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Procedures for the Design of Roads in Harmony with Wildlife

Maintenance Handbook

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Maintenance Handbook

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Executive summary

This document provides a Handbook for the maintenance of road verges and wildlife mitigation features such as wildlife overpasses. The purpose is to provide practical advice that can be used both by managers and by the personnel involved in the maintenance activity. Much of the document is made up of an alphabetical list of mitigation measures, large and small. For each of these, there are practical recommendations on what maintenance issues may arise and how they can be addressed.

1 Introduction

So what explains why animals get near to roads at all, and in some cases spend their whole lives there? The reason lies mainly in differences in resource variables along a road compared with the surrounding landscape (see Figure 1). If the difference is such that the detrimental effects of living near a road can be overcome, animals may prefer to live there or to visit the road or its neighbourhood temporarily. The following report will go into the details. It will also become clear that, considering the attractiveness of verges, the width of the verge plays an important role.

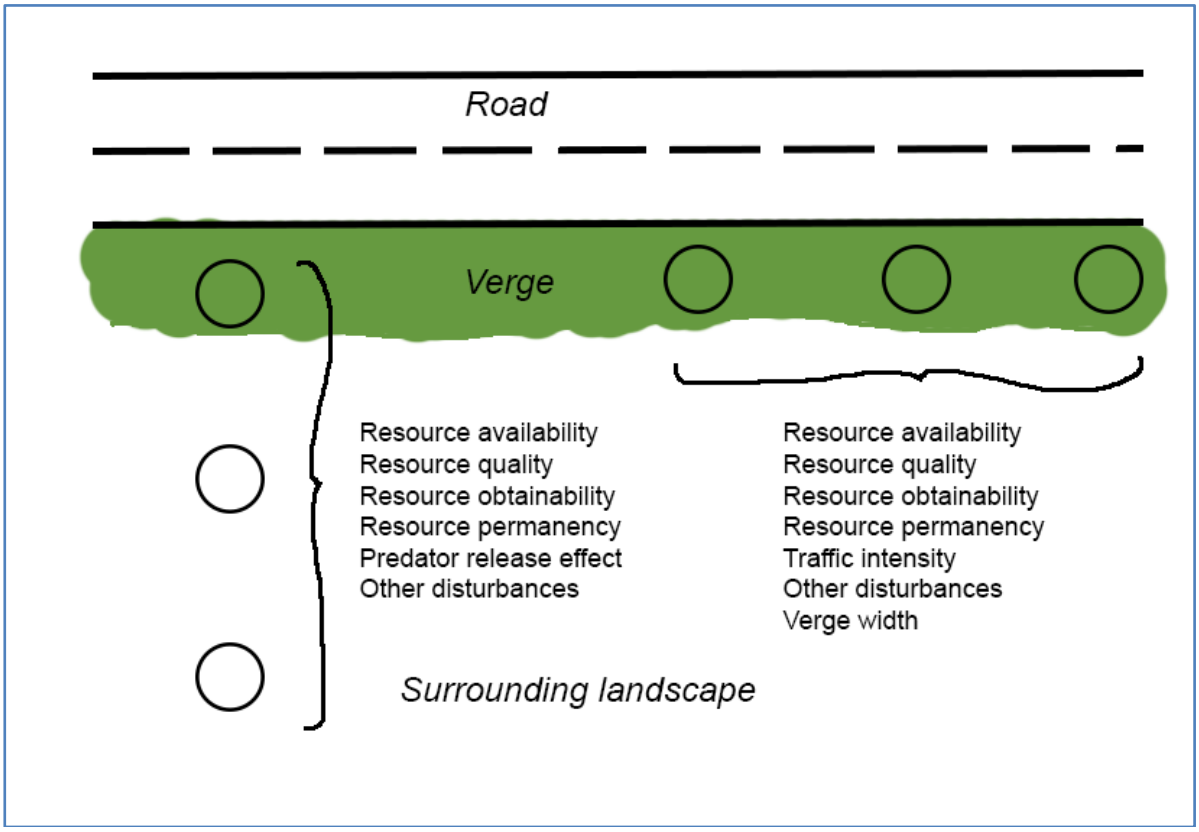

Figure 1 Factors affecting the use of roads – Differences in the factors between the surrounding landscape and the road (verge) (left) can lead wildlife to the road (verges) while differences in the factors in the verge (right) explains differences between road stretches

Scientific information about the effects of maintenance on the ecological functions of roads is limited. In general, a lot of research has been done on the use of road components and mitigation measures for wildlife, but only the effect of mowing the grass cover in verges has been the subject of significant scientific study.

For some butterfly species the conditions in road verges are always better than further away from the road, at least in highly cultivated countries. For other animal species, road verges are only attractive during certain periods. Laurian *et al*. (2008) for instance found a temporary deficiency of sodium as a driving force for Moose (*Alces alces*) to visit roads. Sodium has many fundamental physiological functions in animals but is rare in boreal ecosystems where Moose thrive. In Québec (Canada), sodium is readily available in aquatic vegetation and in pools with de-icing salt that form along highways. Moose appeared to visit the pools when

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the need was greatest and the aquatic vegetation had not fully developed, even though the pools were near to highways that they usually avoided and required long-distance movements. A comparable effect was observed by Groot-Bruinderink *et al*. (2009) with Wild Boar (*Sus scrofa*) and Roe Deer (*Capreolus capreolus*) in the Netherlands. In years with a high quantity of beech and oak nuts (so-called 'mast years') the animals stayed in the neighbourhood of this food source. In years with a low quantity, they travelled longer distances with a higher chance to cross roads. The likelihood to be hit by a car was highest for Wild Boar because they find alternative food sources in the verges of roads. For Roe Deer it was lowest, and not significant, because for this species alternative food sources are available in the neighbourhood of the beech and oak trees.

Work on and around a mitigation measure should be combined with regular maintenance work in the natural area of a road network. In general, roadside verges and ditch banks have to be mowed at certain times of the year. The cleaning of ditches can take place in the post-mowing period, typically from mid-September until mid-October. Combining maintenance work also reduces the time of disturbance.

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2 Verge Maintenance

Road verges offer relatively undisturbed habitats and in highly urbanised areas or in areas with extensive agricultural fields, they may be the only semi-natural habitat remaining. They provide a suitable habitat for a variety of species to feed, breed, nest, disperse and recolonize (Bennet, 1998). Many insects can benefit from the use of verge habitat (Noordijk *et al*., 2009; Nordbakken *et al*., 2010), including red listed grasshopper species like *Chortippus montanus* (Figure 2) and endangered butterflies (Munguira & Thomas, 1992).

(a) **(b)**

Figure 2 (a) – Chortippus montanus is found in roadside verges (photograph: Jurgen Fischer). (b) – Dutch highway, A12, with a flower rich verge (photograph: Paul Boddeke).

Verges can be a permanent habitat (for the whole life cycle) or just part of the home range of animal species. For other animal species, road verges are only attractive during certain periods or in certain circumstances.

