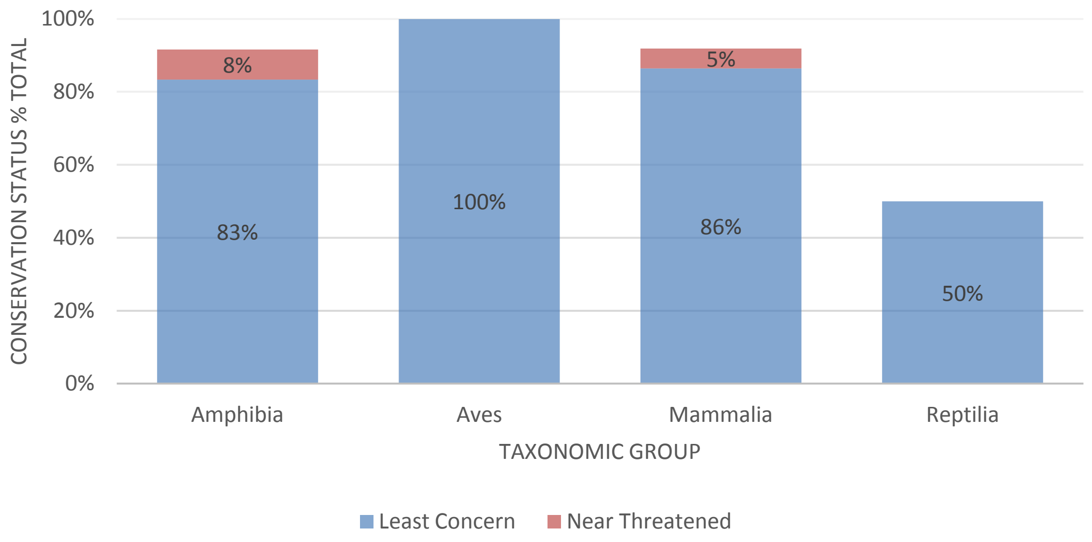


Figure 8 – Conservation status (IUCN Red List categories) of animal species using mitigation measures in the literature review.

2.3 General results

2.3.1 The organisation of maintenance

As described in Tschan *et al*. (2016) different contracting strategies are used in Europe to procure maintenance of road components and mitigation measures. Either the national or county road authority is responsible for the maintenance and carries it out or procures it through a specialised company. When a road building company is responsible, it carries it out or procures it to a specialised company. In most of the countries studied by Tschan *et al*. (2016), both strategies are applied. From the interviews about maintenance it was noted that in some countries, notably Austria, Hungary, Ireland, Belgium and the Netherlands, landowners or volunteers carry out the maintenance of mitigation measures, especially green bridges.

Based on the interviews, it was noted that in all countries, maintenance contracts are applied. Most projects seem to have maintenance contracts for up to five years, which can be extended (e.g. in Spain, Norway, Sweden and the UK). There are also contracts that last for 30 years, e.g. where conditions or requirements do not change much over time (e.g. in the UK). A landscape manual is often drafted which may include environmental measures or landscape requirements, for example the management of balancing ponds, the use of herbicides and the control of invasive species. Some contractors are encouraged to improve biodiversity of road corridors with a biodiversity plan.

2.3.2 Maintenance & Inspection practice

To have the desired effect (less roadkill, suitable habitat, functional overpass etc.) road components and mitigation measures must be properly maintained. The work consists of regular maintenance, such as yearly mowing of the vegetation, and inspection, such as checking fences for holes.

In 68% of the organisations involved in the interviews, guidelines on the maintenance of road components and mitigation measures are available and in 89% of the organisations specific inspection regimes exist. Some guidelines are based on the COST 341 Handbook (Iuell *et al*. 2003), others on experience in the organisation. In was noted that having guidelines on maintenance of mitigation measures is found to be five times more likely when maintenance is prioritised in the organisation that is involved in road maintenance. Also, having inspection regimes for mitigation measures was found to correlate significantly with the availability of guidelines for maintenance. Countries are fifteen times more likely to have inspection regimes for mitigation measures when guidelines for maintenance are available.

However, having guidelines or being prioritised in the organisation does not mean that the maintenance is carried out properly. One quote from an interviewee stated: ‘‘In theory all aspects of maintenance are important; in practice maintenance of fauna measures and vegetation management receives less attention, also in the process of contract control’’. From the interviews a view develops that maintenance and inspection of road components and mitigation measures for wildlife are not treated seriously everywhere. For example, it was noted that inspection is mainly carried out on structural condition; it is questionable whether functionality for wildlife is truly inspected. This kind of inspection is more complicated and is likely to be outside the current scope of standard road inspection and maintenance activities. Therefore the requirements for wildlife mitigation measures should be incorporated into road maintenance programmes (Van der Ree *et al*., 2015).

When maintenance is laid down in contracts, not all the necessary information is always passed into the contracts. Requirements for specific mitigation measures, such as mowing regimes, are often not incorporated in the contract. In Spain, a specific contract for maintenance of mitigation measures is committed for the first two years, but after this period specific tasks are not provided to contractors. Under those circumstances contractors do not always know how to maintain in a way that benefits wildlife.

Figure 9 Inspection guidelines for mitigation measures

Most often contractors are technicians or engineers and are not trained in Ecology. Consequently some interviewees are concerned at the lack of knowledge among the contractors. Contractors in Belgium and also in Sweden did get education in maintenance on mitigation measures that benefit wildlife. Some provide ecological information in the contract for the contractor. In Sweden, technical or engineering consultants from the road authority help contractors to control the maintenance specified in the contract.

In the Netherlands, companies need to deliver a yearly report to the road authority about the mitigation measure(s) they are responsible for, with information about the inspection and maintenance they have carried out. Sometimes the road authority provides contractors with specific instructions, often part of the maintenance contract (e.g. in Belgium, Spain, Norway, the Netherlands and Sweden). In the Netherlands the national road authority provides companies that carry out inspection and maintenance with a geographical information system that shows the location of mitigation measures that should be inspected and maintained and provides specific inspection guidelines for mitigation measures (Den Ouden & Piepers, 2008; Figure 9). These guidelines offer information about the optimal condition of the mitigation measure, the frequency of inspections, what to inspect and how to repair damages, and they provide information about the target species.

Their recommendations form the basis of much of the guidance given in Deliverable G, Part B.

Some of the advice given by the interviewees is far-reaching. It was suggested to count the number of individuals of target and non-target species during inspection, so that maintenance can be adjusted to fit the ecological function according to the number of individuals or species that use the mitigation measure. This requires quite some knowledge by the inspector about animal species. Special courses will be needed to educate the inspectors (see also Rosell *et al*. 2016).

The mitigation measures are maintained through visual inspection by car or by foot. It is important to realise that inspections done by car are often not ideal since damaged mitigation measures may be overlooked. As an illustration, in the Netherlands wildlife-adapted culverts with wooden ledges are sometimes damaged by mowing or human use and cannot be seen from a car and consequently are not repaired. Given that damage as a result of mowing or human use is hard to avoid, inspection must be performed well to identify the damage and take appropriate actions to maintain the ecological function of the mitigation measures or road components.

Damage by humans is more frequent in urban areas, which must be remembered when scheduling inspection. Repairs should be done manually, immediately after the damage is noticed.

2.3.3 Problems during maintenance

Of the interviewees, 53% have experienced problems with wildlife during maintenance. Some of the problems mentioned include:

- beavers that construct dams and obstruct culverts (e.g. in Sweden);
- mowing of red-listed plants at an improper time;
- animals may be lured into the verge area and hide which poses an increased collision risk;
- increase in marten and otter populations in the country resulting in an increase in the numbers of road kill;
- huge numbers of big-game that constitute a danger for traffic.

The most mentioned problems however were those caused by legal restrictions. All European countries have national species protection laws and EU Member States also have to comply with the Habitat and Birds Directives. According to these laws certain activities cannot be carried out during specific times of the year because it may disturb protected species. For example, in Ireland streams cannot be cleared of debris when aquatic animals like salmon or amphibians are spawning. When scheduling inspection, susceptibility of wildlife to disturbance should be taken into account. Susceptibility to disturbances depends on the species and the season. For example, underpasses made for amphibians should be inspected before their massive migration in spring starts. Birds should not be disturbed during the breeding season. It is important to avoid scheduling maintenance activities during these times of the year. On the positive side, less mowing means less maintenance costs and can result in a more species-rich vegetation (Kociolek *et al*., 2015).

With appropriate measures taken, maintenance can be carried out in the sensitive period of protected species. An exemption is possible but the procedure to get the exemption can take a long time (months). In some countries (Netherlands and UK) solutions to prevent delays are found. It is possible to describe all possible maintenance activities and the measures taken to avoid disturbance or other impacts on protected species in a code of conduct and get an exemption for all the work based on this code of conduct. It takes the road authority some time to develop the code of conduct, but it diminishes the administrative burden of the maintenance companies.

Another problem often mentioned by interviewees and participants of the workshop was the difficulty finding mitigation measures. Small mitigation measures, like tunnels for amphibians, reptiles or medium-sized mammals, are difficult to find in the field. This is especially the case when they are infrequently maintained and partially covered by vegetation. Also, it appears that the road owner sometimes is not aware of the existence of these small mitigation measures or for what purpose or target species they were built. This can happen when the mitigation measure was constructed before the current civil servant responsible for maintenance was employed. It is advised to register all mitigation measures in a database, including location coordinates (e.g. GPS), the target species and the function it should fulfil, immediately after their construction.

2.3.4 Costs

About half of the interviewees have little knowledge about the costs of maintaining effective mitigation measures in relation to the overall road management costs (Figure 10). If they do, they estimate it to be between 0 and 1%, on average. Interestingly, interviewees working for maintenance companies estimate the yearly costs to be much higher than interviewees working for the road authorities: 5 to >10% and 0 to 1% respectively. The same applies to the maintenance of habitat, e.g. maintenance of road verges and ponds. On average the costs are estimated to be between 0 and 1% (Figure 11), but interviewees of maintenance companies estimate the costs to be 1-5%, while interviewees of road authorities estimate the costs to be 0-1%.

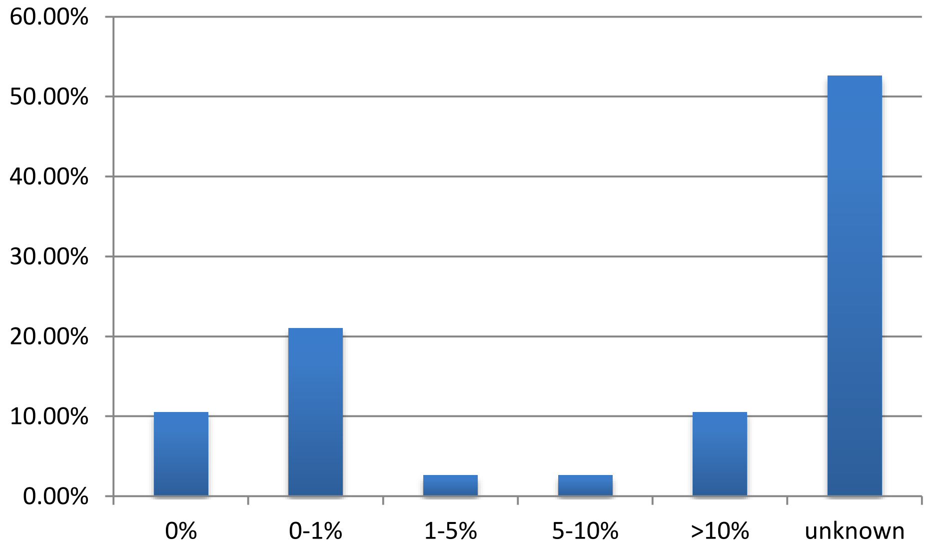


Figure 10 – Yearly costs of mitigation measures maintenance in relation to general road management costs.

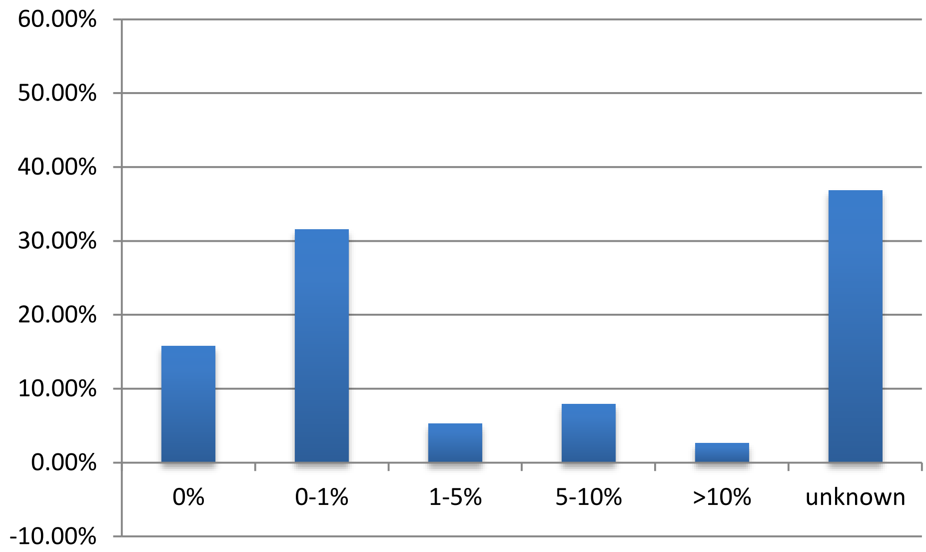


Figure 11 Yearly costs of habitat maintenance in relation to general road management costs.

The cause for the differences in estimated costs between road authorities and maintenance companies is not known. The results suggest that outsourcing of maintenance is not cost-efficient, but nevertheless several interviewees working for road authorities consider outsourcing of maintenance a way to diminish the costs of maintenance, especially when landowners or NGOs are contracted. A possible explanation may be that a maintenance company considers all costs, including overhead, while a road authority only considers the costs of the personnel involved in the maintenance.

Employees of road authorities mentioned several drawbacks of outsourcing maintenance, like:

- the contractor delivers less quality;
- the contractor makes more mistakes;
- no knowledge / experience is gained by the NRA or passed on to the next contractor.

According to some interviewees these drawbacks also exist within road authorities where the maintenance department is independent of the department that builds roads or mitigation measures. These drawbacks can be overcome by education, better communication, better contracts and a system to store experiences (institutional memory). In general, the PDCA-circle of quality management (Figure 12) should be applied more consistently, whereby extra attention is given to communication between road authority and contractor and between different departments of the road authority. More intensive exchange of experiences will result in better recommendations and guidelines for maintenance and this will result in cost-savings.

Figure 12 The PDCA-circle of Deming

Though the costs are not high, relatively, the interviewees do think that reducing the costs of maintenance is important and they do have ideas about this. For example, the interviewees mentioned:

- the accessibility of the road component or mitigation measure as an important issue;
- durability of materials used;
- life cycle analysis of the structures should be applied;
- evaluating maintenance contracts;
- increasing competence of the contractor/personnel
- use of more modern maintenance techniques;
- verges with bushes cost less;
- involving volunteers in maintenance.

