Road maintenance guidelines to improve wildlife conservation and traffic safety

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SAFEROAD
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Road maintenance guidelines to improve wildlife conservation and traffic safety

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Executive summary

Context, aims and methods

Road operators are increasingly aware of wildlife-related issues because of the rise in wildlife hazards, particularly ungulate-vehicle collisions, the need to maintain the numerous wildlife mitigation measures that have been implemented and the environmental regulations that require greater protection of habitats and wildlife-inhabited roadsides.

In this context, this report aims i) to provide an overview of current road maintenance practices regarding wildlife in Europe, ii) to identify opportunities and best practices that enable adaptive management of wildlife-related issues, and iii) to provide guidelines for road maintenance to reduce hazards for road users and wildlife, enhance biodiversity and reinforce the European Green Infrastructure.

Our research was based on interviews with 24 professionals involved in road maintenance from 11 European countries, analyses of technical documents on road maintenance and wildlife provided by road operators and a workshop that brought together road and wildlife experts to discuss how road maintenance could be improved for the benefit of wildlife and traffic safety. Our analysis was complemented with a literature review to gather evidence-based knowledge that could be used to determine best practices. Finally, we drafted guidelines for road-wildlife maintenance by compiling all the information gathered.

Providing standards for road-wildlife maintenance

- Guidelines for the maintenance of wildlife mitigation measures and other wildlife provisions should be included in general Road Maintenance Guidelines (RMG) documents to ensure the proper inspection, maintenance and assessment of compliance with standards during road operations. The drafting of additional technical documents focusing on particular aspects of wildlife-related maintenance, such as wildlife crossings and roadside habitat management, is a positive trend that is already being applied in many European countries.
- Standards for the goals and conditions to be achieved by wildlife provisions (also considering legal requirements for nature conservation) may help road authorities to supervise maintenance or operator contractors and ensure compliance. Measurable indicators and thresholds will help to determine when a practice must be improved.

Adopting an adaptive strategy

- Conditions of ecosystems, habitats and species may vary greatly over time due to changing environment conditions, human activities and climate change. Variations require the proper adaptation of road-wildlife maintenance practices to cope with new conflicts or to provide new benefits for biodiversity.
- The adoption of an adaptive maintenance strategy led by road authorities and operators will benefit from closer cooperation between experts in the environment, land planning, water and roads. These authorities can also improve the adaptation of general guidelines to each particular landscape, taking into account not only the ecosystems and the ecology of the species that inhabit surrounding landscapes, but also the human activities

and land uses on roadsides, which could strongly influence the effectiveness of road-wildlife maintenance practices.

- A lifecycle approach will help improve the effectiveness of wildlife mitigation measures and identify better cost-benefit strategies. It may also provide wildlife conservation opportunities.
- An adaptive road-wildlife maintenance strategy should include: standards for wildlife mitigation measures to be met according to both the instructions provided by designers and constructors and the road safety and operation requirements; scheduling inspection and maintenance tasks adapted to the local conditions of wildlife and habitats; establishing procedures for identifying conflicts or their deviation and how to solve them; defining proper training programmes for maintenance crews; defining procedures for monitoring and reporting compliance with standards and disseminating this information to road planners and other stakeholders involved.
- Creating inventories of wildlife provisions for each road infrastructure, web-based databases and other smart technologies will help to integrate and assess all the information about wildlife facts in a road infrastructure. The inventories may also form the basis for identifying new opportunities to improve guidelines.
- Training maintenance staff on road-wildlife guidelines is crucial. Including wildlife experts in a maintenance staff and regularly training maintenance crews can help to ensure that they have the knowledge needed to undertake tasks and record relevant wildlife events, such as road casualties, or detect invasive alien species. When roads are privately operated, maintenance crews should provide evidence of a certain level of expertise in ecological issues. Nevertheless, as the ecological facts and maintenance guidelines are strongly site-dependent, training programmes should be adapted to each road context.

Maintaining wildlife mitigation measures

- We have provided guidelines for maintaining wildlife measures that include checklists of structural and functional points for inspection and that focus on features that could influence the effectiveness of mitigation measures.
- Wildlife fencing and screens, wildlife crossings and wildlife awareness signs are road elements that may need specific guidelines for inspection and maintenance. All of them must be managed to improve traffic safety, but also to funnel animals to safe crossing points. The maintenance of vegetation and other conditions of habitats and refuges for fauna may deserve particular attention because this could greatly influence the effectiveness of wildlife mitigation measures.
- Making human and fauna uses of wildlife crossings compatible also requires the development of proper maintenance tasks. Information for users, education and regulations need to be applied and incorporated into road management.

Maintaining roadside habitats

- A total of 75% of the countries surveyed reported that they had already carried out practices to enhance biodiversity in roadside habitats. Some tasks undertaken by road managers could be highly valuable for biodiversity conservation and Green Infrastructure development and may even benefit human activities by providing ecosystem services, such as pollination and landscape amenities.

- Road verges and other landscaped areas such as ponds and other aquatic habitats associated with drainage systems require maintenance guidelines to enhance wildlife habitats and reduce the hazards of road mortality. Early detection and removal of alien invasive species that could damage local habitats or species is also envisaged as an area that requires attention. The proper management of habitats must help to create legal regulations to protect endangered species and protected areas.
- Attracting animals to roadsides could also create ecological traps, increase the road mortality of endangered species and could increase traffic hazards. Proper maintenance practices play a relevant role in preventing these negative effects.
- An overall strategy that considers and integrates information on the maintenance of wildlife mitigation measures and roadside habitat management will provide appropriate risk assessment and identify the Best Management Practice (BMP) to be applied.

Strengthening cooperation

- Cooperation between all the stakeholders involved in road and wildlife management, and between European countries will greatly help to improve future road-wildlife maintenance practices. It is vital to avoid repeating mistakes and to rapidly adopt the most efficient strategies for road management related to wildlife issues. Platforms for exchanging information will facilitate the sharing of all useful evidence-based knowledge and the application of new innovative solutions for the benefit of road users and wildlife.

1 Introduction

Road authorities have recently stressed the importance of road infrastructure maintenance to ensure the on-going economic and social benefits of this major public asset (ERF, 2014; PIARC, 2014). According to OECD Stats data, over 5.5 million kilometres of public roads are in operation in Europe (ERF, 2014). Since 2008 budgets for road infrastructure maintenance have declined as a consequence of the global economic crisis. The lack of appropriate investments in the maintenance of the road infrastructure reduces the value of the asset, causes adverse impacts and endangers traffic safety. Hence, the identification of strategies to optimize the costs/benefit ratio of road maintenance investments has become a priority. Consequently, wildlife management issues in road corridors have to be addressed in the most efficient way.

During the last 20 years the attention paid to the effects of roads on wildlife has increased notably. Wildlife mortality due to vehicle collisions, the road barrier effect that impedes free fauna movements across the landscape and other issues, such as impacts of traffic noise or road lighting, have been reported to influence wildlife conservation (Forman & Alexander, 1998; Sherwood et al., 2002; Forman et al., 2003; Van Der Ree et al., 2015).

Awareness of the phenomena in Europe reached an inflexion point with the publication of the first European handbook 'Wildlife and Traffic', a product of the COST341 Action (Iuell et al., 2003), and the national handbooks that followed, in which the European guidelines were adapted to the local situation in the country (Trocmé 2015). The European handbook was a result of close collaboration between wildlife and road professionals, not only to highlight the conflicts, but also to propose solutions. Mitigation measures were described in detail; hence, practitioners would be better able to implement them.

A vast number of wildlife crossing structures and other mitigation measures have been constructed on roads across Europe since then. These measures, together with road verges, have been recognised as potential elements of the Green Infrastructure in Europe ('a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services', European Comission, 2013), that can play an important role in wildlife conservation, particularly in intensively managed landscapes (Geessink et al., 2000).

The land occupied by large motorways is estimated to be about 10 ha per kilometre (Rosell et al., 2003). This includes adjacent green areas, resting and parking areas and other complementary services. Road verges are estimated to occupy about 3.5 ha per kilometre of road, which is about 2% of the European territory (Nissen et al., 2015). Hence, road verges offer considerable opportunities to provide habitats for flora and fauna; many of the red-listed species have been found on roadsides (see review in Helldin & Bennett, 2015; Milton et al., 2015). Old trees along roadsides have been pointed out as important refuges for wood-inhabiting beetles and as habitats and guides for the movements of bats and many other species (Reck & Nissen, 2014). Similarly, verges with native plants can provide habitat and act as a corridor for ground-dwelling invertebrates and, if properly managed, could provide ecosystem services such as pollination (Réseau Biodiversité pour les Abeilles, 2014).

However, negative effects have also been reported. Invasive species may spread through road verges or roadside habitats may act as ecological traps (Forman & Alexander, 1998; Taylor et al., 2012). The attraction of animals to roadsides can increase mortality risk and cause a population drop in some species, such as endangered carnivores (Barrientos & Bolonio, 2009; Grilo et al., 2012), raptors and other birds (Meunier et al., 2000; Erritzoe et al.,

2003). Several papers have highlighted the influence of verge-vegetation structure and composition on the occurrence of wildlife in road verges and on the mortality risks for such animals (e.g. Huijser et al., 2006). Bird mortality due to collisions with noise screens has also been reported (Klem, 2008), and the effect of screen design on bird mortality has been investigated (Rössler et al., 2009).

Roadside management can also affect the occurrence of animal-vehicle collisions (AVCs), which are a major concern for road safety. Currently, the number of road traffic accidents involving animals, now estimated at about one million annually, is rising in most European countries (Apollonio et al., 2010). Some road elements, such as road verges or medians, have been reported to have an effect on this problem (Seiler, 2005; Mata et al., 2005; Gunson et al., 2011; Jägerbrand, 2012; Clevenger & Kociolek, 2013).

Although road maintenance practices can have a major influence on the long-term effectiveness of wildlife mitigation measures by contributing to wildlife conservation and reducing AVCs, little information is available about present practices in European countries. Applying a set of maintenance guidelines for wildlife issues may help road authorities to implement the maintenance needed to reduce the negative effects of roads on wildlife, enhance wildlife conservation and increase road safety by diminishing the risks of animal-vehicle collisions.

This study aims i) to provide an overview of current road maintenance practices regarding wildlife in Europe, ii) to identify opportunities and best practices that enable an adaptive management of wildlife-related issues and iii) to provide guidelines for road maintenance to reduce hazards for road users and wildlife, enhance biodiversity and reinforce the European Green Infrastructure.

2 Methods

Data collection on current road maintenance practices related to wildlife issues included: i) interviews with professionals involved in road maintenance in a selection of European countries; ii) a literature review on technical reports on road maintenance and wildlife in those selected countries iii) a workshop that brought together road and wildlife experts to discuss how road maintenance could be improved for the benefit of wildlife and traffic safety.

We complemented this information with a literature review and, after globally analysing all the information we drafted a set of guidelines to improve road maintenance practices related to wildlife issues.

2.1 Interviews with professionals involved in road management

We interviewed professionals involved in road maintenance from 11 selected countries across Europe (Figure 2.1). A total of 24 interviews were carried out during winter 2014 and spring 2015 (Table 2.1). Most interviewees belong to organisations that carry out road management, although some representatives of research centres and consultancies were also included (Figure 2.2). Interviews were conducted by nine researchers from the SAFEROAD and HARMONY ('Procedures for the Design of Roads in Harmony with Wildlife') CEDR project teams, either face-to-face, by telephone or via online meetings.

Table 2.1. List of selected countries and number of interviews carried out. The abbreviations used in the report are also provided.

Country (abbreviation)	Number of interviews
Austria (AT)	2
Belgium (BE)	1
Germany (DE)	3
Spain (ES)	3
France (FR)	1
Hungary (HU)	3
Ireland (IE)	4
The Netherlands (NL)	1
Norway (NO)	2
Sweden (SE)	3
United Kingdom (UK)	1
	24

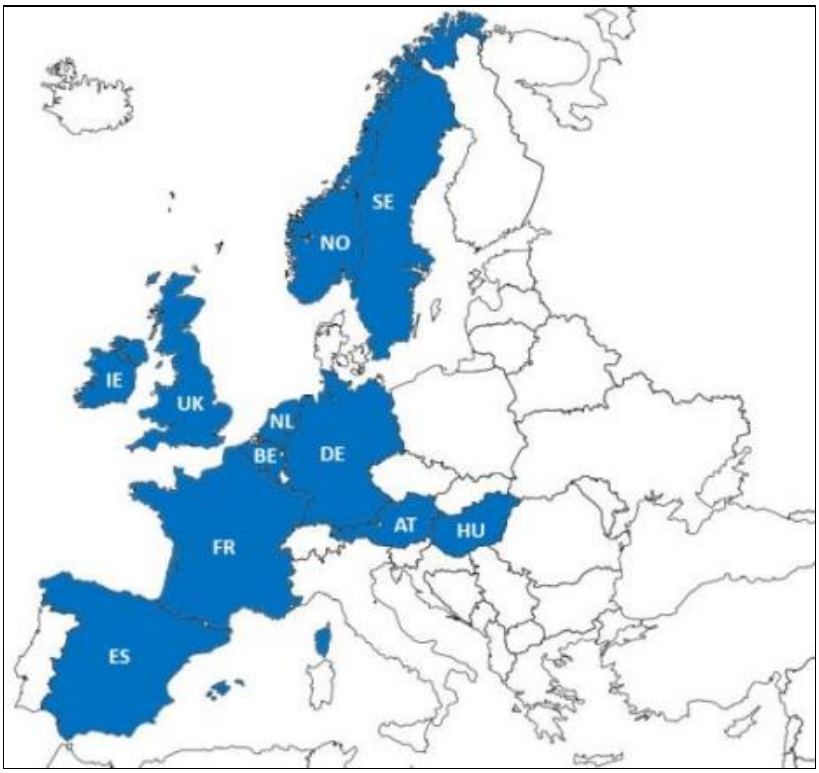

Figure 2.1. Countries where interviews were carried out and guidelines for road maintenance reviewed (in blue).

The majority of interviewees belonged to national and regional road authorities' staff, but public and private companies responsible for road maintenance and one road research centre were also included (see Figure 2.2).

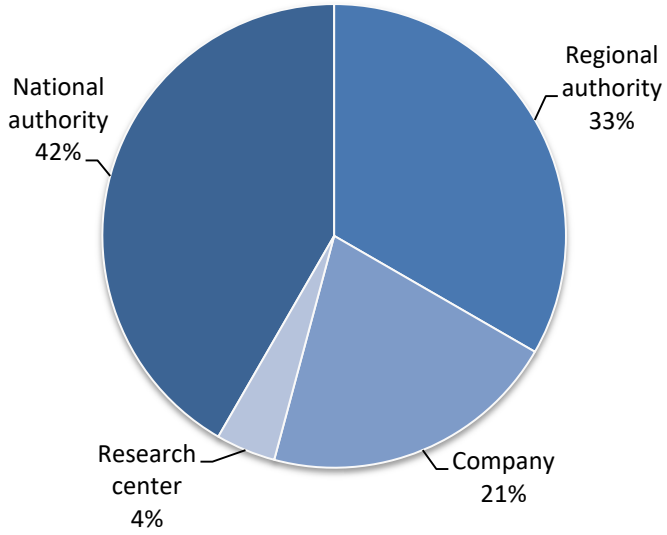

Figure 2.2. Type of organisation involved in road management to which the interviewees belong.

The interviews were structured around 29 questions (interview form presented in Annex A), grouped into five categories:

- General information (existence of guidelines, handbooks and databases; road kill management).
- 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).
- Costs and effectiveness of maintenance (cost of mitigation measures, maintenance and other wildlife topics; monitoring and evaluation of cost-effectiveness).
- Status and improvement (proposals for reducing costs and increasing the effectiveness of road maintenance practices in regard to wildlife).
- Additional information (documents and images provided by the interviewee).

The interview form was often sent to the interviewee before the meeting. In a few cases, the interviewee answered in writing, but more often the information was provided orally in a meeting. The interviews were, whenever possible, held in the interviewee's mother tongue. The answers and responses to each question were then summarised and translated into English by the interviewer.

2.2 Technical and scientific literature review

Technical prescription documents (Codes of Practices, Handbooks, Guidelines, etc.) from the selected countries regarding road maintenance were collected and analysed to identify wildlife-related issues. The documents were provided by the interviewees, acquired through an internet search, or collected from our own archives. Most technical documents were hard to find as they were usually not included in scientific literature databases or found through on-line searches. Some of them were found through the websites of the responsible organisations.

The documents for Road Maintenance Guidelines (RMG) were checked to identify wildlife-related issues by searching for terms such as 'wildlife', 'fauna', 'animal' 'biodiversity', 'habitats', 'verges', 'nature', 'landscape' and 'fences'. The contents of RMG were also analysed to determine which sections could potentially include information on wildlife and which new prescriptions could be included.

We also did a general literature review to research evidence-based knowledge about factors that could be managed during the road operation to reduce road traffic accidents involving wildlife, fauna mortality and other negative effects.

2.3 Workshop about road maintenance at the IENE Conference 2014

The feedback and opinions of professionals - ecologists and road engineers - who deal with road-wildlife issues on a daily basis were collected through a workshop. The workshop was organised as part of the IENE (Infra Eco Network Europe) International Conference 2014, which was held in Malmö in October 2014. A total of 25 experts from 12 countries (Austria, Czech Republic, Denmark, France, Germany, Ireland, the Netherlands, Poland, Russia, Spain, Sweden and Switzerland) participated in a structured discussion about how to optimise the maintenance of: i) road verges and medians, ii) wildlife overpasses, iii) bridges and other drainage structures and iv) fencing and screens. After a brief presentation of the

workshop goals, participants were divided into four groups to discuss the topics. This activity was followed by a plenary discussion. The final output was a list of problems identified for current maintenance practices and possible solutions to both reduce conflicts and increase the effectiveness and durability of wildlife mitigation measures and habitat restoration practices. See Annex B for more details.

2.4 Development of guidelines

We first identified the current practices in the countries studied by combining the information provided by interviewees and reviewing the technical documents they provided, following a structured analysis form. Several topics were investigated:

- Wildlife mitigation measure maintenance.
- Road verges and other roadside habitats management.
- Road casualties and AVC management.
- Maintenance organisation, stakeholders involved, training and monitoring.

From that information we identified opportunities to develop Best Management Practices (BMPs) based on the activities that allow the achievement of these goals:

- To maintain wildlife mitigation measures more effectively, focusing not only on structural but also on functional features.
- To maintain verges and other green areas in a way that benefits biodiversity, reduces negative effects of roads (particularly road mortality and barrier effect) on wildlife and avoids other effects that could affect biodiversity, such as exotic invasive species dispersal.
- To perform an adaptive strategy that includes monitoring the actions carried out, identifying the most successful actions and retrofitting the road management plans and the design of future roads.
- To conduct road maintenance at the lowest cost and the greatest benefit to wildlife and road safety.

We also identified opportunities to improve current practices by reviewing complementary scientific literature and selecting information about road features that can be managed during operation. All the information provided by practitioners and researchers was used to produce a final set of guidelines that can be applied to the maintenance of the roads in Europe, while adapting general prescriptions to local conditions.

3 Current practices on wildlife road maintenance

3.1 Existing guidelines and handbooks

In all the countries studied, routine road maintenance activities are undertaken on the basis of accurate technical prescription documents usually drawn up by national, regional or local road authorities, but also by concessionary companies that operate motorways.

These documents describe the inspection and maintenance tasks of the entire road network in a region or a country, but can also refer to a single road, e.g. a motorway managed by a concessionary company. A great variety of titles are given to these guidelines, such as 'Operation and maintenance requirements', 'Codes of practices for road management' or 'Technical prescriptions for road maintenance'. In this report, we refer to them in general as 'Road Maintenance Guidelines' (RMGs).

Despite variation in structure and content, the RMGs usually include detailed instructions on how to carry out periodical inspections of different road elements; when and how to undertake their maintenance; and the required standards and conditions to meet for different road elements, most of them not related to ecological issues. The sections that were most often included were:

- Pavements
- Road equipment (traffic signs, road marking, road lighting, monitoring, control and information for traffic systems)
- Fences, screens and noise barriers
- Embankments and cuttings
- Landscaped areas (also called green areas)
- Bridges, tunnels and other transversal structures
- Drainage systems, including ditches and ponds
- Pedestrian and cycle tracks
- Special provisions for constructions beside roads (e.g. cultural heritage).

In most countries RMGs include only brief and general information about wildlife. Fencing and road vegetation management are included in all guidelines, but often with no particular focus on wildlife-related issues. Other items included in RMGs in some countries are control of invasive alien species (e.g. NL, NO, UK), road verge maintenance in relation to biodiversity (e.g. AT, SE), animal-vehicle collision management (e.g. ES, in Catalonia regional), and wildlife crossing maintenance (e.g. NO, SE). Structural inspection and maintenance of transversal structures is also established in the RMGs and fauna passages are assumed to be included, but often features that influence their ecological function are not particularly checked or maintained according to their targets. A particular case is found in Germany, where a wide number of specific regulations (28 from a total of 425 in the RMGs) provide prescriptions about ecological issues and road maintenance.

In addition to general RMGs, 45% of the countries studied drafted additional monographs that describe how to carry out the maintenance of road verges and other green areas to provide wildlife habitats, to reduce road mortality or to accomplish other goals related to biodiversity (see examples in Table 3.1 and Figure 3.1). The publication of these documents shows an increasing trend as most of them were drafted in the last five years. Some documents refer to a particular measure (e.g. to enhance habitats for pollinators, FR); however, most refer to green area management (e.g. BE, NL, DE) and also to wildlife mitigation measures in general (e.g. NL and NO). Other complementary regulations and

guidelines are provided by federal states and municipalities in Germany, where site-specific management regulations have been developed, corresponding to the procedures defined in the European directives on Strategic Environmental Assessment and Natura 2000, or corresponding to national approval and impact regulation procedures.

A more recent practice reported in some countries (BE, NL) is the elaboration of 'Road verges management plans' or 'Wildlife road management guidelines' for a single road, often new motorways. These documents are usually drafted by road authorities and provided to maintenance teams or road operators (in the case of Public-Private Partnership, PPP, managed roads).

Guidelines for inspection, maintenance and monitoring are also drafted for many new roads to be undertaken for a short period (3 to 5 years) after its construction. Often road authorities or operators have specific contracts for ensuring a proper maintenance of environmental measures, including wildlife provisions, through this period.

Closely related documents in the countries studied are handbooks for designing wildlife mitigation measures, usually drafted by ecologists and wildlife experts and some of them adapted from the COST 341 Handbook, 'Wildlife and Traffic' (Iuell et al., 2003). These documents are often widely used in road planning, design and environmental impact assessment procedures. However, little attention is paid to mitigation measure maintenance in these handbooks so they are rarely considered in road maintenance procedures.

Table 3.1. Most relevant guidelines drafted in the countries studied dealing with wildlife topics and road maintenance. The titles have been translated from the original language; most documents are only available in the native language. For more detailed information, see Annex C.