Verges that support biodiversity or species of conservation concern and at the same time comply with road safety regulations have to be wide. In monotonous landscapes the species community in the road verge can be more diverse than the species community in the surrounding landscape.

Creating and maintaining a natural verge that supports biodiversity or species of conservation concern is not easy:

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

Species richness depends on verge width, and a broader verge means that more of the original habitat is removed, potentially leaving less space for uncommon species. A wider verge can also have possible side-effects such as facilitating non-native or competing species to reach previously isolated places. It is recommended to study the local situation carefully before taking measures to increase the species diversity near a road. Also a verge may be rich in species, but not in species of conservation concern. If the community near the road consists mainly of common, non-threatened species, one can question if this effect is desirable.

Verges can act as refuges for protected and endangered species, especially in areas where agriculture dominates the landscape. This fact should be taken into consideration when deciding about the priorities of road (side) maintenance:

- The timing and the intensity of maintenance are equally important;
- monitoring and maintenance methods should allow for the migration seasons of animals;
- spatial and environmental differences should be taken into account when deciding about the methods of maintaining different road sections.

The problem with having road sections without maintenance is that, without a transition zone, animals do not perceive the edge of their habitat. Further, drivers may not see the animals (not even mammal species) in time, because moving animals in high grass are not clearly visible. Hence, road mortality can increase significantly.

The taxonomic and conservation value of road verges is high and should not be neglected when the NRA is planning the maintenance periods. No strategy is perfect. For instance, in order to provide a better line of sight for both driver and wildlife, keeping the vegetation in verges short is recommended but this leads to more road kill among butterflies. The tables below highlight the various factors to consider and the possible objectives to have in mind in relation to the maintenance of verges.

Maintenance Objective		
Reduce Wildlife-Vehicle Collisions	Birds	Perches such as signposts, fences, trees, utility poles, etc. should be removed • Birds use the perches for singing, courtship flights, hunting and scanning the surroundings (perches allow a less energy-demanding hunting behaviour than flight-hunting).
		Adjust grass growth lengths • Tall vegetation may provide better cover for small mammals, making it harder for hunting birds to catch them, or it may make it more difficult for prey to be aware of predators.
		Cut back verge closest to the road • This provides a better line of sight for driver and wildlife, directly reducing the number of collisions. • In addition, by reducing roadkill, it reduces the number of carcasses for scavenging birds to feed on.
		Consider Removal of trees and hedgerows • These can attract some bird species that use them to nest, forage and as a retreat when a threat appears.
	Large fauna	Cut back vegetation closest to the road to allow a better line of sight for driver and wildlife • This effect can also be achieved if a broad hard shoulder (of asphalt or other hard material) is in place
Improve Biodiversity	Butterflies	The richness of flowering plants has the greatest effect on mean richness and abundance of both disturbance-tolerant and habitat-sensitive butterfly species
	Spiders	Plant hedgerows • The presence of hedgerows results in a different spider community, compared to sites without hedgerows
	Insects in general	Mowing two times a year (for medium/high production verges), with removal of the cuttings, provides the best feeding opportunities for flower-visiting insects

Factors to consider		
Soil Nutrition		• A less intensive maintenance regime is advisable for nutrient-poor soils • Intensity of cutting of verges will depend on soil nutrition • Applying nutrient-poor topsoil such as sand on nutrient-rich soils has been shown to reduce mowing frequency and thereby maintenance costs • Highly enriched soils often result in lower (flowering) plant diversity • Non-removal of cuttings enriches soils
Removal of cuttings		• Non removal of cuttings enriches soils • Cuttings can be left for a short period to allow seeds to fall on the soil • Cuttings can be transported to composting companies or, preferably, to fermentation companies • Freshly-mowed grass attracts herbivores like deer and moose to feed on young shoots and birds to prey on disturbed mice and insects. For a short period this will increase the risk of roadkill among these species.
Trees and bushes in the road verge		• The presence of bushes and trees will increase the species richness • The maintenance requirements of trees and bushes is low; only some pruning or removal of whole plants, once in several years, is needed. • Trees should not be allowed in the obstacle-free zone, close to the carriageway • There is risk of fire in the dry season • Bushes and trees can restrict the views of drivers and wildlife if they are near to the road
Location/Surrounding landscape		• Road verges less intensively maintained than the surrounding landscape increase in importance – they have a higher plant diversity and cover, resulting in more or more stable food resources, more shelter or less disturbed resting and breeding sites. • The activity in the surrounding landscape can temporally increase the importance and attractiveness of the road verge, e.g., can offer refuge when species population is decimated during harvesting. • The proximity of the verge to the carriageway is important.
Involving the landowners or NGOs		• Landowners can easily incorporate verge maintenance into the maintenance regime of their own land. This can result in lower maintenance costs.
Mowing Regime	Complexity	• Leaving some parts uncut increases the survival of many invertebrates and allows other species to persist. • Complex regimes (e.g. Sine mowing regime (Couckuyt 2015)) have shown promise in promoting species richness but are unproven for road verges. • If a verge rich in butterfly species is the goal, the whole verge should not be mown at once. • Leaving some parts uncut will increase the survival of many invertebrates and will allow other species to persist, while the reduced area mown will cut cost.

		• Maintenance personnel may not always be clear where to mow and where not to mow.
	Intensity	• The intensity of maintenance of road verges significantly determines the ground-dwelling fauna. • The height and width of the mowed grass on the verges is important for the habitats. • Decreasing the intensity of the maintenance regime for verges can provide refuges for several species near fields of agriculture. • High mowing frequency greatly reduces butterfly populations. • Taller vegetation in verges has been found to support small mammal species and increase species richness.
	Timing	• Delaying the mowing to late summer may have positive effects on butterflies. • Road verges on both sides of a road are usually mown at different times. This is undesirable as it makes crossing the asphalt a more favourable option when grassland cover is low in the surrounding landscape. • At the time of amphibian migration, all maintenance on roadside habitats should be suspended.
Grazing		• Grazing can be considered as a maintenance method to support biodiversity in road verges and has relatively low cost. • Due to the fences needed to keep in the animals, grazing can only be applied to the verge outside the obstacle-free zone.

3 Maintenance of Mitigation Measures

Many species benefit from mitigation measures (Bank *et al.,* 2002; Van der Grift *et al.,* 2003/2009; Lambrechts *et al.,* 2008; Clevenger, 2012), using them to safely cross roads. The ecological functions of crossing structures are not only to provide routes for migration or dispersal, but also appear to offer feeding, breeding, resting and hibernation sites (Wansink, 2016).

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

3.1 Inspection and Institutional Memory

Involving maintenance companies or personnel in the concept and design phase of a road project will cut costs in the operational phase. The requirements for wildlife mitigation measures should be incorporated into road maintenance programmes (Van der Ree *et al*., 2015). When maintenance is specified in contracts, not all the necessary information is

always included. For example, requirements for specific mitigation measures, such as mowing regimes, are often not incorporated in the contract.