About half (48%) of the interviewees said that the requirements for efficient maintenance are not incorporated in the design of road components and mitigation measures and that doing this will reduce the costs, either because it will be easier to carry out the work (saves time) or because maintenance machines cause less damage to mitigation structures (saves repairs). Ignoring maintenance requirements in the early stage of a building project may result in bad maintenance in the Operational phase, leading to an ineffective mitigation measure, which is a waste of money and can even endanger wildlife and the road user.

Other cost-saving advice mentioned was to consider the durability of materials from a life cycle perspective, whereby metal and concrete are preferred. In some countries, low prices for initial building of the objects get priority. However, small savings of money during construction may lead to large additional maintenance costs. Cost-savings can be made when a mitigation measure requires low maintenance.

Figure 13 – A new design of roadside ditches (with a gentle slope) made the maintenance easier and increased the ecological value of the ditch (photograph: Sergé Bogaerts).

2.4 Fences

Fences and screens are used to keep animals off the road or to guide them to an over- or underpass. To keep fences in proper condition is a prerequisite for their effectiveness. Unfortunately, they are possibly one of the structures that are most easily damaged. Damage can be caused by:

- people, e.g. illegal trespassing, vandalism;
- cars, e.g. as a consequence of a road accident;
- wildlife, e.g. by digging burrows under it or by forcing a way through;
- maintenance machines, e.g. a mowing machine that hits a screen;
- vegetation, e.g. branches falling on a fence or bushes growing through the meshes;
- weather, e.g. by accelerating the deterioration of materials.

Several solutions to these problems were mentioned during the interviews and the workshop. Most solutions do not concern maintenance, but a clever design or the use of stronger or special materials. In the case of people destroying fences, solutions like educations, signs explaining the purpose of the fence and penalties were mentioned. Also measures to obstruct climbing on and over fences, such as using a small mesh size or barbed wire, were mentioned. Instead of barbed wire it was recommended to plant thorny bushes next to the fence. It keeps both humans and animals away and the bushes do not need much maintenance.

Concerning maintenance, the most mentioned problem was vegetation growth on or against fences and screens. The vegetation can damage the construction, but it can also offer animals support to climb over the fence or screen. Regular removal of vegetation is needed, but according to a Czech study thorny bushes should not be removed. Repairs of the fence are only needed where the thorny bush damages the fence.

The frequency of vegetation removal depends on the growth speed of the local vegetation, which depends on soil conditions, climate and plant species. It is recommended to inspect fences and screens at least four times a year (Den Ouden & Piepers, 2006). Inspection should happen shortly before the active period of the target species and during the active period of the target species (Struijk, 2010). During the inspections everything that may diminish the effectiveness of the fence or screen is registered and appropriate actions are taken. For effective and efficient inspection the inspector should know for which purpose or for which animal species the fence or screen was installed. Small mammals, reptiles and amphibians can pass through very small holes in the fence or burrow under the fence. If these are the target species than the inspection must be more secure than for bigger animals that can only pass through big holes.

2.5 Overpasses

The maintenance of the natural part of overpasses depends a lot on the target species for which the overpass was built or adapted. An overpass that has only large mammals (deer, wolf, bear etc.) as target species hardly needs vegetation and hence hardly needs maintenance. Overpasses for smaller animals have a more complicated vegetation structure. Reptiles, for example, need hiding places, sunny places and well-vegetated soil, amphibians need ponds with well-vegetated edges, and butterflies need flowering plants. Within the small animals a distinction is also possible between species that use the overpass to cross the road at once or species that need generations to travel from one side of the overpass to the other side. In the latter case, lifetime habitat should be present on the overpass, which usually means diverse vegetation, the presence of other structures, relief and water. The more diverse the natural cover of the overpass is, the more complicated the maintenance will be, in so far as it will be more difficult to carry out the maintenance with machines. Of course it is possible to let nature take its course, but then the natural cover of the overpass will finally develop into forest. In general, maintenance is needed to keep the natural cover in a condition that suits the target species best.

It was noted that the interviewees and the participants of the workshop provided only two recommendations about the maintenance of the natural cover of overpasses:

- use slow growing vegetation, and
- integrate the natural cover of the overpass with the landscape in the hinterland.

The latter recommendation coincides with the trend to outsource the maintenance of the natural cover to landowners and NGOs that maintain the land next to the overpass. Establishing the same vegetation on the overpass as in the surrounding area promotes the use of the overpass by the target species living in the surrounding area. At the same time the landowner or NGO can easily incorporate the maintenance of the natural cover of the overpass into the maintenance programme for its own land. This will keep the maintenance costs low.

The literature review did not reveal any studies about the effect that maintenance of the natural cover on overpasses has on wildlife. But see the paragraph about verges (Section 2.7) for recommendations about mowing and grazing that can also be applied to the natural cover on overpasses. In support of grazing as a maintenance regime it is worth noting that a study by Reck (2013) on overpasses with tall grass in Germany showed a threefold increase in activity of ground beetles on the trampled vegetation of deer paths than at control sites. Many vertebrates are important for the survival and movement of invertebrates by creating suitable habitat conditions (Reck & van der Ree, 2015). Passages designed to maximise habitat heterogeneity by providing many suitable habitat conditions will support the crossing of many species and may even function as stepping stones in the network of a species' habitat (Wansink *et al*. 2013).

The interviewees and participants of the workshop did have ideas about other maintenance issues, for example, about hunters waiting for prey at the entrances of overpasses, vehicles illegally using overpasses and garbage left on multipurpose overpasses. In areas where these are an issue, more frequent inspections are needed as well as education of locals or signs near overpasses explaining their purpose and the effect of the presence of humans or their traces on the overpasses' effectiveness.

Other overpasses, like tree bridges for squirrels and martens, or hop-overs for bats, require specific maintenance, such as regular pruning of branches, repairs of ropes etc.. These maintenance activities can easily be incorporated in the inspection and maintenance programme of fences.

2.6 Underpasses

In underpasses natural vegetation is usually absent, because light does not reach the soil. Only in the case of large underpasses (viaducts) or bridges with openings in the median strip, some vegetation will grow in the underpass. In these circumstances the maintenance can be incorporated in the maintenance of the surrounding landscape or waterway.

In small underpasses (small bridges, tunnels, culverts or siphons) maintenance depends largely on the construction of the underpass and the material used. For example, ledges in culverts can be made of wood, metal (aluminium) or concrete. Metal and concrete need least maintenance, but metal is sometimes stolen. Installing a concrete ledge in an existing culvert is difficult. However, the frequency of repairs may be different for the three materials. All have to be inspected regularly anyway, because humans may use the ledge for angling and damage it, leave garbage or damage the vegetation planted to attract animals. These inspections should be carried out on foot to detect damage and abuse and to remove the garbage.

In small underpasses very specific measures are taken in a small space to make them attractive for animals. This makes them very vulnerable. Small damage or obstructions can make small underpasses ineffective. Therefore, small underpasses need regular inspection, e.g., at least four times per year (Den Ouden & Piepers, 2008). One of the inspections should happen shortly before the target species needs it, e.g. before bats wake up from hibernation or before toads, birds or herbivores start migration.

With small underpasses the main maintenance issues are:

- damage by (maintenance) machines;
- damage or erosion of the soil cover inside the underpass;
- damage or wear of specific devices like tree stubs or fascines;
- damage or wear of guiding structures (fences and vegetation);
- vegetation growth in front of the entrance;
- garbage left by humans or debris brought by water.

Some maintenance issues can be prevented by clever design. For example, water in the underpass can be prevented by a slope with the highest point in the centre of the underpass.

An alternative solution is to make a hole in front of the entrance filled with gravel. Rainwater will sink through the gravel before streaming into the tunnel.

Inspection and maintenance of small underpasses is preferably incorporated into the inspection and maintenance programme of fences to save time and money.

2.7 Verges

Verges can offer habitat for many species, especially when they are wide. In intensive agricultural or urbanised areas, verges can also give an added value to the biodiversity in the region and may in some cases be the last resorts for threatened or rare species (Wansink 2016). Often it is said that creating habitat in verges will lure animals nearer to the road and increase the risk of animal-vehicle collisions. However, studies on butterflies showed that the relationship is more complex. Skórka *et al*. (2013) found that the number of species and the number of butterflies killed on roads were positively correlated with both the abundance of butterflies in the road verges and with traffic volume, but negatively correlated with the richness of plant species in the verge. However, the proportion of individuals killed was negatively correlated with the abundance of butterflies in the road verges, the richness of plant species in the verges and the share of grassland in the surrounding landscape. Skórka *et al*. (2015) explain these results as follows. High grassland cover in a landscape causes an influx of individuals into roads intersecting butterfly habitats. When the plant species diversity in the verge is low, the animals will continue their search for flowers and cross the road. When the verge is rich in plant species the butterflies will stay here. Tracking studies by Ries *et al*. (2001) showed that butterflies were less likely to exit flower-rich prairie roadsides, indicating that their mortality rates may be lower along these verges. It would be interesting to test if these findings also apply to other species groups.

Skórka *et al*. (2015) also found that high mowing frequency led to the emergence of blackspots (places with relatively high numbers of road kill). The effect of mowing on blackspot occurrence was especially high for roads with low grassland cover in the landscape. Either the mowing disturbed the butterflies forcing part of them to flee onto the road, or the mowing machine itself killed butterflies. This effect may also be amplified by the fact that road verges on both sides of a road are usually mown at different times, making crossing the asphalt a more favourable option for butterflies when grassland cover is low in the surrounding landscape.

The studies of Skórka *et al*. (2013, 2015) and Ries *et al*. (2001) indicate three things:

1. keeping the vegetation in verges short (e.g. to create a line of sight for drivers) may actually lead to more road kill among butterflies;
2. the attractiveness of a road verge depends on the conditions in the surrounding landscape (see Wansink 2016 for more examples);
3. if a verge rich in butterfly species is the goal, mowing the whole verge at once should not be done.

In addition to the first conclusion, freshly mowed grass attracts herbivores like deer and moose to feed on young shoots and birds to prey on disturbed mice and insects. For a short period this will increase the risk of road kill among these species.

The effects of different mowing regimes, especially on invertebrates, have been studied frequently. Valtonen (2006) suggests that lowering the mowing intensity by phased mowing or delaying the mowing to late summer may have positive effects on butterflies along road verges without increasing costs or decreasing traffic safety. Mowing two times a year with removal of the cuttings provides the best feeding opportunities for flower-visiting insects throughout the year, according to a study by Noordijk *et al*., (2009). The highest number of flowers was found under this treatment on medium-productive to high-productive grassland verges. For ground dwelling invertebrates it provides sites where much sunlight can reach the ground preferred by the cold-blooded invertebrates (Noordijk *et al*., 2010). Noordijk *et al*. (2010) suggest mowing the entire verge two times a year with removal of the cuttings while mowing a narrow strip (e.g. 10% of the total width) only once a year. This will increase the chances of successful insect reproduction since it provides a refuge. Leaving some parts uncut will increase the survival of many invertebrates and will allow other species to persist as well. The actual area mown is reduced which will cut back on maintenance costs.

A less intensive maintenance regime is advisable on nutrient-poor soils. The vegetation close to the road should be mown once a year with removal of the cuttings. On nutrient-poor soils, trees and shrubs should be removed in a different part of the total area of highway verge in such a way that all sites receive this treatment once every eight to ten years to leave some trees and bushes for animals dependent on these plants. Applying nutrient rich topsoil is highly dissuaded (Noordijk *et al*., 2009). However applying nutrient poor topsoil such as sand on nutrient rich soils has proven to reduce mowing frequency and thereby maintenance costs (e.g. in Belgium).

A risk exists when vegetation refuges become too large, or are at exactly the same place for several years. The repeated disturbance will create conditions that decrease its suitability for grassland invertebrates. Couckuyt (2015) developed a mowing regime that creates a high diversity in vegetation structure with sites that are not mowed, mowed once, mowed twice and even mowed three times a year. In this so-called 'sine' mowing regime, the first cut is an irregularly winding path of only 1 m wide (the 'sine' – Figure 14.1). A few weeks later all grass on one side of the path is cut, but not the path itself (Figure 14.2). After a few weeks a second 'sine' is cut but it follows a different course (Figure 14.3). After a few weeks more the grass on one side of this second sine is cut (Figure 14.4). In high-productive grasslands a third sine may be possible. After every mowing the cutting is left in the field for a few days to dry and to give arthropods the chance to flee to uncut places. The results in species-richness of this mowing regime are promising, but the method is very labour-intensive and asks for some creativity and understanding in the maintenance personnel. It works well in small nature reserves, but has not been tested in road verges yet.

With every mowing regime the removal of cuttings is necessary, especially on nutrient rich soils since otherwise the cuttings will only enrich the soil even more. Highly enriched soils often results in lower (flowering) plant diversity. The cuttings are sometimes removed instantly with a certain mowing suction system which is less labour-intensive and therefore cheaper. Cuttings are in some countries removed after a week to allow seeds to fall on the soil and give invertebrates the opportunity to flee. However, a study by Plat (1996) showed no significant differences in invertebrate diversity between immediate removal of the cuttings and removal a week later.

The cuttings are usually transported to composting companies, which is quite expensive. There is however a cheaper and more sustainable method: transporting the cuttings to fermentation companies. In the Netherlands composting costs €25 for each tonne of cuttings, while fermentation costs €18 (Gemeente Cuijk, 2012). Transportation of cuttings to fermentation companies is not only cheaper, it is also sustainable, since green gas is produced from the cuttings. This means that road authorities can decrease their carbon footprint and save costs at the same time.