Country	Documents
Austria	Documents about the maintenance of particular wildlife mitigation measures and verge management included in general RMG drafted by the Austrian Association for Research on Road - Rail - Transport (FSV): - Implementation, planting and maintenance of green areas (FSV, 2006) - Amphibian Protection: Maintenance of amphibian fences and guiding elements (FSV, 2007) - Environmental measures: maintenance concept is required for all measures (FSV, 2015)
Belgium	Specific guidelines about ecological maintenance drafted in addition to the RMG. - Handbook Nature Technology - Installation and management of roads (Roads and Traffic Administration, 1996) - Handbook Verge Grass Mowing - Restriction and processing verge cuttings (Department of Environment, Nature and Energy, 2006) - Work on the roadside! Manual botanical verge management (Zwaenepoel, 1998) Some roads have specific guidelines that describe wildlife mitigation measures or verge management plans.
France	Several handbooks about the design of wildlife mitigation measures include brief instructions about maintenance. A handbook on road verge management drafted in addition to RMG. - Facilities and measures for small fauna. Technical Guide (SETRA, 2005) - Arrangements of roadside verges of the national network for pollinators (Chagué & Bagnis, 2014) A new book about fauna passages and ecological continuity that will include recommendations about maintenance is under preparation. Some roads have specific guidelines that describe wildlife mitigation measure or verge management plans.
Germany	28 documents about ecological issues are included in standard RMGs. Specific guidelines about fauna passage maintenance and restoring linkages with ecological corridors as well as about ecological vegetation management: - Guideline for fauna passages and ecological maintenance of roadsides in Baden-Württemberg (Research Society for Roads and Transportation, 2004) - Green roadsides. Ecologically oriented maintenance of grass and woodlands to roads (Ministry of Transport and Infrastructure of Baden-Württemberg, 2015) - Design and maintenance of road verges as a contribution to Germany's Green Infrastructure (MAQ, 2016) Some roads have specific guidelines that describe wildlife mitigation measure or verge management plans.
Hungary	Wildlife topics not specifically included in the RMG. Specific guidelines about fauna passage design but with no particular focus on maintenance.
Ireland	Wildlife topics not specifically included in the RMG. Some roads have specific guidelines that describe wildlife mitigation measure or verge management plans.
Netherlands	Several documents with specific guidelines about ecological maintenance have been drafted in addition to the RMG: - Guidelines of fauna facilities along roads (Department of public works, 2005) - Guidelines for inspection and maintenance of wildlife provisions along roads (Ouden & Piepers, 2008) - Guidelines of landscape management (Department of public works, 2013b) - Management of green equipment (Department of public works, 2013c) A code of good practices was drafted to prevent damages to protected species that live in road verges.
Norway	Some information about wildlife topics is included in the RMG: road verges, fences and fauna passages maintenance and control of invasive alien species. Some additional documents deal with wildlife topics with some information about maintenance: - Handbook on roads and wildlife (State road administration, 2014a) - Vegetation along arterial roads (State road administration, 2014b)
Spain	A section about animal-vehicle collision management is included in the RMG by the Catalan road administration. Some brief instructions about the maintenance of fauna passages and fences are included in a handbook: - Technical prescriptions to design wildlife crossings and perimeter fencing. (Ministry of Environment, 2006)
Sweden	Some information about wildlife topics is included in the RMG, and additional documents deal with wildlife topics including some information about maintenance: - Wildlife and infrastructure - a handbook of measures (STA, 2005) - STAs factsheets about wildlife and the maintenance of verges, culverts, bridges (STA, 2014) New guidelines regulating operation and management in maintenance contracts procurement, which will include ecological measure maintenance, are under preparation.
United Kingdom	Some information about wildlife topics is in the RMG, including a section on the legal regulations of, for example, endangered species and alien invasive species control. In addition to environment guidelines, there is also some information about maintenance: - Guidance on the environmental assessment of material resources (DBFO, 2011)

Figure 3.1. Examples of monographs about wildlife issues and road maintenance drafted in different European countries.

3.2 Maintenance of wildlife mitigation measures

3.2.1 Main activities undertaken

Fencing and wildlife crossings (different types, under- or overpasses, specific or multifunctional ones) as well as the installation of wildlife awareness signs to raise driver awareness are the most common measures used to mitigate road effects on wildlife. But many other measures to reduce wildlife mortality and perturbations generated by traffic on surrounding sensitive areas are applied in particular sites.

Mitigation-measure inspection and maintenance schemes vary widely among countries and regions and also differ according to road features, traffic capacity and regulations in relation to environment conditions in the surrounding landscape. Despite the variety of practices, six main elements in the countries studied have been pointed out by road managers as targets of wildlife-related maintenance practices (see Table 3.2). They are listed below according to the frequency with which they were mentioned by road operators interviewed:

- Wildlife fencing, including accessory elements such as exit escape devices and cattle grids.
- Wildlife warning signs, including temporary signs and animal detection systems.
- Road verge maintenance with respect to wildlife topics: in some sites to enhance biodiversity, such as providing habitats suitable for fauna, while in others trying to avoid attracting animals. Provision of wildlife refuges and nesting places on road sides for small mammals, bats, birds, otters and other species are reported particularly in BE, DE, NL and the UK.
- Drainage systems (ponds and ditches) to enhance biodiversity, but also to prevent protected species from entering these road elements in some cases.
- Wildlife crossings and, more rarely, adjacent land to link them with natural habitats.

In many countries, wildlife crossings are inspected regularly (once or twice a year) to check their compliance with the structural standards and against inadequate use. However there were often no reports on evaluating habitat features to ensure that they are suitable for target species. There were also no reports about road designers providing road operators with information about target species and their habitat requirements for each wildlife crossing. This is a critical aspect because maintenance must be adapted to the goals of each wildlife crossing. So, despite the high investment in and the important role of wildlife crossings in preserving or restoring ecological connectivity, particularly between the habitats of endangered species, there generally seems to be little maintenance of these structures to ensure their long-term effectiveness.

The large ecoducts with a complete restoration of their surfaces are a unique situation because their maintenance is transferred to environmental agencies, conservation NGOs or to adjacent landowners in some cases (e.g. BE, DE, NL). The wide surfaces, often including mosaics of trees, shrubs and grasslands, could involve management practices such as livestock grazing, which exceed the road operator's tasks. Involving local stakeholders is done by agreements – often long-term – that could be a good tool to regulate standards for maintenance practices.

New motorways also present a unique situation. In the first 3 to 5 years of road operation, the inspection and maintenance of wildlife mitigation measures is done in accordance with the Environmental Impact Assessment procedures or as an obligation of road construction contractors. During this period, maintenance tasks related to roadside vegetation are more intensive than in the following years. In some regions, research about the use of wildlife crossings by target species is also carried out during this period, and recommendations for improving defects in their construction are produced after inspection (Laje et al., 2014). Periodic reports provide all the information about the maintenance carried out in this period and sometimes contain information about whether a measure is considered to meet standards or objectives. Transferring the knowledge gained during this period of monitoring and follow-up to final road maintenance teams is highlighted as an opportunity for improving practices.

Finally, a practice mentioned by wildlife experts that was not referred to by road operators was the habitat restoration undertaken as compensatory measures in areas far from the road corridor. Road managers did not refer to these tasks because their management is transferred to other stakeholders (environmental agencies, NGOs, etc.). In these cases agreements such as those made for ecoducts could regulate maintenance standards in the same way.

Table 3.2. Current maintenance practices in relation to wildlife issues reported to be applied by road managers in the countries studied. The checklists and periodicity of the inspections is not standardised.

Mitigation measure	Maintenance practices reported
Wildlife fences and screens	▪ Inspection and repair of breaks, holes or mismatches of meshes and soil. ▪ Inspection and repair of amphibian fences (and installation of temporary ones). ▪ Inspection of exit gates and cattle grids. ▪ Clearance of vegetation in a strip of land beside fences to facilitate inspection and repair. ▪ Reinforcement of fences with special meshes for wild boar (*Sus scrofa)* and rabbit (*Oryctolagus cuniculus*) in conflict sections with frequent damage. ▪ Installation of screens to reduce traffic noise or light disturbance. ▪ Marking of transparent screens to avoid bird collisions.
Wildlife warning signs	▪ Inspection and repair. ▪ Installation of temporary signs. ▪ Relocation according to variations of conflict road stretches.
Road verge management	▪ Mowing of herbaceous plants and reseeding when needed, e.g. to promote target species. ▪ Removal of noxious invasive alien species. ▪ Clearance of a strip near the causeway by cutting high herbs and shrubs and pruning trees to increase the visibility of the animals and reduce animal-vehicle collisions. ▪ Installation of nesting or resting boxes for birds and bats.
Ponds and ditch management	▪ Removal of debris. ▪ Vegetation control and removal of invasive alien plants (control of animal- exotic species is not reported in any interview). ▪ Water management in ponds.
Wildlife crossings (specific or multi-use)	▪ Inspection and removal of debris in adapted culverts and underpasses. ▪ Clearance of vegetation that may obstruct entrances. ▪ Inspection to check structural standards. In most cases habitat suitability or specific wildlife provisions are not checked in routine monitoring.

3.2.2 Standards, inventories and performance indicators

Inspection and maintenance standards of mitigation measures are poorly incorporated into the routine tasks of road managers' operation teams as they are not yet fully integrated into the RMG in most countries studied (see section 3.1). Road designers or constructors usually do not provide road operators with standards for mitigation measure maintenance, and even the list of mitigation measures is often not provided. The road staff interviewed pointed this out as the cause of maintenance failures. The existence of integrated inventories including a description of wildlife mitigation measures (especially, but not only, about wildlife crossings) was reported in only a few countries or regions (e.g. in NO and Catalonia, ES). These inventories could provide a basis for establishing a proper maintenance scheme. Nevertheless, some databases are promoted by environmental authorities and not linked to road maintenance programmes. One exception is Norway, where the National Road Data Base (NRDB) provides an inventory of wildlife crossings and other environmental measures. The inclusion of a wildlife mitigation measure in this database ensures that maintenance contractors know about them and can then carry out proper maintenance.

In general, the regular inspection of wildlife provisions (fences, wildlife crossings, etc.) is undertaken according to standard technical prescriptions about the general structural - but not particular functional - conditions to be satisfied. The inspections are done by field crews, who check the correct status of the elements and materials and test structural conditions. Maintenance activities consist of replacing damaged or stolen elements, removing debris, mowing and pruning vegetation, etc. Nevertheless, habitat features that may influence the functionality and effectiveness of the measures require some ecological expertise, which was rarely provided.

The lack of performance indicators to evaluate the correct functional status of the wildlife mitigation measures is also remarkable. Despite all countries applying a set of indicators to evaluate the correct functioning of many road elements, wildlife aspects are often not included at all.

The checklists and the frequency of the inspections are key factors to ensure the appropriate maintenance of mitigation measures and guarantee their long-term effectiveness. Some of the road staff interviewees remarked that severe budget restrictions over recent years and limited resources available for road maintenance have led to prioritizing the maintenance of elements that are most directly involved in traffic safety, such as pavement, signposting and road markings. Inappropriate maintenance of wildlife crossings, road verges and fences is not identified as an important topic in relation to road traffic accidents except in northern countries where moose (*Alces alces)* collisions have a big safety, social and economic impact. In those countries road managers are investing considerable efforts in maintenance activities aimed at reducing animal-vehicle collisions: not only fencing, but also road clearance and other methods (see section 3.4).

3.2.3 Consideration of maintenance issues during road design

Most interviewees (82%) stated that maintenance issues were taken into account during the design of road mitigation measures but only with regard to two topics: to guarantee easy access for operators and machinery (46%) and to reduce future maintenance costs (36%).

Other aspects, such as the durability of the materials and the low need for irrigation or mowing, are reported to have not received much consideration. Interviewees mentioned many other design features to reduce the maintenance tasks. For example, in BE a nutrient-poor substrate in the top layer of wildlife overpasses is applied to reduce vegetation growth.

Road operators stated that the time and budget required to undertake the appropriate conservation of wildlife mitigation measures were directly influenced by the road's design. However, there was no report of any formal communication of maintenance teams' recommendations to road design authorities.

3.3 Wildlife habitat management on road sides

In 73% of the countries studied (Figure 3.2.), road managers apply maintenance practices to enhance biodiversity in some element of the infrastructure, mainly along road verges and in drainage elements (ponds and ditches). Many of these practices are undertaken to benefit endangered species and are required or promoted by nature conservation authorities. In 18% of countries that undertake these practices, the activities reported focus on flora by controlling alien invasive species and promoting native vegetation and insects, specifically providing habitats that are suitable for pollinators. In an additional 55% of the countries studied, other actions to enhance biodiversity are applied to provide habitats for a variety of species, such as amphibians, bats, hazel dormice (*Muscardinus avellanarius)*, red squirrels (*Sciurus vulgaris*), otters (*Lutra lutra)* and badgers (*Meles meles)*. For road traffic safety reasons (because attracting large animals to roadsides can increase AVC risk), most of the target species are small terrestrial animals and aquatic animals.

These specific management practices are not applied throughout the road network, but only in sensitive, protected areas or in sections where the road crosses Natura 2000 sites or endangered species' habitats. Specific practices such as reducing mowing frequency, using reduced-impact machinery or avoiding the use of pesticides are reported to be applied in such places.

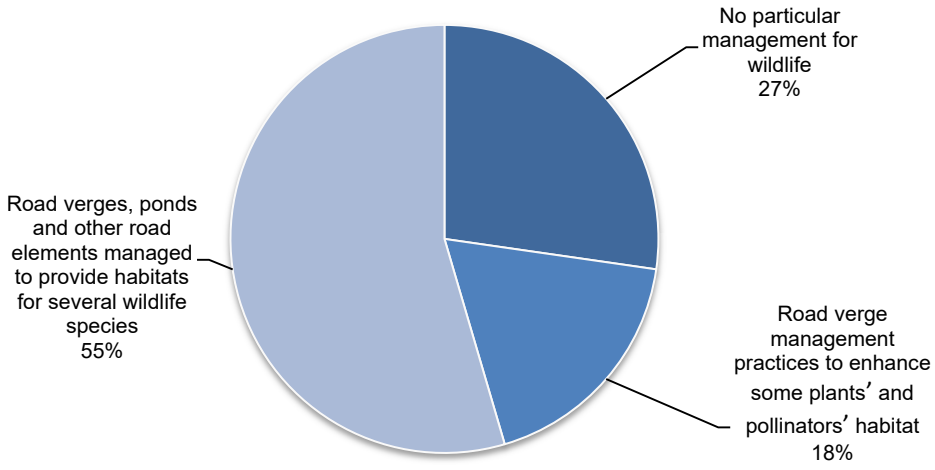

Figure 3.2. Percentage of the countries studied that include some form of road management practices to enhance biodiversity on verges and other elements of road infrastructures.

Table 3.3 lists the practices reported to be undertaken by road managers. In most countries, the focus is on adding biodiversity to the aesthetic and structural criteria used in road verge maintenance. The creation of suitable habitats for pollinating insects, which are currently in decline, is an emerging topic in many countries. This usually means adapting the composition of soil and seeds, regulating the use of pesticides and/or changing mowing procedures. Another quite common activity is improving aquatic habitats associated with drainage systems, such as ponds or ditches. The proper conservation of these habitats is mainly referred to by road managers as a means to avoid mortality and to provide habitats for amphibians (frogs, toads, newts or salamanders), for fish and aquatic invertebrates (freshwater mussels, crayfish or dragonflies) and otters.

Table 3.3. Measures that are reported to be applied by road managers for creating suitable wildlife habitats. Most of them are only applied in particularly sensitive natural sites.

Type	Habitat management measures applied as part of road maintenance to enhance biodiversity and prevent road mortality	Percentage of the countries studied that reported these practices
Road verge management to enhance biodiversity	▪ Development of vegetation with high conservation interest and removal of invasive alien plant species.	55%
	▪ Creation of habitats attractive to pollinators through sowing herbaceous plants that feed them, but also through a change in mowing regime and the provision of refuges.	45%
	▪ Management of tree rows and old trees along small local roads, providing refuges for insects and birds but avoiding attracting large animals that could compromise traffic safety.	9%
	▪ Avoidance of suitable habitats in road verges and medians for small to medium-sized mammals (e.g. rabbits) that may attract predators (carnivorous mammals and birds of prey) to areas with high mortality risk.	27%
Management of drainage elements	▪ Performance of pond and ditch maintenance to avoid damaging the animals living there, and to improve habitats for invertebrates, fish, amphibians, otters and other aquatic or semi-aquatic species.	27%
	▪ Installation of measures that provide passages for semi-aquatic mammals (otter, European mink) across drainage channels, and remediation of migratory barriers in stream crossings.	27%
Providing wildlife refuges	▪ Installation of nest boxes for birds or bats under bridges or in underpasses.	18%
	▪ Creation of stone or wood piles and rows in wildlife crossings to provide refuges for small animals.	27%

Drainage structures (culverts and bridges) are sometimes adapted in the framework of road maintenance to facilitate the passage of small animals by installing dry ledges or providing structures that can be used as refuges or resting places.

Bats and some bird species are reported to be the target of other actions undertaken in three of the countries studied (BE, NL, UK) by installing nesting and refuge boxes below viaducts and bridges and refuge boxes for bats in some small underpasses. Hazel dormouse and red squirrel are also target species to benefit from the provision of refuges, mainly in overpasses and adjacent land (DE, UK). In Mediterranean regions (ES, FR) refuges such as dry stone walls or piles are also provided in over- and underpasses for invertebrates, reptiles and small mammals. NGOs and environmental authorities are often involved in maintaining and monitoring such provisions.

Road managers have also reported habitat restoration for some endangered species (e.g. hazel dormouse) requiring relatively costly and difficult management.

Some interviewees noted the negative aspects of providing refuges or habitats to attract fauna to roadside habitats. The colonisation of retention ponds by invasive alien species was mentioned as an important problem, but also the attraction of species listed in Appendix IV of the Habitats Directive 92/43/ECC, that leads to compulsory changes in maintenance procedures, including the mowing and clearance regimes of roadside vegetation or in the regime of retention pond maintenance. These changes cannot always be easily made compatible with the road management needs.

Road managers from 3 of the 11 countries studied (27%) reported maintenance practices aimed at avoiding the creation of refuges or attractive wildlife habitats in road verges. The attraction of fauna to areas near road causeways is identified as a conflict for two reasons:

- Reducing traffic safety when ungulates or large carnivores are attracted to areas close to traffic lanes.
- Increasing the road mortality of predators attracted by the abundance of small animals along road verges (e.g., rabbits attracting carnivores or small mammals attracting birds of prey to road verges).

In these cases, road managers reported practices such as clearing vegetation, avoiding planting trees or shrubs that produce attractive fruits for birds or other animals and, in general, eliminating any element that could attract fauna (see also section 4.4.2), including the fast collection of debris or recovery of animal carcasses to avoid attracting scavengers, including wild boar. Frequent cutting of shrubs and tree pruning were also reported in areas where the forest is expanding and clearing vegetation is needed to enhance the visibility of traffic signals and to guarantee traffic safety.

With regard to adjacent land uses, interviewees mentioned problems caused by inadequate use or elements developed near fauna passages (e.g. fences installed by land owners or trash containers attracting wild boar) that reduce the effectiveness of mitigation measures and increase conflicts involving animals. Road managers can decide how to manage the strip of public land beside roads and they can also influence the uses and activities that can be undertaken beside roads with respect to traffic safety reasons. For example, in Spain it is forbidden to construct ponds near roads, to plant trees or high bushes that could reduce visibility for drivers or to install electric fences in the strip of public land. These activities can only be authorised if they do not involve risks for traffic safety.

Forest fire management is another, mainly Mediterranean, constraint for habitat management beside roads. Vegetation that may facilitate the starting or spreading of forest fires should not be planted along road verges. In some regions, there is even a legal requirement that a minimum ‘safety area’ of 1 m must be maintained on each side of the causeway where no bushes or trees can be planted.

Another kind of action applied in some countries (e.g. FR, DE, ES) is habitat restoration practices applied outside the road corridor, in adjacent or even quite distant lands, as compensatory measures in new road projects or in the framework of defragmentation programmes. In just two of the countries studied, road managers identified management practices in areas where compensatory measures had been undertaken. The number of road managers reporting these practices is probably low because, in most cases, maintenance is carried out by environmental authorities, municipalities or NGOs.

Other minor conflicts reported by the interviewees are spider webs and small mammals causing problems in instrument boxes; the large number of bird nests under viaducts that should be removed because of droppings that damage the structure; beavers constructing dams that obstruct culverts; big numbers of rabbit burrows that cause embankment instability and ungulates attracted to roadsides by salt used for de-icing.

3.4 Animal-vehicle collision management

3.4.1 Registration of road casualties

The tasks of road maintenance crews frequently involve removing the carcasses of road-killed animals, and carrying out inspections and repairs at places where accidents involving

wildlife have taken place. Nevertheless, there was no report of a standardised registration of wildlife mortality by road maintenance crews in any of the countries studied.

In 64% of the countries, wildlife mortality is registered by road managers only on some new highways or on strongly conflicting stretches of conventional roads with a high frequency of animal-vehicle collisions. Road managers mainly register large animals, such as ungulates, but sometimes medium-sized mammals such as foxes, badgers or otters are also registered. Smaller animals are rarely registered by road field crews.

Two countries (HU and ES) reported the existence of AVC databases maintained by traffic police for the whole road network but only registering accidents in which people were injured. Such databases are also known to exist in other countries, but traffic police often do not report data to road operators. In one interview in Catalonia (ES) road authorities periodically complete and analyse the database provided by traffic police by adding AVC data provided by road managers (government staff and several private road operators) and game authorities.

In two more countries (NO and SE), where moose-vehicle accidents cause a major conflict, AVC data on ungulates are compiled in integrated databases that include reports from several stakeholders. Drivers that hit a large animal must report it to the police, and this notification activates a procedure for collecting the carcass or finding the animal that was injured with the help of local hunters and trained dogs. Data about the accident, including location, and about the animal involved are registered in centralised web-based databases (see Figure 3.3). In the Swedish case, a council (the Swedish National Wildlife Accident Council) has been created to manage these procedures together with road management staff, the police, land managers, and hunters. In Norway a similar procedure is undertaken, with municipalities being strongly involved in managing the database. In Denmark (that was not included in the list of countries studied) also a database compiling road traffic accidents involving deer and red fox is reported (Elmeros et al 2014); the information is registered by tracker dog handlers and by the Nature Agency and includes data on the coordinates of the collision site, the time of collision and the sex and age class of the animal involved.

As traffic safety is the main reason for registering roadkill by traffic police and road managers, most databases focus on accidents caused by large mammals, mainly ungulates. No interviewee reported road operations that made use of information about roadkill compiled by NGOs and other environmental organisations involved in wildlife conservation, despite the huge number of initiatives currently being undertaken many countries.