It is necessary to inspect the mitigation measure or road component regularly. Regular inspection reveals malfunctions at an early stage, before they turn into real problems or disasters (e.g. vehicle collision with a moose). Inspection is a continuous check on whether the mitigation measure or road component still fulfills its ecological function. The execution of maintenance should always be verified and evaluated. This applies, irrespective of who is responsible for the implementation: the road authority or a contractor. The inspection frequency and detail, as well as the maintenance techniques and frequency, depend on the target species, materials used, fertility of the soil etc..

The term "target" indicates that the mitigation measure is initially designed and made for these animal species. That does not say that other species can or do not use this facility. It is recommended that during inspection and maintenance, attention is given to evidence of use by species other than the target. This information could be used to adjust the maintenance and/or design of the mitigation measure in the future.

Timing and Frequency of Inspections
For each component, an indication is given as to what details should be focussed on during inspection and what actions are expected to be taken to keep the mitigation measure functioning properly. It is advised to note the findings during the inspection and archive them properly. Perhaps lessons can be learned about the functioning of the facilities after analysis of all accumulated findings.

An inspection schedule should be provided that specifies how often and when inspections are needed. A dark green box (see below) indicates that a complete inspection should be carried out. A light green box indicates that only inspection for vandalism and litter is needed. In order to facilitate inspectors, a year table is provided in Appendix A, which shows at a glance, when each mitigation measure must be checked.

j	f	m	a	m	j	j	a	s	o	n	d

Other factors to be taken into consideration besides timing and frequency are:

- Preferably, maintenance should not take place in periods when the facility is heavily used, e.g. during spring or autumn migration or in the mating season.
- Damage to mitigation measures can occur during mowing of verges so an extra inspection after mowing is recommended.
- In the sowing and harvesting season many tractors use roads and damage is more likely. It is recommended to carry out additional inspection rounds in rural areas at that time.
- Facilities located near residential areas or busy parking areas are prone to vandalism and misuse. It is recommended to visit the mitigation measures in these locations more often.
- After specific incidents, such as damage by cars or a storm, additional inspections are necessary.
- Discovery of a fauna traffic casualty in the vicinity of a mitigation measure could be an indication of a malfunctioning system. A thorough inspection is then advisable.

Institutional Memory

A database of characteristics of each mitigation measure should be created with (some or all) of the following information:

- GPS-coordinates of each mitigation measure (helps overcome difficulty with finding the item).
- Age
- Ecological goal and target species
- Requirements of the measure (e.g. height)
- Details of the maintenance contractor/NGO
- Previous inspection date + intensity, i.e., was it a full or partial inspection
- Previous maintenance issues
- Access rights needed
- Specific inspection guidelines & elements for special attention
- Occurrence of protected plant and/or animal species
- Signs of use/non-use
- Signs of improper use

An institutional memory at the Road Authority level needs to be established not only with the data mentioned above but also in terms of maintenance techniques and methods.

- If a contractor is employed to carry out maintenance, detailed records should be kept by the authority to ensure that knowledge/experience is gained by the NRA and used in future work.
- Knowledge/experience should be disseminated through road authorities and various contractors.
- Knowledge/experience should be used to inform future contracts.

Maintenance and inspection should get the attention in the organisation it deserves. Not taking it seriously will lead to badly functioning mitigation measures that result in high costs of repair or replacement and may even endanger the traffic. Effective inspection and maintenance takes time. Sufficient budget should be set aside to facilitate successful long term operation.

In the following sub-sections, recommendations are made for the effective maintenance of a range of mitigation measures, listed in alphabetical order. These recommendations are derived from the work of Den Ouden and Piepers (2006). The recommendations, although useful in themselves, are used here as an illustration of good maintenance guidance for practitioners. Hence, they may not be universally applicable for all road authorities to apply for their given jurisdictions. For instance the timing of inspections will differ greatly between north and south Europe, given the difference in climate and target species.

3.2 Amphibian Pond

Ponds should not be too deep so that the water can be rapidly heated by the sun, but deep enough (or with deeper parts):

- to provide sufficient water in the summer for the development of larvae and,
- so as not to completely freeze in winter.

Planting for shade is allowed, but care should be taken that enough sunlight can reach the pond to warm the water sufficiently. In addition, there should be no tall vegetation (bushes or trees) within about 20 metres of the water's edge. Falling leaves will eventually fill the pond.

A pond has to be part of a network of amphibian habitats, and therefore, a connection to this network is of great importance.

What to check?	What to do?
Optimal water depth: 0.8 – 1.2 m	Phased dredging, so that a part of the pond will remain intact and damage is reduced as much as possible: • in clay and peat areas, once every 4-5 years; • in very fine sandy areas, once every 7 years; • in sandy areas, once every 10 to 20 years.
At least 50% open water	Cleaning (mowing), but leave some of the vegetation; remove excess dead plant material away from the pond.
Enough incoming sunlight	Curb shading by pruning and felling.
Gradually sloping shore	Level the shore by removing soil.
Well connected to existing corridors and habitat in the surrounding area	Use planting to make or restore the connection.
Disturbance	Take steps to ensure limited access of people.
Litter	Remove litter.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Conduct the work between mid-August and mid-October.

Target species

Frogs, toads and salamanders. Ponds can also offer a place to drink or forage for other animals, such as mammals, birds and insects.

(a) (b)

Figure 3 (a) Pond with sufficient exposure to sunlight (b) Tall vegetation restricts sunlight
(den Ouden & Piepers, 2008)

3.3 Amphibian Screen / Guide Wall

In order to keep amphibians from roads and to guide them to a safer place, screens or walls with a minimum height of 50 cm are used. Some low bushes along the walkway protect the animals against dehydration and predation (e.g. by birds of prey). Care should be taken that animals cannot use the bushes to climb over the screen or wall. At entry ramps and side roads, structures should be made that prevent the animals from reaching the road. For more information see Struijk (2010).

Amphibian Screen	
What to check?	**What to do?**
Damage (young amphibians, in particular, make use of the smallest gaps and holes). In Winter, check for damage caused by snow-ploughs.	Repair the damage.
Is the screen well dug into the ground?	Make sure the screen is 10 cm deep below ground.
Seamless connection to underpass.	Improve the connection.
Height at least 50 cm.	Adapt.
Presence of barrier or other structure at the end of the screen to prevent animals from reaching the road at that point.	Add a barrier or other structure.
Overgrown with vegetation.	Remove the vegetation.
Litter.	Remove litter.

Figure 4 Screen to keep reptiles from road is less effective due to vegetation (Photograph: Sergé Bogaerts)

Amphibian Walkway	
What to check?	**What to do?**
Overgrown with vegetation.	Remove the vegetation to clear the walkway, but without removing the cover against dehydration and predation.
Litter and obstacles (branches, stones etc.).	Remove litter and obstacles.
Flooding (preferably the path has an inclined course).	Improve walkway.
Width of the walkway not reaching the target of at least 30 cm.	Cut the grass and herbs twice per year and remove the cuttings.