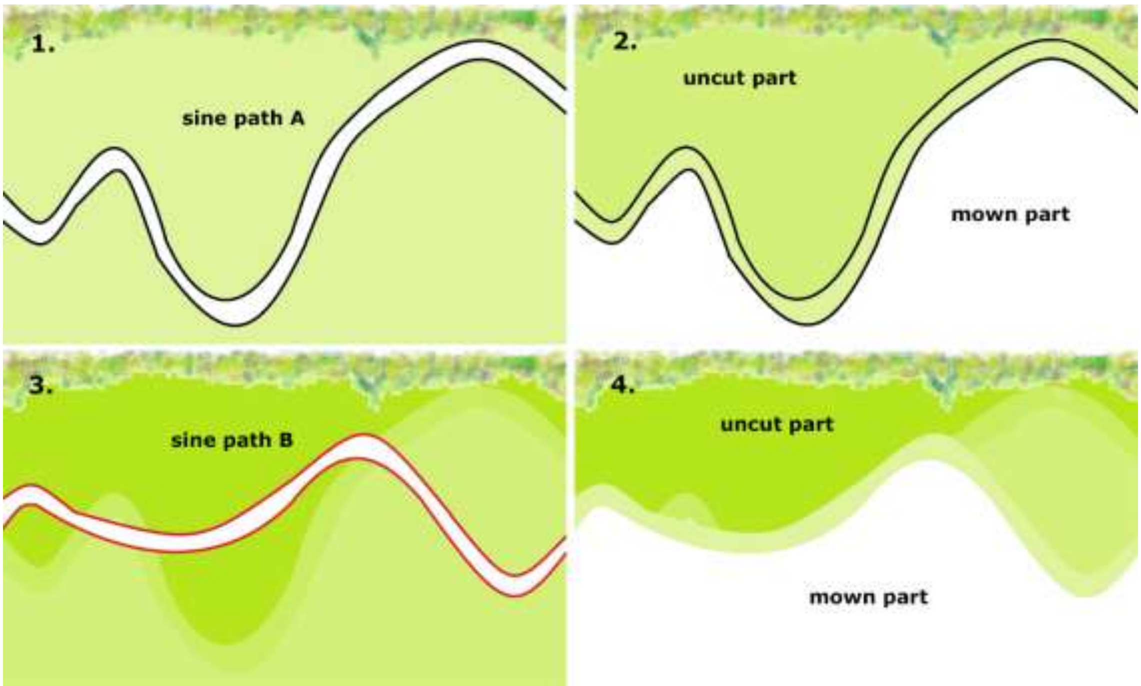


Figure 14 – Sine mowing regime (from Couckuyt, 2015)

Grazing is a possible alternative to the 'sine' mowing regime. Herbivores tend to create the diversity in vegetation cover that the 'sine' mowing regime aims at. Moreover, herbivores also defecate, creating differences in productivity between patches, and scrape the ground, creating bare patches that may attract ground-breeding insects or sunbathing reptiles. According to Reck & van der Ree (2015) many vertebrates are important for the survival and movement of invertebrates by creating suitable habitat conditions, but care should be taken to prevent overgrazing.

In a meta-analysis of literature about the effects of grazing and mowing on the biodiversity in grasslands, Tälle *et al*. (2016) found that grazing generally has a more positive effect on the conservation value of semi-natural grasslands compared to mowing. However, the difference was not always that clear and in some grassland types the difference was absent or mowing had a more positive effect on biodiversity than grazing. The biggest advantage of grazing is its lower cost.

Applying grazing in road verges, however, has its drawbacks. Most importantly, fences are needed to keep the sheep or cattle from the road and to have a big part of the verge grazed means the fences have to be close to the carriageway. This is not allowed for road safety reasons: within several metres of the carriageway the area should be free of obstacles. Possibly, temporary electric mesh fences could be used instead, or the area near to the carriageway could be mowed and grazing only applied to the verge outside the obstacle-free zone. The solution will depend on the local situation, but grazing should certainly be considered as a maintenance method to support biodiversity in road verges at relatively low cost.

Grass and herbs are not the only vegetation in verges. The presence of bushes and trees will increase the species richness in verges even more (Wansink 2016) and the maintenance requirements of trees and bushes are low; only some pruning or removal of whole plants once in several years is needed. However, as with fences, trees are not allowed in the obstacle-free zone, but bushes sometimes are. In Mediterranean regions, however, there is also a restriction on bushes, or certain species of bush, because of the risk of fire in the dry season. Also, bushes and trees restrict the view of drivers on wildlife near to the road, increasing the risk of animal-vehicle-collisions.

Creating and maintaining a natural verge that supports biodiversity or species of conservation concern is not easy. General conclusions of all the pros and cons are:

- a zone of several metres wide along the carriageway should be kept unattractive to wildlife; this can, for example, be achieved by a broad hard shoulder (of asphalt or other hard material, see Figure 15), or by keeping the vegetation short on a regular basis;
- wildlife should be kept away from the road by fences and screens, depending on the species living near the road. If the danger of animal-vehicle-collisions for big animals or for species of conservation concern is absent, than fences and screens are not needed;
- attractive habitat for the target species or for biodiversity in general should be created behind the unattractive zone and/or the fences/screens. This only applies in regions where the road passes through 'ecological deserts', i.e. landscapes that are unattractive to wildlife;
- the more diverse a verge is in plant species, vegetation structure, relief and non-vegetated patches the more species it can accommodate.

Figure 15 – To keep deer and wild boar away from the carriageway, concrete blocks with holes are placed in the first metres beside the carriageway. Grass will grow through the holes, but the concrete is not nice to walk on or dig in and therefore deer and wild boar will avoid the proximity of the carriageway. In addition, de-icing salt will not spread to the verge, but will sink through the holes directly into the ground

.

These recommendations imply that verges that support biodiversity or species of conservation concern and at the same time comply with road safety regulations have to be wide. As was shown in several studies (overview in Wansink 2016), wide verges support the highest species diversity.

If mowing is applied to create diversity in the verge, than a method has to be developed to guide the employee in the field. With a GPS controlled system it is possible to guide the personnel. Alternatively, a robotic mowing machine (as used to mow lawns) can be programmed to mow a predefined pattern. A simpler solution is to place coloured signs in the verge (and on overpasses) to indicate where to mow and where not.

2.8 Conclusions of Desk Study

To find an inspection and maintenance regime that is low-cost but supports the ecological functions of roads, is not easy. Ensuring the safety of drivers at the same time further limits the possibilities. However the consultation with specialists and the literature review did reveal important insights and ideas that are summarised here.

Organisation / management

- Maintenance and inspection should get the attention in the organisation that it deserves. Not taking it seriously will lead to badly functioning mitigation measures that result in high costs of repair or replacement and may even endanger the traffic.
- The execution of maintenance should always be verified and evaluated. This applies notwithstanding who is responsible for the implementation, the road authority or a contractor.
- The PDCA-circle (Figure 12) of quality management should be applied more consistently, whereby extra attention is given to communication between road authority and contractor and between different departments of the road authority.
- More intensive exchange of experiences will result in better recommendations and guidelines for maintenance and this will result in cost-savings.
- An institutional memory should be established, e.g., a database with locations of the mitigation measures and experiences with maintenance techniques and methods.
- Combine the maintenance of overpasses and verges with the maintenance of the surrounding landscape, for example, by involving the landowners or NGOs that own the land next to the road. The landowners can easily incorporate the maintenance into the maintenance regime of their own land. This will result in lower maintenance costs.

Design

- Maintenance costs can be reduced by better designs of road components and mitigation measures. Consulting maintenance companies or personnel during the concept and design phase of a project will help to incorporate these improved designs.

Inspection practice

- The inspection frequency and detail depends on the target species, materials used, fertility of the soil etc. Thorough inspection takes time because it has to be carried out on foot and/or several times per year (see Figure 16). Enough budget should be set aside for a long period.

Maintenance practice

- Delays and administrative loads resulting from compliance with legal obligations can be prevented through the use of a legally approved code of conduct.
- Diverse habitat offering food and shelter near roads will attract animals and increase the risk of animal-vehicle-collisions. However, this does not have to lead to negative effects at the population level, at least for butterflies. Research is needed to find out if this applies to other species groups.
- To create and maintain attractive habitat for invertebrates and small mammals in grassland vegetation (on overpasses and in verges), mowing only twice per year on

medium- and high-productive soils is advised. On low-productivity soils, only once per year will suffice.

- The frequency of mowing on nutrient rich soils can be reduced by applying sand.
- The mowing regime should lead to diversity in vegetation cover. The so-called 'sine' mowing regime gives good results but is labour-intensive.
- Diversity in vegetation cover, plus diversity in fertility between patches and bare soil patches, can also be created by grazing. The use of domesticated herbivores may cut the costs of maintenance. However, care should be taken to prevent overgrazing and measures are needed to prevent road kill among the grazers.
- To create and maintain a diversity of habitats to support different species, large areas are needed. This implies that verges and overpasses must be wide to offer enough space and fulfil road safety regulations at the same time.
- Maintenance is a long term issue. Enough budget should be set aside for a long period.

Measure / Facility/ Utility	Section	Month for inspection											
Amphibian pond	Pool	j	f	m	a	m	j	j	a	s	o	n	d
Amphibian screen / guide wall	Screen / Guide Wall	j	f	m	a	m	j	j	a	s	o	n	d
	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
Amphibian underpass	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
Bat dwelling	Stay / Dwelling	j	f	m	a	m	j	j	a	s	o	n	d
Bridge with path underneath	Ongoing bank	j	f	m	a	m	j	j	a	s	o	n	d
Ecoduct, green bridge	Landing Strip Run & Slope	j	f	m	a	m	j	j	a	s	o	n	d
	Sound & sight screen	j	f	m	a	m	j	j	a	s	o	n	d
	Drinking pool	j	f	m	a	m	j	j	a	s	o	n	d
Fence, electric	Wire / Fence	j	f	m	a	m	j	j	a	s	o	n	d
Fence, large mammals	Poles, mesh & wire work	j	f	m	a	m	j	j	a	s	o	n	d
	Cattle grid	j	f	m	a	m	j	j	a	s	o	n	d
	Return facility (mound)	j	f	m	a	m	j	j	a	s	o	n	d
	Gates	j	f	m	a	m	j	j	a	s	o	n	d
	Wild Boar Gate	j	f	m	a	m	j	j	a	s	o	n	d
Fence, small mammals	Poles, mesh & wire work	j	f	m	a	m	j	j	a	s	o	n	d
	Return hatch	j	f	m	a	m	j	j	a	s	o	n	d
	Return facility (mound)	j	f	m	a	m	j	j	a	s	o	n	d
	Gates	j	f	m	a	m	j	j	a	s	o	n	d
Gangway / dam	Gangway / dam	j	f	m	a	m	j	j	a	s	o	n	d
Guiding vegetation	Plants	j	f	m	a	m	j	j	a	s	o	n	d
Large bridge or viaduct	Underpass	j	f	m	a	m	j	j	a	s	o	n	d
Large fauna underpass	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
Ledge under bridge or in culvert	Ledge / shelf	j	f	m	a	m	j	j	a	s	o	n	d
Ramparts	Planting	j	f	m	a	m	j	j	a	s	o	n	d
Sand martins nesting site	Wall	j	f	m	a	m	j	j	a	s	o	n	d
Small fauna underpass/badger tunnel	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
	Manhole	j	f	m	a	m	j	j	a	s	o	n	d
	Gravel pit	j	f	m	a	m	j	j	a	s	o	n	d
	Lighting shaft	j	f	m	a	m	j	j	a	s	o	n	d
Stub wall (tree stumps)	Tree stumps (Stub wall)	j	f	m	a	m	j	j	a	s	o	n	d
Tunnel/viaduct (with underpass)	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
Viaduct (with wildlife overpass	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
	Sound & sight screen	j	f	m	a	m	j	j	a	s	o	n	d

Figure 16 – Time schedule for inspection of mitigation measures (Den Ouden & Piepers 2006). Darker green: all aspects must be inspected, lighter green: inspection can be limited to damage by vandalism and the presence of garbage.

3 Field experiment

3.1 Introduction

The different types of modern road are relatively new ecological habitats. Most biological studies on linear infrastructure focus on fragmentation, road kills, invasion by exotic species, effect on animal behaviour of air, noise and chemical pollution or the effect of maintenance and mitigation measures . As a result, relatively little attention is paid to the habitat function of roads and motorways, even though their areas increase year by year. Also, highway networks are very different from lower-level roads (Sabino-Marques & Mira, 2011, Podlussány *et al*., 2014). What they have in common is the fact that they can function for hundreds of years and they could offer subsistence for a great number of different living organisms besides human beings (Knapp *et al*. 2013). They also form an ecological corridor for different living organisms including not only the so called ‘hitchhiker insects’ but also protected species of invertebrates (Carabid beetles, butterflies) and vertebrates (amphibians, reptiles, bats etc.).

The Hungarian road network is an important part of the Middle-European infrastructure network. It joins the Athens – Brussels and Rome – Kiev highway axes. In the near future, the quality and extent of construction and delivery of the whole Hungarian road network will develop considerably.

The first road ecology research in Hungary focused on the effects of different types of habitat changes (loss, fragmentation etc.) on protected species. The growth of the traffic in recent decades gave rise to a considerable increase in the number of wildlife-vehicle collisions. Nowadays, several research projects study the prevention of road kill of different animal groups (http://vadelutes.elte.hu/en/roadecol.html). Since 2000, a very intensive road development period has started. In parallel with the infrastructure projects, research and monitoring programs of wildlife mitigation measures have started. The new approach is that different types of habitat along the roads not only function as invasive species pathways but also offer habitats to protected and endangered species. The first complex faunistic research on this topic in Hungary started in 2010 (e.g: Kozár *et. al*., 2013).

Our approach was that besides faunistic research, the effects of different road maintenance regimes on wildlife should also be investigated in order to determine the most environmentally friendly approach for road maintenance. To collect information about different aspects of maintaining the linear infrastructure, the presence and relative abundance of eleven different types of ground-dwelling animal groups were investigated during a complex two-year-long study along Hungarian roads. The research focused on the impacts of maintenance regimes on these animal groups.

The hypotheses are:

1. Different maintenance regimes have a measurable impact on the ground-dwelling fauna groups monitored at the investigated road stretches.
2. Different ground-dwelling fauna groups react in different ways.
3. No maintenance is not necessarily more environmentally-friendly.
4. Based on these results, an order of preference can be made towards the maintenance regime that favours the most important environmental goal (e.g. the protection of a Habitat Directive Annex 2 species, a community structure, etc.).

This chapter summarises the results of the research over three seasons in 2014 and 2015.

3.2 Methods

3.2.1 Research areas

Four sampling areas were chosen, representing the main types of verge habitat along Hungarian roads. Each sampling area was divided into three sampling sections of the same size. The distance between sections was 100 m. Each section had five pitfall traps and the distance between them was 5 m. The traps stayed in the field for three weeks. Before selection of the sampling sections and start of the experiment, a one week long botanical and zoological reference sampling was made in the spring of 2014 by the National Road Authority and field experts in order to measure the biotic and abiotic environmental parameters of each sampling area.

<u>Sampling area Pilisjászfalú</u>

The first sampling area was along Road No. 10: Pilisjászfalú (Budapest-Esztergom, Pest-county) (Figure 17). The sampling area consisted of arid grassland with some small bushes.

Figure 17 – Sampling sites along Road No. 10 (Pilisjászfalú). wm: without maintenance, nm: normal maintenance, em: enhanced maintenance, yellow line: location of sampling sites along the road

<u>Sampling area Dány</u>

The second sampling area was situated in the agricultural areas in the lowland and hilly landscape of Hungary. The sampling area was along Road No. 1: Dány (Budapest-Győr, Fejér-county), between two roads (Figure 18). The roads were bordered by agricultural land.