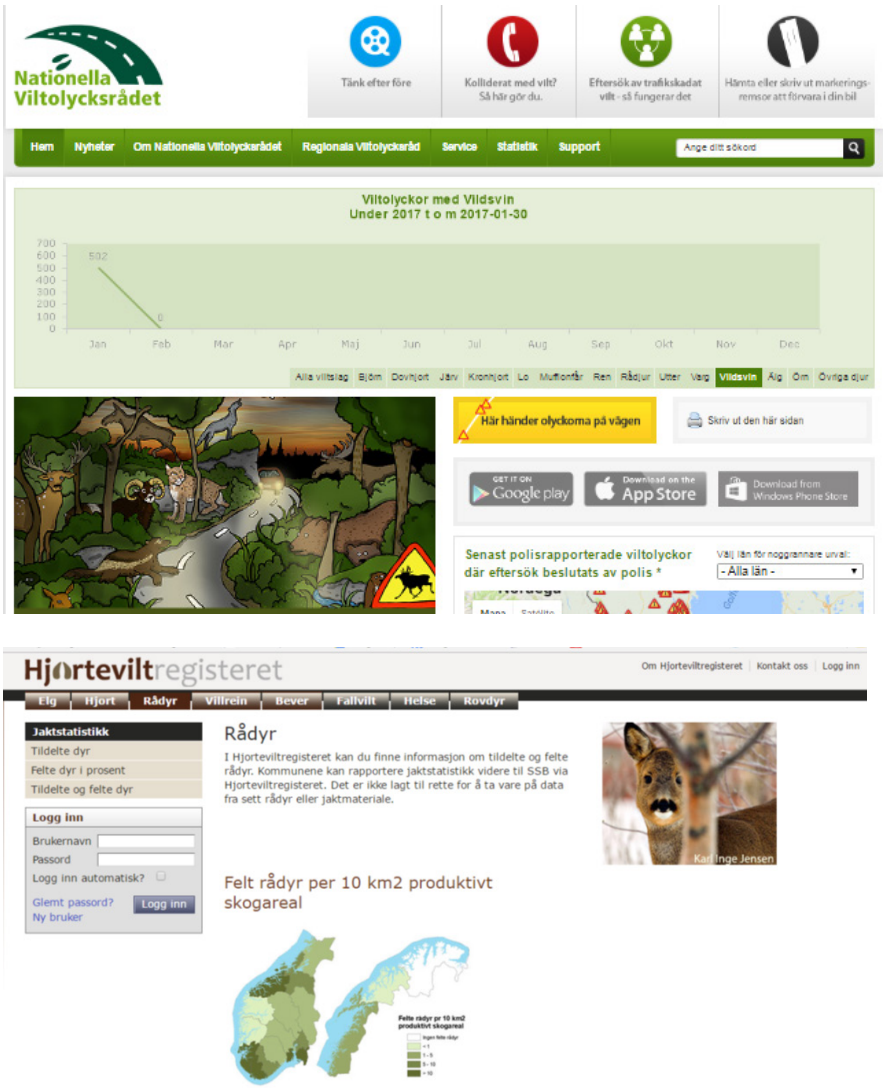

Figure 3.3. Sweden and Norway use integrative web-based databases for registering information on animal-vehicle collisions with many stakeholders involved: drivers, traffic police, hunters and municipalities.

The accuracy of data is a crucial cross-cutting theme. Three aspects are particularly important: the identification of the road-killed species, the accuracy of the location and the representativeness of the findings.

- Identifying the species from the remains of carcasses is reported to be difficult for road crews. This is due to the difficulties in identifying small animals' remains, the logistical difficulties in transporting and conserving carcasses and a lack of knowledge or time to complete the entire procedure required to identify an animal. Only ungulates and large carnivores are more properly identified.
- With respect to location, only 50% of the countries studied registered the location using coordinates, some of them with the assistance of web- and GPS-based tools. The remaining 50% register location mainly by mileage, giving the kilometre-point to different accuracies (usually 100 to 500 m). Nevertheless, many of the interviewed road managers are planning or already beginning to change their reporting activities, using GPS devices that allow the geo-location to be registered.

- In general, there is a lack of information about the methods applied, particularly what are the criteria for registering an event involving animals and whether or not such criteria are applied in a standard way for the entire road network. For this reason, it is not easy to know to what extent wildlife mortality data gathered are representative of the whole phenomenon in a region. The only exception is data registered by traffic police about accidents in which people have been injured; such reports are usually exhaustive. Other data registered by road managers (and also by NGOs or local hunters) often does not include the frequency and length of the road inspected or the methods applied. The lack of standardised methods does not allow a proper identification of the most hazardous road sections because reported hotspots could be sites where volunteers or road manager patrols are more aware of the phenomena.

Finally an increasing conflict reported by many interviewees is the difficulty in removal procedures for carcasses that must comply with waste management regulations in many countries. The increasing number of big ungulate carcasses that have to be removed from road causeways and verges force road managers to use specially equipped trucks to undertake the task, to develop proper reception centres and to transport the carcasses to incinerator centres. The whole process requires a large investment of time and budget.

3.4.2 Assessments based on data about road casualties

An important topic associated with the registration of wildlife mortality and accidents caused by animals is how this information contributes to the diagnosis of the conflict, to the design of mitigation measures and to the evaluation of their effectiveness. Periodic analysis and evaluation of the data is rarely reported by the interviewees, although relevant hotspots with high numbers of AVCs are usually identified.

Table 3.4 lists several remediation measures reported to be implemented by road managers to mitigate the conflict at hotspots. Fences and warning signs are the most common measures applied when a cluster of AVCs is identified, together with clearing road verges (cutting shrubs and any vegetation that obstructs drivers' or animals' vision) along smaller local roads, mainly in Scandinavian countries (NO and SE) but also in Mediterranean ones (ES). In addition, some interviewees referred to the application of visual, olfactory or sound deterrents, even if some of them are aware that these methods have been reported to be ineffective in the long-term. Nevertheless, road managers highlight the need for new research to identify effective measures because the high rate of AVC on conventional roads where fauna passages and fences could not be installed remains a problem. Several countries (DE, ES, FR, NL, SE) reported current or planned tests of new deterrent warning devices and of signs activated by an Animal Detection System (ADS).

Less commonly, some road managers (e.g. from DE, IE, NL, UK) focus on reducing small animal casualties by applying measures such as changes in the management of road verges to try to reduce casualty numbers.

There are rarely any thresholds applied to the number of road casualties above which mitigation measures are required. In one country (ES, in Catalonia), road managers apply a threshold to the number of ungulate-vehicle collisions (UVC) along a road section, which can lead to its classification as a 'UVC priority road section' and to the application of mitigation measures. Thresholds are also applied in other countries (e.g. AT and DE) to require the installation of warning signs.

There were occasional reports (e.g. DE, NL, ES) of applying measures to adapt existing under- or overpasses and culverts for use by wildlife and constructing new fauna passages at existing roads as part of defragmentation projects.

Table 3.4. Measures reported to be applied by road operators in the countries studied in sections where clusters of accidents involving animals or a high frequency of road casualties are registered.

Type	Measures reported to be applied to reduce AVCs
Installation of signs, fences and other infrastructure adaptation	▪ Installation of wildlife warning signs (as well as temporary or reinforcing signs). Often complemented by speed limits.
	▪ Fence repair or reinforcement, or installation of new ones. Target species are often deer and wild boar, but also reinforcement of fences to avoid amphibian, reptile, otter and badger mortality has been reported.
	▪ Wildlife deterrents (mirrors, reflectors, olfactory repellents, etc.).
	▪ Measures to avoid bird-screen collisions: specific screens, marks or special reflecting glasses are applied to transparent noise screens and other devices.
	▪ Changes in the illumination systems to reduce the mortality of insects and bats, or even bird mortality due to collisions induced by glare.
Vegetation and roadside habitat management	▪ Adaptation of mowing practices to reduce fauna casualties.
	▪ Clearance of shrubs and higher plants on road verges to reduce refuges and to increase visibility of large animals.
	▪ Changes in maintenance activities (ponds, verges, etc.) to avoid the mortality of otters, bats and birds.
Defragmentation measures	▪ Adaptation of culverts or other transversal structures to allow the fauna crossing (e.g. by installing dry ledges)
	▪ Construction of fauna passages including installation of treetop overpasses to reduce squirrel and dormouse mortality.
	▪ Identification of areas that need a defragmentation plan to improve connectivity.

3.5 Road maintenance procedures and stakeholders

An analysis of road maintenance organisations was not the main objective of our report. Nevertheless, stakeholders involved have been identified because they are targets for developing best maintenance practices. Knowledge about the organisation is also a key factor to improve management practices by properly disseminating key information and implementing adequate monitoring and evaluation procedures that are the basis for an adaptive management.

The vast majority of the road network is a public asset, and the organisations responsible for guaranteeing its correct conservation are the road authorities. In the same region, three different administrations – national, regional (state, province, autonomous regions) and local – are usually responsible for part of the network; they apply general, national standards as well as specific regulations. National authorities are often responsible for highways and international roads with high traffic intensity, while regional and local administrations are responsible for smaller roads. However, we saw a wide range of situations in the countries studied. In many countries, there is a vast network of small country and forest roads owned by private organisations or people, but they are not the subject of this report.

Governments are mostly responsible for guaranteeing the proper quality of the road network. However, operation and management tasks may be undertaken differently (and some mixed formulas exist):

a) By the staff of road authorities.

b) By specialised maintenance companies contracted by the road authorities. In this case, the road network is usually divided into sectors, and several companies are contracted and undertake maintenance tasks for a certain period of several years. Usually, each respective area is assigned to a single road contractor that must provide all the services and experts to ensure an appropriate maintenance; landscape and wildlife experts may be part of the team or subcontracted by the company. The contents of technical prescriptions in the contracts establish which activities should be undertaken and the standards and conditions that must be met.

c) By concessionaires in public-private partnership (PPP) systems. In this case, a private organisation finances, constructs and operates a road for the period of the concession, which is usually about 30 years. The contracts and payment mechanism options (such as tolls and shadow tolls) vary from project to project, but all conditions for road maintenance are stated in the concession contract between the company and the road authority.

The financial constraints of European governments in recent years have led to a strong increase in the third formula, and build-operate-transfer (BOT) management contracts are presently a common way to construct and operate large roads. Nevertheless, conventional roads still comprise the largest part of the road network and are operated by road authorities and maintenance contractors.

Maintenance contracts – with often detailed technical descriptions – are a key factor in improving road maintenance practices that address road-wildlife issues. Tasks that are not agreed on or stated in the contracts are not undertaken and will require new contracts. Providing standard prescriptions (that must be adapted to local or regional ecological conditions) to be included in these contracts has been reported to be an important tool to achieve fast improvements in wildlife-related road maintenance practices. The ecological aspects reported to be included in these contracts are:

- Landscape requirements.
- Mowing and clearing regimes and techniques.
- Control of noxious invasive species.
- Regulation of herbicide and pesticide use.
- Erosion and soil substrate management in verges.
- Inspection regime of fences, screens and gates.
- Removal and treatment of carcasses.
- Maintenance of drainage systems (culverts, ditches and ponds).
- Maintenance of transversal structures, including wildlife crossings.

Specific conditions for the maintenance of wildlife habitats are in some cases mentioned to be included in contracts. As an example, specific habitat management for fauna or flora is included because of commitments to the Habitats Directive in DE. Specific measures for maintaining wildlife provisions must be offered by companies applying for new highway BOT contracts in the UK.

In relation to roads operated by road authorities, interviewees were asked about road managers' opinions on the positive and negative aspects of maintenance undertaken by maintenance contractors instead of road authority staff. Different, often completely opposite, views were given, as listed below.

The positive aspects reported are:

- Maintenance companies can be more efficiently organised and have better machinery.

- Inspections are carried out by specialised professionals. Ecologists, zoologists or other wildlife experts could participate in the company's team.
- Road authorities can adopt the role of supervisor and carry out quality control to ensure that a consistent approach and proper practices are applied.
- Staff from the road authority may analyse the effectiveness of practices used by different contractors, identify those with the best cost/effectiveness balance and include new requirements in all maintenance contracts.
- Different visions are combined, so that road authorities and the private expert companies' approaches and knowledge are merged.

The negative aspects reported are:

- Lack of consistency of work between different contracts. Different criteria could be applied to the maintenance of different road sections with no feedback on the methods applied and the results between companies working in different sections.
- Knowledge about local conditions and features could be better guaranteed by the more permanent road authority's staff than by changing staff of different contractors.
- Quality control by road authorities is more difficult when it has to be applied to the activities of many different companies. The lack of staff and time to undertake this control is highlighted as an obstacle for proper supervision.
- A large amount of time should be invested in the legal aspects of tenders and contracts that must be renewed every few years.
- Costs of road maintenance are higher because of the companies' profits.

Moreover, economic and organisational constraints and different ways of developing private-public cooperation and partnerships are pointed out as key factors for developing more effective wildlife-friendly road management. Several interviewees remarked that contracts provide a framework for including all the important requirements for best maintenance practices, but that introducing changes is not as easy as in public staff management systems.

Cooperation with other local and environmental stakeholders is an increasing trend (e.g. reported in BE, DE, NL and UK). Wildlife conservation organisations, landowners, farmers, hunter associations or municipalities are already cooperating in many countries to maintain and monitor wildlife provisions, e.g. wildlife crossings or adjacent land to connect the passages with natural habitats.

3.6 Training in wildlife-friendly road management

Usually, maintenance teams are led by a civil engineer and composed of technicians and several field operation teams; the knowledge of these staff about wildlife related to their tasks is considered to play a key role in the effectiveness of wildlife road maintenance. Some of the interviewees reported that contracts awarded to maintenance companies ask for the inclusion of landscape and ecology experts, or a wildlife consultant is asked to be part of the inspection staff (e.g. in IE).

A total of 64% of the countries studied reported that some kind of training is provided to maintenance staff on wildlife issues, such as the collection of carcasses, noxious invasive species and road verge management. However, the training methods are diverse. It could be based on periodical internal seminars where environmental road staff provide information to field crews or be delivered only at the beginning of a new contract. In France, seminars about wildlife mitigation measures are being prepared by a road research centre in cooperation

with environmental organisations, and in Sweden an environmental education programme was developed for all project leaders of maintenance tasks as part of a Life Project entitled REMIBAR.

3.7 Costs of wildlife-related maintenance measures

The budget for road maintenance is provided mainly by the national road authority, but regional and local authorities also contribute. In PPP systems, the budget is provided by the concessionaire, and it could be paid for by public administrations, obtained from tolls, or through other combined systems.

The yearly costs of maintaining wildlife mitigation measures or enhancing habitats for wildlife is generally difficult to determine because it is not registered separately from other maintenance tasks. Nevertheless, most interviewees estimated that less than 1% of the total road maintenance budget is devoted to the maintenance of wildlife mitigation measures, and the same percentage is estimated to be invested for habitat management (mainly road verges). In two cases the budget for habitat maintenance and wildlife mitigation measure maintenance was stated to be between 1-5% (NL) and between 5-10% (DE) of the total management budget. In Hungary also 5-10% or even more than 10% was reported to be invested in each issue, although there is no data to support the estimate.

Some countries reported studies evaluating damage costs related to claims that followed accidents in which animals were involved, but those costs were not estimated by road managers. Detailed data were provided by one interviewee from a regional road authority (Catalonia, ES). An estimated mean cost of 10,785 euros per UVC includes 6,215 euros related to the accident itself – damage to the car, administrative and legal costs, police involvement, and road maintenance – and 4,570 euros per accident associated with the victims. Despite the high cost of the accidents involving large animals and the increasing tendency reported by many interviewees, no one reported any cost-benefit analyses comparing the overall cost of AVCs and the wildlife mitigation measures taken.

3.8 Monitoring and reporting

Road operation and management are assessed on many indicators related to traffic, water and air quality, noise levels, etc. However, the interviewees did not identify any statutory indicators to assess proper wildlife mitigation measures and other maintenance practices related to wildlife.

In 64% of the countries, the effectiveness of maintenance strategies and practice are reportedly monitored to assess the compliance with standards. The projects referred to by the interviewees are mainly related to road verge management and to mitigation measures to reduce AVCs. The interviewees provided data about compulsory monitoring activities undertaken during routine maintenance and also research conducted by external consultants, universities and research centres often not linked to the road operator. Most monitoring focuses on a single topic or sensitive place as a result of the compulsory application of environmental impact assessment procedures.

Many monitoring projects cited do not really evaluate the incidence of maintenance practices, but more general aspects of the effectiveness of the measure to reduce a conflict or impact on wildlife. But some examples mentioned that involved maintenance are listed below:

- The role of road verges as part of the Green Infrastructure was investigated by the Federal Agency for Nature Conservation in Germany.
- Road maintenance practices and wildlife maintenance are evaluated by external consultants in Germany. The research is funded by the Federal Highway Research Institute (BASt) together with other organisations.
- The effectiveness of the mowing programme for roadside verges of state-owned roads and some provincial roads was evaluated in the Netherlands.
- Evaluation of road maintenance mainly related to verge maintenance is part of a research programme (TRIEKOL) led by the Swedish University of Agricultural Sciences.
- A research programme to evaluate the biodiversity interest of ponds in terms of insects, amphibian and fish habitats and the effects of maintenance practices was reported for Sweden.
- A project analysing whether bumble bees are more common along roadsides that have a high botanical diversity and their relationship with verge management and other factors was undertaken by the Norwegian University of Life Sciences. The Norwegian road authority carries out road verge maintenance to benefit a threatened bumble bee species.
- The relation between the effectiveness of mitigation measures and the costs of their maintenance was studied in Norway.
- Fauna passages have been monitored by consultants and universities commissioned by the road and water management authorities in the Netherlands, although it is not clear if and which maintenance practices have been analysed.
- Before/After monitoring of fences, wildlife signs and road management strategies has been carried out in the Netherlands, Norway and Spain.

The results of these monitoring projects were mainly described in unpublished reports, most of them in national languages, with only some reports having an Executive Summary in English. A small proportion of the results were published in peer-reviewed journals or presented at international conferences (e.g. IENE, ICOET). This fact was identified as a restriction to sharing knowledge between European countries.

Road administrations are the main provider of funds for these projects, although regional governments, nature conservation administrations, public companies, municipalities, research councils and foundations also contribute.

4 How can we improve maintenance practices?

4.1 Providing guidelines and standards to be met

Making roads safer for wildlife and people is a big challenge for road operators that can provide social and economic benefits to communities. Major investments are already being made by road managers to reduce the hazards that large animals pose to traffic, mitigate the effects of roads on wildlife and enhance biodiversity on roadsides. Road managers are increasingly aware of wildlife-related issues because of:

i) The rise in wildlife hazards, particularly ungulate-vehicle collisions, registered in many European countries as a result of an increase in ungulate populations (Apollonio et al., 2010; Langbein, 2011; Massei et al., 2014) in recent decades, combined with more and faster traffic.
ii) The numerous wildlife mitigation measures, such as fauna passages that have been constructed or installed in road infrastructures, and the need for their maintenance.
iii) Environmental regulations that require a greater protection of species and habitats, e.g. the EU Birds Directive (EC, 1978) and Habitats Directive (EC, 1992; see overview in Helldin et al., 2016).

There is a consensus that to make the investment efficient, wildlife provisions should be maintained appropriately for as long as a road is in operation (Van der Ree et al., 2015). To provide guidelines for improving current practices, we have compiled information from road managers and wildlife ecologists (see Chapter 2 and Annex B). We reviewed the literature in search of information about factors that could be managed by road maintenance teams during road operation and that could positively influence the effectiveness of the wildlife mitigation measures or reduce the negative effects of roads on wildlife. We have integrated all this information to identify opportunities to improve current practices and BMP that could be applied. This evaluation was the basis of the guidelines we present in Chapter 5.

The maintenance of wildlife mitigation measures and other wildlife-related issues have not been fully integrated into general standards for the RMGs in the European countries studied (see section 3.1). Road managers consider this information crucial to their proper management practices and, specifically, to their regular and systematic inspection and maintenance of the wildlife provisions. Fortunately, the number of ecological issues included in the RMGs has increased over the last decade, and the latest update of guidelines in many of the countries studied includes information about wildlife-related topics. Despite this, however, information is often brief and generalist. Wildlife fencing, roadside habitat management (on verges and drainage elements), control of invasive alien species and, more rarely, the maintenance of wildlife crossings have already been included in the RMGs of many countries.

On the other hand, handbooks dealing with the design of wildlife mitigation measures (e.g. Iuell et al., 2003) only deal briefly with maintenance issues, which make it harder for road managers to consider wildlife topics. To fill this information gap, road authorities in several of the countries studied have drafted guideline monographs on maintaining specific wildlife provisions and green areas (e.g. BE, DE, FR, IE, SW and UK). Similar documents have also been drafted in Denmark (Hogen et al 2010) and Switzerland (numerous Directives drafted by the Office Federal for Roads (ASTRA).

A good practice also applied in some countries (e.g. NL and DE) is the drafting of a ‘Road verge management plan’ or a ‘Wildlife road management plan’ for a single road infrastructure. This practice reportedly allows a greater specificity of and adaptation to the

landscape features (habitats and species) in the maintenance plan and schedule. Such plans are reportedly applied mainly to roads crossing sensitive areas, such as Natura 2000 sites, and to large motorways operated by concessionary companies.

Based on current experiences and expert opinions, we think that the following BMP can improve current guidelines and standards:

- To include in general national or regional RMGs and in contracts with road maintenance or concessionaire companies operating roads, clear and feasible inspection and maintenance instructions for each road element concerning wildlife issues.
- To draft wildlife-road maintenance guideline monographs to be applied to the whole road network operated in a country or region and addressing different road elements (fencing, green areas, road signs, transversal structures, etc.).
- To draft and apply 'road verge management plans' or 'road-wildlife maintenance guidelines' to a single road adapted to the local landscape, habitat and species features.
- To establish clear requirements concerning wildlife in the procurement of road operation and maintenance contracts.

The cooperation of road and wildlife experts in producing these guidelines is crucial to ensur a proper consideration of both issues. Moreover, the cooperation between road, environmental and other (water, land use) authorities is needed to ensure the appropriate consideration of all regulations, plans or programmes.

Another general recommendation provided by practitioners is the elaboration of inventories and databases of wildlife mitigation measures constructed or installed in roads. This is considered to be a fundamental step to apply proper maintenance. Those databases can also be adapted to register any relevant wildlife event (newly threatened or alien invasive species detected, road mortality caused by any road element, etc.). Specific maintenance guideline sheets for sensitive areas, focusing on goals to be achieved, targets (particularly endangered habitats and species) and prescriptions for maintenance practices in these areas are also strongly recommended by wildlife experts. Some countries (NL, NO and SE) have already applied such BMPs and road operators have guideline sheets and databases to register relevant biological observations.

4.2 Improving the maintenance of wildlife mitigation measures

Road managers have reported a wide number of maintenance tasks related to wildlife. Fencing warning signs and road verge vegetation management are the most frequent (see section 3.2). There are many opportunities to improve these practices.

The first obstacle to be overcome is to provide inventories of all wildlife provisions in a road and describe their maintenance needs. General standards for each mitigation measure type can be then provided based on the existing elements in a road; in addition, specific management plans can be drafted for particular elements (e.g., an ecoduct, a pond adapted to host amphibians, box refuges provided for bats, etc.; see section 5.1). Recent experiences in France and Catalonia (Spain) show that integrated inventories of existing wildlife mitigation measures are an interesting step to improve maintenance (Bielsa & Pineau, 2007; Sorolla & Solina, 2014). Road operators may apply more focused, effective maintenance when these inventories are provided by road constructors, who should identify not only the location and features, but also the targets, goals and key elements to be inspected and maintained.

Budget restrictions could pose difficulties when undertaking all recommended maintenance tasks. For this reason, it could be useful to prioritise the activities to be done. This

prioritisation should be based on the results of site-specific analyses. In some sensitive areas the priority may be adaptive management to avoid negative effects on endangered habitats or species, while at other sites priority should be given to reduce the risk of collision with large animals such as deer or wild boar that have a strong safety, social and economic impact (Seiler, 2005).

Monitoring and evaluating the effects of site-specific maintenance practices is essential to allow the application of adaptive maintenance strategies (Van der Ree et al., 2015). Monitoring projects with a BACI design – measuring variables Before-and-After the application of a practice, with Control and Impact (places where the practice is applied and others where it is not) sites – can be performed to assess the effectiveness of maintenance practices or strategies or to test the effects of a maintenance practice on wildlife and road traffic. This approach will help to guarantee that more efficient mitigation is applied in the future and that investments have appropriate benefits (Van der Grift et al., 2013). This approach is also important to identify measures that do not achieve the goals for mitigation (Ward et al., 2015).