Inspection scheme for Amphibian Screens and Walkways

j	f	m	a	m	j	j	a	s	o	n	d

Once every 6 months in December-January and June-July.

Target species

Frogs, toads, salamanders and small mammals, such as shrews.

(a) (b)

Figure 5 (a) walkway is easily accessible (b) walkway (right of screen) is overgrown, escape is possible. (den Ouden & Piepers, 2008)

3.4 Amphibian Underpass

The tunnel should be the meeting point of guiding structures in the area. All structures should be without holes and connect with each other and with the tunnel and should be clear of high barriers. The tunnel may be enclosed or, at minor roads, have a grid on top (partly). Light entry is an important condition for the proper functioning of the tunnel. Therefore, grids should always be free of dirt and other obstacles. Sometimes, a light shaft is included in the tunnel. Preferably, but depending on the width of the migration zone, several tunnels may be placed in close proximity to each other. Also, entry ramps and side roads should be passable.

The ambient temperature is one of the factors that affects the start of the toad migration. A temperature of 4-5 °C is known to be the lower limit. This is the lowest temperature that is allowed in the underpass/tunnel. Toads will go back into hibernation if the temperature drops under this limit. However, toads are more eager to migrate during rain so if the temperature drops below the critical level while it rains, then the toads continue migration. Hence, rain compensates for cold temperature.

Figure 6 Amphibian Tunnel (den Ouden & Piepers, 2008)

Amphibian Underpass Entrance and Tunnel	
What to check?	**What to do?**
Ability to enter and pass through the tunnel.	Remove vegetation, twigs, branches, leaves and other obstacles.
Difference in height between the tunnel entrance and the ground in front of it.	Equalize.
Damage.	Repair.
Flooding.	Find ways to prevent flooding.
Litter.	Remove litter.
Insufficient cover around the tunnel entrance.	Plant shrubs.
Tunnel with a grid: remains of oil and de-icing salt in the tunnel.	Clean the tunnel.
Grid has trapped vegetation and obstacles.	Remove vegetation and obstacles.
Loose grid.	Fasten the grid.
Passable entry ramps and side roads.	Construct tunnels. The same points of interest apply.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 6 months in December-January and June-July.

Target species

Frogs, toads and salamanders.

(a) (b)

Figure 7 (a) Tunnel is easily accessible (b) Tunnel is less accessible due to step (den Ouden & Piepers, 2008)

3.5 Bat Dwelling

Bats use, inter alia, rows of trees and other linear landscape features as flyways. Connecting the bat dwellings to these routes is vital. See also Limpens *et al*. (2005).

Bat Dwelling	
What to check?	**What to do?**
Damage.	Repair.
Light and sound disturbance (as little light and sound as possible).	Keep the surroundings as dark and silent as possible.
Connection with linear landscape features.	Improve by planting trees or bushes.
Vandalism.	Repair damage and report to enforcers.
Efficacy (check for excrements).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 2 months in February, April, June, August, October and December.

Target species

Almost all European bat species use buildings as a residence, either in summer, winter or the whole year round.

(a) (b)

Figure 8 (a) Good example of bat dwelling (b) Sign needs to be cleaned/replaced (den Ouden & Piepers, 2008)

3.6 Bridge with Path Underneath

Animals can pass under a road by following a continuous bank along a bridged river/canal. Such banks can be modified for this use. To protect the embankment from erosion, a revetment can be placed. A row of tree stumps can provide cover and guidance while a fence should prevent wildlife from entering the road.

Bridge with Path Underneath	
What to check?	**What to do?**
Ability to enter and pass under the bridge.	Remove obstructing vegetation, branches and other obstacles.
Damage to revetment.	Repair.
Potholes.	Fill with soil.
Litter.	Remove litter.
Disturbance by unauthorised users (anglers, vandals, poachers).	Make the passage impenetrable for humans. Report vandalism and poaching to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months: in February, May, August and November.

Target species

Mainly small animals, such as mice, voles, shrews, hedgehogs, hares, rabbits, amphibians, grass snake, but also roe deer, fox polecat, badger and otter.

(a) (b)

Figure 9 (a) Tree stumps leave room for access to the side (b) Bank blocked by stones (den Ouden & Piepers, 2008)

3.7 Wildlife overpass, Landscape Bridge

Slopes with guiding vegetation should connect the wildlife overpass to the adjacent habitats. The vegetation on the slopes and the wildlife overpass should resemble the habitat of the target species. The design of the structure should include a sound- and sight screen and/or planting on a rampart along the edges. This ensures cover and shielding against the noise and light of traffic. A drinking pool may be present to make the wildlife overpass more attractive to wildlife and to be used by amphibians.

Wildlife overpass/Landscape Bridge – Slope	
What to check?	**What to do?**
Extension of the vegetation to the borders of the wildlife overpass, in particular the trees (they may constitute a danger if falling from the bridge onto the carriageway).	Prune and remove the cuttings or pile it up to form cover for small animals. If necessary remove vegetation from the borders. In particular, trees >3 m high must be taken care of.
Does the composition and structure of the vegetation correspond with the design or maintenance plan?	Adjust the vegetation to the requirements of the target species.
How are the plantings doing?	Replace dead plants with new ones, after finding the cause of death.
Litter and obstacles.	Remove litter and obstacles.
Soil erosion.	Add new soil where needed to maintain the function of the wildlife overpass for the target species.
Disturbance by unauthorised users (anglers, vandals, poachers).	Make the passage impenetrable for humans (e.g. place thorny bushes). Report vandalism and poaching to enforcers.

Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 4 months in March, July and November.

Target species

Large mammals (wild boar, red and roe deer, bear, wolf, lynx), but also bats have large home ranges and travel long distances in search of food and mates. They will use wildlife overpasses/landscape bridges. Smaller animals, such as mice, amphibians, reptiles, insects and even birds, will also use wildlife overpasses/landscape bridges to cross roads.

Wildlife overpass/Landscape Bridge – Sound/Sight Barrier/Screen	
What to check?	**What to do?**
Damage to the natural or artificial construction.	Add new earth to rampart. Repair or replace screen.
Stability.	Repair / straighten.
Extension of the vegetation, in particular trees (they may form a danger if falling from the bridge onto the carriageway).	Prune or remove as necessary. Especially trees >3 m high must be taken care of.
Does the composition and structure of the vegetation correspond with the design and/or maintenance plan?	Adjust the vegetation to the requirements of the target species.
How are the plants doing?	Replace dead plants with new ones, after finding the cause of death.
Litter.	Remove litter.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 4 months in March, July and November.