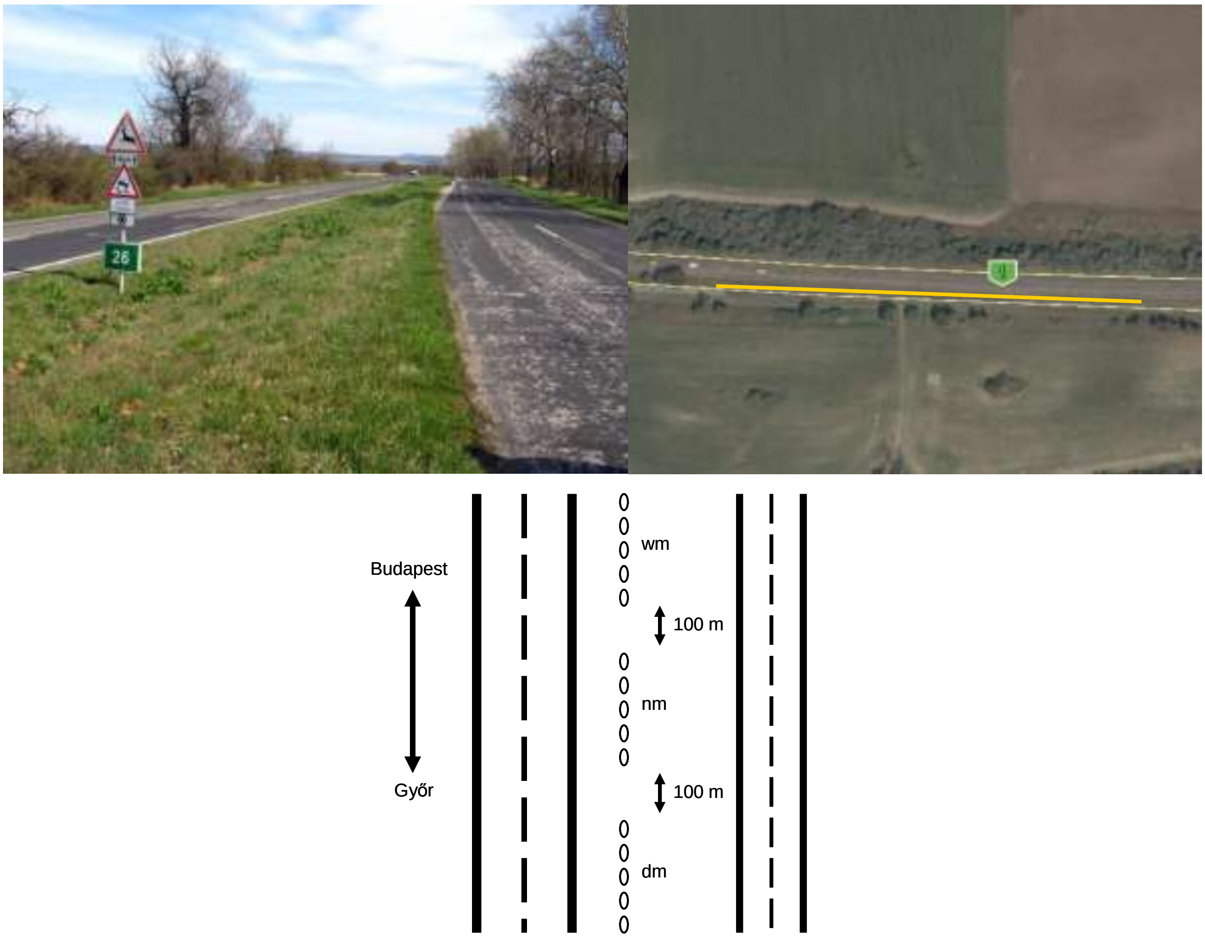


Figure 18 – Sampling sites along Road No.1 (Dány). wm: without maintenance, nm: normal maintenance, em: enhanced maintenance, yellow line: location of sampling sites along the road.

Sampling area Herceghalom

Avenues (roads bordered by trees) and forest can be found along road sections in Hungary. They provide a diversity of habitats with different functions and different species and these habitats are very important in the agriculture-dominated landscape. The sampling area was along Road No. 1: Herceghalom (Budapest-Győr, Pest-county) and was situated between the road and a forest (Figure 19). The forest was dominated by two tree species, the invasive acacia (*Robinia pseudoacacia*) and hybrids of poplar (*Populus* sp.).

Figure 19 Sampling sites along Road No.1 (Herceghalom). wm: without maintenance, nm: normal maintenance, em: enhanced maintenance, yellow line: location of sampling sites along the road

<u>Sampling area Agárd</u>

Hungary is very rich in different types of water and wetlands and several roads cross these sensitive habitats. The sampling area was along Road No. 7: Agárd (Budapest-Székesfehérvár, Fejér-county) and crosses a wetland area in the west section of Lake Velence (Figure 20). The construction of this road section was finished in 2013. The entire length of the road has a fence, guide wall and tunnels for amphibians, reptiles and small mammals.

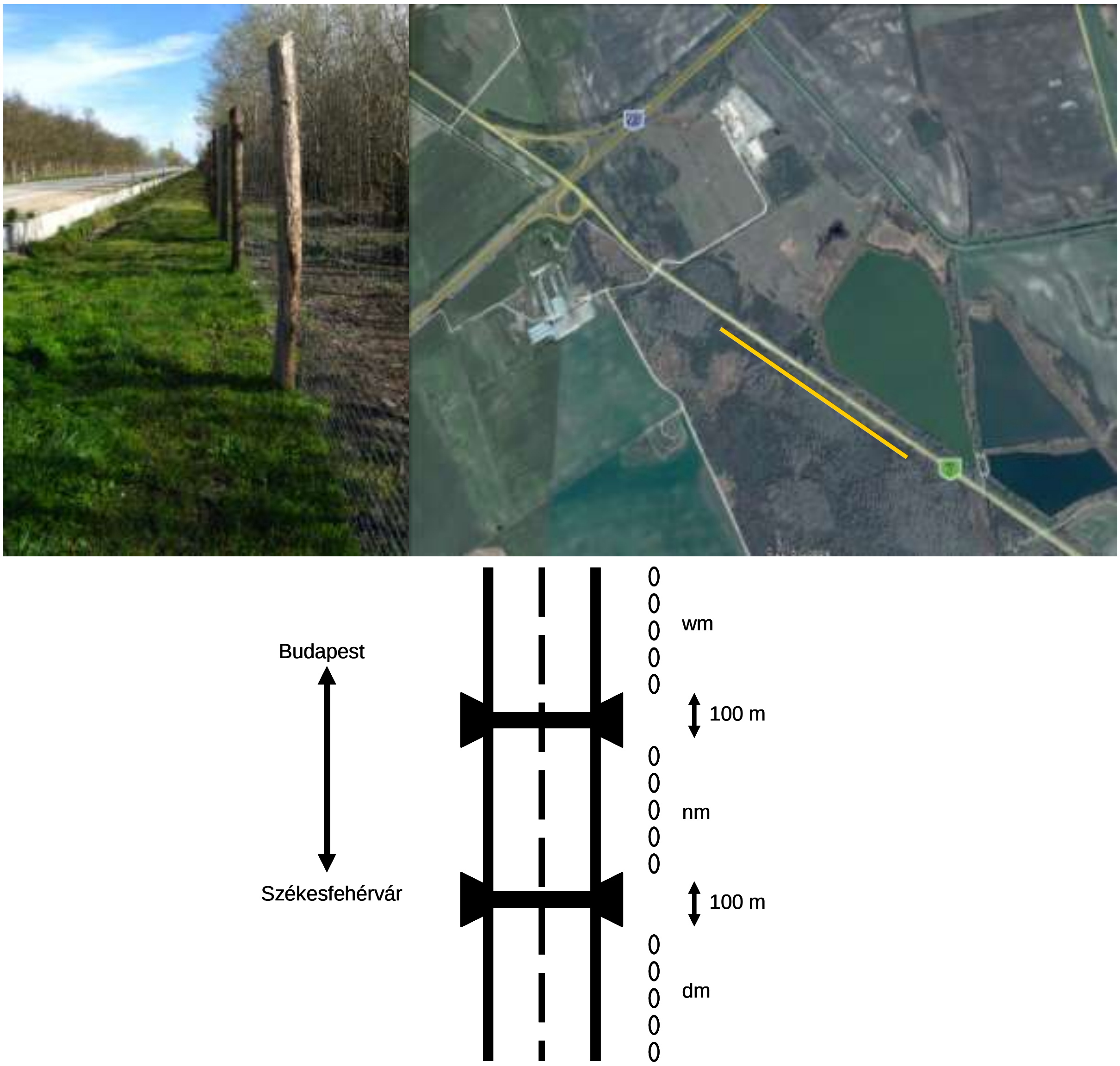


Figure 20 – Sampling sites along Road No.7 (Agárd). wm: without maintenance, nm: normal maintenance, em: enhanced maintenance, yellow line: location of sampling sites along the road, black lines: tunnels under the road

3.2.2 Sampling methods

Two methods were used to collect the animals in the Hungarian road verges: pitfall traps (with ethylene glycol) and visual observation of vertebrate species. Sampling was carried out three times a year in different seasons (spring, summer and autumn). In each season the traps were active for three weeks. The living vertebrates were identified in the field and conserved individuals were sorted and identified in the laboratory by experts. Eleven ground-dwelling taxonomic groups were separated: two types of gastropod molluscs (snails and slugs), Coleoptera (beetles), Orthoptera (grasshoppers, crickets, etc.), Cicadea (cicada), Isopoda (woodlice), Araneae (spiders), Diplopoda (millipedes), Acarid, Ampihibans and Mammals.

3.2.3 Methods of maintenance

The National Road Authority Company (Magyar KÖZÚT Nonprofit Zrt.) uses different methods for maintaining verges and wildlife mitigation measures. The research focused on the mowing periods and intensity, because this method is used for each sampling area by the directorates of the National Road Authority (NRA). All sampling areas were divided into three sections. In one section the normal, periodic maintenance by the NRA (mowing two times per year on average) was applied, in one section an enhanced maintenance regime (compared to the normal, periodic maintenance by the NRA) was applied, and in one section no maintenance was carried out. Enhanced maintenance consists of mowing 4 times in a humid year and three times in an arid year. The maintenance regimes extended from 10 m before the first to 10 m after the last traps in order to eliminate the effects of ecotones (transition area between two different types of habitat). When traps are in the zone of ecotones, they cannot properly represent the effect of different maintenance regimes.

3.2.4 Statistical methods

At first the aim was to explore the seasonal differences of ground-dwelling taxonomic groups and the whole biotic assemblage within each maintenance regime. For this we plotted the mean abundance values and confidence intervals (95%) of the examined taxa in whisker style plots. We used a nested design, in which we grouped our dataset into seasons (reference period before the maintenance experiment, spring, summer, autumn) within the maintenance regimes (enhanced, normal, without). On the x-axis the abundance values, and on the y-axis the nested grouping variables (seasons within maintenance regime) are shown in Figures 21-24. We also examined the differences in taxon abundances between maintenance regimes (enhanced, normal, without) within sampling areas (Agárd, Dány, Herceghalom, Pilisjászfalu) using whisker style plots. We used also whisker style plots with mean abundance and confidence intervals (95%) of the examined taxa. We decomposed our dataset into maintenance regimes (enhanced, normal, without) within sampling areas (Agárd, Dány, Herceghalom, Pilisjászfalu). On the x-axis the abundance values, and on the y-axis the nested grouping variables (maintenance regimes within sampling areas) are shown. In all cases whisker plots were drawn for the three taxonomic groups (molluscs, arthropods, vertebrates) separately and for the whole assemblage containing all three taxonomic groups. The non-overlapping whiskers in the plots provide statistical certainty for differences between two datasets.

<u>ADONIS</u>

Permutational multivariate analyses of variance using distance matrices (ADONIS) were used to test for differences in the composition of mollusc, arthropod and vertebrate assemblages in a spatially and temporally nested hierarchical design accounting for the maintenance regime (enhanced, normal, without) within sampling areas (Pilisjászfalu, Dány, Herceghalom, Agárd) and with separate seasons (spring, summer, autumn) within years (2014, 2015) (Oksanen 2011). A total of 999 runs were performed on the Bray-Curtis distance matrix for the taxonomic datasets. Sampling occasions (4 sites × 2 years × 3 seasons × 3 maintenance regimes × 5 traps; overall: 300 samples) were used as objects, abundance data of taxonomic groups as response variables, and sites (4 levels), maintenance regimes (3 levels), years (2 levels) and seasons (3 levels) as grouping variables within one model. Two models for the two taxonomic groups of molluscs and arthropods were conducted separately, and one for the whole assemblage of all three taxonomic groups (molluscs, arthropods, and vertebrates). We could not execute the ADONIS model for the vertebrate group separately. Vertebrates were found on a few sampling occasions only, which caused incomparability of groups between sites, maintenance regimes, years and seasons.

This statistical analysis was performed with software R ver. 2.14.0 (R Development Core team 2011) using the packages ‘vegan’ for ADONIS.

3.3 Results

A total of 24,408 (2014: 18128; 2015: 3212) individuals of 196 species of 11 taxonomic groups were caught in the two years. The summer of 2014 was more humid than average and 2015 had several hot periods throughout the year.

3.3.1 Results of whisker plots

It was found that the mean abundance of the whole assemblage containing all ground-dwelling taxa was significantly higher in spring than in the other seasons (Figure 21). In the sections without or with normal maintenance, the mean abundances showed similar values in summer, autumn and in the reference period. In the sections with enhanced maintenance, the mean abundance was significantly lower in the reference period and summer than in autumn and spring. When exploring the three taxonomic groups separately, significantly higher mean abundances in spring for all maintenance regimes were also found for arthropods, but not for molluscs and vertebrates (Figures 22-24). The resemblance between the results of arthropods and the whole assemblage is understandable, because arthropods were the most abundant group in the study, with 13,616 individuals, 56% of the samples belonged to this group.

In the case of molluscs two peaks of mean abundances were found: one in spring, and one in autumn (Figure 22). In these seasons the mean abundances showed high variance, but were nevertheless significantly different from the other two seasons (reference period, summer). The seasonal patterns of molluscs did not show differences between the three maintenance regimes. In the case of vertebrates the mean abundances were highest in summer, followed by spring, in sections without or with normal maintenance. In the sections with enhanced maintenance the mean abundances were similar in the reference, spring and summer periods and these were higher than in autumn.

When analysing the sampling sections of the four sampling areas, differences were found in the mean abundances of the whole ground-dwelling species assemblages. For example, in the case of the normal maintenance section and the section without maintenance, different results were found in the abundances of all taxa in Agárd than at the other three sampling areas. In the Agárd sampling area the mean abundances in the sections with enhanced maintenance and without maintenance were lower than in the section with normal maintenance, but only the difference between normal and no maintenance was significant (Figure 21). Looking only at arthropods in Agárd (Figure 23), the mean abundance in the section without maintenance was significantly lower than in the section with normal maintenance. The mean abundance in the section with enhanced maintenance was also significantly lower than in the section with normal maintenance. In Herceghalom the opposite pattern was found, characterized by the lowest mean abundance of the arthropod community in the section with normal maintenance (Figure 23). In Dány and Pilisjászfalu the mean values of arthropod abundance increased from sections with enhanced maintenance regimes to the sections without maintenance.