Technical documents (see Annex B) and experts involved in road management practices provided interesting practical recommendations for improving wildlife mitigation measure maintenance, which has been used to provide guidelines (see Chapter 5) that include checklists for the inspection status and proper functioning of some measures. Although most scientific papers focus on measure design, many of them provide results about factors that affect wildlife mitigation measures that could be managed during road operation. Maintenance cannot solve failures of the design, such as inappropriate dimensions, shape or location of wildlife structures, but it can improve the maintenance of vegetation, refuges, multi-use wildlife crossings and many others. We have included some relevant information on wildlife-road maintenance below and have taken this into consideration in drafting the guidelines (see Chapter 5).

a) Wildlife fencing

Fence maintenance should be conducted regularly throughout the road operation period and should take into account structural integrity and human or naturally induced breaches as well as the growth of vegetation that can help wildlife to cross the fence (Van der Ree et al., 2015). Proper maintenance improves the effectiveness of fencing and prevents casualties even during the construction period (Weller, 2015), but particularly during the operation period by reducing the risk of road traffic accidents involving animals. Inappropriate fence maintenance in a road section has been pointed out as the cause of an increase of animal-vehicle collisions (Zuberogoitia et al., 2014). Fences could also play an important role in funnelling animals towards crossing structures (e.g. Ng et al., 2004) and, depending on the design, can also act as screening (Van der Ree & Tonjes, 2015). Therefore, the correct maintenance of fences may provide cumulative benefits for mitigation measures. Escape devices, such as right-of-way gates (e.g. Reed et al., 1975; Sielecki, 2007) and climb-outs (Gagnon et al., 2014; Siemers et al., 2014), are installed along some fenced roads; these elements usually have high maintenance costs to avoid corrosion and other damage. A lack of maintenance may have deleterious effects because some animals could use the exit gates as a way to enter the causeways (MMA 2016).

Practitioners particularly highlighted the following improvements to fence maintenance:

- Fence should be constructed with durable materials and low vulnerability to vandalism. Road operators must, in some cases, balance a requirement of making continuous repairs against the substitution of deficient fences with better ones.

- The maintenance of a corridor along the fence free from brushes and branches has been pointed out in Mediterranean regions as a means of reducing damage to the mesh and the time invested in the recurrent inspection tasks.
- Reinforcing fences against some problematic species was a common practice in road operation but the lack of knowledge about suitable reinforcement designs was highlighted.
- Damage caused by people is reported to be a major problem in some areas, and proper information, education and penalties together with appropriate materials, were pointed out as possible solutions.
- The barrier effect of concrete medians is also marked as a problem when no perimeter fence is provided, thus causing hotspots of road mortality; the use of permeable medians such as steel rope is cited as a possible solution that also complies with traffic safety regulations.

b) Screens to reduce disturbance

Noise, chemical emissions, or light produced by traffic has a notable effect on fauna in habitats surrounding the road, and even a negative effect on the use of wildlife crossings (Barber et al., 2010; Brown et al., 2010; McClure et al., 2013). Road managers could help to reduce these effects by providing appropriate screens. Bush screens, wood or concrete panels may be installed to reduce disturbance (noise, light and dispersal of contaminants) to adjacent land. Also, adapting lighting could reduce disturbance of light on wildlife by adjusting the timing (daily or seasonal) of lighting, the shielding of lights, the type of lighting technology, etc. (Blackwell et al., 2015). On the Canary Islands, properly managed motorway illumination during the fledging period reduced the mortality of young Cory's shearwater (*Calonectris diomedea*), an endangered bird species, that collide because of glare (Ministerio de Agricultura Alimentación y Medio Ambiente, 2013). Road and wildlife experts have strongly recommended providing appropriate maintenance to the screens and inspecting their connections with perimeter fences as these points are often left open.

c) Wildlife crossings

The use of these structures by many species of wildlife is influenced by different features that require proper periodic maintenance. The restoration of the structures and their entrances and the conditions of the habitats and land uses in the hinterland are factors to be considered (Reck 2013; Schulz et al 2013). The installation of stone-built refuges in Mediterranean areas enhanced the use of fauna passages by small fauna (invertebrates, reptiles and small mammals; Buton et al., 2014). Proper vegetation maintenance enhanced the use of a wildlife overpass by forest insectivorous birds (Jones et al., 2014), and vegetation cover at the entrances of wildlife crossings is associated with a higher use by several species of mammals (Rosell et al., 1997; Clevenger et al., 2001). Focusing on a proper maintenance of the habitats surrounding the road is another factor that contributes to reducing the barrier effect for small animals (Georgii et al., 2011; Nissen et al., 2015). Different species have different requirements from the surface, entrance and surrounding features, which must be taken into account during road operation to improve passage functionality. Appropriate maintenance is vital to ensure that the characteristics of the surface and surroundings of a passage guarantee its long-term effectiveness. A proper restoration of the structure may also be an important factor, and this requires proper inspection and maintenance (Van der Grift et al., 2013; Rosell et al., 2015). The effects of human activity on the use of wildlife crossings by fauna is also an important factor that could have an impact on their effectiveness (e.g. Clevenger & Waltho, 2000; Barrueto et al., 2014) and should be considered in maintenance practices, particularly in

multi-use structures. Human and wildlife uses could be compatible if the structures are appropriately designed and maintained. During operation, defragmentation actions, aimed to reduce the barrier effect by providing new wildlife crossings, can be undertaken. Modifying transversal structures to adapt them to be used by wildlife could be a useful practice to reduce road casualties in conflict points. Properly restoring surrounding habitats, funnelling wildlife to adapted transversal structures, e.g. with correct fencing (Ng et al., 2004) or placing ledges to facilitate mammals' movements across flooded culverts (Villalva et al., 2013) can be undertaken to improve road permeability to wildlife. Flooded culverts can also act as passages for fish if maintenance works take their requirements into consideration (e.g. García Sánchez-Colomer et al., 2014).

Practitioners provided interesting ideas about practices that could improve the maintenance of wildlife crossings:

- Developing a maintenance plan based on the structure's purpose is recommended to improve the maintenance of large wildlife crossings that often require the particular maintenance of vegetation, screens, fences or refuges provided to animals. Maintenance crews must have a detailed plan of inspection and maintenance tasks to ensure that proper conditions are maintained.
- The use of drones to undertake inspections may reduce the time required and the human disturbances in particularly sensitive wildlife overpasses.
- New maintenance challenges derived from joint human-wildlife needs have to be appropriately managed. Removal of debris or maintenance of vegetation to provide calm places for fauna as well as to provide proper information to the users were positive actions proposed. Wildlife and multi-use underpasses are often used by people for many unforeseen activities; the frequent inspection and adoption of corrective measures has also been pointed out as a priority to guarantee proper conditions for wildlife crossing.
- The use of nutrient-poor soils is seen as good practice to reduce the vegetation maintenance needs as it decreases the rate of vegetation growth. Agreements on livestock grazing are already a common practice in many countries that also help to reduce the vegetation maintenance costs in large ecoducts.
- Rocks, dead wood, resting-boxes and other elements to provide shelter for small fauna on wildlife crossings should also be included in the maintenance plan as they are often not identified or even known by maintenance crews. A proposal to reduce the high maintenance costs of these structures – that often require wildlife expertise – is cooperation with conservation organisations.
- Long-term conservation of wildlife crossings and their surroundings may be improved by involving local people and landowners.

d) Wildlife warnings signs

Those signs, which aim to make drivers aware of the presence of large animals on hazardous road sections, are a widely applied measure that also require proper inspection and maintenance, not only to ensure the proper state of materials, but also the proper location of signs coinciding with clusters of road traffic accidents involving animals. Scientific literature suggests that the efficacy of these signs is limited to short periods after installation (Found & Boyce, 2011) due to driver habituation. In recent years, signs associated with Animal Detection Systems (ADS), detecting large animals and activating flashing signs, have been tested at many sites (e.g. Huijser et al., 2010). However, these require high maintenance to keep the area of detection clean from obstacles, and improper maintenance has been pointed out of as the cause of failures in the activation of these signs. Temporary reinforcing signs may also enhance effectiveness (Sullivan et al., 2004; CDOT, 2012; Rosell et al., 2013) but require more frequent maintenance as signs

must be installed (or activated) at the beginning of a critical period and removed at the end. AVCs involving ungulates show a critical period mainly from early autumn to late winter in Europe (Groot Bruinderink & Hazebroek, 1996; Apollonio et al., 2010; Lagos et al., 2012). The installation of temporary signs based on the assessment of the most hazardous period could be a way to improve the effect of this mitigation measure. Wildlife and road experts foresee the registration of accurate data about AVC and periodical assessments of clusters as the basis for defining the proper locations of the wildlife awareness signs. Registration of small animals could also help identify hotspots of road casualties (e.g. Guinard, 2013; Shilling & Waetjen, 2016). However, in those cases wildlife awareness signs often do not provide solutions, and other mitigation measures should be designed by wildlife experts. The opinions and reactions of drivers regarding different types of wildlife awareness signs could be investigated to improve the management of this mitigation measure (Bond & Jones, 2013).

4.3 Improving wildlife habitat management

In most countries (73%), road managers have reported that they are strongly involved in wildlife issues since their maintenance work on verges, drainage ponds and other road elements includes practices to benefit biodiversity. Such practices focus on the most sensitive areas, especially road sections that cross Natura 2000 sites or the habitats of endangered species. For traffic safety reasons, in most countries these actions focus on providing habitats for small (e.g. pollinators or other invertebrates) or aquatic animals and on recovering endangered flora. Attracting medium and large sized mammals is considered hazardous because of the risk of vehicle collisions.

Some verge and habitat management practices that are undertaken by road operators could be highly valuable for biodiversity conservation and Green Infrastructure development. They may even benefit human activities by providing ecosystem services such as pollination. Some good practices that are already applied in many countries are the removal of alien invasive species that could damage local habitats or species, the creation of suitable habitats for pollinators on verges and other green areas and the proper road verge and median vegetation maintenance to avoid providing habitat for problematic species, such as voles or rabbits, that are the prey of endangered carnivores or raptors, which increases their mortality risks (Planillo & Malo, 2013). Wildlife refuges for birds, bats and dormice have been installed (e.g. BE and UK). Piles or rows of stones or wood have been placed to host small mammals in many countries and in dry Mediterranean regions as well (FR and ES). In many countries, an adapted management of drainage elements (ponds, ditches and culverts) is used to enhance aquatic wildlife (e.g. BE, FR, NL). In Mediterranean countries, fire risk limits verge management, and there are legal requirements about removing bushes or trees from the vicinity of roads.

Scientific literature provides evidence of practices that could be applied during road operation to benefit wildlife. Several alien invasive species use roads as a vector for spreading and colonizing new areas. Their early detection and removal, which is one of the most widely applied management practices in road verges, could be seen as a BMP, as invasive species threaten native ecosystems (e.g. Hansen & Clevenger, 2005; Christen & Matlack, 2006; Jodoin et al., 2008; Helldin & Bennett, 2015). Cars can also act as long-range dispersers, as was observed in Germany (Von Der Lippe & Kowarik, 2007). The soil, humidity and vegetation cover of road verges could be a determining factor that may allow – or impede – the implantation and expansion of invasive species' seeds transported by vehicles. Exotic invertebrates have also been reported to colonize local ecosystems as a result of road verge restoration; in northern Spain, alien flatworms have colonized new areas after their first

detection around a new road, apparently transported by plants grown in nurseries that were used on verge restoration (Alvarez-Presas et al., 2014). Several methods and management practices have been suggested to avoid the expansion of exotic species in road verges. Jodoin et al. (2008) suggest reducing disturbance and planting hedgerows and salt-resistant shrubs to slow reed expansion in Quebec. In tropical Australia, Brown et al. (2006) suggest avoiding open areas in verges to hinder the dispersal of invasive toads along roadsides. Suitable measures to identify and remove invasive species depend on their ecology, and their eradication has positive effects on the ecosystem, as observed using butterfly populations as indicators (Ries et al., 2001).

Butterflies and many other pollinating insects could benefit from good management practices; the mowing regime, for example, has a beneficial effect on butterfly populations (Valtonen et al., 2007). However, proper management is strongly site-dependent: in Finland, frequent mowing reduced butterfly communities on verges (Saarinen et al., 2005), and in the Netherlands mowing twice a year has shown benefits for flower-visiting insects (Noordijk et al., 2009).

Verges can also host endangered species particularly if adequate management actions are applied (Helldin & Bennett, 2015). Reducing soil fertilisation is suggested as a good practice to reduce the expansion of common plants; this diminishes the need to remove the debris of grass cuttings or avoiding the use of mud removed from ditches to fertilize verges. Machinery movement on verges should be limited to avoid compacting and disrupting the soil (Sýkora et al., 2002).

Verge management plays an important role in providing habitats for wildlife, and particular features influence the composition of wildlife populations, as has been registered for small mammals (Bellamy et al., 2000; Ruiz-Capillas et al., 2013). In highly humanised areas, verges properly maintained can act as natural habitats and also as corridors (Meunier et al., 1998). The maintenance of hedgerows along roads contributed to an increase in plant and ant diversity in France (Le Viol et al., 2008). In the UK, a specific management practice was suggested that combined cut and uncut areas on verges; uncut areas provide fruits and harbour invertebrate communities and could make these food resources easily available to birds (Perkins et al., 2002). Installing perching sites on verges has also been proposed to make them a more suitable hunting habitat for raptors (Meunier et al., 2000). However, other authors warn that this action could induce road mortality (Orłowski, 2008).

The registration by maintenance crews of protected flora and fauna living in road verges in the Netherlands is identified as a BMP. According to these results, management plans for the maintenance of green areas are developed to reduce the risk of damage to this flora and fauna.

In some regions attracting fauna to verges has been reported to have negative effects. Rapid removal of carcasses from road verges is seen as a BMP and is widely applied to reduce the risks of attracting scavengers to roadsides, which can increase mortality risk. Other unforeseen elements may attract problematic fauna; e.g. wild boars are attracted by trash containers located at junctions of small forest roads in rural areas, which is a factor associated with an increase in the risk of road traffic accidents (Torrellas, 2015). In some areas, verges provide food and shelter for rodents and rabbits, allowing them to reach high densities. In Spain, this has been pointed out to have negative effects on the conservation of endangered species: the polecat (Barrientos & Bolonio, 2009) and the Iberian lynx (Ferreras et al., 2001). These animals are attracted to roadsides to capture rabbits, increasing their risk of mortality due to road casualties. Robles (2004) recommends cutting bushes near road

verges as dense vegetation was associated with an increase of carnivore mortality in Doñana.

The diverse effects of road management practices, depending on site conditions, highlights the importance of applying appropriate maintenance informed by local ecological expertise since the practices that are suitable in one place may have negative effects in others.

De-icing with salt is also a practice that may cause negative effects by changing the habitats along causeways. Draining roadside salt pools has been shown to reduce moose casualties in Canada (Leblond et al., 2007). The alternative, but more expensive, calcium magnesium acetate, has been shown to reduce or eliminate the effect on plants and is indicated for sensitive areas (Akbar et al., 2009).

Practitioners have provided complementary information and suggestions:

- Road operators strongly suggested considering traffic safety requirements as a priority. Trees, dense shrubs or other elements reducing the driver's visibility were pointed out as increasing the risk of collision with large animals.
- Reducing the attractiveness to scavengers, birds of prey and carnivores that predate on small mammals or rabbits along roadsides was considered to reduce mortality risk.
- The use of proper machinery for mowing was suggested to reduce the risk of injuring or killing animals. Sensitive places could be regularly pruned instead of cut with machines
- Rough vegetation patches may be maintained in certain areas to provide shelter for wildlife, but bearing in mind that population sink effects must be avoided.
- The adaptation of drainage areas to mitigate extreme weather events such as floods due to climate change is seen as an opportunity to adapt them to wildlife use.

4.4 Improving registration and evaluation of fauna mortality

The increase in AVC in recent years in Europe (e.g. Camps et al., 2012; Gren et al., 2015) has posed a challenge for road managers who deal with the growing social and economic costs resulting from this conflict (see Saferoad report 7, Seiler et al., 2016).

Although carcass removal and damage inspection and repair at collision locations is a common task of road maintenance teams, standardised methods for recording this information are not widespread. In 64% of the countries studied, the collection of this information reportedly focuses only on large animals, critical road sections or only some new roads. Traffic police usually register accidents involving injured people, but these databases are rarely transferred to road authorities, so data is not analysed to identify hotspots and design measures to prevent further accidents. Probably due to the major conflict caused by collisions with moose, Sweden and Norway are the countries studied that have complete, integrated AVC databases including all accidents involving large animals. They have also established procedures for recovering dead or injured animals with the cooperation of hunters and trained dogs (Sjölund & Sävberger 2012)). In these countries, all relevant information is registered in databases with the help of municipalities. The cooperative and coordinated work carried out in Scandinavia is a good practice that could be implemented in other European countries. Denmark is also compiling data about game animals involved in animal-vehicle collisions with the cooperation of hunters and tracker dogs (Elmeros et al., 2014).

Registering accurate data on AVC and other road casualties can help to identify hazardous road stretches and the factors that cause road sections to have a high collision risk. It can also contribute to designing appropriate mitigation measures to minimise the conflict.

However, the information is often not analysed or is only used to roughly identify collision hotspots. With respect to accuracy, it has been reported that only half of the countries collect accurate GPS positions of road casualties, and most field teams lack the expertise required to identify small animals. This problem could be reduced by providing specific training on wildlife for maintenance crews, preparing specific field guides that highlight key features to check on carcasses to identify them, or by collaborating with research centres for species identification. Technology may also help to simplify the data collection of maintenance crews. Devices allowing the geo-location of collected data (particularly apps or web-based systems) are useful tools (some already launched by research centres and conservation organisations). Smartphones and tablets are easy to use, can register GPS positions and can take pictures for carcass identification by wildlife experts. The application of these tools may lead to an improvement in current methods. They are already being applied by a large number of projects that monitor road mortality in Europe (Shilling & Waetjen 2016); these projects are often led by wildlife conservation organisations or nature agencies and involve numerous volunteers. However, the data collected are rarely transferred to road managers. Coordinating these activities with road authorities would help to improve mitigation measures.

The use of this information to improve mitigation measures may clearly benefit wildlife conservation, increase the economic efficiency of investments in mitigation measures and reduce the economic and social costs of accidents. Moreover, AVC analyses by road and wildlife experts allow new mitigation measures to be designed and existing ones to be re-located or improved. The definition of thresholds to identify AVC hotspots and assess the efficacy of mitigation measures is also a good practice and will offer an objective parameter to help make decisions on when and where a new mitigation measure is required. The inclusion of standard procedures for road maintenance to manage a conflict is the basis for the adaptive management action that is required to reduce it.

Other BMP that can improve accuracy based on experience are:

- Establishing cooperative networks to collect as much accurate information as possible for a single road or an entire road network. Web-based, well-coordinated systems, where data collected by many stakeholders (including citizens) should be considered.
- The analyses of data on endangered roadkill species provide valuable information to help reduce such an impact on their populations by applying measures at the hazardous sections.
- Roadkill data can also be used to identify areas where endangered species live. The knowledge about target species' location and activity periods helps identity the best management practice to adapt road maintenance works (methods and periods) in these sections to reduce the impacts on wildlife.

4.5 Improving road maintenance procedures and strategies

Road-wildlife management needs to strengthen relationships between the stakeholders that are involved in the different phases of the road lifecycle. These stakeholders include maintenance companies, road and environment authorities, planners, construction companies and operators. Such management may also provide wildlife conservation opportunities. Feedback from managers to planners about inappropriate designs that do not meet goals or that hamper maintenance have been highlighted and can provide designers with useful information on improving wildlife mitigation measures in new road plans and avoid repeating mistakes.

The road authority's role is considered crucial because it is in the best position to provide links between all stakeholders involved throughout the road's lifecycle. Road authorities could guarantee the information flow and ensure that information is properly transferred from different maintenance companies that could change over time. Supervision and quality control have also been identified as a task for road authorities since many different organisations are currently involved in road network maintenance tasks. Closer cooperation between environmental planners, land planning, water and road authorities is required; road management must be adapted to each particular landscape, taking into account not only the valuable ecosystems and the ecology of the species that inhabit surrounding landscapes, but also the human activities and land uses on roadsides that could strongly affect the effectiveness of wildlife maintenance practices. Cooperation with water management agencies has been particularly highlighted as crucial to appropriate planning and maintenance of culverts, retention ponds and other elements of road drainage systems. Climate and global change adaptation and mitigation require strong cooperation to guarantee the proper adaptive management of road-wildlife provisions.

Cooperation between European countries is considered a great strength to adopt the most efficient strategies for wildlife mitigation. However, the exchange of information is hindered because most technical reports and guidelines are only drafted in the country's language. European organisations such as CEDR could play an important role in identifying relevant documents, helping to translate them into several European languages, creating platforms for information and providing opportunities for information exchange.

Many interviewees emphasised the lack of inventories of wildlife provisions and detailed instructions on inspection and maintenance as the cause of inadequate maintenance. Many countries already provide easy access platforms to disseminate information about wildlife mitigation measures (e.g. web-based databases in SE, NO or ES -in Catalonia-) that can be a good basis for defining maintenance plans. Some countries also provide sheets and databases related to wildlife facts and wildlife mitigation measures (e.g. DE and NO).

Contracts that regulate activities undertaken by maintenance or operation companies are another key issue mentioned by many practitioners. At present, road maintenance is based on standards provided by road authorities, which can be implemented by their own staff (national, regional or local), by expert maintenance companies that are hired by road authorities (several companies are contracted and undertake maintenance tasks for a certain road and for a period of several years) or by concessionary companies in public-private partnership (PPP) systems in which private organisations finance, construct and operate roads for long periods of around 30 years. In the last two cases, all management practices need to be clearly established in the contracts to ensure that wildlife-related prescriptions are known and correctly applied. The practitioners encouraged the provision of standards and goals to be accomplished by wildlife mitigation measures, based on European legal requirements for nature conservation; such standards can serve as a basis for supervision of and compliance with contracts regulations. Measurable indicators and thresholds are also important tools to determine when a practice must be improved or changed due to negative effects on road traffic safety or wildlife conservation.

Monitoring the effectiveness of wildlife mitigation measures and maintenance strategies was also considered critical. Monitoring should be properly linked to road operation because, at present, a huge number of reports and scientific literature dealing with wildlife and roads pay little attention to maintenance. Proper monitoring and dissemination of maintenance results could be an important step forward.

Another obstacle to be overcome is the maintenance teams' lack of knowledge about basic wildlife facts. Criteria on the staff's ecological competences are rarely included in tenders for maintenance contractors. However the cooperation of wildlife expert teams and road experts could strongly improve the quality and adaptation of practice to local wildlife features. Regular training of crews is considered to be an essential action to ensure that the maintenance staffs has all the knowledge needed to undertake tasks and record relevant wildlife events, such as road casualties, or detect invasive alien species. Nevertheless, this knowledge is strongly site-dependent and therefore needs to be adapted to each road context. Regular training meetings are planned in some countries. One particularly useful example are participative training meetings where wildlife experts meet maintenance crews and exchange knowledge about conflicts identified and potential solutions to be applied.