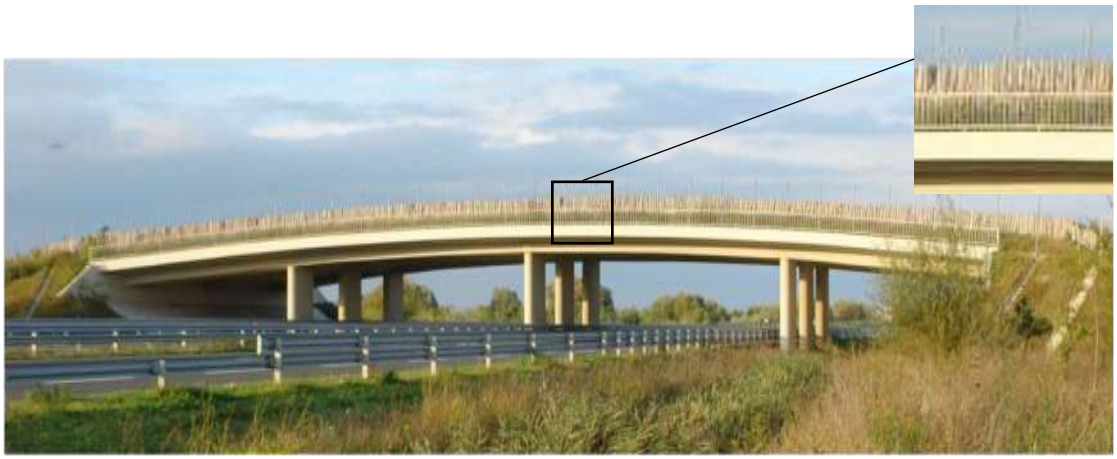

Figure 10 Figure 13 Fauna overpass in southern Hungary (Photograph: Jones 2010)

Wildlife overpass/Landscape Bridge – (Drinking) Pool	
What to check?	**What to do?**
Optimal water depth: 0.8-1.2 m	Phased dredging, so that a part of the pond will remain intact and damage is reduced as much as possible: • in clay- and peat areas once every 4-5 years; • in very fine sandy areas once every 7 years; • in sandy areas once every 10 to 20 years.
At least 50% open water	Cleaning (mowing), but leave some of the vegetation; remove excess dead plant material away from the pond.
Enough incoming sunlight	Curb shading by pruning and felling.
Gradually sloping water's edge.	Level the edge by removing soil.
For amphibians: well connected to existing corridors and habitat in the surrounding area.	Use planting to make or restore the connection.
Leakage from the pool.	Repair.
Disturbance.	Take steps to limit the access of people.
Litter.	Remove litter.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Conduct the work between mid-August and mid-October.

Figure 11 Small pond created on a wildlife overpass in the Netherlands (Photograph: D. Wansink, BUWA)

3.8 Fence, Electric

The target species determines the number of wires and the height above ground level. The voltage can be drawn from the 220V mains or from a battery. Tension springs are used in order to keep a constant tension on the wires at varying temperatures. There are facilities for operation and monitoring of the electric fence system. Electric fencing is expensive to purchase and maintain. It can be used on a temporary basis in specific cases.

Electric Fence	
What to check?	**What to do?**
Damage.	Repair.
Litter.	Remove litter.
Anchoring to the ground.	Improve.
Leakage of electric current.	Secure connections; improve isolation where there is leakage of current.
Vegetation near the fence (risk of short-circuiting).	Remove vegetation.
Safety (are signs installed?)	Install signs with warnings

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every month from January to December.

Target species

Electric fencing is mainly used to keep wild boar away from roads.

(a) (b)

Figure 12 (a) Warning sign in present (b) High grass comes up to level of fence (den Ouden & Piepers, 2008)

3.9 Fence, Large Mammals

Fences ensure that animals cross the road at certain places only. Besides impeding they also have a guiding function. Cattle grids should be placed where roads pass through fences. There should be a facility for small animals to climb out of the cavity under the grid. If animals do get on the road, return facilities (e.g. local elevations along the fence) should be provided to ensure that the animals can easily turn back to the safe side of the fence. Planting relatively close to the fence (but not under it!) can ensure that animals do not try to jump over it. A gate ensures that maintenance staff can easily pass through the fence. If the fence is combined with a screen for small mammals and amphibians/reptiles (a combined grid), then check also according to the instructions in section 3.10.

Figure 13 Multi-purpose fencing in The Netherlands

Fence, Large Mammals – Poles/Stakes, Mesh and Wire Work	
What to check?	**What to do?**
Height (at least 2.2 m for red deer, 1.8 m for roe deer and 1.5 m for wild boar).	Adjust.
Damage (check for holes and the position).	Repair and erect; replace parts if necessary.
Attachment and tension of the wires.	Improve.
Stability (difficult to push over). Anchoring to the ground (check for signs of scour).	Improve.
Continuous connection to the wildlife overpass/underpass.	Make sure there is no damage or gap in the fencing that connects the fence to the animal overpass/underpass that would allow target animals across the road.
Litter and obstacles.	Remove.
Vegetation near to the fence.	Remove vegetation that grows against and over the fence.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every six months in March and September.

Target species

Large mammals (wild boar, red and roe deer, bear, wolf, lynx),

(a) (b)

Figure 14 (a) Easily accessible for inspection (b) Vegetation overgrown through fence (den Ouden & Piepers, 2008)

Fence, Large Mammals – Cattle Grid	
What to check?	**What to do?**
Damage.	Repair or replace the grid.
Connection between fence and cattle grid	Make sure the target animals cannot pass through the opening in the connection.
Leaves and dirt under the grid.	Clean the grid and the cavity under it.
Presence of a facility for small animals to climb out of the pit.	Place, repair or improve climbing facility.
Connection to the wildlife overpass/underpass.	Make sure the target animals cannot pass through an opening in the connection.
Stability of grid / frame (in relation to traffic safety)	Improve.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every six months in March and September.

(a) (b)

Figure 15 (a) Grate is clean (b) Grate is clogged with sand

Fence, Large Mammals – Return Facility (Mound) (see picture)	
What to check?	**What to do?**
Height (the mound should reach the top of the fence).	Increase the height of the mound.
Signs of scour.	Add soil.
Vegetation on or behind the return facility.	Remove vegetation that obstructs the passage of the target animals.
Litter.	Remove.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every six months in March and September.

(a) (b)

Figure 16 (a) Easily accessible in the flat landscape (b) Vegetation is too dense (den Ouden & Piepers, 2008)

Fence, Large Mammals – Gate	
What to check?	**What to do?**
Damage.	Repair or replace.
Opening and closing.	Close open gate. Design a gate that closes by itself.
Connection between fence and gate.	Make sure the target animals cannot pass through the opening between fence and gate.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every six months in March and September.

Fence, Large Mammals – Wild Boar Gate	
What to check?	**What to do?**
Damage.	Repair or replace.
Opening and closing.	Close open gate. Place a gate that closes by itself.
Connection between fence and gate.	Make sure the target animals cannot pass through the opening between fence and gate.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every six months in March and September.