In the case of molluscs, two types of abundance patterns can be seen between the maintenance regimes (Figure 22). In Agárd and Pilisjászfalu the lowest abundances were found in the sections without maintenance. In Dány and Herceghalom the opposite pattern was found: the mean abundances of the mollusc taxon was slightly higher in the sections without maintenance.

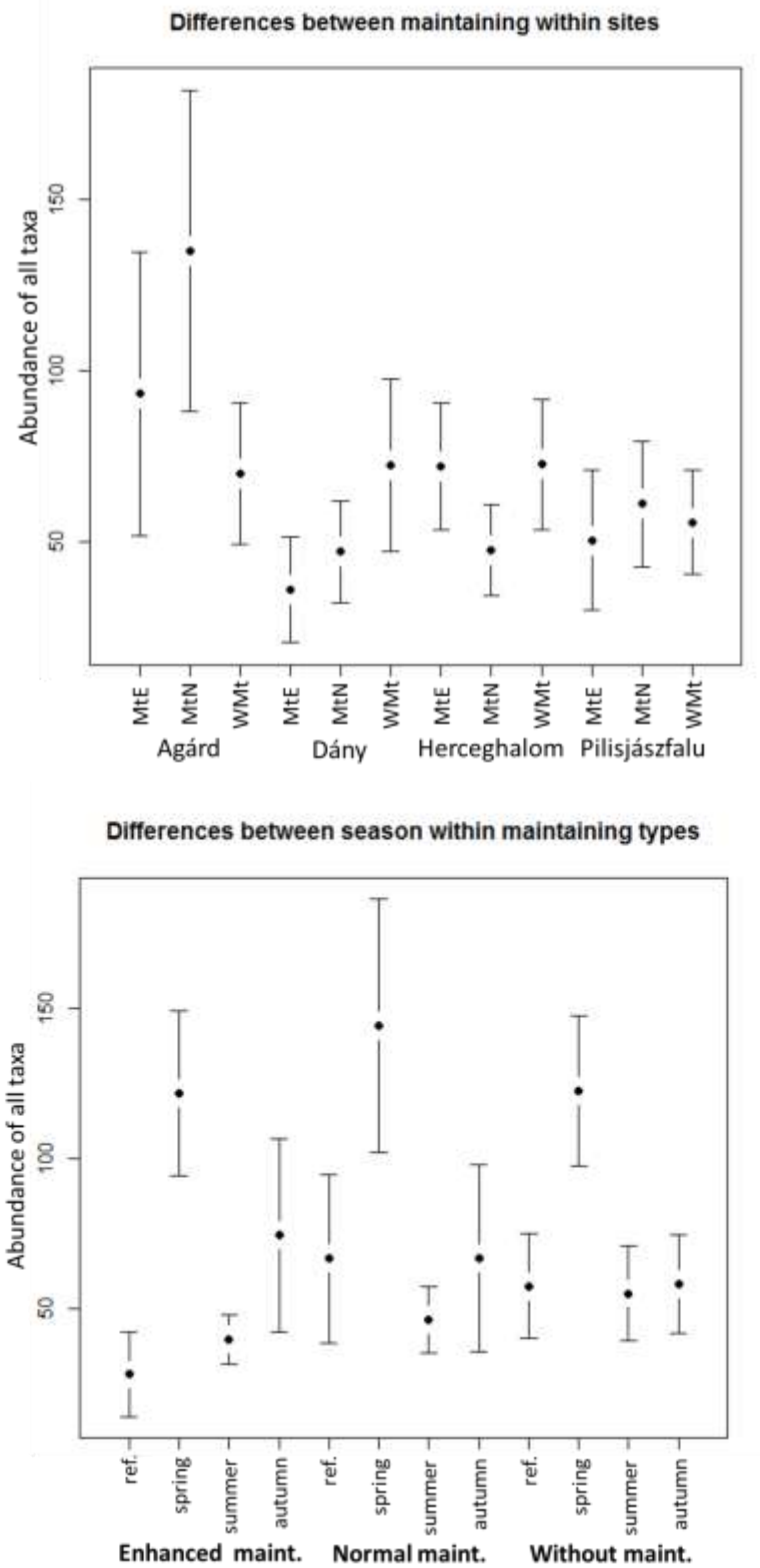


Figure 21 – The abundance of all taxa, depending on maintenance regime, sampling site and season. MtE: enhanced maintenance, MtN: normal maintenance, WMt: without maintenance

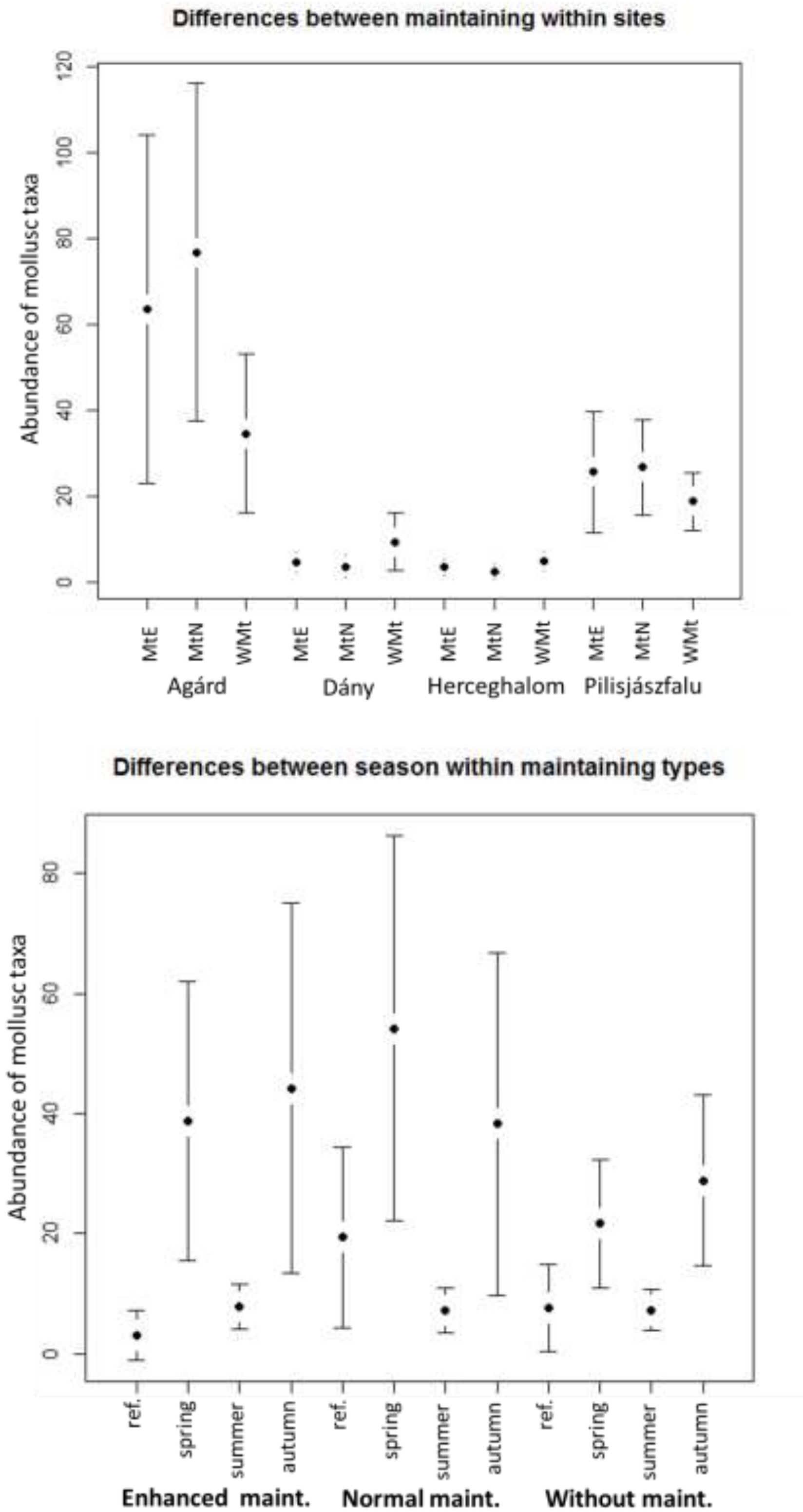
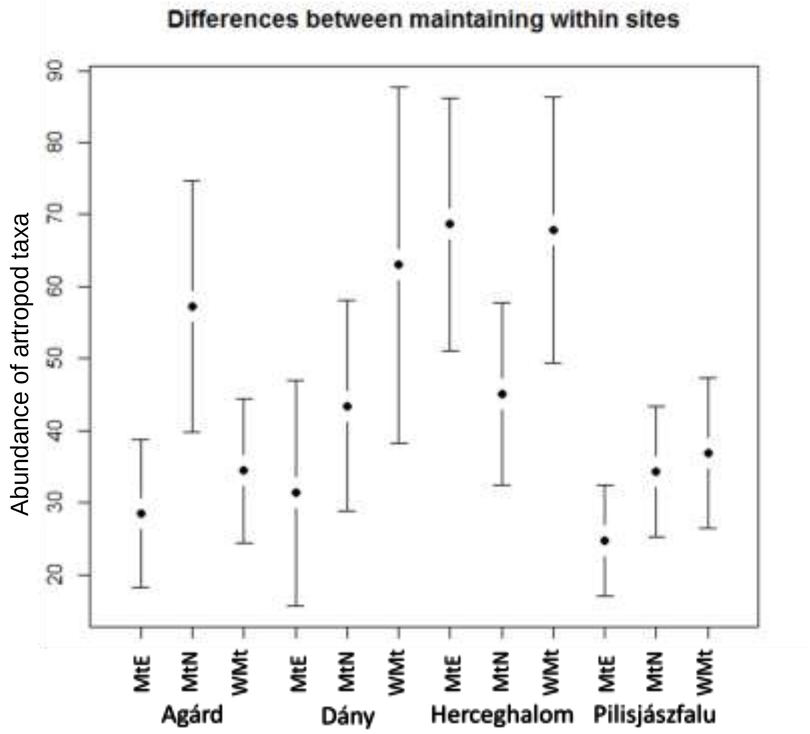


Figure 22 – The abundance of molluscs (snails and slugs), depending on maintenance regime, sampling site and season. MtE: enhanced maintenance, MtN: normal maintenance, WMt: without maintenance.



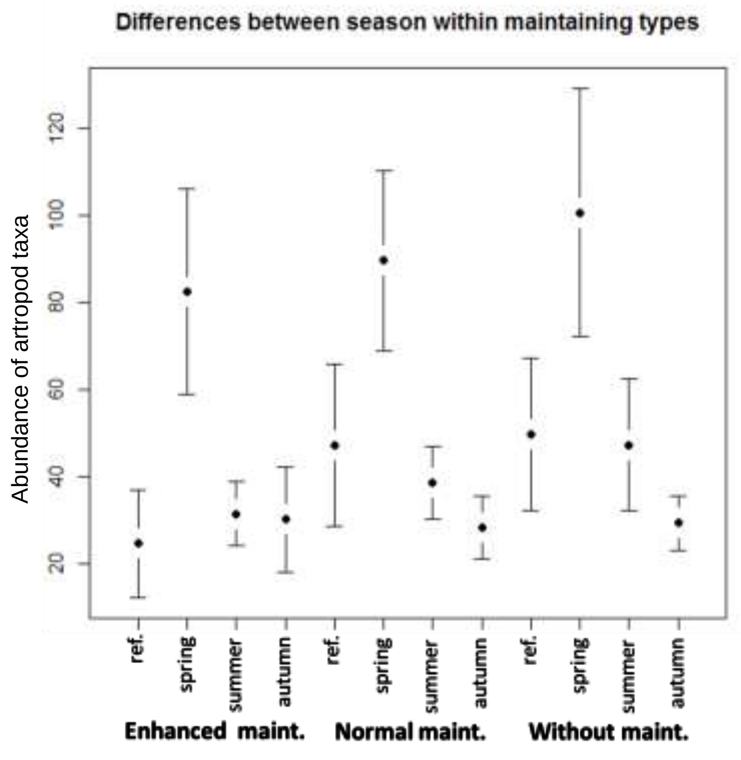


Figure 23 – The abundance of arthropods (Coleoptera, Orthoptera, Cicadea, Isopoda, Araneae, Diplopoda, Acarid), depending on maintenance regime, sampling site and season. MtD: enhanced maintenance, MtN: normal maintenance, WMt: without maintenance.

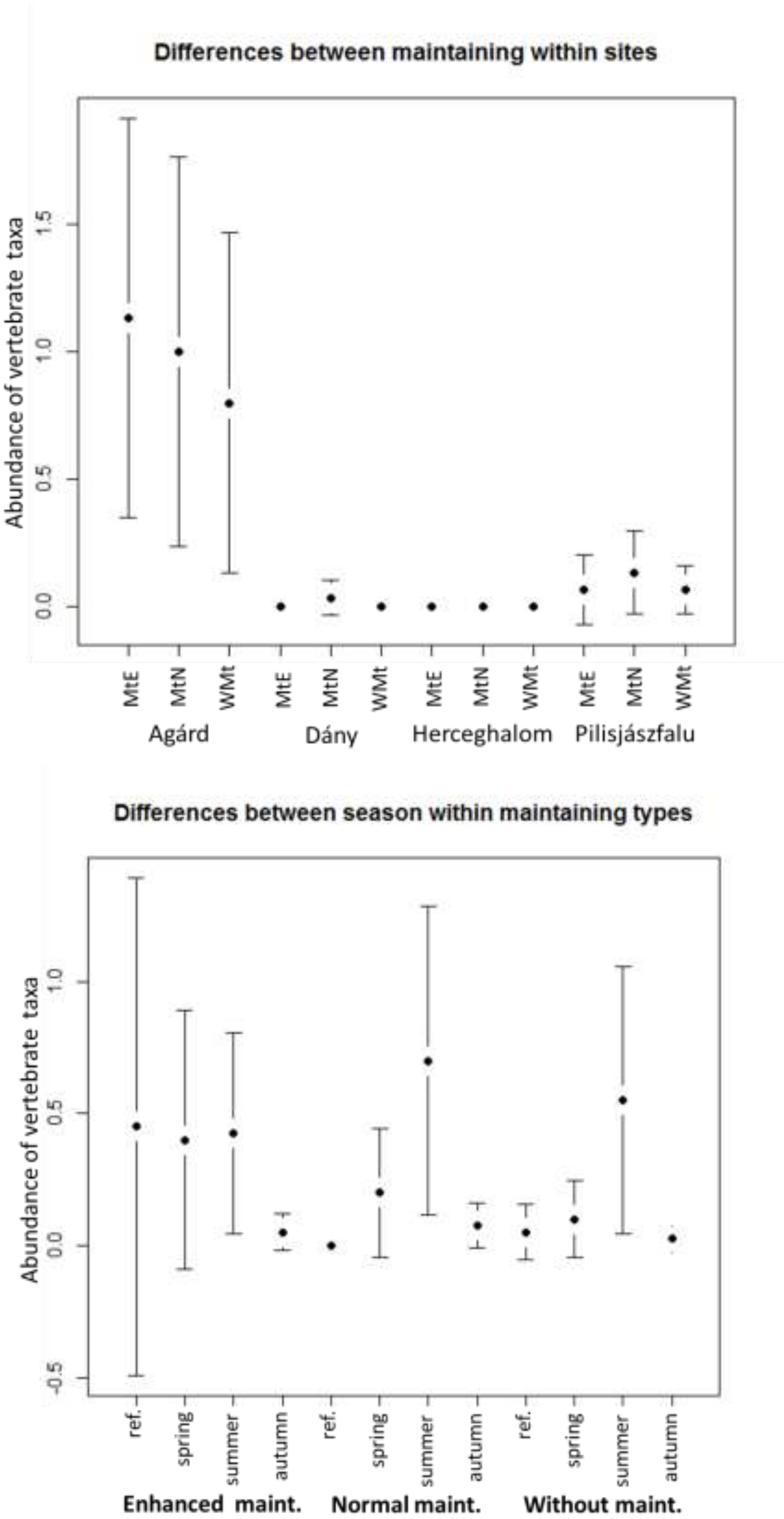


Figure 24 – The abundance of vertebrates (amphibians and mammals). MtE: enhanced maintenance, MtN: normal maintenance, WMt: without maintenance.