5 Guidelines for maintenance to improve road safety and enhance wildlife conservation

5.1 Framework and goals to be achieved

The guidelines provided in this section comprise a set of practices to be adopted by road operators to improve the management of all wildlife-related issues. The main goals to be achieved are:

a) To improve traffic safety by reducing the risk of road traffic accidents involving wild animals.
b) To reduce the impact of roads on wildlife by reducing road mortality, the barrier effect and other effects.
c) To enhance the role of road verges and other landscaped areas as elements of the Green Infrastructure of a country or region -particularly in humanised areas where natural habitats are scarce-, while avoiding the creation of sink effects due to road mortality or other adverse effects.

The guidelines are organised into different road elements, as in most RMGs. The main sections are:

- Strategy and general procedures
- Wildlife fences and screens
- Wildlife crossing structures
- Wildlife warning awareness signs
- Road verges and other green areas
- Ponds and other elements of drainage systems
- Management of road casualties and road traffic accidents involving animals

In each section, we provide a brief introduction about the relationship between each road element and wildlife and a general view of the activities involved. This is followed by one section including guidelines on planning and scheduling maintenance and a second one providing instructions on inspection and maintenance, with indications about some particular topics that differ from one road element to another.

The European diversity of landscapes, climate, ecosystems and wildlife features, does not allow detailed prescriptions to be applied throughout the continent. The current practices that were evaluated (see Chapter 4) show a diverse baseline situation, as some countries already include several wildlife topics in their RMG, while others only deal with road traffic accidents caused by animals. Therefore, the guidelines must be envisaged as general indications on topics that should be addressed. They need to be adapted to the conditions of each country or region (road network, environment and economy), and specific standards must be defined for each one.

Although the guidelines focus on maintenance and management practices, many road elements could be modified, removed or replaced during road operations. Therefore, some prescriptions also deal with changes in the design of a road element. However, no details are provided on design, and other specific handbooks on the design of mitigation measures may provide the required information.

The first chapter dealing with procedures, cooperation with other stakeholders, training and monitoring provides the essential information for a global management adaptive strategy that

will allow practices to continuously improve based on an assessment of the results of existing ones.

5.2 Establishing an adaptive road-wildlife maintenance strategy

5.2.1 Who should lead the development of the road-wildlife maintenance practices?

Road authorities are responsible for guaranteeing the proper quality of the road network, but operation and management tasks may be undertaken directly by road authorities' staff, by hired maintenance companies or by concessionaires that operate in varied formulas of PPP systems. All of them must adopt the guidelines to ensure a proper road-wildlife maintenance strategy. However, road authorities are the organisations that must provide the general framework and rules to be adopted by all road operators, according to the features of the road infrastructure or network they manage. They also play an important role in ensuring that information flows between road designers, constructors, operators and other authorities involved in road and wildlife management, such as environment, water and land planning authorities.

Properly harmonising wildlife and road issues and integrating wildlife regulations into road management begins during the road planning phase and must be ensured by properly constructing all wildlife provisions and mitigation measures. Information must flow appropriately in the entire road lifecycle to achieve successful results (see Figure 5.1). This includes the proper communication of results gathered during operation. In this phase, new conflicts could appear that had not been foreseen, and the solutions that are applied could be useful to improve future roads. Other problems caused by the inadequacy of materials or designs will be detected, and road authorities must provide ways to share this information with all stakeholders involved in road planning, construction and operation.

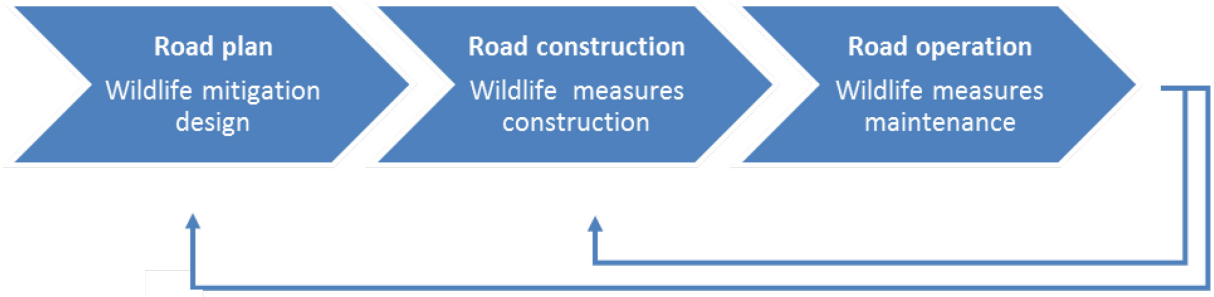

Figure 5.1. Road-wildlife maintenance guidelines must be based on the information and standards provided by road planners and constructors. Retrofitting by providing planners and constructors with information about failures and success gathered during operation will lead to an improvement in wildlife mitigation strategies.

5.2.2 Planning road-wildlife maintenance to foster continuous improvement

The scope of road-wildlife maintenance guidelines could be a country's entire road network, a region's road network or even a single road infrastructure, e.g. a motorway managed by a road operator in a PPP system.

Road-wildlife guidelines should be integrated into general RMGs including wildlife topics for the inspection and maintenance of each road element. But a road-wildlife maintenance plan could also be conceived as an additional document complementing RMGs. Whatever the scope and the way in which it is applied, the approach should provide a framework for an adaptive management strategy.

We suggest applying the following procedure:

Step 1. Define which road elements included in the RGMs require guidelines related to wildlife topics.

Step 2. Identify topics that could require additional maintenance-guideline documents (wildlife crossings and roadside green area management are recommended).

Step 3. Define a cooperation platform: stakeholders that could contribute to define, apply, or monitor the maintenance practices and that may be involved in developing guidelines.

Step 4. Draft a general structure of the maintenance strategy and specific guidelines for all road elements: fences, barriers and screens; wildlife crossings; wildlife warning signs; roadside verges and other green areas management; ponds and other elements of the drainage system management; road casualties and animal-vehicle collision management are recommended.

Step 5. Define and apply training programmes for technical staff and field crews for road maintenance.

Step 6. Apply the inspection and maintenance guidelines.

Step 7. Monitor and report the results. Define future improvements and new innovative practices to be applied.

Common elements that should be considered for planning the maintenance practices regarding wildlife are:

a) Environmental regulations.
b) Wildlife and habitat facts.
   - Wildlife target species' (including protected species) requirements.
   - Ecosystems, ecological corridors and natural protected areas linked to wildlife provisions on the road.
   - Alien invasive species.
c) Wildlife mitigation measures and provisions.
   - Inventories of wildlife fences and screens, wildlife crossings (specific to wildlife or multi-use transversal structures), wildlife warning signs.
   - Standards based on information provided by road designers and constructors to be maintained or achieved during road operation.
   - Structures installed to provide refuges for wildlife.
   - Road verges and other habitats enhanced or managed to host wildlife.
d) Wildlife-vehicle accidents and other conflicts with wildlife.
   - Databases compiling information about incidents caused by wildlife and affecting road operation or traffic safety.

The maintenance plan for each road element should be related to the wildlife:

- Describe the general standards to be met according to both the instructions provided by designers and constructors and the road safety and operation requirements.
- Describe the inspection and maintenance tasks for to each element.
- Identify the location of particular elements or road sections to be inspected and maintained.
- Schedule inspection and maintenance tasks adapted to local conditions of wildlife and habitats.

- Establish procedures for identifying conflicts or deviations from standards and how to proceed to solve them.
- Define proper training of maintenance staff and field crews.
- Define procedures for monitoring and reporting the effects of the maintenance procedures and strategies applied.
- Define systems to retrofit the information for road planners and constructors and platforms that facilitate cooperation with other stakeholders involved.
- Provide procedures for updating maintenance tasks, including the BMPs identified, changing practices that cause negative effects on wildlife or on traffic safety, and incorporating new innovative solutions to solve the failures or conflicts that have been detected.

The following sections contain more specific guidelines for the maintenance and management planning of main road elements in relation to wildlife.

Properly applying these road-wildlife maintenance practices will provide a framework to develop adaptive successful strategies (see Figure 5.2).

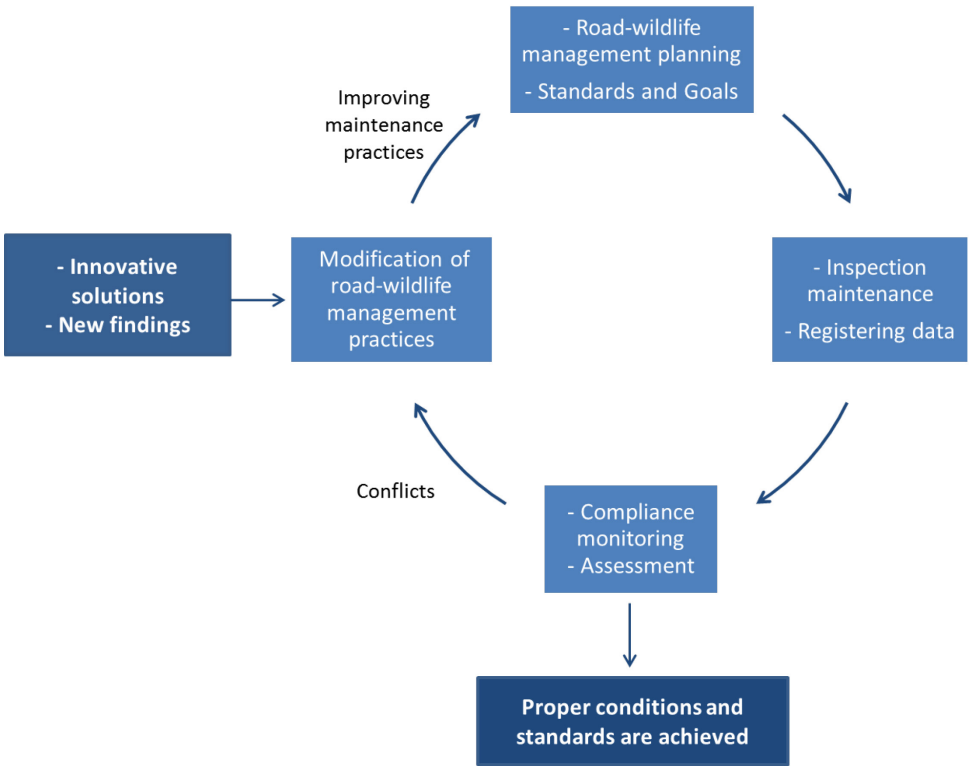

Figure 5.2. Adaptive road-wildlife maintenance strategy.

5.2.3 Including road-wildlife requirements in maintenance contracts

To ensure that all road operators apply correct wildlife-road maintenance procedures following the general guidelines provided by road authorities, these requirements must be clearly included in the tender and finally in the contracts of maintenance companies and concessionaires that operate roads. In PPP contracts in which a company is to plan, construct and operate a road for a long period of time (such as 30 years), it is even more

important to clearly state in the contract the standards that must be met in the maintenance of wildlife mitigation measures.

A set of indicators (e.g. the number of animal-vehicle collisions) to evaluate whether the standards have been met could be also a good practice. The provision of indicators will allow road authorities to check compliance with the goals established in road-wildlife maintenance guidelines.

Including detailed prescriptions about wildlife-related road elements in contracts will also lead to more standardised maintenance practices and to controlling the application of ineffective measures.

Other ways to improve practices are to include criteria that consider the ecological knowledge of the technical team in tenders for hiring maintenance contractors. The participation of wildlife experts could also be specified.

In a PPP situation, it is a challenge for legal contracts to specify maintenance actions that are valid not only at present but also in future decades (the contract may be established for long periods of 20-30 years' time). Important environment changes could occur along this timeline (e.g. on climate and ecosystems conditions or target species populations). To allow an adaptive management, maintenance actions must be specified in detail for the first 5 or 10 years, but it should be stated that, after this period, a review will be required to adapt maintenance tasks. Indicators and standards to be achieved play a key role in clearly identifying which are the goals to be achieved. Applying the Prime-Cost Sum (PC Sum) approach could be considered: establishing a portion of the budget clearly appointed for wildlife issues but without specifying tasks that, in the long term, require flexibility to be adapted to potentially new conditions.

5.2.4 Training maintenance staff and field crews

Regular training seminars and meetings that allow knowledge sharing, the provision of information about best practices and the compilation of data from staff who undertake maintenance activities may provide the best framework for adaptive management.

Providing wildlife training on road maintenance practices for all staff and stakeholders involved in road management is a basic first step towards implementing suitable management practices. Training could provide useful information to all stakeholders involved in road and traffic management. Some benefits are:

- Field staff: to obtain practical knowledge about the maintenance actions, tools and devices that must be applied and the way of recording wildlife information according to the road-wildlife maintenance guidelines.
- Technical maintenance staff: to understand the utility of wildlife mitigation measures and provisions and to be able to adapt maintenance to obtain the defined standards.
- Road designers and planners: to incorporate wildlife maintenance needs into the design of roads and wildlife mitigation measures and to consider the lessons learned from road operators in future road plans.
- Road authority's staff: to increase the ability of their own staff or that of maintenance or operator companies to assess compliance with maintenance requirements, according to the road-wildlife management plan.
- Traffic authorities: to understand the role of maintenance and traffic regulations in animal-vehicle collisions and to include them in data registration.

The training strategy should cover two main aspects: i) provide technical information for conducting adequate wildlife-related maintenance and ii) provide background information on each wildlife maintenance action so that technical staff can take decisions independently to resolve unforeseen conflicts.

To create a good training programme:

- Define purpose and goals.
- Set a training curriculum that is suitable for all staff (team leaders, technicians and field crews).
- Identify topics and staff needs and schedule regular training seminars that include field trips, when possible, to update knowledge.
- Meetings and field visits must be organised in a participative way to gather information from field crews and technical maintenance staff and learn from it. Listening to practitioners must be an important component of training sessions, which will also be useful to focus training on more critical aspects.
- Trainers must combine teaching skills, expert wildlife knowledge and a good comprehensive knowledge of the roads and the context where maintenance tasks are applied.
- Provide specific training materials: sheets, field guides to identify target species and other elements must be drafted to adapt the general contents to each road maintenance plan. Website-based applications could also be envisaged as a useful tool for updating content and using them in the field.

5.2.5 Compliance monitoring, reporting and research

Proper inspection and assessment of road-wildlife maintenance practices will lead to improvements in the cost-effectiveness of current practices, the adoption of an adaptive strategy and the identification of the BMP. The objectives are:

- To maintain updated information about all relevant wildlife facts that could affect traffic safety and proper road management.
- To collect information to ensure that effective, adaptive maintenance practices are undertaken.
- To identify which practices provide the most benefits at the lowest cost.
- To avoid wasting money on measures that are ineffective or cause undesirable effects on roads and nature.

Road operators may organise the monitoring of wildlife-related issues in a similar way to that of other road elements, by carrying out inspections in the field to supervise the application of maintenance practices, inspecting and assessing the standards that are achieved, etc. Nevertheless, some new procedures and tools must be developed that require the proper adaptation of regular compliance monitoring for road maintenance.

Aspects that should be registered include:

- **Information about the maintenance practices used**
  For each road element, all the maintenance tasks that are undertaken in relation to wildlife issues should be registered, including information about periods and methods.
- **Information needed to assess standards**
  Appropriate standards and indicators that identify the conditions required for wildlife measures should be registered. Inspecting and registering different variables should provide suitable data to assess whether maintenance tasks achieve the standards provided.
- **Information about conflicts and incidents involving wildlife**
  Some aspects that could be registered are animal-vehicle collisions, small fauna road

casualties; fauna injured in the maintenance of verges or drainage systems; fauna trapped or killed on kerbs, gullies, screens, median barriers or any other road element; detection of alien invasive species.

- **Other wildlife data**
  Detection of endangered species or any other species of special concern during road maintenance may provide interesting information to avoid risks and identify opportunities to enhance habitats for those species. Maintenance staff in the field can help collect information about wildlife facts and monitor the effectiveness of wildlife mitigation measures or wildlife-friendly management actions.

The assessment of these practices should be carried out by teams that include maintenance and wildlife staff because expert knowledge about fauna and habitat management is required.

Proper inventories of mitigation measures and databases (based on website applications when possible) must be developed to integrate all data related to wildlife.

Data must be recorded in a standardised way, which must be established in the road-wildlife maintenance plan, to allow proper analysis and assessment. The final goals are to identify whether wildlife mitigation measures achieve the standards and to establish new standards when required.

The final, crucial step is drafting comprehensive reports that help to understand failures, to re-design practices and to change road maintenance strategies or practices when required. Reports should contain the outcome of monitoring results and should be disseminated to maintenance staff and other stakeholders. The number, periodicity and contents of assessment reports could vary greatly depending on the scope of the maintenance plan (i.e. whether it covers a road, the road network in a region or the entire road network in a country) and the features of the road and the natural areas, habitats and species in the surroundings. Nevertheless, some general recommendations could be provided:

- Draft at least annual reports, including the contents defined in the road-wildlife maintenance plan. Be aware that:
  - All road elements involving wildlife should be included. Several sections must provide information about fences, barriers and screens; wildlife crossing structures; wildlife warning signs; road verges and other green areas; ponds and other elements of the drainage systems.
  - The management of animal-vehicle collisions and other road mortality events must be reported and assessed as they may require the design and application of new mitigation measures.
  - A final section should evaluate all the information and provide a general assessment as wildlife can move across different elements of the road (verges, drainage, etc.) and the surrounding landscape and be strongly influenced by environment and climate. Therefore, a general ecological approach is needed to properly evaluate interrelations as some maintenance actions could affect others (e.g. road verge management could have an effect on road casualties).
- Annual reports should answer several questions: What have we done? What problems have we found in applying the guidelines? What failures have we detected in wildlife mitigation measures? Which unforeseen conflicts with fauna occurred? Which solutions and innovative ideas can be provided to solve them?
  Some specific aspects to be included for future improvement and adaptive management are:

  - Identification of sites at which wildlife mitigation measures are repeatedly damaged by wildlife and need to be repaired. Species identification is required to design proper solutions.
  - Identification of road sections or points where wildlife is a risk to traffic safety or causes any other conflict.
  - Identification of road sections where elements of wildlife provisions are vandalised or stolen.
  - Description of any aspect that causes problems for the maintenance of wildlife mitigation measures.
  - Definition of solutions to all recurrent conflicts with the help of existing handbooks about mitigation techniques and cooperation of wildlife experts and other stakeholders.
  - Information about successful solutions and failures that will be equally useful for improved future maintenance practices and for design and construction.
  - All existing inventories and databases must also be updated.
- At intervals of 3-5 years, the entire road-wildlife maintenance strategy should be assessed and reviewed. The assessment procedures must establish the need to define feasible alternative practices to achieve standards, solve conflicts and identify negative effects. Therefore, these reports should provide a good basis for decision-making about wildlife maintenance practices.

Regular coordination meetings between all stakeholders based on assessment reports will allow compliance monitoring to be coordinated with other environmental monitoring carried out by environment agencies or other stakeholders. Forums should be organised to share information about conflicts and find solutions.

Ecological monitoring should also be performed and appropriately integrated into the road management plan to identify the effects of road maintenance on wildlife populations and the effectiveness of wildlife mitigations.

5.2.6 Cooperation: stakeholders to be involved

Road authorities may organise and provide platforms to establish fruitful cooperation with environment, water or other authorities and other local stakeholders.

Organising cooperative platforms for stakeholders at the national, regional or local level may be a useful tool to coordinate actions for roads that involve wildlife topics. The main stakeholders and the topics of concern are listed below:

- **Environment administrations**. Information about wildlife populations and the habitats that host them, Natural Protected Areas, ecological corridors and actions to reinforce the European Green Infrastructure. Conservation strategies, plans and regulations that affect particular areas, habitats or species are provided by environmental agencies. Active cooperation with this stakeholder will ensure appropriate integration of wildlife management and regulation into a road maintenance plan. Environment authorities are also actively contributing to managing wildlife mitigation measures, such as large wildlife crossings or habitats. These connecting structures are restored or managed appropriately to provide proper connections between them and habitats that are suitable for target species in the hinterland.
- **Water administrations**. Elements of the drainage system such as culverts, ditches or ponds play an important role in road-wildlife management strategies as they may provide habitats of interest for aquatics species and can also be adapted as wildlife crossings to reduce the road barrier effect. Water management strategies that are appropriately coordinated with road-wildlife management may help to coordinate the actions that are

undertaken on roads to improve aquatic habitats and to provide connections for rivers and wetlands. Cooperation with this stakeholder is also crucial to adapt road-wildlife mitigation to climate change consequences.

- **Land-planning administrations.** The main role of these authorities in relation to wildlife and roads is to regulate uses in areas adjacent to wildlife crossings and other roadside habitats particularly managed to enhance wildlife conservation.
- **Traffic administrations.** This stakeholder could also be involved in road-wildlife management, particularly in collecting data on road traffic accidents involving wildlife.
- **Local administrations**. Proper coordination with this stakeholder may help to involve local organisations and citizens in maintaining wildlife mitigation measures. In many areas, municipalities also contribute to managing habitats linked to wildlife crossings, which could enhance benefits for ecological connectivity. In northern countries, local administrations also actively contribute to managing databases that collect information about road traffic accidents caused by ungulates and involve local hunters in recovering injured animals or those that died as a result of a collision.
- **Other stakeholders** may be considered to participate in cooperative platforms as they can play a role in undertaking, monitoring and evaluating the maintenance practices applied to the road or surrounding areas. The main stakeholders that should be considered are:
  - Owners of adjacent land.
  - Farmers and forest managers.
  - Universities and research organisations.
  - Nature conservation organisations.
  - Hunters' associations.
  - Volunteer networks.

5.2.7 Benefits and contribution to achieve environmental regulations

The application of road-wildlife maintenance guidelines can help i) to reduce the risk of road traffic accidents involving animals and wildlife mortality; ii) to enhance habitats for wildlife and the role of wildlife crossings as connections between natural habitats and protected areas, reinforcing European Green Infrastructure (see section 5.1).

Moreover, properly applying road-wildlife management will contribute to identifying the best wildlife mitigation measures and avoid investing the budget in ineffective measures.

Road regulations often do not establish statutory standards or indicators for wildlife mitigation measures, except those that regulate the conditions of general fencing or warning signs and general standards for traffic safety.

Suitable inspection and maintenance of wildlife issues related to road operation will help to achieve environmental regulations and target strategies by reducing disturbance, preventing injury and mortality of endangered species or destruction of breeding sites, stopping alien invasive species from spreading and contributing to ecological connections and habitat restoration. The most relevant European regulations are listed below:

- Bern *Convention* (EC, 1970) *Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats*
  Art. 6. Each Contracting Party shall take appropriate and necessary legislative and administrative measures to ensure the special protection of the wild fauna species specified in Appendix II. The following will in particular be prohibited for these species:
  a. all forms of deliberate capture and keeping and deliberate killing;
  b. the deliberate damage to or destruction of breeding or resting sites;

c. the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation, insofar as disturbance would be significant in relation to the objectives of this Convention;

- *Habitats* Directive (EC, 1992) *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*
  Art. 12.
  1. *Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range, prohibiting:*
     (a) all forms of deliberate capture or killing of specimens of these species in the wild;
     (b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration;
     (d) deterioration or destruction of breeding sites or resting places.
  3. *The prohibition referred to in paragraph 1 (a) and (b) and paragraph 2 shall apply to all stages of life of the animals to which this Article applies.*
  4. *Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a). In the light of the information gathered, Member States shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned.*

- EU Birds Directive (EC, 2009) *Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds* - art. 5
  Without prejudice to Articles 7 and 9, Member States shall take the requisite measures to establish a general system of protection for all species of birds referred to in Article 1, prohibiting in particular:
  (a) deliberate killing or capture by any method;
  (d) deliberate disturbance of these birds particularly during the period of breeding and rearing, in so far as disturbance would be significant having regard to the objectives of this Directive;

- EU 2020 Biodiversity Strategy (COM(2011) 244 final) *Our life insurance, our natural capital: an EU biodiversity strategy to 2020* – Targets 1, 2 and 5.
  Target 1
  To halt the deterioration in the status of all species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status so that, by 2020, compared to current assessments: (i) 100% more habitat assessments and 50% more species assessments under the Habitats Directive show an improved conservation status; and (ii) 50% more species assessments under the Birds Directive show a secure or improved status.
  Target 2
  By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems.
  Target 5
  By 2020, Invasive Alien Species and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS.