(a) (b)

Figure 17 Damaged fencing left unrepaired or not maintained (Photograph E. Finnerty)

3.10 Fence, Small Mammals

Fences ensure that animals do not cross a road except in places where crossing facilities are installed. They thus have an impeding as well as a guiding function. A fence is effective if:

- it is at least 100 cm high:
- animals cannot crawl under it – the fence must be buried for at least 20 cm deep;
- the lower side of the fence is also folded over at least 30 cm in the opposite direction to the road, so that digging animals cannot burrow underneath;
- the poles are on the road side; otherwise animals can use them to climb over the fence.

If a fence becomes overgrown with vegetation, some animals can use the vegetation to climb it. Vegetation also hinders visual inspection. However, especially when the overgrowth is woody vegetation, it has benefits because the fence will be less prone to damage by mowing or vandalism. Hence vegetation removal depends on the local circumstances.

If the fence is combined with a screen for amphibians/reptiles, then check also according to the instructions of section 3.3.

Fence, Small Mammals – Poles/Stakes, Mesh and Wire Work	
What to check?	**What to do?**
Height (at least 1 m).	Adjust.
Damage (check for holes and the position). Damage can be induced by maintenance and agricultural machines.	Repair and erect; replace parts if necessary.
Attachment and tension of the wire.	Improve.
Signs of digging.	Make sure the fence continues to 20 cm deep into the ground.
Litter and obstacles.	Remove.
Connection to the wildlife overpass/underpass.	Make sure the target animals cannot pass through the opening in the connection.
Vegetation (especially woody) near to the fence.	Prune, cut, or remove vegetation that grows against or over the fence.
Vandalism (e.g. cut wire at resting sites).	Repair and report to enforcers.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Small to medium-sized mammals such as hares, rabbits, otters, badgers and hedgehogs

(a) (b)

Figure 18 (a) The fence is deep enough (b) Fence is not suitable for situation (den Ouden & Piepers, 2008)

Fence, Small Mammals – Return Hatch

What to check?	What to do?
Accessibility.	Remove vegetation/obstacles.
Presence of concrete slab (to prevent the development of vegetation); good connection between hatch and slab.	Place slab and ensure good connection with the hatch.
Damage.	Repair or replace hatch.
Attachment of hinges and frame.	Improve.
Presence of stop grid perpendicular to hatch.	Place stop grid and ensure a good connection between the grid and the hatch.
Vegetation around the hatch and presence of sand/soil, which prevents the hatch from closing.	Remove the sand/soil. Cut the grass on both sides of the hatch more often than the road verge.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

(a)(a)

(b)(b)

Figure 19 Badger hatch at the base of exclusion fencing; (a) vegetation cleared for ease of opening; (b) excessive vegetation restricting the opening (Photographs: E. Van der Grift)

Fence, Small Mammals – Return Facility (Mound)	
What to check?	**What to do?**
Height (the mound should reach the top of the fence).	Increase the height of the mound.
Signs of scour.	Add soil.
Vegetation on or behind the return facility.	Remove vegetation that obstructs the passage of the target animals.

Litter.	Remove.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

(a) (b)

Figure 20 (a) easily accessible from the road and reaches to the top of the fence (b) Collapsed and accessible to wildlife on incorrect side

Fence, Small Mammals – Gate	
What to check?	**What to do?**
Damage.	Repair or replace.
Presence of concrete slab or pavement.	Place slab or pavement.
Slab or pavement sagged.	Repair.
Space between gate and slab/pavement should be less than 5 cm and there should be almost no opening between gate and fence.	Improve the connections; if amphibians are the target species, the openings can be blocked with flexible material.
Does the mesh of the fence continue on the gate?	Place netting on the gate.
Opening and closing.	Close open gate. Provide a gate that closes by itself.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

3.11 Gangway/Dam

To help small to medium sized mammals to cross broad ditches and canals near to wildlife overpasses/underpasses, dams with a culvert or gangway are constructed from bank to bank. In order to prevent these facilities from being used by livestock or humans, fences are often placed on the boardwalk or dam, with an opening which is sufficient for the target species to pass through. Planting can be used to guide animals to the facility, and to provide cover.

Trails are paths that are regularly used by animals. Sometimes they are used by one particular individual, sometimes by more individuals of one species, but often by multiple species simultaneously. The width of a trail is an indication of the species. Trails of hare and rabbit for example, are 10-20 cm wide.

Figure 21 Dam allows route for wildlife (den Ouden & Piepers, 2008)

Gangway/Dam	
What to check?	**What to do?**
Stability.	Improve.
Damage (check also for rot and sagging).	Repair or replace shelves. In the case of sagging, add soil.
Slipperiness (due to moss on the shelves).	Remove the moss. Attach chicken wire to the shelf if necessary.
Litter and obstacles.	Remove.
Connection to the bank of the ditch/canal.	Improve the connection.
Vegetation (in case of a dam).	Vegetation that obstructs the passage by wildlife must be pruned or removed.
Damage to the fence.	Repair or replace the fence.
Can the fence be passed by the target species?	Make sure the opening in the fence fulfils the requirements of the target species.

Vandalism.	Repair and report to enforcers.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Small and medium sized mammals such as fox, badger, wild cat, hedgehog, mustelids, mice, hare and rabbit, and amphibians can use this mitigation measure.

(a) (b)

Figure 22 (a) Plank with is good, fence restricts access to only target species (b) Gangway is damaged and very narrow (den Ouden & Piepers, 2008)

3.12 Guiding Vegetation

Guiding vegetation serves to guide the animals to a wildlife crossing structure and should offer cover. The guiding vegetation should connect woody vegetation or reeds in the surrounding area to the wildlife crossing structure itself. Vegetation that hinders the passage of target species should be pruned. If there are gaps in the guide, it is advised to fill them with native trees and shrubs, which occur in the area. If disturbance by humans occurs (e.g. in the vicinity of residential areas) then it is advised to use thorny bushes or trees such as hawthorn or bramble. The advantage of hawthorn is that it does not proliferate. In reed banks, woody vegetation must be removed immediately.

The guiding vegetation needs to be maintained to keep the right structure and density for the target species. For badgers and bats it is known that the animals will search for an alternative route when the bushes along their normal commuting route become too dense and form a barrier.

Guiding Vegetation – Plants

What to check?	What to do?
Litter.	Remove litter.
Storage of vehicles and other materials.	Remove them.
Misuse by people, such as moto crossers or horse riders.	Inform the warden or terrain owner.
Vandalism and poaching.	Inform the warden, terrain owner or enforcer.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Twice a year in June-July and September-October.

Target species

Guiding vegetation is used to guide a wide variety of animal species to the various wildlife overpasses/underpasses. Virtually all land-based and tree-dwelling mammals can use the vegetation as cover while travelling. Depending on the composition, it may also be used as a source of food. Bats use line plantings as flight paths.