The vertebrate taxon was most abundant in Agárd, where the mean values of abundance decreased from sites with enhanced maintenance to sites without maintenance (Figure 24). Here, 96 individuals of amphibians were caught, of which 87% were common spadefoots (*Pelobates fuscus*), 10% were fire-bellied toads (*Bombina bombina*) and 3% were smooth newts (*Lisotriton vulgaris*). In the other three sampling areas the mean values of abundance did not show remarkable differences between the maintenance regimes. One amphibian (*Bombina bombina*) and one mammal (*Crocidura leucodon*) species are listed in Annex II of the Habitat Directive of the European Union. The bicolored shrew (*Crocidura leucodon*) was only captured in Pilisjászfalú.

3.3.2 Results of ADONIS

Table 3 shows the summary of the activity (maintenance regimes within sites) and temporally (seasons within years), nested effects on the taxonomic composition of molluscs, arthropods and all taxa together, analysed by ADONIS. The three models explained 39-43% of the total variance in the datasets. Taxonomic compositions were significantly ($p<0.05$) affected by all of the activity and temporally nested factors. In order of importance, the variance in taxonomic composition was firstly explained by year and secondly by sampling area, 10 to 15% and 11 to 14% respectively (see column R^2 in Table 3). Maintenance regime had a significant, but weak effect on the taxonomical composition of the examined taxonomic groups: 4 to 6% (column R^2 in Table 3).

Table 3 – Summary of the nested ADONIS analyses performed on the taxonomic compositions of mollusc, arthropod and the whole assemblage containing all three taxonomic groups (molluscs, arthropods and vertebrates). Abbrev.: Sampling area – differences between sampling areas; Year – differences between years; Maintenance regime – between maintenance regimes within one site; Season – between seasons within one year; df – degree of freedom; *F* – the value of test-statistic; R^2 – adjusted correlation coefficient; *p* – level of significance.

Source of variance	*df*	*F*	R^2	*p*
Molluscs				
Sampling area	3	14.09	0.11	0.001
Year	1	56.79	0.15	0.001
Maintenance regime	8	1.81	0.04	0.005
Season	3	11.31	0.09	0.001
Residuals	226		0.61	
Arthropods				
Sampling area	3	17.78	0.12	0.001
Year	1	44.14	0.10	0.001
Maintenance regime	8	3.25	0.06	0.001
Season	3	17.47	0.12	0.001
Residuals	273		0.61	
All taxa				
Sampling area	3	21.98	0.14	0.001
Year	1	66.88	0.14	0.001
Maintenance regime	8	2.90	0.05	0.001
Season	3	17.96	0.11	0.001
Residuals	274		0.57	

3.3.3 Main results

1. The influences of maintenance regime were different between the main taxonomic groups. However, these differences could be caused by the differences in selectivity of traps between the invertebrate taxonomic groups and visual observation of vertebrates.
2. In the case of arthropods and molluscs the mean abundances were found to differ between seasons for all maintenance regimes.
3. In the case of vertebrates the mean abundances were highest in summer, followed by spring, in sections without or with normal maintenance. In the sections with enhanced maintenance the mean abundances were similar in the reference, spring and summer periods and these were higher than in autumn
4. The influence of maintenance showed different patterns depending on the sampling areas, which can be explained by different biotic and abiotic environments and the extent of human disturbances.
5. Differences in temporal dynamics were found during the two year long study, because 2014 was more humid than average and 2015 had several hot periods.

3.4 Discussion and conclusions

The results prove that road verges can provide habitat for several ground-dwelling animal groups. It is important to note that these verges are not mere invasion pathways for arthropod species but also refuges for protected and endangered species in the agriculture-dominated landscape in Hungary. This fact should be taken into consideration when deciding about the priorities of road (side) maintenance.

One species and one species group have been essential in our research where data shows clearly how road maintenance affects their spreading: the invasive Lusitanium slug (*Arion lusitanicus*) and the species-rich Aranea.

The vegetation of each sampling area has its own dynamics, which determines the quality and quantity of road verge habitats. Regardless of the different types of vegetation (arid grassland, forested areas, wetland) population explosions of several species were observed in spring in both years. However, several slug species had also a second increase in numbers in the rainy periods in autumn. At that time the juvenile individuals of the invasive Lusitanium slug (*Arion lusitanicus*) were present in high numbers in the samples. The invasive slug species did not have accurately determined dynamics. The data show that in the humid season the species was found everywhere. It was detected in low numbers in the enhanced maintenance section only, but the difference was not significant. In arid periods in summer and autumn the species was present in sections with normal and without maintenance, while its abundance was significantly lower in the enhanced maintenance section. This result shows how road maintenance affects the spreading of species. In our view, this information can be used especially at those areas where species are in their migration and dispersal phase.

In the case of Araneae, special dynamics was observed at all sampling sections. Several spider species were found only at one sampling area. In spring the juvenile individuals were dominant at all sampling areas, but after maintenance started, the different sections had different spider communities. The enhanced maintenance sections of Agárd, Dány and Pilisjászfalu were dominated by ground-living species (e.g.: *Pachygnatha degeeri, Aulonia albimana, Xysticus kochi*), while the net-casting spider species (e.g: *Argiope bruennichi*) dominated in the sections without maintenance in summer and autumn. The difference in species composition between the areas can explain the differences in fauna composition and abundance patterns.

The observed species and their habitat preferences and conservation status indicate that the taxonomic and conservation value of the selected areas in road verges is high and should not be neglected when the NRA is planning the maintenance periods. This applies in particular to the area of Agárd, where several protected amphibian species use the road verges.

The results of this two-year study show that different maintenance regimes for road verges have an impact on the community of several ground-dwelling taxonomic groups. The mean abundance of the community containing all taxa was significantly higher in spring than in the other seasons for all maintenance regimes. In the sections without or with normal maintenance regimes the mean abundances showed similar values in summer and autumn. In the sections with enhanced maintenance the mean abundance of all taxa was significantly lower in the reference period and summer than in autumn. The differences are higher in 2015. We divided the whole community into higher taxonomical groups to explore the finer differences between the seasonal pattern of molluscs, arthropods and vertebrates within the three maintenance regimes. We found a different pattern in the case of arthropods as compared with that of molluscs and vertebrates. This is understandable, because they were the most abundant group with different types of taxa and guilds in our study, which corresponds with previous road research in Hungary (e.g: Kozár *et al*., 2013).

Based on the analyses, seasonal differences in mean abundances of the whole species assemblages exist between the four sampling areas. However, at present the Hungarian NRA uses the same monitoring and maintenance methods in all sampling areas and does not follow and monitor the migration seasons of animals. In the future, the financial and technical background of maintenance regimes will no longer be supported by the State, which obviously brings about an increase in the number of sections without maintenance.

The problem with having road sections without maintenance is that without a transition zone, animals do not perceive the edge of their habitat. Nor can drivers see the animals (not even mammal species) in time, because moving animals in the high grass are not visible. So the road mortality can increase significantly. During this study, the protected bicolored shrew (*Crocidura leucodon*) was detected directly near the road in the section without maintenance of Pilisjászfalú (Road No. 10), but in the case of the normal and enhanced maintenance sections, the species was detected visually within 5 metres of the road.

Our results show that the timing and the intensity of road maintenance are equally important. Timing is important because several arthropods and amphibians were detected in the habitats along the roads during their invasion and migration periods in spring and summer. At the time of amphibian migration, all maintenance on road habitats should be avoided. For example, in the Kiskunság National Park, where a lot of protected wetland areas are near roads, the maintenance of road verges and wildlife mitigation measures at the time of the migration of amphibians and reptiles has been stopped since 2009. Here, maintenance is carried out only once a year, at the end of summer.

The intensity of road maintenance (i.e. the height and width of the mowed grass on the verges) is also important for the habitats. The data of Isopod and Arthropods (e.g. spiders) showed that these species groups were dominant in two subsequent summer seasons. In hot periods the vegetation ensures a shield for these taxonomic groups. By decreasing the intensity of the maintenance regime, verges can provide refuges for several species near fields of agriculture. Not only different invertebrate species but several protected and endangered vertebrate species (amphibian, reptiles, small mammals, etc.) use these habitats. The number of species and individuals were the lowest in autumn, and the differences between the three maintenance regimes were the least in all areas in this season.

The final conclusion of our field experiment is that the intensity of maintenance of road verges significantly determines the ground-dwelling fauna. The NRA needs to take the spatial and environmental differences into account when deciding about the methods of maintaining different road sections.

4 Developing a strategy for cost-effective maintenance

4.1 Introduction

From the desk study (Section 2) it follows that cost-effective maintenance starts with a good design of road components or mitigation measures. So, developing a maintenance strategy should start at an early stage in the road building or modification project. The following sub-sections are based on this assumption. However, many roads and mitigation measures already exist and the design cannot be changed anymore. For these situations sub-sections 4.6 to 4.8 are relevant.

4.2 It all starts with a concept

Developing a cost-effective maintenance strategy to support the ecological functions of roads starts at an early phase of a road building or modification project. For example, design and the materials used have a high impact on the durability and strength of mitigation measures. Design also affects the effort of inspection and maintenance workers to carry out their work. The less time these workers lose in finding and reaching the places to be checked, repaired or maintained or the less time they lose carrying out their work, the lower the costs will be. Hence, when the first ideas about a new road or the modification of an existing road develop, one should also consider the maintenance of its components and what the requirements are for cost-efficient maintenance in regard to the ecological functions.

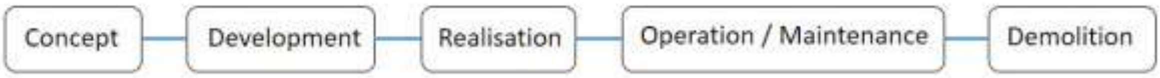


Figure 25 – The phases of a building project

Figure 25 shows the phases of a building project. It is applicable to the procedure of building a new road, retrofitting an existing road, building a mitigation measure or modifying an existing road component (culvert, siphon, verge etc.) into a mitigation measure. In all cases, the end product must be maintained so as to operate as planned. Finding the best maintenance strategy for this starts in the Concept phase. During this phase the following aspects are considered:

- The requirements of the users of the road components;
- The requirements of other stakeholders;
- The problems that may arise during the life cycle of a road, mitigation measure etc.;
- The methods used during Realisation and Operation to check if the road components fulfil their purposes and if the Maintenance is effective.

These aspects are considered regarding the ecological functions of the road and its components. Hence, the most important users are the wildlife. In the Concept phase the ecological aims of the road components or the mitigation measure have to be described. Questions asked are, for instance:

- Are there currently problems between wildlife and roads or are they expected in the future? What is the cause of the problem?
- Does the new or retrofit road offer opportunities to support wildlife in general, a specific species or biodiversity?
- For which target species are mitigation measures needed?
- What function should the mitigation measure fulfil for the target species? Should it keep them from the road, help them to cross the road safely or offer them new habitat?
- When (time of the year or day) should the mitigation measure be available for the target species? Every day or only during migration?
- Can existing road components be used as mitigation measures? If yes, what modifications are needed?

The target species and the function(s) the road component or mitigation measure has to fulfil for these target species determine the first requirements for the specification of the design of the mitigation measure or (modified) road component and also of the maintenance needed in the Operational phase.

The requirements of other stakeholders form the next input for the specification. Among these stakeholders are the inspection and maintenance personnel or companies. These people should be consulted about their experiences with materials, machines and methods that lead to less damage to mitigation measures or make their work easier. Materials that decay fast or break easily when hit by machines require more repairs or replacements and will make the maintenance more expensive. All knowledge and experience about ways to diminish the maintenance costs should be used in the Concept phase of a road project.

Some other stakeholders that have wishes that must be considered are people living next to the road (their property may be used as part of a mitigation measure), drivers, auxiliary and emergency services, etc. Their wishes or requirements will influence the specification of the mitigation measure or (modified) road component. For example, a terrain management organisation owning land next to the road can carry out the maintenance of the mitigation measure or road component but their customary maintenance practice asks for specific requirements for the design of fences. The requirements of other stakeholders are important to consider but these should not lead to a specification that is imperfect for the primary users, the wildlife.

Actually, when building or retrofitting a road system that should also support ecological functions, such as offering habitat or passageways for fauna, many more aspects have to be considered. Figure 26 gives an overview of some of the most important ones.

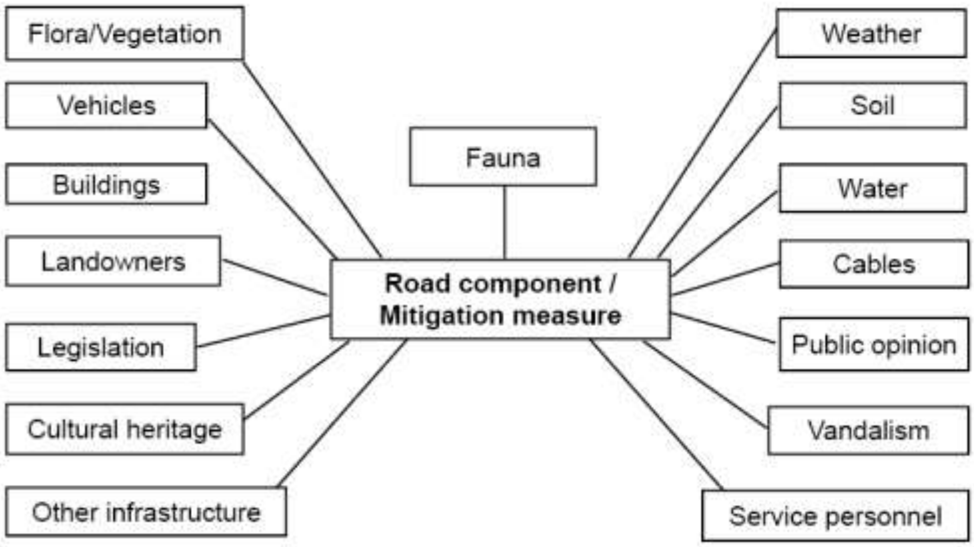


Figure 26 – Context diagram, showing the aspects to consider when building or retrofitting part of a road system that should also be used by fauna.