- Aichi targets (Biological Diversity Convention COP10, 2010)
  Target 9
  By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.
  Target 11
  By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 12
By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.
Target 15
By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. Green Infrastructure (GI). Enhancing Europe's Natural Capital /* COM/2013/0249 final.

5.3 Maintenance of wildlife fences and screens

Wildlife fences are used to stop animals getting onto roads and to funnel their movements to wildlife crossings. Screens reduce disturbance (light or noise) at wildlife crossings or in sensitive habitats. The proper design of screens and wildlife fences, adapted to site conditions and the requirements of target species, is the first step in reducing maintenance costs and guaranteeing effectiveness. Durability of materials and proper installation are also points to be considered. Inappropriate fencing design and installation leads to higher maintenance costs during road operation.

Activities included are the inspection, maintenance and repair of all fences and screen elements: meshes, poles and escape devices (ramps or gates) as well as cattle grids if they are provided. Reinforcing fencing or even replacing old fences with more appropriate ones along hazardous stretches of roads must also be envisaged as a road maintenance activity.

5.3.1 Guidelines for maintenance planning

- Work out a fencing maintenance plan.
- Describe the general standards to be met for any fence, screen or associated element; escape devices and cattle grids must be included. Include information about main target species (to be provided by the designer) for which the standards for the fence must be maintained.
- Describe the inspection and maintenance tasks according to each element.
- Identify the location of particular points to be inspected and maintained:
  - escape devices
  - cattle grids
  - junctions with perimeter drainage and transversal structures
  - junctions between fences and screens
  - any other sensitive points
- Appropriately schedule inspection and maintenance tasks according to the instructions provided by designers and constructors, as well as climate or biological events (e.g. periods of migration or other events that increase target species' attempts to get over the fences). A wildlife expert is required to provide the information needed to adapt the schedule to each site's conditions.
- Establish procedures for identifying conflicts or deviations from standards and how to solve them. Consider as possible solutions: repair, reinforcement (appropriate to target species) and replacement.
- Modify the maintenance plan according to the species causing the conflicts. The expansion of the distribution range or an increase in numbers in some conflict species (such as rabbits or wild boars that are particularly skilled at getting around fences by

passing under meshes or breaking them) may require additional inspection and maintenance tasks.

5.3.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Check the fence regularly according to the time schedule established in the maintenance plan. Use the following checklist and identify all the points with shortfalls:
  - Poles are well fixed.
  - Mesh is not broken or deformed, allowing animals to enter.
  - Fence is perfectly continuous and connected without a gap to wildlife crossings and other transversal structures.
  - Fence is perfectly continuous with screens (acoustic or any other type).
  - Intersections of fences with perimeter drainage ditches have been well protected to stop animals from entering.
  - Reinforcing meshes (when applicable) are well attached to the lower part of the main mesh.
  - Branches or other elements are not damaging the fence.
  - Escape gates are in good working order.
  - Vegetation is controlled to allow for ease of inspection and so that it cannot be used to climb fence.
- Inspect the wildlife fences and screens (see Figure 5.3) once a year after the second year of road operation. During the first two years of operation, inspect the wildlife fences every 3 months and identify conflict points where animals have made repeated attempts to get through the fence. Define appropriate fence reinforcement at these locations to reduce future maintenance costs.
- Schedule additional inspections right before the periods in which potential crossings of migratory species (e.g. elk and amphibians) take place. Wildlife experts could provide accurate schedules according to the local behaviour of target species.
- Schedule additional inspections after periods with floods, wild fires, snow or dust storms.
- Escape devices (when applicable) require specific inspections. Check the functioning of escape gates every 6 months, including functional checking to guarantee that doors can be opened by the target species and close perfectly after being used. Escape ramps must be checked once a year to identify any inadequacy.
- Fences constructed for amphibians (or other small animals) with synthetic polymer or wood need more frequent inspections as the materials are less durable than concrete.
- Where they are allowed, consider using drones to inspect fences in areas that are hard to access.

Figure 5.3. Screen maintenance must guarantee perfect continuity with fences and other road elements. Photo: Carme Rosell

Maintenance of meshes and poles

- Change any pole that is broken or damaged and fix any unstable posts.
- Replace broken or deformed meshes (see Figure 5.4).
- Reinforce the anchorage of the mesh to the soil and poles when needed.
- Restrict access and/or educate and inform local stakeholders in case of repeated damage caused by people.
- Consider replacing the existing fence when its design or materials are inappropriate and it requires considerable effort and cost to maintain.

Figure 5.4. Anchoring the mesh to the poles and repairing mesh damaged by wildlife are important to reduce the risks of wildlife-animal collisions. Photo: Department of Territory and Sustainability, Catalan Government.

Maintenance of vegetation along fences and screens

- In areas with dense forest or bushes maintain a corridor of around 1 m wide on both sides of the wildlife fences. The corridor should be free from trees and bushes as this will facilitate access and thus reduce maintenance costs (Figure 5.5). Using nutrient-poor soil near fences should be considered.

- In areas with croplands, meadows, or other open ecosystems, planting bushes adjacent to the fence's outer side may be help to discourage deer from jumping over the fence or forcing their way through (see Figure 5.6).
- Prune bushes and trees to avoid damage caused by branches on the mesh and to reduce the risk of some species climbing the fence.
- Schedule regular mowing and pruning activities in the corridor along the fence or screen, depending on climate and vegetation conditions.

Figure 5.5. Mowing and pruning of a corridor along the fence in sections crossing dense forests or bushes will reduce damage to mesh and facilitate fence maintenance tasks. Photo: Tunels de Barcelona-Cadí.

Figure 5.6. In open landscapes such as meadows and cropland the outer hedge may reinforce the function of the fence, making it more difficult for deer to jump or boar to beach it (at left). It can also create a corridor along the road guiding the animals towards wildlife crossings and reducing dispersal of pollutants or other disturbance. Photo: Marguerite Trocmé.

Maintenance of escape devices

- Undertake proper maintenance to ensure that escape gates close perfectly. Doors that do not close properly allow animals to get onto fenced-off roads and cause hotspots of wildlife mortality and/or road traffic accidents.
- Maintenance tasks might be adapted according to the type of device: gate or ramp.
- Gates require high maintenance activities:
  - Apply antioxidant and oil to the gate hinges once a year to avoid corrosion and ensure that the gate works properly.
  - Remove rocks, sand or woody debris whose accumulation could stop the gate from closing after heavy rain or a storm. Gate obstructions keep the gate open and create a vulnerable point that animals could use to enter the fenced perimeter.
  - Mow herbaceous vegetation and prune bushes on both sides of the gates once a year. Inside the fenced area: vegetation (when applicable) must be maintained to help the animals know that they can leave and funnel their movements to the gate. Outside: an area free from obstacles must be provided for the animal to leave and reach natural habitats.
- Escape ramp maintenance activities are:
  - Mow herbaceous vegetation and prune bushes on both sides of the ramp once a year. Inside the fenced area: vegetation (when applicable) must be maintained to help animals know that they can leave. Outside: an area free from obstacles must be provided where the animal can jump out safely.
  - Provide adequate maintenance of wood or other materials when applicable.
- Consider removing escape devices if they cannot be appropriately maintained and regular inspections show that the doors do not close properly (see Figure 5.7).Removing inoperative escape devices could reduce wildlife casualties and maintenance costs.

Figure 5.7. Escape gates require high maintenance and frequent inspection to guarantee proper functionality and ensure that they do not remain open as wildlife could use them to enter the fenced area. Photo: Tunnels of Barcelona-Cadí; Joana Colomer (right).

Maintenance of cattle grids

- Ditches under cattle grids require regular inspections to remove sands, rocks or other debris that could accumulate inside, particularly after strong rain.

Maintenance of permanent amphibian or small fauna fences or screens

- Undertake maintenance activities to ensure that amphibian fences are in good condition just before the beginning of the reproductive period that usually takes place at the end of the winter. Adapt these activities to each site as they depend on the species' behaviour.
  - Maintain a corridor free of bushes, high grasses, rocks or sand all along the amphibian fence to prevent amphibians from climbing up and facilitate their movements through the amphibian passage (see Figure 5.8).
  - Ensure that no traps (such as gullies) cause mortality in areas beside fences (see Figure 5.9).
  - Repair any discontinuity between the mesh and the soil that could allow amphibians to pass below the fence.
  - Ensure that there is perfect continuity between the end of the fence and the entrance of the passage so that animals cannot reach roads through small openings, which could produce a hotspot of wildlife mortality.
  - Replace any damaged pieces of synthetic polymer or wood fences.

Figure 5.8. Amphibian guiding fences could be made from concrete, metal or polymeric materials and maintenance should be adapted appropriately. A corridor along the fence must be kept free from obstacles. Photo: Miklos Puky (left); Carme Rosell (right).

Figure 5.9. Inspections should detect ecological traps such as gullies beside fences for small fauna. Proper solutions must be provided to prevent the accidental fall of animals. Photo: Heinrich Reck.

Reinforcement of fences

- Consider the reinforcement of fences along road sections where some conflict species recurrently succeed at getting over the fence.
  - As reinforcement features vary according to the target species, with wild boar and rabbit being the most problematic (although brown bear and others often require fence reinforcement), follow the prescriptions of handbooks or guidelines to choose the best reinforcement to reduce maintenance tasks or consult a wildlife expert to decide on proper reinforcements for the site and target species of concern (see Figure 5.10).
  - Reinforcement elements could be applied on the roadside or outside, depending on the target species and the site conditions. Anchorages to wire meshes or elements to fix the wires to the soil need to be regularly replaced.
  - Inspections and repairs of electric components must be undertaken when electric fences are installed at some conflict points.

Figure 5.10. Wire mesh fences could be reinforced to stop specific target species from entering. On the left is specific reinforcement that is resistant to wild boar; on the right, reinforcement for small fauna. Photos: Carme Rosell.

Marking screens or wires to reduce bird collisions

- Make transparent screens or wire meshes visible to birds when recurrent bird mortality is recorded due to collisions. Several methods for marking can be applied as long as the material, colour and dimensions are suitable, while other methods (such as bird's silhouettes) are not effective. Consult an expert on which solution is the most suitable in each site.

5.4 Maintenance of wildlife crossing structures

Wildlife crossings must be regularly inspected and maintained to ensure their long-term effectiveness. Moreover, structural points, other features related to vegetation, wildlife refuges, human uses and other factors could have a major impact on the fauna that uses the structures. Land uses and environmental changes in adjacent areas may also radically modify the wildlife use of the structures.

Some passages are specific for wildlife, while others are multi-use and combine functions such as drainage or recreation. Cooperation with water and environmental land planning authorities, as well as other local stakeholders, may be envisaged as an option to reduce maintenance costs.

Activities included are the inspection, maintenance and repair of fences, screens and other structural elements; repositioning and pruning of vegetation, as well as removal of exotic invasive species and other inappropriate flora; maintenance and replacement of refuges (stumps, rocks, nesting boxes or any other provided); regulation and management of human uses and cooperation with other local stakeholders on habitats and ecological corridors on adjacent land.

5.4.1 Guidelines for maintenance planning

- Work out a wildlife crossing maintenance plan, preferably for each motorway or main road infrastructure.
- Draft a specific maintenance plan for particular structures such as large ecoducts. Maintenance instructions must be based on the structure's plan, which must include clear data about target species and the maintenance that is required.
- Provide a database including an inventory of all wildlife crossings (any specific wildlife or multi-use passages) constructed on each road. The database must include:
  - Physical features: shape, dimensions, elements, construction materials, etc..
  - Goals: target species and/or ecosystems to be connected, according to the design project.
  - A section to record the maintenance activities that are undertaken.
  - A section to record any incidents.
- Describe the general standards to be met for any type of wildlife crossing.
- Appropriately schedule the inspection and maintenance tasks for each type of fauna passage:
  - Ecoducts
  - Wildlife and multi-use overpasses
  - Canopy bridge
  - Viaducts
  - Wildlife and multi-use underpasses
  - Modified culverts
  - Amphibian tunnels
- Use the information provided by road and wildlife experts who drafted the mitigation measures for roads and particularly the wildlife-crossing projects to define appropriate maintenance activities (see Figure 5.11). Ask road designers to provide the standards to be met and features to be maintained in the wildlife crossing.
- Include a wildlife expert in the team that is responsible for adapting the project instructions to each site's conditions.
- Define a procedure for early detection and removal of invasive alien species. Be aware that restored areas beside roads are prone to be colonised by invasive organisms.
- Establish procedures for identifying conflicts or deviations from standards and how to proceed to solve them.

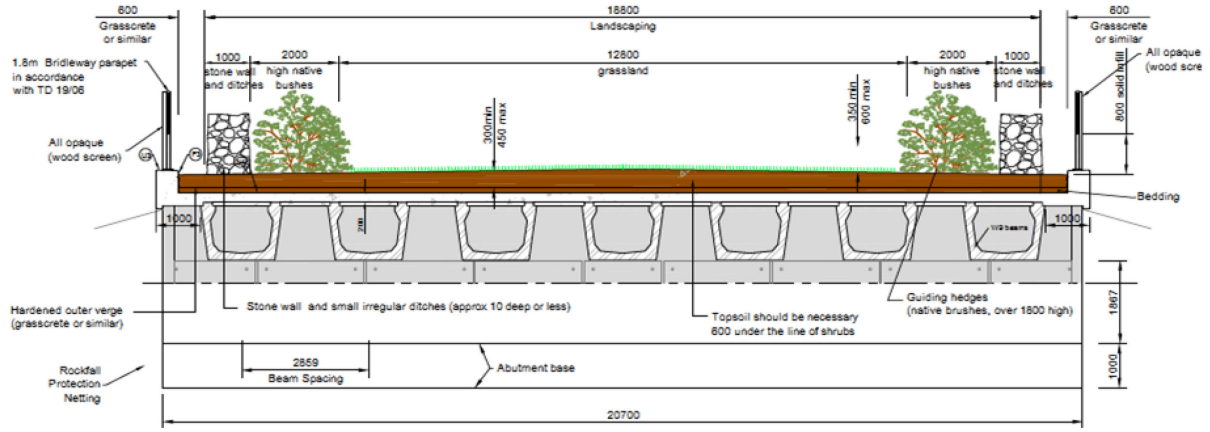

Figure 5.11. Maintenance tasks should be defined to achieve the standards and functions provided in wildlife crossing projects. This example shows a particular structure plan that sets the conditions to be achieved and that must be guaranteed by good maintenance tasks. Image: Ferrovial-Minuartia.

5.4.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Check standards for structural features (materials, resistance tests, etc.) once every 5 years.
- Check the standards of vegetation, refuges and other wildlife elements once or twice a year, depending on the wildlife crossing type and the site conditions. Use the following checklist and identify all the points with shortfalls (when applicable):
  - Vegetation height, composition and patch design is consistent with the standards.
  - No exotic alien invasive species were detected.
  - The fence is perfectly continuous and anchored to wildlife crossing entrances (see section 6.2. for more details).
  - The fence is found to be perfectly continuous with screens.
  - Refuges for fauna (stumps or stone rows, nesting-boxes, box-refuges, etc.) are in good condition.
  - Provisions to make human and wildlife uses compatible are properly maintained.
  - No debris, branches or other elements pose obstacles or degrade the wildlife crossings.
  - Dry ledges on modified culverts are in a good state.
  - Modified culverts are not blocked by rocks, wood or other elements carried by the water.
  - No negative human practices are registered in underpasses (storage of materials or machinery, etc.) or in any of the other uses of the over- or underpass.
- Adapt the checklist to each wildlife crossing type
- Schedule additional inspections right before the periods in which potential crossings of migratory species (e.g. elk, amphibians) take place. Wildlife experts could provide accurate schedules, according to the local behaviour of target species.
- Schedule additional inspections after periods with floods, snow or dust storms.
- Consider using drones to inspect wildlife crossings (particularly large wildlife or multi-use overpasses).

Maintenance of vegetation in ecoducts, wildlife and multi-use overpasses

- Maintain the vegetation at entrances and over the structures according to the requirements of target species, which should be established in the maintenance plan (see Figure 5.12). Some endangered species are particularly affected by habitat structure, such as the hazel dormouse, red squirrel or many invertebrates.
- The frequency of repositioning plants, pruning and other vegetation maintenance activities must be established according to the species and climate conditions, or once a year if there are no other instructions.
- Apply the most suitable practices to maintain vegetation features according to the function that vegetation must accomplish in each sector of the wildlife crossing: providing habitats for small fauna, guiding animals to the structure's entrances, screening the passage against disturbance (light, noise, etc.), or prevent people from using areas sensitive for wildlife.
- Undertake proper plant mowing, pruning or any other maintenance activities according to each structure type and goals.
- Consider grazing to control vegetation growth in large wildlife overpasses. Follow the grazing plan, which must define livestock species (consider cattle, sheep and horses, etc.), numbers, the frequency and period in which grass must be pastured. Agreements should be made for livestock grazing (see Figure 5.12).
- Remove all debris generated by repositioning plants or pruning to avoid soil fertilisation that could increase plant growth and consequently maintenance needs.
- Prune bushes and trees beside screen and fences to ensure they are not damaged by branches.

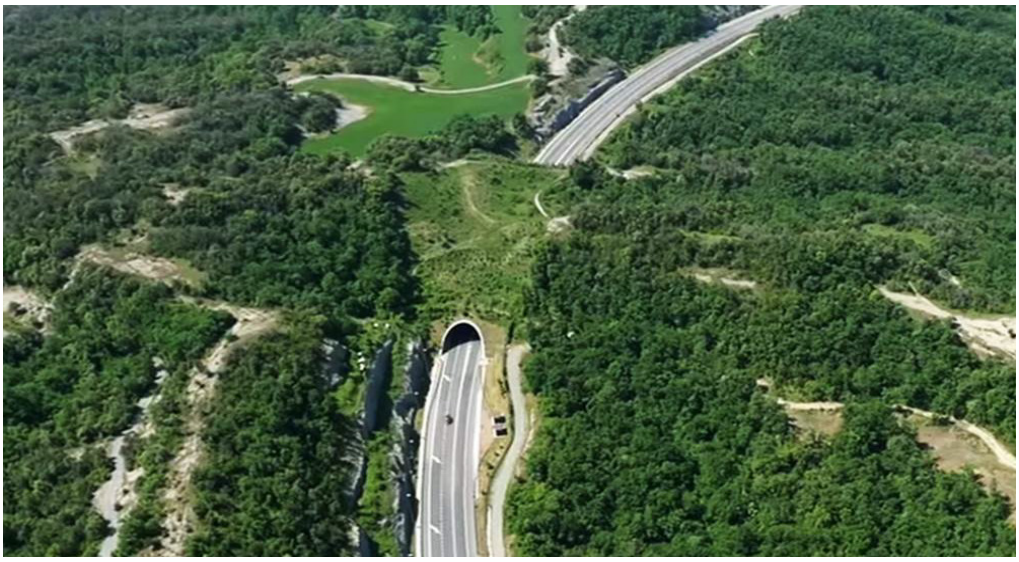

Figure 5.12. Proper vegetation maintenance in wildlife passages and in its surroundings is a crucial aspect to enhance ecological connections between the structure and the natural habitats. Photo: Minuartia.

Habitat management in the surroundings of wildlife crossings

- Establish cooperation agreements with landowners and other local stakeholders (see Figure 5.13) to regulate the use and management of adjacent lands and thus ensure that proper habitat management is applied. The main goal for habitat management practices must be to provide habitats that connect wildlife-crossing entrances with other natural

habitats. These lands are outside of the road area, and the cooperation of other stakeholders is essential and could radically affect the benefits that the connectivity structure will provide.

Figure 5.13. Cooperation agreements could provide properly managed grazing. Photo: Björn Schulz.

Maintenance of artificial refuges for fauna

- Ensure proper conservation of tree stumps or stone rows (see Figure 5.14), piles or walls located on the wildlife crossings to provide protection and refuge to invertebrates, amphibian, reptiles and small mammals. Make sure that these elements remain in a suitable arrangement, according to the maintenance plan, to provide refuge or guidance to the animals to find their way through to the other side of the structure.
- Remove debris, branches or other elements (sometimes carried by animals) from nesting boxes and bats' refuges. Clean and repair all damage before the periods in which the structures are most frequently used.

Figure 5.14. Woodpiles, dry stone walls and bat refuges installed under a viaduct. All of them require adapted maintenance tasks to ensure their long-term conservation. Photo: Minuartia.

Management of human uses of multi-use underpasses and overpasses

- Avoid undesirable activities that can deter wildlife or damage the structures. Underpasses are particularly prone to inadequate uses: there are reports of their being used as storage space for agricultural machinery and straw, as barnyards, as sleeping places for humans, etc. (see Figure 5.15).
- Replace elements damaged by vandalism as quickly as possible and consider the possibility of using designs and materials that are less sensitive to vandalism.
- Maintain the proper state of large rocks or any other barrier elements located at the point of access of wildlife overpasses or underpasses to stop vehicles from entering.
- Plant dense hedges of thorny bushes on overpasses instead of installing wire fences, to separate wildlife and human areas.
- Provide information for hunters and obtain the cooperation of rangers to prevent hunting on wildlife crossings.
- Provide information at the entrances to large wildlife crossings. The function of the structure should be clearly explained and instructions provided about the behaviour that is expected to preserve the place. Wildlife spotting activities should be discouraged as they could increase the presence of humans on the structure at night, sunrise and sunset, which are the main periods of activity for many wild mammals. The advice of communication teams will be helpful to choose the most appropriate messages for information panels.
- Unpaved roads and wildlife uses requiring particular maintenance activities could also be combined (see Figure 5.16).

Figure 5.15. Unforeseen human uses must be identified and corrected during maintenance. In this case, a farmer installed a gate to prevent his sheep from using a wildlife underpass. Photo: Luis Ramajo / Junta de Andalucía.

Figure 5.16. Multi-use overpasses require the maintenance of screens, fences, vegetation and refuges, but also other factors related to traffic and human uses. Photo: Mats Lindqvist.

Maintenance of canopy bridges

- Undertake appropriate maintenance of ropes and wood that are usually integrated into this type of wildlife crossing (see Figure 5.17). Cleaning away materials transported by animals could also be needed.

Figure 5.17. Canopy bridges require the maintenance of wooden structures that provide passages for arboreal mammals. Photo: Hans Bekker.

Maintenance of modified culverts

- Modified culverts need additional maintenance tasks after each flood or storm: remove stones, sand or branches that obstruct structures or make it difficult to use dry ledges (stone, sand, branches; see Figure 5.18).
- Check that dry ledges are kept in a good state and replace wooden ledges when required.
- Consider relocating or installing new ledges if they are covered by water for long periods of the year. Adaptation to climate change could include modification of these structures to ensure wildlife can use them.