(a) (b)

Figure 23 (a) Plants lead way to stumps well (b) Guiding plants are missing (den Ouden & Piepers, 2008)

3.13 Large Bridge or Viaduct

Especially in places where roads pass through valleys, the use of bridges or viaducts can create space for animals to pass under the road. The large spans provide the advantage that enough light reaches the area under the bridge to sustain natural vegetation.

Large Bridge/Viaduct	
What to check?	**What to do?**

Continuity.	Fill the gaps with new plantings.
Vitality.	Replace dead or dying plants.
Good connection to wildlife crossing structure.	Improve the connection. When vegetation blocks the entrance to the passage, prune it and remove the cuttings.
Poor connection with woody or reed vegetation in the surroundings.	Improve the connection.
Did the composition and structure of the vegetation develop as planned (see design and maintenance plan)?	Adjust the vegetation to the requirements of the target species.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Large mammals (red and roe deer, bear, wolf, lynx and wild boar), but also smaller mammals (marten, foxes, hares, rabbits, hedgehogs, mice, bats, etc.), reptiles, amphibians and insects.

(a) (b)

Figure 24 (a) A natural situation without obstacles (b) Bales of hay and a fence blocking passage (den Ouden & Piepers, 2008)

3.14 Large Fauna Underpass

Underpasses for large mammals are used at points where roads are elevated relative to the landscape. The underpass should connect to existing animal trails and to guiding fences. Guiding vegetation (see section 3.12) from the tunnel entrance is to ensure cover and guidance to the tunnel. The plants should also offer food to the animals; helping the animals to find the underpass.

Large Fauna Underpass	
What to check?	**What to do?**
Ability to enter and pass through the underpass.	Remove vegetation, twigs, branches, leaves and other obstacles, but save vegetation that offers cover to approaching animals.
Litter	Remove litter.
Flooding.	Improve the drainage or add soil. However, some humidity or a small gully is beneficial.
Damage.	Repair.
Enough cover at the tunnel entrance.	Plant shrubs that provide cover.
Disturbance by unauthorised users (vandals, poachers)	Make the passage impenetrable for humans (e.g. place thorny bushes) if possible. Report vandalism and poaching to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Large mammals (wild boar, red and roe deer, bear, wolf, lynx), but also bats have large home ranges and travel long distances in search of food and mates. They will use large fauna underpasses. Also smaller animals, such as mice, amphibians, reptiles, insects and even birds, use large fauna underpasses.

(a) (b)

Figure 25 (a) Easily accessible and no water pollution (b) Waterlogged (den Ouden & Piepers, 2008)

3.15 Ledge Under Bridge or in Culvert

In order to make it possible for smaller animals to pass under a road where a bridge or culvert is present, a ledge of wood, concrete or plastic may be attached to the sidewall(s) of the bridge or culvert. An upright border on the waterside of the ledge provides cover to passing animals. The border also keeps soil on the ledge if needed. A nearby fence should prevent animals from coming into contact with the road and vegetation should direct the animals to the bridge or culvert. If amphibians use this feature too, then the lower portion of the fence must contain an amphibian screen. For more information see (Wansink, 2013).

Figure 26 Poorly maintained mammal ledge in a culvert (Photograph: H. Bekker)

Bridge/Culvert with Ledge	
What to check?	**What to do?**
Ability to enter and pass through the tunnel/culvert.	Remove vegetation, twigs, branches, leaves and other obstacles, but save vegetation that offers cover to approaching animals.
Litter	Remove litter.
Damage (e.g., rot in wooden ledge).	Repair.
Stability.	Replace broken pieces.

Seamless connection between ledge and embankment.	Improve the connection.
Seamless connection between ledge and wall of bridge or culvert.	Improve the connection.
Soil on ledge (if needed).	Add soil when the layer is thin or gone.
Enough cover at the bridge/culvert entrance.	Plant shrubs.
Disturbance by unauthorised users (anglers, vandals, poachers)	Make the passage impenetrable for humans (e.g. place thorny bushes). Report vandalism and poaching to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Small animals, such as mice, voles, shrews, hedgehogs, amphibians, but also fox and mustelids.

(a) (b)

Figure 27 (a) Good connection to the shore (b) Missing sand layer (den Ouden & Piepers, 2008)

3.16 Hop-over

Closed vegetation, a high screen or rampart may force bats, birds and butterflies to cross the road at a safe altitude. The vegetation or construction should connect to the landscape. For bats, the crossing location should be unlit and closure crowns (over the road) are important for them. The planting should be kept as dense as possible. If the crowns touch above the road, they offer a crossing opportunity for squirrels, dormice and pine martens. On motorways this effect is mimicked using trees to connect to road portals that serve as a guiding structure for bats or can support a 'tree bridge'). See also Limpens *et al*. (2005).

Hop-over **– Planting**	
What to check?	**What to do?**
Continuity.	Fill the gaps with new plantings.
Vitality.	Replace dead or dying plants.
Good connection to vegetation in the surroundings. In the case of bats, lines of plantings may be necessary.	Improve the connection with new/extra plantings.
Height of branch-free stem.	Prune the trees to create a branch-free space until above the height of trucks (about 5m).
Tree health, dead branches	Check if regular inspection of trees is part of the maintenance plan of the hop-over.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Twice per year in the months June-July and September-October

Target species

Bats are the main target. Additionally, butterflies and birds, especially species that forage or hunt at low altitude, such as owls and harriers.

(a) (b)

Figure 28 (a) Large tree crown provides safe crossing (b) Removing trees (road widening) create a gap too great to bridge (den Ouden & Piepers, 2008)

3.17 Sand Martin's Nesting Sites

Sand martins dig nesting holes up to one metre deep in sandy soils. Nesting opportunities can be provided by adapting existing sites or by drilling holes in a concrete wall and providing a back-fill of sand behind the wall. It is important that the nests are cleaned once a year due to the possible presence of parasites.

During the construction of the N11 in the Netherlands, nesting Sand martins were discovered on a side slope by the proposed road. The Dutch National road authority stopped the work temporarily and built a substitute for the nests in an artificial wall. The birds moved to the wall. On average some 16 pairs of sand martin breed in the wall annually.

Sand Martin Nesting Site in Wall	
What to check?	**What to do?**
Stability and construction.	Improve.
When walls are not made of concrete, the slope may become less than 60^{o} to the horizontal (90^{o} is optimal)	Increase the slope by removing soil.
Vegetation.	Remove vegetation if more than 50% is covered.
Approach flight path contains obstacles.	Remove obstacles.
Nesting holes unclean.	Clean the holes and fill again with sand when the distances between holes are less than 30 cm or always if it is an artificial wall.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once per year September-February.

Target species

Sand martins are choosy birds of open terrain. The breeding area must fulfil two important conditions: there must be a barren, sandy or loamy steep wall, in which the nesting burrows can be dug, and there must be enough food (mosquitoes or other insects).