4.3 A baseline study improves the concept

When the concept is clear it is time to collect data about the current situation at the project location; the baseline study. Data about the current use of the location by wildlife has to be collected, as well as information about the landscape (soil, hydrology, vegetation, land use etc.), ownership of the land next to the (new) road, presence of cables, fences, archaeological heritage, current maintenance practice etc. Information about the wildlife might be:

- which species live there;
- how many of them are there;
- how do they use the area, including existing road components;
- what is their conservation status;
- what is the current impact of the road on their lives or populations;
- etc.

The information about the actual situation may be a reason to reconsider the specification developed in the Concept phase. For example, the soil may not be suitable for the vegetation planned in the Concept phase, or in the nearby arable land, pesticides may be used that will kill invertebrates in the road verge. The baseline study may come to the conclusion that modification of road components will facilitate the spread of invasive species or – a more positive example – a rare species is found nearby for which the road verge may become additional habitat, given the right design and maintenance.

It is important that the baseline study is not limited to the impact zone of the road. Many studies (see overview in Wansink 2016) showed that the ecological functions of a road and its components depend on the differences between the situation near the road and the situation farther away. In certain situations, notably in intensive agricultural and urbanized areas, a road and its components can have an added value for the wildlife in the region. Only a baseline study that covers a larger area than the impact zone will reveal the possibilities.

After the baseline study it is clear which species are involved in the project. When rare or threatened species are involved then national laws (Species Protection Law) or international laws (Habitat and Bird Directives) may give rise to modifications of the specified design or maintenance strategy.

The modified specification may ask for some extra field studies to fine-tune the specification to the local situation. This fine-tuning of the specification is an iterative process. At the end of the Development phase a specification for the mitigation measure or road component is available. The specification describes, among others, the design and the maintenance of the mitigation measure or road component. The specification, including the data and arguments that lead to the specification, must be written down clearly because the specification is needed in the Realisation phase of the project to check whether the end product follows the specification and in the Operational phase to check if the end product really fulfils its purposes as defined in the Concept phase. The baseline data are also the reference for the monitoring in the Operation phase.

4.4 Thorough specifying in the beginning saves costs later

Going through all the steps of the specification process is especially important for large and / or innovative projects, where the costs of failure can be very large. For smaller projects (change of the current maintenance practice to a more biodiversity friendly maintenance practice, for example) the specification can usually be carried out in a less expanded form. However, it is also good to follow the process steps for small projects. Following a complete specification process forces one to consider all aspects that may affect the efficacy and the costs of the structure or the maintenance practice in the long run.

Because everything is recorded during the specification process, it will be easier to pinpoint the causes for successes and failures and to improve the design or the maintenance practice.

4.5 Realisation is a piece of cake

If everything is specified so meticulously, then realising the mitigation measure or modified road component should be easy. Unfortunately, this is often not the case. During construction, unforeseen problems are still popping up. The problems can be very diverse, from local stakeholders that argue that their wishes are not incorporated enough to physical conditions on the location that are somewhat different than expected. Also the contractor may have different, more innovative ideas about the best ways to realise the construction (less likely in Early Contractor Involvement contracts). These unforeseen conditions will affect the specification. In fact it will make the construction fit better to the local situation. However, it should always be remembered that good ecological functioning of the road is the goal of the construction or maintenance scheme and changes in the specification should not harm this.

4.6 Management plan

In the Operation phase good functioning of a mitigation measure or a road component depends largely on maintenance and inspection. Maintenance of mitigation measures or road components to maintain their ecological function is mainly directed towards vegetation management. Vegetation must be maintained to ensure that it retains its function (guiding of fauna or offering shelter to fauna) or to prevent it from obstructing the proper functioning of a mitigation measure (e.g. high grass at the entrance to a small underpass). Because it is easy to predict when maintenance is required, it can be included in a management plan. The management plan describes:

- the ecological goal of the maintenance (which ecological function to achieve or maintain);
- the requirements for the end situation, like the height of the vegetation, the diversity in structure, the condition of objects etc.;
- the maintenance practice, e.g. the method (mowing, grazing, cutting, removing sods) or the frequency (number of times per year);
- the equipment that is allowed to be used; e.g. near to a fence a mowing vehicle is not allowed because the chance for damage is greater than when a hand mower is used;
- practices that are not allowed, e.g. because of legal obligations, like no burning of the verge or no maintenance in the breeding season of birds;
- the people that have to be informed or consulted, or from whom permission is needed to enter their land;
- how to act in unforeseen or emergency cases, like when a protected species or an alien species is present.

Roads and their components usually exist for many years. During these years the ideas and knowledge about maintenance regarding the ecological functions will change. Therefore management plans have a limited life span. But also during their lifespan it is good practice to reconsider the maintenance practices and check whether adjustments are needed, either because new knowledge is available or because the inspection (see next paragraph) showed that the current maintenance practice does not result in a mitigation measure or road component fulfilling the ecological function specified in the Development phase.

One failure during maintenance is very common. Even though everything is specified in a contract it happens that the person in the field does not carry out the maintenance as specified. Often this happens because the operative is not aware of the importance of a certain maintenance practice for the ecological functioning of a mitigation measure or road component (see Section 2.3.2). Therefore, maintenance personnel should not only get a technical education but also a basic ecological education.

The complexity of the maintenance practice may also be a cause for failure. For example, the mowing scheme to develop a species rich verge can be pretty complex (see, e.g. 'sine' mowing regime in Section 2.7). For the maintenance worker in the field it may not always be clear where to mow and where not. A GPS based scheme or small signs along the verge (green stick = mow, red stick = don't mow) may help. But most often a good communication strategy is needed to make sure that the requirements specified by the client are transferred through all layers of the client and of the contractor to the man in the field.

4.7 Inspection

Everything may be very well thought of in the Concept and Development phases, but nevertheless something may go wrong in the Operational phase. Illegal trespassers or a car accident may have damaged a fence, cows may have damaged the edges of a pond, garbage or leaves are blown into an underpass etc. Therefore, it is necessary to inspect the mitigation measure or road component regularly. Regular inspection reveals malfunctions at an early stage, before they turn into real problems or disasters (e.g. vehicle-wildlife collision with a moose). Actually, inspection is a continuous check if the mitigation measure or road component still fulfils the ecological functions specified in the Development phase.

A problem or failure may be very small and not detectable from a car. Therefore, inspection is preferably performed on foot. The inspector should not only register and report the failure but s/he should also try to find out the cause of the failure. Often it is possible to find the cause while in the field. Causes may be related to (poor) management, weather, unauthorized use by residents, vandalism, deterioration of materials or use by wildlife itself.

The inspector can perform small repairs immediately, but more often specialised personnel are needed or a change in a procedure is needed. Who is responsible for the inspection and for solving problems or damage should be clear from the beginning of the Operational phase. Actually, the issue of responsibility should already be tackled in the Concept and Development phases. One thing is certain, the inspector should be independent from the maintenance personnel or company.

As for maintenance, it is possible to develop a plan for the inspection of mitigation measures and road components. It includes:

- the ecological goal of the mitigation measure or road component (which ecological function to achieve or maintain);
- which elements need special attention during the check;
- the requirements for the end situation, like the height of the vegetation, the diversity in structure, the condition of objects etc.;
- the frequency of the inspection rounds (number of times per year; see Figure 16);
- the people that have to be informed or consulted, or from whom permission is needed to enter their land;
- how to act in unforeseen or emergency cases, like when a protected species or an alien species is present.
- the management plan of the maintenance company should also be available for the inspector, so s/he knows what the company should or promised to do.
- a description of how to register and report the findings of the inspection and recommendations for follow up actions. Preferably, standardised forms or an application is used.

It has been noted that an often-mentioned problem during inspection (see interviews) is the difficulty to find the right place with the mitigation measure or road component. This is especially so for small mitigation measures, e.g. small underpasses are quite often installed and not maintained or inspected for many years. When a new maintenance scheme is developed it appears that no one knows the exact location of the object anymore. Constructing a database with the GPS-coordinates will diminish this problem but it is also good to mark the location in the field (Figure 27). It will facilitate the work of the inspector and the maintenance personnel.

Figure 27 – Mark to identify the location of a fauna underpass (Photograph Rijkswaterstaat).

4.8 A continuous learning process

To come to a cost-efficient maintenance strategy to support the ecological functions of roads is a continuous learning process. In every phase of a building project ideas develop, designs are made, data is collected, ideas and designs are modified, things are made or done, new data is collected, ideas, schemes and design are modified again etc. Deming's PDCA circle applies here (Figure 12).

To learn something about the effectiveness of maintenance verification and validation are important. The purpose of verification and validation (V & V) is to demonstrate clearly and objectively whether the result is in accordance with the specification and the intended use. A direct check of the requirements alone is not enough; it is essential to monitor whether the construction still satisfies the original needs of the customers (the wildlife in our case). Reflecting on verification and validation therefore begins with the formulation of the requirements. With each requirement a V & V plan should be laid down formulating what must be demonstrated and how and when this is done. In the Development, Realisation and Operational phases V & V are performed by means of checks and tests. The results are recorded in V & V reports. If the specifications are updated and further detailed, the V & V plan will change too. It is a continuous and cyclic process.

The ultimate test is whether the mitigation measure or road component fulfils the ecological functions it was intended to. A monitoring study in the Operational phase should give the answer to this question.

4.9 Concluding remarks

This report gives general guidelines for a method to develop a cost-effective maintenance strategy. It is not possible to give detailed guidelines that apply to the whole of Europe. The fauna, the landscapes and the legislation in the countries is too diverse. A cost-efficient maintenance strategy is location-specific. However, two important considerations lie at the base of a cost-efficient maintenance strategy that apply to the whole of Europe:

1. Plan ahead;
2. Consider the function that the road component or mitigation measure has to fulfil for fauna.

The earlier in a project one considers maintenance, the better. Considering all possible options, the requirements of the target species and consulting the people involved in inspection and maintenance in an early phase will diminish the costs in the operational phase. It cannot be said too often: cost-efficient maintenance starts with a good design of the road component or mitigation measure. Secondly, it must be clear from the beginning which species are to be supported with a wildlife friendly design and maintenance and especially which functions the road component or mitigation has to fulfil for these species (daily movements, dispersal, life time habitat etc.). For both considerations it is important to involve biologists in the early stages of a project. They have knowledge about the requirements of species and can help to decide what to do, where and when.

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6 References

Bank, F. G., Irwin, C. L., Evink, G. L., Gray, M. E., Hagood, S., Kinar, J. R., & White, P. (2002). *Wildlife habitat connectivity across European highways* (Report no. FHWA-PL-02-011). Retrieved from http://international.fhwa.dot.gov/Pdfs/wildlife_web.pdf

Bellamy, P. E., Shore, R. F., Ardeshir, D., Treweek, J., & Sparks, T. (2000). *Road verges as habitat for small mammals in Britain*. Mammal Review, 30(2), 131-139. doi:10.1046/j.1365-2907.2000.00061.x

Benitez-Lopez, A., Alkermade, R., & Verweij, P. A. (2010). *The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis*. Biological Conservation, 143(6), 1307-1316. doi:10.1016/j.biocon.2010.02.009

Bennett, A. F. (1998). *Linkages in the landscape: The role of corridors and connectivity in wildlife conservation*. Gland, Switzerland: IUCN.

Clevenger, A. P. (2012). *15 Years of Banff Research: what we've learned and why it's important to transportation managers beyond the park boundary*. Paper presented at International Conference on Ecology and Transportation, Seattle, US. Retrieved from http://www.icoet.net/ICOET_2011/documents/proceedings/Session-CRB-1.pdf

Couckuyt, J. (2015). *Sinusbeheer: Maaibeheer op maat van dagvlinders en insecten* (Vlaamse Vereniging voor Entomologie werkgroep Dagvlinders). Retrieved from http://www.phegea.org/Dagvlinders/Documenten/VVE_WG_Dagvlinders_Onderzoek-2015-02_Couckuyt_Jurgen_Sinusbeheer.pdf

Den Ouden, J. B. & Piepers, A. A. G. (2008). *Richtlijnen voor de inspectie en onderhoud van faunavoorzieningen bij wegen* (3rd ed.). Kicks Concept & Design, Voorschoten, Netherlands.

Gemeente Cuijk. (2012). *Ecologisch bermbeheer in de Gemeente Cuijk*. Retrieved from http://www.cuijk.nl/document.php?m=5&fileid=33047&f=4c014a80161572c842c679af92dd9ae0&attachment=0&c=31139

Hopwood, J. (2010). *Pollinators and Roadsides: Managing roadsides for bees and butterflies*. Retrieved from http://www.xerces.org/wp-content/uploads/2010/05/roadside-guidelines_xerces-society1.pdf

Iuell, B., Bekker, H., Cuperus, R., Dufek, J., Fry, G., Hicks, C., & Wandall, B. (2003). *Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions*. Retrieved from www.iene.info

Jones, D. N. & Bond, A. R. F. (2010). *Road barrier effect on small birds removed by vegetated overpass in South East Queensland*. Ecological Management & Restoration, 11(1), 65-67. doi:10.111/j.1442-8903.2010.00516.x

Kociolek, A., Grilo, C. & Jacobson, S. (2015). *Flight doesn't solve everything: Mitigation of road impacts on birds*. In R. Van der Ree, D. J. Smith, & C. Grilo (Eds.), Handbook of road ecology (pp. 281-289). Chichester, UK: John Wiley& Sons. Ltd.

Lambrechts, J. (2008). *Snelle kolonisatie van een waterplas op het ecoduct Kikbeek*. Nieuwsbrief Libellenvereniging Vlaanderen, 2(2), 2-6. Retrieved from http://odonata.be/nl/pub32b.htm

Mata, C., Bencini, R., Chambers, B. K. & Malo, J. E. (2015). *Predator-Prey interactions at wildlife crossing structures: between myth and reality*. In R. Van der Ree, D. J. Smith, & C. Grilo (Eds.), Handbook of Road Ecology (pp. 190-197). Singapore, India: Markono Print Media Pte ltd..