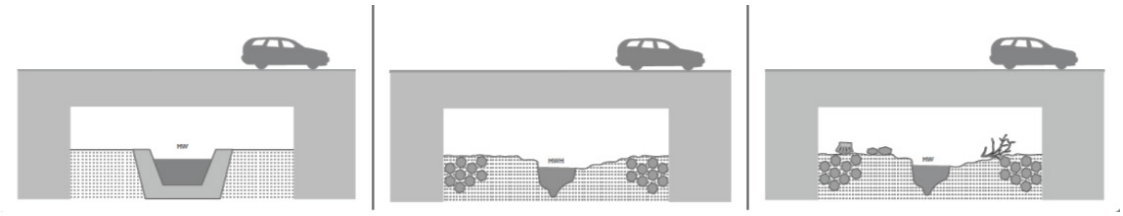

Figure 5.18. Modified culverts could be improved during road operation by installing refuges for fauna. These practices may not be suitable in Mediterranean areas, and water regulations must always be met. Image: Heinrich Reck and Mona Damen.

Maintenance of amphibian tunnels

- Undertake maintenance activities once a year just before the migration period begins.
- Repair any damaged fences as they have an essential role in guiding the amphibians to the entrances of crossing structures (see section 5.2.).
- Remove any element that could obstruct or hinder amphibian movements.
- Modify any element that could be a trap for small animals, such as gullies located beside the guiding fences or close to the amphibian tunnels.

5.5 Maintenance of wildlife warning signs

The increasing number of collisions with large animals has led to the widespread installation of wildlife awareness signs. This fact and the lack of adaptation of the location of signs to hazardous road sections have been identified as the cause of drivers' habituation and, consequently, the low effectiveness of wildlife awareness signs. To solve these problems, road operators install reinforcing signs that include warning messages, reflective panels, temporary signs and Animal Detection Systems (ADS), in which animal detectors activate warning signs.

Appropriate management of all these types of wildlife awareness signs to ensure the appropriate status of the elements and their correct location based on wildlife movements and activity patterns is crucial to improve the effectiveness of this mitigation measure. Activities included are the inspection, cleaning, repair, relocation or even removal of wildlife warning signs to adapt them to the location of animal-vehicle collision hotspots; maintenance of electric and electronic components and animal detector devices.

5.5.1 Guidelines for maintenance planning

- Draft a wildlife awareness sign management plan based on an inventory of existing warning signs.
- Provide accurate information about each sign's location and type (standard, reinforced, temporary, ADS signs or any other) in the inventory.
- Describe the general standards to be met for any type of wildlife awareness sign.
- Include wildlife-vehicle accident density thresholds to determine the installation of new signs or the removal of existing ones.
- Describe and schedule inspection and maintenance tasks according to each sign type.
- Plan to conduct appropriate analyses of updated animal-vehicle collision databases to assess locations where the wildlife awareness signs must be installed.
- Define periods of activation for temporary signs according to risk assessments based on the species.
- When warning signs are combined with other mitigation measures (fencing in some road sections, fauna passages, etc.), a cohesive maintenance strategy must be defined in the maintenance plan.

5.5.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Check the signs regularly according to the time schedule established in the maintenance plan and based on risk assessment, or by default annually. Use the following checklist and identify all the points with shortfalls:
  - Signs are clean and well fixed.
  - Signs are installed along all the highly hazardous road sections established in the maintenance plan.
  - Signs are installed at a proper distance along hazardous road stretches that have a higher risk of animal-vehicle collisions. Distance must be determined by road features and design speed.
  - Signs are located on both sides of roads in the hazardous road sections.
- Adapt the checklist to each sign type. Temporary signs and ADS signs require specific, more frequent tests to guarantee proper functioning.

Maintenance of standard wildlife awareness signs

- Signal repair or replacement must be carried out when damage is detected in inspections.
- Move wildlife warning signs to adapt to changes in the location of animal-vehicle collision. Signs can be positioned correctly by regularly assessing the location of road traffic accidents involving animals. Spatial distribution analyses and identification of the most hazardous stretches must be undertaken periodically and adapted to local conditions and risk assessment, or by default every 5 years.
- Add complementary information for drivers about the length of the hazardous stretch of road in a panel under the standard or enhanced warning signs. The distance indicated must be based on the length of the hazardous road section identified by regular assessments based on analyses of wildlife-vehicle accidents.

Temporary signs

- Consider the installation of temporary signs that only operate during the most critical period of the year to increase driver awareness (see Figure 5.19). Some large mammal-vehicle collisions show a marked temporary pattern; wild boar and deer-vehicle collisions often increase at the end of autumn and winter, overlapping the main rut period; roe deer-vehicle collisions tend to register another peak in spring that coincides with the territorial

period. A proper assessment by local experts will help to choose the best period to activate the temporary signs adapted to each target species and site.
- When temporary warning signs are provided with dynamic enhancing devices (flashing lights or other devices), ensure the proper maintenance of light and electronic elements during the operational period.

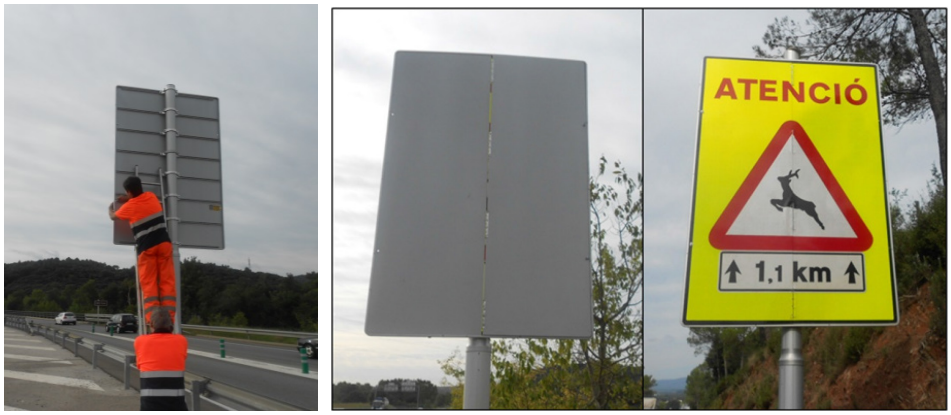

Figure 5.19. Temporary wildlife warning signs require higher maintenance than standard ones, but allow adaptation to the risk period and reduce the risk of drivers' habituation. Signs with covers reduce the time required to activate them. Photo: Catalan Government-Department of Territory and Sustainability.

Signs activated by ADS systems

- ADS systems provided by animal detectors that activate flashing signals require high maintenance (see Figure 5.20). Test the system's functioning once a month using the following list of inspection points:
  - Sensors detect movement appropriate to the target animal's size.
  - Location and orientation of the detector is correctly maintained.
  - Obstacles (rocks, broken branches or other objects) do not impede the correct detection of the animals approaching the road.
  - Solar panels, batteries and connections function properly.
  - LED lights function properly when a detection event occurs.
  - The sign activation period is correctly adapted to the target species (adjusted to its behaviour and required crossing time).
- ADS systems that provide remote control and testing of the device save trips to the system location for testing or programming.
- Solve any problem detected and replace any system elements at the end of their life cycle.
- Replace batteries, solar panels or any other elements damaged by vandalism or theft.
- Appropriately maintain the vegetation in the detection area or in between the transmitter and receiver elements. These areas must be kept free from tree branches, bushes or tall grass vegetation that could make animal detection difficult.
- Accumulation of snow during the winter requires additional maintenance tasks.

Figure 5.20. Detectors and other electronic components as well as illuminating signs must be frequently inspected to avoid failures in the ADS systems. Photo: Carme Rosell.

Species-specific warning signs

- Standard wildlife warning signs are inappropriate for reducing the road mortality of small animals (e.g. amphibians or reptiles) or other sensitive species (e.g. otters, lynx, etc.). Enhanced specific warning signs providing an image of the target species (see Figure 5.21) could be installed in sensitive areas to meet each country's road sign standards and increase driver awareness. However, these signs must be combined with other mitigation measures defined by wildlife experts according to target species.

Figure 5.21. Species-specific warning signs are used in many particularly sensitive areas despite effectiveness is not well established. Statutory standards for road signs should always be considered. Photo: Carme Rosell.

Driver information and cooperation

- Information campaigns for drivers will help to increase driver awareness and adaptation of driving behaviour to comply with wildlife awareness signs.
- Opinion surveys can be carried out to assess drivers' reactions to current signalling. This could provide valuable information to adapt signs and increase their effectiveness. This knowledge might be useful to understand the results of maintenance practices and subsequent adaptation.
- Support public systems for reporting wildlife-vehicle accidents and for information about the location of the hotspots via navigation systems or website-based applications.

5.6 Road verges and management of other green areas

The primary purpose of road verge and median maintenance is to promote, sustain, manage or encourage vegetation growing on them and to comply with a variety of regulations and standards. Both traffic safety and wildlife conservation topics must be considered as well as how best to contribute to the European Green Infrastructure.

Vegetation defines the main features of animal habitats, and its maintenance has a strong effect on the animal community established along roadsides. Consequently, it is a key factor to be managed during the operational period to attract or repel fauna species targets. Management of landscaped green areas along the roads may have positive or negative effects on these issues depending on how they are managed.

Vegetation management strongly depends on site conditions. The cooperation of ecologists will allow the general rules in this document to be most suitably applied to local conditions: climate, habitats and target species in the surrounding landscape.

Activities included are mowing, pruning, replacement, removal and any other task (e.g. soil management) needed to conserve or improve vegetation and habitats. Mechanical and biological methods to maintain the vegetation can be included. The maintenance of structures that support the verge's vegetation and provide refuges to particular species should also be included.

5.6.1 Guidelines for maintenance planning

- Work out the green area management plan, including all the information to be considered for the maintenance of:
  - Road verges
  - Medians
  - Resting areas and other landscaped zones
- Provide information about climate, ecosystems, natural protected areas, ecological networks, wildlife endangered species or any other biodiversity features that must be considered to define the best maintenance practices to be undertaken.
- Define proper zoning of green areas, identifying areas that will require homogeneous differentiated management according to safety objectives and conditions established by road and environment regulations.
- Describe the general standards to be met for each area. Some aspects to be considered when establishing standards for green roadside areas are:
  - Avoid attracting species that cause a risk for traffic safety.
  - Provide habitats for small species that are endangered or in decline, but avoiding areas where they can suffer an increase of mortality risk.
  - Avoid traps where animals could be injured or die.

  - Avoid barriers that can pose an obstacle for animal movement (kerbs deserve particular attention).
- Describe and schedule inspection and maintenance tasks according to the functions and standards in each area. Proper scheduling of mowing and pruning activities must be provided according to climate and vegetation conditions and to provide a mosaic of habitats with different features where they are needed.
- Include invasive alien species control by identifying such species that could be detected in the area and planning proper procedures to detect and eliminate them.
- Provide particular instructions to manage sensitive areas with a high interest for biodiversity (natural protected areas, wetlands, rivers, etc.)
- Define procedures to register threatened fauna and flora detection during the maintenance tasks.

5.6.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Check the proper state and condition of vegetation according to the standards provided in the maintenance plan.
- Check the proper state and condition of refuges provided for small animals at least once per year, when applicable.
- Apply procedures to detect exotic invasive species with the frequency and methods established by the risk assessment or by default at least twice per year in the periods where they are easier to identify.

Definition of different zones with homogeneous vegetation maintenance

- A ‘clear zone’ beside roads must be kept open by being regularly mown so that drivers have a wide enough field of vision. Vegetation should be cut at the maximum height regulated by road authorities in each country or by default, at 30-40 cm.
- The verge beside the ‘clear zone’ should be managed to provide suitable habitat for the small fauna living in the area, to retain them on the verge and prevent them from moving onto the causeways. This goal can be achieved by managing the verge for a range of cover types (grasses, shrubs and trees) and by retaining as many of the pre-existing structural features (e.g. rocks and logs) as possible.
- Design a gradient of increasing plant diversity and complexity with increasing distance from the road (Figure 5.22). The size and patch of each zone will depend on local safety standards, size of the right of way and local conditions on.

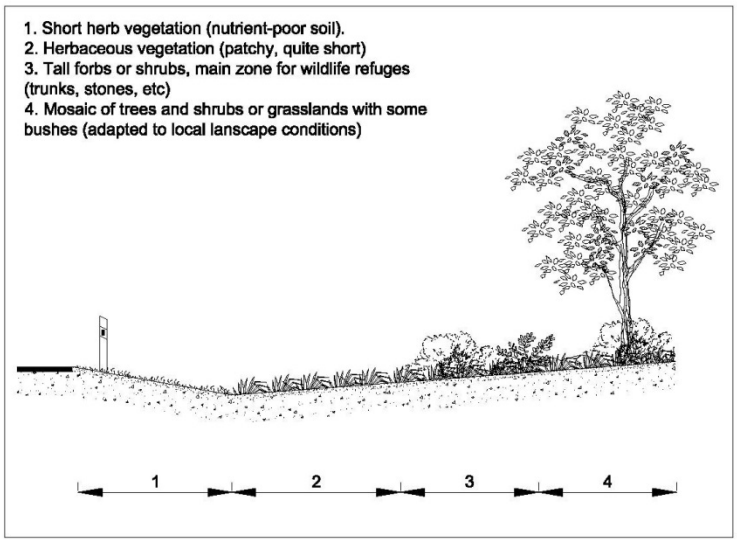

Figure 5.22. A sequence of verge vegetation types suggested to reduce road mortality and to provide wildlife habitats. The recommendations must be adapted to local conditions.

General vegetation maintenance tasks

- Mow the grass and prune the bushes and trees as frequently as appropriate and using suitable tools, according to both the green areas maintenance plan and its goals and to legal regulations.
- Use only native and well-adapted species from the surrounding natural region when sowing or planting. Do not use species that are too competitive, which would make it difficult for other species to grow.
- Mowing must be undertaken according to the following instructions:
  - Frequency, periods and methods for mowing should be adapted to reach the goals and targets in each road section according to the habitats and species conservation and maintenance plan.
  - Mow once plants have finished flowering, but before winter. Insects and other invertebrates do not find refuges for wintering when mowing is undertaken too late in the year. Mowing by sections in intervals of one month should be considered to create a mosaic of habitats with different features.
  - Avoid excessively frequent and therefore costly mowing and be sure to keep patches or margins where plants can develop.
  - Remove mowed or cut vegetation within 10 days after mowing or cutting to avoid the fertilisation effect of decomposing remains.
- Mowing frequency must be adapted according to local conditions. An indicative frequency (but that is largely variable, according to climate conditions and conservation goals) is:
  - Median: once to three times a year
  - Clear area for driver's field of vision: twice or three times a year
  - Embankments: twice or three times a year
  - Ditches: once or twice a year when and where necessary. It is better to mow them at the end of summer/ beginning of autumn when the development of many plants, insects and other small fauna that breed in these wet structures is finished.
- Mowing, pruning or other tasks must be adapted to the annual life cycles of wildlife, to stop animals getting on to the road and to reduce fauna casualties. Sensitive periods, such as during breeding, should be avoided.

- In sensitive areas, regularly prune vegetation instead of using cutting machines to avoid splitting branches and spreading tree diseases. This will also enhance the appearance of vegetation.
- Vegetation surfaces should not all be treated at the same time if possible. Establish sub-areas, bands or similar sections so as to alternate treatments over time. The combination of cut and uncut areas on verges provides refuge for invertebrates and other small fauna. Mowing or pruning should be carried out in a stepwise pattern, alternating between sections of ca. 50 m each or, even better, alternating in parallel strips. A time interval of one month between mowing activities of adjacent sections or strips will reduce the negative effects on protected species. Moreover, some areas could be left to evolve through natural succession after the soil has been disturbed by maintenance work.
- As a general rule, do not use pesticides or herbicides. When necessary to inhibit the growth and spread of injurious weeds or to fight against an animal plague:
  - Ensure compliance with the legal requirements in the country.
  - Apply biological control methods and avoid any use of toxic products. The use of biological controls should be envisaged in the maintenance plan as they may have to develop before become effective.
  - If chemicals are required in a well-justified, extreme case, choose products that have low toxicity and are objective-specific, with short permanence in the environment, and carefully follow the product use instructions.
- Avoid using fertilisers as they enhance vegetation growth and increase the requirements of maintenance tasks. When fertilisation is needed use organic fertilisers that reduce the risk of sudden death in plants and the insect plagues that are sometimes favoured by mineral fertilisers. Moreover, mineral fertilisers can produce water pollution due to an excess of nutrients washed away by runoff.
- In areas with a high density of ungulates (e.g. deer and wild boar), managing the vegetation on road verges could reduce the risk of collision. Undertake appropriate maintenance tasks according to the target species and local conditions (wildlife expert assessment is needed) and considering the following recommendations:
  - Do not provide palatable vegetation that attracts deer.
  - Do not provide refuges for wild boar: open grassland is suitable for this purpose. Avoid having dense bushes or giant cane (*Arundo donax)* growing along verges.
  - Provide a large strip from 3 to 5 m (depending on the species, landscape and road speed limit) of poor soil with short grass, to ensure a good field of vision that gives drivers time to adapt their driving behaviour if an animal approaches the road.

Machinery

- Avoid machinery movement on verges as much as possible to avoid compacting and disrupting the soil.
- Provide mowing machines with digitalised maps indicating the location of sensitive road sections where specific maintenance tasks must be undertaken.
- Once plants have finished flowering, the higher the cutting surface, the less damage to small animals such as amphibians, reptiles and small mammals (such as mice and shrews).
- At sensitive sites, consider avoiding disc mowers and shredder machines that can harm animals. Instead, use machinery with swinging cutting devices, such as scythes or mower bars, which diminish fauna mortality (see Figure 5.23).
- The use of suction mowers is not recommended in sensitive sites; they should be restricted to sites where the cut grass could not be removed by other reasonable means or for road safety reasons.

Figure 5.23. On the left: trucks equipped with different tools working at the same time to cut strips of vegetation at different heights and to remove mowing debris. On the right: in sensitive places, manual mowing could be done. Photo: ASFINAG.

Providing habitats for pollinators and other fauna

- All the activities in this section could enhance biodiversity and increase the roadside function as green infrastructure. Nevertheless, proper assessment by wildlife experts is essential to obtain the benefits without negatively affecting any species.
- Sow and plant herbaceous and flowering aromatic plants to feed pollinators. When this action is well-designed and applied, it can contribute to the recovery of pollinator species with declining populations and provide ecosystem services as some crops pollinated by insects could increase productivity (see Figure 5.24).
- Choose the plants to be seeded according to the nutritional needs of the target insect species. Be aware that each pollinator feeds on a specific plant species. Only native species that are already present in the natural ecosystems should be planted.
- Choose plants that need a low mowing regime and adapt mowing activities according to the phenology of each plant.
- Install insect refuges. The best method is to provide patchy vegetation with small areas of open soil and other areas with dead wood. As an exception, insect refuges (‘bee-hotels’ or posts with holes) could be installed; the hole size and arrangement need to be adapted to the target species of the pollinator.
- Providing beehives for honey bees is not recommended in general, as honey bees could act as competitors for many other species of endangered pollinators.
- In areas where pollinator habitat creation is an important target, maintenance work should be undertaken mostly when the flowering period of the majority of plants has finished.
- Other refuges for small fauna could be provided by installing wood or stone piles and rows. These elements provide refuges for small animals such as invertebrates, reptiles and small mammals and could even stop them from getting onto roads when the measures are properly designed. Stumps and logs in particular should be kept to offer habitats for endangered xylophage insects.
- Consider installing refuges for bats and nesting boxes for birds in areas where they cannot be affected by vehicle collisions. Under large viaducts or underpasses could be a good option.
- Keep existing rows of trees as they can provide refuges for insects, birds and bats (see Figure 5.25).

Figure 5.24. Properly managed road verges could enhance habitats for pollinators. Photos: Heinrich Reck (left) and Magnus Stenmarck (right).

Figure 5.25. Rows of trees along roads not only have aesthetic benefits, but also provide refuges for insects, birds and bats. Proper pruning could enhance their benefits as habitats for wildlife. Photo: Minuartia.

Avoiding attracting fauna that cause conflicts

- Some road verges and medians must be managed to avoid providing suitable habitats for some particularly problematic prey species, such as rabbits. High densities of this species not only damage the structural condition of embankments due to burrow construction, but also attract endangered predators, which increases their mortality risk. This effect has been reported for polecats and Iberian lynx.
- Removing dense shrub vegetation along road verges is recommended in some areas to reduce attracting wild boar and consequently the risk of wild boar road collisions.
- Consider that trees or shrubs producing attractive fruits for birds or other animals could also attract other species and increase their mortality risk. Avoid planting these plant species close to the highways.

Control of alien invasive species

- Do not sow or plant alien species along road verges that could spread and invade natural habitats beside roads.
- Strictly apply the procedures established in the maintenance plan for controlling alien invasive species. Field teams must be provided with:

- A field guide of animal and plant alien invasive species
- Instructions for an 'early awareness' detection system
- Procedures for fast removal of the invasive species to stop them spreading and to reduce the risk of re-colonisation by the removed species. Specific control methods must be defined in each maintenance plan as they are strongly dependent on the ecology of each alien species.

Reducing fire risk in Mediterranean regions

- Do not plant tree or bush species that may facilitate the starting or spreading of forest fires along the road verge.
- Evaluate whether tree and bush removal could be necessary in areas with a high risk of fire (see Figure 5.26). Their removal can also help to make large animals more visible to the driver. These measures must be assessed by local wildlife experts as they can have the negative effect of attracting deer to roadsides.
- Some regions have legal regulations that must be applied, including a list of species that cannot be planted on road verges.

Figure 5.26. Road verge management may be adapted to several functions. In this case, an area has been cleared of shrubs to reduce the risk of wild boar-vehicle collisions. Photo: Carme Rosell.

Adaptation of kerbs, safety barriers and other elements to reduce their barrier effect

- Replace or adapt any kerbs on roadsides and medians that cause a barrier effect for small animals and stop them from getting off the road when they are crossing it. High mortality of some small fauna species could be associated with these risk areas. Define the required adaptations with the cooperation of wildlife experts.
- In critical road stretches with high numbers of road casualties, consider replacing concrete safety barriers with permeable ones such as steel rope barriers.
- Gullies could also be a trap for small animals and must be adapted or an escape structure must be provided to avoid road mortality.

The impact of de-icing salt

- Prevent deer, chamois or other Bovidae from being attracted to roadside salt pools.
- Evaluate the use of calcium magnesium acetate as an alternative to sodium chloride to be applied in sensitive areas with endangered flora species.

- Prevent salty runoff from reaching roadside ditches, ponds or any other freshwater habitat.

5.7 Ponds and other elements of drainage system maintenance

Road and drainage systems include perimeter ditches, retention ponds, culverts and other transversal structures. The main function of drainage systems is to ensure standards for water evacuation and road safety. However, most of these road elements also provide habitats for wildlife. Ponds and ditches can provide habitats for aquatic organisms. They can host invertebrates and fish, attract amphibians as breeding sites and provide shelter and food for semiaquatic reptiles, mammals and birds. Maintenance practices applied to drainage system elements can enhance biodiversity by creating or restoring aquatic habitats. However inadequate management could also create ecological traps that attract animals to polluted or hazardous areas.

Draining transversal structures can also play a key role in ecological connectivity, providing links for Green Infrastructure aquatic elements (wetlands, channels, rivers, etc.). Culverts, open-span bridges and viaducts (see section 6.3) are relevant elements.

Activities included are the inspection and cleaning of all the drainage systems elements. Removing debris, stones and other obstacles that can hinder animal movements in culverts must also be envisaged.

5.7.1 Guidelines for maintenance planning

- Draft a maintenance plan based on the identification of drainage elements that can play a role as habitats for wildlife. Identify drainage elements that are hazardous and where fauna access must be avoided if no optimisation is possible.
- Maintenance practices must be defined primarily to maintain the function of drainage. Water, road and wildlife experts must work together to design a successful drainage system maintenance plan.
- Provide information about aquatic habitats beside the roads and identify sections of road where appropriate maintenance of retention ponds, ditches and other drainage system elements could be managed to enhance habitats for aquatic fauna species.
- The maintenance plan should:
  - Be adapted to the site and consider wildlife species that are actually present and species that could use the habitats provided according to local species requirements.
  - Perform pond and ditch maintenance to avoid harming animals that are living there and to improve habitats for invertebrates, fish, amphibians, otters and other aquatic or semi-aquatic species.
  - Identify potential risks for road safety and animal mortality.
  - Evaluate the opportunity to modify some features of ponds or ditches to allow the habitat to host endangered species.
  - Define proper procedures for drainage systems according to the fauna living in these areas.

5.7.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Create a database to register important aquatic species that are already living in drainage system elements detected during maintenance tasks.
- Check which aquatic species are living in retention ponds before they are emptied to provide adequate rescue when needed.

- Inspect culverts to check the proper status of dry ledges when they are provided and to detect the presence of debris or other obstacles that could make it difficult to use these structures as wildlife crossings.
- Undertake specific inspections and corrective measures following periods of heavy rain or flooding.

Adaptation of retention ponds

- The concentration of heavy metals or other pollutants in the water of retention ponds along large motorways with high traffic density can make them unsuitable for aquatic species. A first step in defining the potential of a pond to host wildlife is to analyse water quality and assess toxicity. Fences should be installed to prevent small fauna from getting to the pond when the water quality is poor and potentially hazardous for fauna.
- Enhance the habitat of the pond by modifying the grade of the slopes around the perimeter, the water depth, flow velocity and other habitat features according to the requirements of target species. Vegetation could also be managed to achieve a proper habitat that is similar to those existing in the surrounding areas. Good features for these adaptations strongly depend on target species and local conditions and must be clearly established in the maintenance plan (see Figure 5.27).
- Consider adapting retention ponds or restoring new ones as amphibian breeding sites (see Figure 5.27). In these cases, amphibian fences could also be required to guide amphibian movements from the pond to adjacent habitats and stop them from getting onto the roads. The fish and macrophyte community should be managed properly to enhance the pond's function as an amphibian breeding site.
- The frequency and period of maintenance tasks should be adapted so that they do not affect fauna breeding in the retention ponds.

Figure 5.27. Properly managed retention ponds may be valuable habitats for aquatic species but require appropriate maintenance tasks. Ponds at the entrances of wildlife crossings may also be managed to provide drinking points or breeding sites for animals. Photo: Carme Rosell (left), Heinrich Reck (right).

Adapting culverts as wildlife crossings

- The best design of drainage elements must be selected from the start to determine the most eco-friendly solution. Nevertheless, maintenance practices provide major opportunities to improve designs. Install dry ledges ('catwalks') to be used by mammals inside culverts as this practice will reduce the road barrier effect (see Figure 5.28).

- The durability of dry ledges could be increased by using concrete or stone instead of wood.
- Climate change will require the adaptation of road drainage systems. Some culverts may be enlarged to cope with extreme weather events such as floods. Consider adapting any modified culvert to enhance its use as a wildlife crossing.
- Adapted culverts must be so maintained that they could be used by fish and other aquatic organisms. Cleaning and removing trash, stones and sand must be programmed regularly, and particularly after large storms.

Figure 5.28. Modified culverts require proper inspections and removal of any obstacle (branches, rocks, debris, etc.) that hinder the movements of fauna. Dry ledges could be located on culverts during road operation to improve their function as wildlife crossings. Photo: Minuartia.

5.8 Animal-vehicle collision management

Road traffic accidents involving large animal are increasing in many European regions. The removal of carcasses of small fauna and large animals such as deer or wild boar is a significant task for maintenance crews and has economic and social implications. Recording and analysing road traffic accidents involving animals and road casualties is the basis for identifying hotspots of road mortality and their causes.

Several mitigation measures can be applied by road operators, such as improving or reinforcing fences, adapting existing transversal structures to be used by wildlife, and reinforcing wildlife awareness signs. Investing in proper mitigation measures to avoid animal-vehicle collisions is a cost-effective practice in terms of economic, social and environmental costs.

Activities include registering collision and casualty data, managing carcasses, analysing data and using thresholds to identify road mortality hotspots.

5.8.1 Guidelines for management planning

- Draft accurate procedures for road mortality and animal-vehicle collisions management.
- Provide procedures and appropriate devices and databases for accurately recording carcasses collected by field patrols and road traffic accidents involving wildlife.

- Define carcass management procedures.
- Establish regular analyses of the data collected and proper identification of clusters of road mortality ('hotspots') using standardised thresholds.
- Provide frequency thresholds of road casualties to identify road sections that will require the design and application of proper mitigation measures. Thresholds for both large animal-vehicle collisions and endangered species road mortality must be provided.
- Cooperation between road and wildlife experts is needed to implement appropriate procedures, evaluate the data that is collected, and design appropriate mitigation measures according to each conflict road section.

5.8.2 Guidelines for inspection and maintenance activities

General inspection tasks

- Regular inspections undertaken by field crews during their routine patrols must be adapted to register road casualties of target species.
- Inspections of sites where animal-vehicle collisions are registered should be carried out to remove carcasses and check any damage to road elements. These inspections could be adapted to register data that could be used to identify mitigation measures.
- Particularly hazardous road sections where high frequencies of wildlife casualties are detected should be inspected periodically to systematically record any casualties. The data that is collected could provide the basis for designing mitigation measures. Frequency and proper periods must b e defined according to the target species' behaviour.
- Inspection routes should be systematically checked during the first two years of road operation to identify and apply appropriate mitigation measures so that the cost of future management tasks can be reduced.

Registration of large animal-vehicle collision data

- Accurately register animal-vehicle collision data to provide an opportunity to properly analyse and design mitigation measures. The following information must be registered:
  - Date and hour of the collision
  - Location provided with GPS accuracy
  - Species involved (age and sex when it is possible)
  - Any road element or feature that could have an effect on the road casualty must also be registered.
- Provide tools such as GPS, tablets or smart phones for field crews so that the geographical position of any road casualties can be recorded accurately.
- Train field crews to identify the species involved and provide them with user-friendly field guides to help with identification.
- Proper photos of each carcass on the site with a device that gives its GPS location would be helpful to allow proper identification of the species by experts and to provide accurate information about the site where the event took place.
- Establish cooperation networks of traffic police, hunters and other local stakeholders to incorporate all of the data that is collected. Hunters could also help to find and humanely kill injured animals.

Registration of road mortality

- Consider registering data on the carcasses of medium-size animals found on roads during field crew patrols (see Figure 5.29). Apply the same instructions as those for large animal-vehicle collision management.
- Specific surveys could be undertaken for particular target species. Data representativeness can be ensured by appropriate survey design: the road section to be

surveyed, the methods and the periods in which the task should be undertaken must be defined with the collaboration of wildlife experts.

- Establish cooperation with local conservation or volunteer organisations and research centres to gather road mortality data. Encourage such organisations to improve the quality or length of the road sections along which they are already monitoring and recording road mortality data. Data gathered by citizens could be very helpful when it is registered in a standardised way using suitable methods, and when quality control by experts is provided.

Figure 5.29. Registering accurate data about road casualties provides valuable information to design mitigation measures. Photo: Minuartia.

Carcass management

- Manage carcasses accordingly to the regulations in each country. Field crews must be trained and provided with protective clothing and equipment to ensure hygienic conditions.
- Specially equipped trucks should be acquired or adapted to remove and handle large animals in areas where high numbers of AVC are registered (see Figure 5.30). Consider establishing agreements with research centres or universities. Carcasses can be examined and identified by experts. This is particularly relevant when endangered species are involved.

Figure 5.30. Trucks adapted to remove large animal carcasses from roads and roadsides are being used in some countries to improve the management of the large number of ungulates that should be appropriately processed. Photo: Catalan Government-Department of Transport and Sustainability.

Proper analysis of the data that is gathered and design of mitigation measures

- Conduct regular analyses of the data that is registered to identify hotspots where investment in mitigation measures will provide the best cost-benefit balance. Cooperation of wildlife experts is required.
- When the frequency of road casualties reaches the thresholds defined in the management plan, mitigation measures must be designed and implemented that are adapted to the site and conditions of the target species populations. Appropriate monitoring and evaluation will establish whether the actions that are undertaken are effective.

6 Conclusions

The current road maintenance practices on wildlife issues vary widely among different European countries. Despite the large number of wildlife mitigation measures present in road networks, the implications of animal-vehicle collisions for traffic safety and the legal regulations for wildlife conservation, most Road Management Guidelines developed by road authorities and operators include only brief and generalist information about wildlife issues. Nevertheless, some countries have already drafted guidelines for specific wildlife topics, such as roadside verges or wildlife crossing maintenance.

Information provided by practitioners, including road maintenance staff and wildlife experts, together with a literature review of scientific and technical documents are useful to identify best practices. We have provided guidelines for road-wildlife maintenance practices that can be adopted by road operators to improve traffic safety, reduce the risk of roadkill and road traffic accidents involving wild animals, the barrier effect or any other effect on wildlife. These guidelines need to be adapted to the conditions of each country or region (road network, environment and economics), and specific standards must be defined for each one.

Good management practices may also enhance the role of road verges and other landscaped areas as elements of the Green Infrastructure of a country or region by providing habitats for wildlife, including endangered species or those whose populations are declining.

Procedures for setting up a solid road-wildlife maintenance strategy are based on the goals and standards of mitigation measures and roadside habitat management. Proper compliance when monitoring and assessing these standards (based on good indicators) is necessary to identify BMP and suggest future improvements.

Cooperation with other stakeholders and training maintenance crews on wildlife issues and how to undertake maintenance practices is crucial. Cooperation platforms and participative training seminars in the field should provide expert knowledge for maintenance staff. They can also be used to gather valuable information about conflicts or opportunities to benefit biodiversity and improve practices.

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Annex 1: Interview questionnaire

Road maintenance practices to improve wildlife conservation and traffic safety

CEDR (www.cedr.fr/home/) Transnational Road Research Programme 2014-2016.

Date:

Name of interviewer:

Name of interviewee:

Organisation:

Title and role in organisation:

General

1. Are there any formal regulations, handbooks 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 how to get them) Are there any reports in which road maintenance is evaluated 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 roadkill? (Y/N)
4. If Yes, do you identify carcasses? (Y/N)
5. Do you register their exact location in a database? (Y/N), How? (Based on mileage/kilometre 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 organisation

7. Roads offer habitats 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 maintenance taken into account (e.g. access provided for maintenance machines)? (Y/N). If Yes, please provide further information.
10. Who is responsible for the maintenance of road components and mitigation measures for wildlife? (□ road authority, □ road builder, □ maintenance company, □ landowner, □ NGO, □ volunteers, □ other_____)
11. Who carries out 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 the different ways you organise the maintenance?

13. Are field inspection teams sufficiently educated or trained for their job? (Y/N)
14. If Yes, please provide details (How and how often (with or without refresher courses)? What subjects are covered (e.g. do you teach how to collect dead animals on the road, to identify carcasses, to recognise 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 examples of contracts?
16. Can you suggest any maintenance practice(s) that would improve effectiveness for wildlife?
17. Have any other problems with animals been 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 requests 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 Yes, 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 prioritised? Y/N
27. Can you identify ways to make the maintenance of mitigation measures more cost-effective? (the organisation of the maintenance, the maintenance methods, the construction of the mitigation structures, the materials used or any other aspect).

Additional

28. Is there anything you would like to add?
29. Do you have illustrations (photos, 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 2: IENE International Conference 2014 Workshop

‘Road maintenance practices to improve wildlife conservation and traffic safety’

The workshop was held at the IENE (Infra Eco Network Europe) International Conference 2014, in Malmö in October 2014.

It was co-authored by Carme Rosell, Dennis Wansink, Edgar van der Grift, Andreas Seiler, Eugene O’Brien and Miklós Puky[†].

A total of 25 people (mainly ecologists but also road engineers) from 12 countries participated. Austria, Czech Republic, Denmark, France, Germany, Ireland, the Netherlands, Poland, Russia, Spain, Sweden and Switzerland were the countries with representation.

A structured discussion about how to optimize the maintenance of: i) road verges and medians, ii) wildlife overpasses, iii) bridges and other drainage structures, and iv) fencing and screens was conducted. After a brief presentation of the goals, participants were divided into 4 groups to discuss the topics. This activity was followed by an open discussion. The final output was a list of improvements that could be made in current practices, to increase the effectiveness and durability of wildlife mitigation measures and habitat restoration practices is listed in the tables below.

Abstract
The projects SAFEROAD- ‘Safe Roads for Wildlife and People’ and HARMONY- ‘Procedures for the Design of Roads in Harmony with Wildlife’ are carried out as part of the Transnational Road Research programme ‘Roads and Wildlife’ funded by the Conference of European Directors of Roads (CEDR). Both projects will develop guidelines for Best Maintenance Practices (BMP) that help to reduce the adverse impacts of roads on wildlife, prevent animal-vehicle collisions, and take advantage of the ecological potential of infrastructure corridors in wildlife conservation. BMPs can provide opportunities for adaptive management for wildlife conservation. They are also a key factor for ensuring the effectiveness of road mitigation measures that aim at reducing barrier effects and habitat fragmentation. However, opinions on BMPs vary greatly among countries, as they depend on the organizational and geographic context. The goal of this workshop is to explore maintenance practices as perceived by experts from different countries and to discuss how this may contribute to the development of guidelines for BMPs. An overview of BMPs will be presented and the participants will be invited to present their own insights, experiences or new ideas. In particular, we will address the following questions: How can we optimize the maintenance of verges and medians? Our focus is 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 can be highlighted. Which are the key maintenance practices for ensuring long term functionality of wildlife crossings? 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 reducing wildlife mortality caused by other elements such as bird collisions with screens?

Results

a) Verges and medians

Problems identified	Solutions proposed
Conflict between traffic safety and works.	Stakeholder involvement (traffic policy, road manager, wildlife scientists, etc.) in the evaluation of best maintenance practices.
Location of sensitive areas and mitigation measures is not known by field crews and can be destroyed unintentionally.	Regularly updated databases must be provided to road maintenance patrols. Databases with areas of natural values must also be created and plans for a management that don't damage them must be drafted
Verge can create a sink effect for endangered species attracting them to areas with high mortality risks.	Species studies at landscape scale, including migration habits must be conducted to identify effects of road verges practices on wildlife mortality. Science-based maintenance practice. Keep vegetation well mowed and cleared.
Verge's maintenance may kill animals.	Adapt the period of mowing, apply procedures allowing the small fauna to escape, and choosing the proper machinery to reduce the risk to injure or kill animals. Removing the grass manually may be recommended in highly sensitive areas.
Verge's eutrophication may be a problem for species that prefer nutrient poor habitat (e.g. sand lizard).	Mowed grass should be removed from road verges.
Large destructive machines used to cut bushes and branches of trees in verges.	Use regular pruning instead to avoid splitting branches and spreading trees diseases. It also will allow getting a better aesthetic.
Exotic invasive plants are a major issue and must be avoided.	Maintenance procedures must be adapted to an early detection and removal of invasive species.
Maintenance practice may damage wildlife road signs and cultural features (milestones).	Information about sensitive points and instructions must be delivered to machine's drivers.
Some types of medians are concrete barriers that impede the movements of small animals.	Consider substitution of concrete by other median barriers. Make holes on concrete safety barriers may allow passage of small fauna. But traffic safety must be also considered.
Vegetation of median strips attracts animals increasing their risk of mortality.	Keep median vegetation well mowed to avoid attracting animals or maintain it with no vegetation.
In Mediterranean areas, fire is a major risk that must be taking into account in the verge maintenance.	Specifications for maintenance are needed in those areas with high fire risks. Only herbaceous vegetation should be allowed to growth.

b) Bridges and other drainage structures

Problems identified	Solutions proposed
Management planning is problematic because the data needed is not available or different databases are not merged.	Planning of the maintenance must be based on knowledge about the problems and the needs using all information available.
Short planning time horizon difficult to get success results.	Cooperate is needed (with water management agencies and other stakeholders) to develop proper planning from an early stage.
An increasing risk and higher frequency of extreme weather events (such as flooding) is expected due to climate change	More culverts will be needed which could be positive to reduce the road barrier effect. New culverts may only be occasionally drain water, and the rest of the time may be used by wildlife if they are properly adapted.
There is a lot of data that is not being evaluated and comparison of results from difference maintenance strategies is not undertaken.	Coordination between different organisations could improve data analyses and comparison. This fact will allow the identification of where to invest efforts to get the best results.
Culvert's exits often have barriers (sometimes created by the erosion of the soil due to water fall) for wildlife movements particularly some elements could be a barrier for fish.	Adapted culverts must be maintained in the way that could be used by fishes and other aquatic organisms. When it's not possible, a second dry passage must be provided at the proper location.
Under bridges or in channel underpasses and culverts ledges must be provided but rooting of wood ledges could destroy them. When ledges are constructed with valuable metals (aluminium was mentioned) gets stolen.	The best design must be selected from the start. Cheap and durable materials (such as concrete or stone) may be used. Wood is also recommended but a proper maintenance must be undertaken.
To apply a minimum maintenance could carry out conflicts with wildlife.	Identify the most eco-friendly solution to adapt drainage structures for wildlife.

c) Wildlife overpasses / Ecoducts

Problems identified	Solutions proposed
Some wildlife overpasses are focused to provide crossing for a single species.	A multi-functional approach is needed. Wildlife bridges should be addressed to multiple species targets. Different habitats should be provided and vegetation must be properly maintained according to different targets of the structure.
Predator could use the wildlife passage for hunting. May be could be an ecological trap for some preys.	Research is needed to identify predator-prey relationships in wildlife overpasses and to identify maintenance actions to reduce risks.
Being too flexible about bridge dimensions leads to bridges less wide. A strip of land is lost for wildlife uses on the edges due to fences are often not placed at the edge to allow inspection and maintenance tasks.	Installing fences at the edge of the overpass will provide a wilder surface available for wildlife. Drones could be used to inspect the bridge (no need for inspection paths). Solution for undertake maintenance was not provided.
Co-use of wildlife passage for recreation (bikers, horse riders, etc.) is a new increasing issue.	New maintenance challenges derived from human-wildlife co-use must be managed. It may be a need to maintain separation of different uses, to clean garbage or other issues.
Lack of money for proper long-term maintenance.	To use vegetation that requires low maintenance for wildlife passage landscaping. To establish agreements for cattle grazing.
Lack of integration of the wildlife passage to natural habitats in the hinterland.	To develop local land plans to guarantee the proper conservation of the hinterland and the connection with other natural habitats.
Inappropriate land uses in the surrounding of the passages may lead to loss of functionality. Clear cutting, fencing of adjacent land or developing of urbanised areas could make the bridge ineffective.	Road or environment authorities could buy the land around wildlife overpasses to ensure a good management. Agreements with land owners and strict regulation of uses could contribute to ensure long-term functionality.
Hunting near, or on the wildlife crossings may reduce the effectiveness.	A better regulation and communication with hunters must be undertaken.
Uncontrolled use of the overpass by vehicles could reduce effectiveness.	Placing large rocks or metal barriers at the entrance of the passage may avoid the entrance of vehicles.
Lack of involvement of landowners of surrounding land and local people.	Cooperation of local people and landowners is already being applied in many countries to get their involvement on the long-term conservation and functionality of the structure.
Loose of relevant information due to changes in the maintenance teams	A database is needed to maintain the knowledge about each wildlife passage and to preserve the ‘institutional memory’.
Monitoring almost focused on large mammals	Monitoring needs to be expanded to investigate effectiveness to provide benefits to other taxa and all habitat types.
Lack of guidelines for maintenance	A maintenance plan for wildlife crossings is needed. Not only must be planned but also provided to road operators. General guidelines (some countries already have it) could help.

d) Wildlife fencing and screens

Problems identified	Solutions proposed
Fences are damaged by people	Education and penalties could be applied. But better design to discourage climbing over fences may contribute to solve the problem
Wood fences poles are difficult to maintain	Wood poles may be replaced by metal ones.
Amphibian fences are not always well designed	Wire mesh fences allow amphibian to enter in the road. Plastic or other opaque fences should replace the wire ones.
Fences design for otters and badgers are not clearly stated. Different recommendations are provided.	New monitoring is needed to clearly establish proper fences for different species of medium-sized mammals.
Vegetation growth beside fences damages the wire meshes and may provide opportunities to climbing animals for entering in the road.	Vegetation needs to be well maintained beside fences to avoid that damages it. Dense hedges of thorny bushes could also be applied instead wire fences.
High distances from fences to the causeway provide a land stripe available for wildlife.	Fence could be moved closer to road. In some sites a second fence may be needed to keep farm land more separated to the road fence.
Fences could not maintain all animals out of the road.	Target species should be stated in each road and fences design must be according to the target species, usually large mammals (deer and wild boar).
Protected fauna present in road verges obligate the operators to adapt maintenance to reduce fauna mortality and cause other conflicts such as road casualties.	Avoid attracting fauna to suitable habitats in the roadsides where they can suffer negatives impacts.
In some particular locations fences are placed but are considered not to be useful.	Less fences means less maintenance costs. It may be necessary to define in which places is more cost efficient not to install fences. Or in which situations may be recommended to remove it.
Effectiveness of fences for different conditions and targets is not well known.	New research is needed to establish in which conditions fences are required and which type of fence may be applied for different target species.
Lack of feedback of the information gathered during maintenance to road planners.	Procedures to provide information to road planners about fence maintenance problems should be established to ensure the best more durable designs, with lower maintenance costs are applied.
A life cycle approach (plan, construct, monitor, evaluate and to use results for improving designs) is not applied.	Procedures that establish the basis for providing feedback from road operators to road planners should be implemented.

Annex 3: List of guidelines and information provided by road managers

In this annex we list all the guidelines on road management, and other technical reports, per country, that were provided by road managers.

Some documents are related to general road management guidelines (not focused on wildlife issues) while others deal about wildlife mitigation measures design, but not about maintenance.

AT- AUSTRIA

Guidelines for Road Management
Austrian Association for Research on Road - Rail - Transport (FSV). [In German] Available at: www.fsv.at

- FSV (Austrian Association for Research on Road - Rail – Transport). 2006. RVS 12.05.11. *Quality Management – Vegetation areas - Implementation, planting and maintenance*. [In German] Available at: http://www.fsv.at/shop/produktdetail.aspx?IDProdukt=902e5445-44f2-4c73-8d79-a18ad2dd9a02
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BE - BELGIUM

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- Roads and Traffic Administration. Plans verge management of motorways. Environmental Plans of Verge Management for different motorways. e.g. [In Dutch] Available at: http://www.lne.be/themas/beleid/milieueconomie/downloadbare-bestanden/bermbeheersplan-antwerpen-e19-noord
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Annex 4: List of acronyms used in this document

ADS. Animal Detection System

AVC. Animal Vehicle Collisions

BMP. Best Maintenance Practices

RMG. Road Maintenance Guidelines

PPP. Public-Private Partnership

BOT. Built-Operate-Transfer

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