Munguira, M. L. & Thomas, J. A. (1992). *Use of road verges by butterfly and burnet populations, and the effect of roads on adult dispersal and mortality*. Journal of Applied Ecology, 29(2), 316-329. doi:10.2307/2404501

Noordijk, J. (2009). *Arhtropods in linear elements: Occurrence, behaviour and conservation management.* (PhD thesis). Retrieved from http://edepot.wur.nl/13357

Noordijk, J., Delille, K., Schaffers, A. P. & Sýkora, K. V. (2009). *Optimizing grassland management for flower-visiting insects in roadside verges*. Biological Conservation, 142(10), 2097-2103. doi:10.1016/j.biocon.2009.04.009

Noordijk, J., Schaffers, A. P., Heijerman, T., Boer, P., Gleichman, M. & Sýkora, K. (2010). *Effects of vegetation management by mowing on ground-dwelling arthropods*. Ecological Engineering, 36(5), 740-750. doi:10.1016/j.ecoleng.2010.01.003

Nordbakken, J. F., Rydgren, K., Auestad, I. & Austad, I. (2010). *Successful creation of species-rich grassland on road verges depend on various methods for seed transfer*. Urban Forestry & Urban Greening, 9(1), 43-47. doi:10.1016/j.ufug.2009.10.004

Oksanen, J. (2011). *Multivariate Analysis of Ecological Communities in R: vegan tutorial*. – R Documentation, R Foundation for Statistical Computing. Available from: http://www.R-project.org.

Plat, S. (1996). *Effecten van het maai-zuig systeem op bodemfauna van wegbermen*. Wageningen, Nederland: Rijkswaterstaat.

Podlussány A., Szita É., Lupták R., Szénási V. & Kiss B. (2014). *Four weevil species new to the fauna of Hungary from motorway rest areas (Coleoptera: Curculionidae)*. Folia Entomolgica Hungarica 75: 74-78.

Polak, T., Rhodes, J. R., Jones, D. & Possingham, H. (2014). *Optimal planning for mitigating the impacts of roads on wildlife*. Journal of Applied Ecology, 51(3), 726-734. doi:10.1111/1365-2664.12243

Reck, H. (2013). *Die oekologische Notwendigkeit zur Wiedervernetzung und Anforderungen an deren Umsetzung*. Natur Und Landschaft, 88(12), 486-496. Retrieved from http://www.kohlhammer.de/wms/instances/KOB/appDE/Natur-und-Landschaft-fuer-freies-Einkaufen/Die-oekologische-Notwendigkeit-zur-Wiedervernetzung-und-Anforderungen-an-deren-Umsetzung/

Reck, H. & Van der Ree, R. (2015). *Insects, snails and spiders: The role of invertebrates in road ecology*. In R. Van der Ree, D. J. Smith, & C. Grilo (Eds.), Handbook of Road Ecology (pp. 247-257). Chichester, UK: John Wiley &Sons, Ltd.

Ries, L., Debinski, D. & Wieland, M. (2001). *Conservation Value of Roadside Prairie Restoration to Butterfly Communities*. Conserv. Biol. 15, p 401-411.

Rodriquez, A., Crema, G., & Delibes, M. (1997). *Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway*. Ecography, 20(3), 287-294. doi:10.1111/j.1600-0587.1997.tb00373.x

Rosell, C., Helldin, J.O., Reck, H., Navàs, F., Cama, A. & O'Brien, E. (2016). *Road maintenance practice to improve wildlife conservation and traffic safety. 4.1 Review of best practices in road maintenance for wildlife conservation and traffic safety* (Draft version, Feb. 2016). CEDR

Ruiz-Capillas, P., Mata, C., & Malo, J. E. (2003). *Road verges are refuges for small mammal populations in extensively managed Mediterranean landscapes*. Biological Conservation, 158, 223-229. doi:10.1016/j.biocon.2012.09.025

Skórka, P., Lenda, M., Moron, D., Kalarus, K. & Tryjanowski, P. (2013). *Factors affecting road mortality and the suitability of road verges for butterflies*. Biol. Conserv. 159, p 148-157. [doi:10.1016/j.biocon.2012.12.028]

Skórka, P., Lenda, M., Moron, D., Martyka, R., Tryjanowski, P. & Sutherland, W.J. (2015). *Biodiversity collision blackspots in Poland: Separation causality from stochasticity in* *roadkills of butterflies*. Biol. Conserv. 187, p 154-163. [10.1016/j.biocon.2015.04.017]

Struijk, R.P.J.H. (2010). *Rasters voor reptielen: een verkennende studie*. Rapportnummer 2009-032. Stichting RAVON, Nijmegen.

Tälle, M., Deák, B., Poschlod, P., Valko, O., Westerberg, L. & Milberg, P. (2016). *Grazing vs. mowing: a meta-analysis of biodiversity benefits for grassland management*. Agriculture, Ecosystems and Environment 222, p. 200-212. [doi: 10.1016/j.agee.2016.02.008]

Tschan, G., Ó Catháin, E., Corrigan, B. & Carey, C. (2016). *Handbook on procurement and follow-up (incl. performance indicators)*. Deliverable E – Part B of the CEDR Transnational Road Research Programme Call 2013: Roads and Wildlife – Cost efficient Road Management. CEDR, Brussels.

Valtonen, A., Saarinen, K. & Jantunen, J. (2006). *Effect of different mowing regimes on butterflies and diurnal moths on road verges*. Animal Biodiversity and Conservation, 29(2), 133-148. Retrieved from: https://dialnet.unirioja.es/servlet/articulo?codigo=2266233

Van der Grift, E. A., Dirksen, J., Jansman, H. A. H., Kuipers, H. & Wegman, R. M. A. (2009). *Actualisering doelsoorten en doelen Meerjarenprogramma Ontsnippering* (Alterra-Rapport 1941). Retrieved from: http://content.alterra.wur.nl/Webdocs/PDFFiles/Alterrarapporten/AlterraRapport1941.pdf

Van der Grift, E. A., Ottburg, F., Pouwels, R. & Dirksen, J. (2011). *Multiuse Overpasses: does human impact the use by wildlife?*. Paper presented at International Conference on Ecology and Transportation, Seattle, US. Retrieved from: http://www.icoet.net/ICOET_2011/documents/proceedings/Session-CNT-5.pdf

Van der Grift, E. A., Pouwels, R. & Reijnen, R. (2003). *Meerjarenprogramma Ontsnippering kenlpuntenanalyse* (Alterra-Rapport 768). Retrieved from http://edepot.wur.nl/38972

Van der Grift, E. A., Verboom, J. & Pouwels, R. (2004). *Assessing the impact of roads on animal population viability*. In: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott K.P. Center for Transportation and the Environment, North Carolina.

Van der Ree, R., Smith, D. J. & Grilo, C. (Eds.). (2015). *Handbook of Road Ecology*. Chichester, UK: John Wiley & Sons, Ltd.

Wansink, D. E. H. (2016). *Maintenance Report- Ecological functions of Roads*. Deliverable F of the CEDR Transnational Road Research Programme Call 2013: Roads and Wildlife – Cost efficient Road Management. CEDR, Brussels.

Wansink, D.E.H., Brandjes, J. & Emond, D. (2013). *The added value of an ecoduct in an open agricultural landscape*. In: Proceedings of the IENE 2013 Scientific Workshop. Infrastructure and wildlife corridors – Learning from experience. 16th – 18th October 2013, Luhacovice, Czech Republic.

Annex A: Interview

CEDR TRANSNATIONAL ROAD RESEARCH PROJECT – WILDLIFE AND ROADS

<u>Road maintenance practices to improve wildlife conservation and traffic safety</u>

Identification code: country code + No of interview, e.g. ES01 (Same as on file with personal data interviewee)
Interviewer (Name, date, place):

General

1. Are there any formal regulations, <u>handbooks</u> or guidelines, etc. that you apply for the maintenance of roads (its verges, ditches, fences etc.) and/or wildlife crossings (Y/N) (Please send them if possible or tell us the procedure to get them) Are there any <u>reports in which road maintenance is evaluated</u> in relation to wildlife topics?
2. When planning your maintenance of verges, medians, ponds, etc., do you consider animal casualties? (Y/N) How? And in what species groups? *
3. Do you collect information about wildlife road <u>kill</u>? (Y/N)
4. If Yes, do you identify <u>carcasses?</u> (Y/N)
5. And register their exact location in a database? (Y/N), How? (❑by mileage/kilometer-point (PK), ❑GPS coordinates, ❑other________________)
6. If Yes, do you use this data to take measures to reduce accidents? (Y/N) If Yes, please provide further information.

Maintenance practice and organization

7. Roads offer <u>habitats</u> for animals. Do you apply any specific procedures to improve the quality of these habitats (e.g., provide refuges or nests for animals? (Y/N) If so, in which road components? (❑*verge,* ❑*median,* ❑*resting areas,* ❑*road drainage ponds and ditches,* ❑*culverts,* ❑*tunnels*,❑ ❑ other________________)
8. Do you have an inspection regime for mitigation measures (e.g., fencing, sound barriers, ecoducts) (Y/N) If yes, please provide details, if possible.
9. In the design of mitigation measures: is their <u>maintenance</u> taken into account (E.g. access provided for maintenance machines)? (Y/N). If Yes, please provide further information.
10. Who is <u>responsible</u> for the maintenance of road components and mitigation measures for wildlife? (❑*road authority,* ❑*road builder,* ❑*maintenance company,* ❑*landowner,* ❑*NGO,* ❑*volunteers,* ❑*other*________________)
11. Who <u>carries out</u> the maintenance of road components and mitigation measures? (❑*road authority,* ❑*road builder,* ❑*maintenance company,* ❑*landowner,* ❑*NGO,* ❑*volunteers,* ❑*other*_________________)
12. What are the pros and cons of different ways you organise the maintenance?
13. Are field <u>inspection teams</u> sufficiently educated or trained for their job? (Y/N)
14. If Yes, please provide details (How and how often (with or without refreshing courses)? What subjects are covered (e.g. do you teach to collect animals dead on the road, to identify carcasses, to recognize bird nests on viaducts, etc.)? Who is responsible for the training?)
15. What do you specify in maintenance contracts in relation to wildlife habitats or measures? Can you provide us with <u>examples</u> of contracts?

16. Can you suggest any maintenance practice(s) that would improve effectiveness for wildlife?
17. Are there any other problems with animals, identified during maintenance practice?

Costs and effectiveness of maintenance

18. Who pays for maintenance? ❑ *national road authority,* ❑*regional or local government,* ❑*road builder,* ❑*landowner,* ❑*NGO,* ❑*other*_______________
19. What are the yearly costs of maintaining suitable habitat for wildlife along roads compared to the costs of road management in general? ❑ 0, ❑0-1%, ❑1-5%, ❑5-10%, ❑>10%
20. What are the yearly costs of maintaining effective mitigation measures (that help animals to cross roads) compared to the costs of road management in general? ❑0, ❑0-1%, ❑1-5%,❑ 5-10%, ❑>10%
21. Do you have an evaluation of the total costs of car accidents with wildlife on national roads? (Y/N) If yes, can you provide us with the report?
22. What are the yearly costs of maintaining measures to prevent wildlife accidents compared to the costs of wildlife accidents? ❑0, ❑0-1%, ❑1-5%, ❑5-10%,❑ >10%
23. Is research about the effectiveness of maintenance strategies and methods carried out? (Y/N). If so, could you please provide us with (examples of) reports or the outcomes of the research?
24. Who commits (gives the assignment?) and pays for the research?
25. Are there studies on the relation between the effectiveness of mitigation measures and the costs of their maintenance? (Y/N) If so, could you please provide us with (examples of) reports or the outcomes of the research?

Status and improvement

26. Is the maintenance in your organization prioritized? *Y/N*
27. Can you identify ways to make the maintenance of mitigation measures more cost effective? (the organization of the maintenance, the maintenance methods, the construction of the mitigation structures, the materials used or any other aspect).

Additional

28. Anything you would like to add?
29. Do you have illustrations (pictures, drawings) of the practice of maintenance, that we can use in 'Guidelines for Best Road Maintenance Practices to improve wildlife conservation and traffic safety' and in the update of the COST 341 handbook?

Annex B: Glossary

Barrier= Any structure that restricts or prevents the movement of flora and fauna.

Barrier effect= The extent to which roads or other linear features prevent, or filter animal movement. The barrier effect can be quantified by species, populations and so on.

Biodiversity= The variety of life at any given spatial scale including all the levels contained within, including genes, species, communities and ecosystems and their complex interactions.

Blackspot= Part of road with relatively high numbers of road kill.

Centre median= The strip of land separating the lanes of a divided road. Often vegetated with grass, shrubs and/or trees.

Clear zone= A strip of land outside the travel lanes of a road that improves driver visibility and serves as an area for drivers to recover control of vehicles. The clear zone is absent of large obstacles (e.g. trees), and may be paved, have a gravel surface and /or mowed grass.

Connectivity= A measure of connectivity between locations, based on actual movement of individuals or genes.

Corridors= Linear strips of vegetation or habitat that differ from the adjacent areas that allow for the movement of individuals or genes between discrete habitat patches. Corridors may also refer to linear landscape elements, such as roads, railways, utility easements, that may facilitate or impede movement across the landscape.

Dispersal= Ecological process that involves the movement of an individual or multiple individuals away from the population in which they were born to another location, or population, where they will settle and reproduce.

DNA= Deoxyribonucleic acid, the substance comprising the genetic material passed from parents to offspring. DNA has major influences on how individuals develop and differ from each other.

Fencing= Fencing specifically to prevent animals from accessing the road and/or funnel animals towards wildlife crossing structures.

Furniture- fauna= Logs, branches, rocks and other enrichment structures placed in wildlife crossing structures to provide shelter and/or protection from predators.

Gene flow= The transfer of alleles or genes from one population to another.

Genetic differentiation= The level of difference of genetic variation among samples.

Genetic diversity= The level of variability of genetic data within a sample or population, commonly measures through metrics such as heterozygosis and allelic richness.

Habitat= The area or environment where an organism or community normally lives or occurs.

Highway= Major road, usually with more than two-lanes in each direction.

Landscape fragmentation= The physical process where habitats become separated, usually through clearing and dividing of habitat.

Mass migration= Seasonal and round-trip movement in aggregations that include hundreds to thousands of animals.

Migration= Journey undertaken by some species in response to chancing seasons or climatic events, such as rainfall.

Mitigation= Methods used to eliminate or minimize the negative impacts of developments.

Overpass= A road or wildlife crossing structure that facilitates movement over/above the road.

Paved road= Road surface made with asphalt, bitumen, concrete or tarmac: also called ‘’metalled’’ in Britain.

Road verge= The vegetated area adjacent to roads, generally located outside the road shoulder.

Target species= The species or group of species for which the mitigation is intended.

Taxa (singular- taxon)= A classification or grouping of animals such as a class (e.g. mammal) or life-history-related characteristic (e.g. ground-dwelling birds).

Tracking surveys= Following the movement path of an animal by reading and recording locations of animal footprints.

Underpass= A road or wildlife crossing structure that facilitates the movements of things under the road.

Wildlife crossing structure= Any structure designed and purpose built to facilitate the safe movement of wildlife across roads.