(a) (b)

Figure 29 (a) Ideal situation (b) Nests not clear, vegetation overgrown (den Ouden & Piepers, 2008)

3.18 Small Fauna Underpass / Badger Tunnel

To assist animals to find an underpass, fences and/or guiding vegetation (see sections 3.10 and 3.12) should be in good condition and well connected to the entrance of the underpass. Underpasses are often connected to existing commuting routes of wildlife, especially in the case of badgers. Animals follow these routes using their sense of smell. It is advised to check if the routes still show signs of recent use. If not, then research into the causes is needed. A boardwalk or dam may be necessary to make it possible for the animals to cross wide ditches (see section 3.11). In poorly drained soil, a gravel pit in front of the entrance ensures that water sinks into the ground instead of flowing into the tunnel. The tunnel should be built at a gradient so that any incoming rain water can run off.

(a) (b)

Figure 30 (a) Tunnel easily accessible, free of obstacles (b) Tunnel full of water (den Ouden & Piepers, 2008)

Small Fauna Underpass/Badger Tunnel – Entrance	
What to check?	**What to do?**
Ability to enter and pass through the underpass.	Remove washed in sand, twigs, branches, leaves and other obstacles, but save vegetation that offers cover to approaching animals.
Litter.	Remove litter.
Flooding.	Find the cause and improve the drainage. A hand pump can be used if necessary.
Damage.	Repair.
Enough cover at the tunnel entrance.	Plant shrubs that provide cover.
Disturbance by humans.	Plant thorny bushes to prevent disturbance.
Vandalism and poaching.	Report to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Figure 31 Culvert with rubbish and construction materials strewn around the entrance (Wansink 2013)

Target species

Small(er) terrestrial mammals like fox, badger, wild cat, rabbit, hedgehog and mice. Otters can also use these tunnels. Otters travel long distances to find food (80% fish). In severe winters otters migrate to areas with open water. In addition, amphibians also make use of these tunnels.

Small Fauna Underpass/Badger Tunnel – Manhole	
What to check?	**What to do?**
Accessibility for inspection.	Remove obstructive vegetation.
Level difference between bottom of manhole and of tunnel. The manhole should not become a death trap for small animals.	Level out any difference.
Locking mechanism of the lid.	Make sure the locking system works properly.
Damage.	Repair.
Flooding (water can enter through entrance, the	Find the cause and repair.

lid, seams or through bad connection between manhole and tunnel).	

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

(a) (b)

Figure 32 (a) Accessible and well sealed (b) Inspection vent full of water (den Ouden & Piepers, 2008)

Small Fauna Underpass/Badger Tunnel – Gravel Pit	
What to check?	**What to do?**
Clogging (when the gravel pit is filled with soil, water will not seep through it anymore).	Clean. Replace the gravel if necessary.
Litter.	Remove the litter.
Vegetation.	Vegetation that blocks the entrance to the tunnel must be removed.

Figure 33 Gravel pit removes water well (den Ouden & Piepers, 2008)

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Small Fauna Underpass/Badger Tunnel – Light Shaft	
What to check?	**What to do?**
Transparency for light and accessibility for inspection.	Remove vegetation that obstructs light or inspection.
Locking mechanism of the lid (it should be silent and free of vibration).	Make sure the locking system works properly.
Damage, especially leakage of the lid.	Repair.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

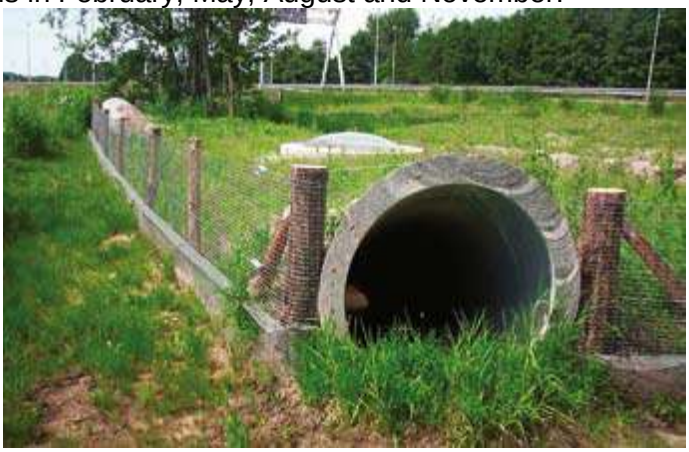

Figure 34 Light shaft used at T-junction (den Ouden & Piepers, 2008)

3.19 Stub Wall (Tree Stumps)

A stub wall is a wall constructed of root stumps of trees. The wall mainly serves as a guide for smaller animals to and through a wildlife passage, such as a viaduct with nature underneath. The stumps offer smaller animals cover for a safe crossing. Guiding vegetation (see section 3.12) connects to the stub wall and guides the animals to the stumps. Sometimes the stumps are covered with wire mesh to prevent people from moving them.

Stub Wall	
What to check?	**What to do?**
Ability to pass.	Ensure the presence of holes for small animals

	and a bare strip along the stub wall for larger animals.
Interconnection.	Add tree stumps.
Erosion due to weather.	Replace tree stumps.
Regrowth of stubs.	Prune the stubs.
Litter.	Remove litter.
Anchoring and damage to the mesh wire (if present).	Improve, repair or replace.
Vandalism (e.g. fire or moving of the stubs).	In case of fire, replace the stubs with boulders. Report vandalism to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Mainly small mammals such as hedgehogs and mice. It is proven that they may use a stub wall also as a residence. As a consequence predators such as weasels and stoats use the stub walls too. Experience shows that for example, foxes, badgers and grass snakes use the stub wall as a possible commuting route. Larger mammals can use the stub wall as a guiding line to a wildlife passage.

(a) (b)

Figure 35 (a) Stumps connected together well (b) Stumps polluted with litter (den Ouden & Piepers, 2008)

3.20 Mixed use Tunnel

Tunnels for vehicles of sufficient width (more than 10 m), that are not intensively used, can be adjusted for shared use with animals. To this end a dirt strip is created. On this strip and as a guide to the strip, a stub wall can be constructed, which can also provide cover. Guiding vegetation (see section 3.12) can also be used as cover, and to guide the animals to the passageway. If reptiles and amphibians are amongst the target species, a screen as a partition between paved and unpaved parts is required. For inspection and maintenance of connecting fences see section 3.10.

Tunnel Walkway	
What to check?	**What to do?**
Ability to pass.	Remove obstacles.
Drainage.	Improve.
Litter	Remove litter.
Erosion.	Add soil.
Disturbance and misuse by traffic (e.g. horse riders, Moto crossers), vandalism and activities of poachers.	Report to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Large mammals (bear, deer and wild boar), small terrestrial mammals (foxes, badgers, martens, hares, rabbits, mice, etc.), bats, reptiles and amphibians.

(a) (b)

Figure 36 (a) Strip clear and passable (b) Strip polluted with litter (den Ouden & Piepers, 2008)

3.21 Mixed Use overpasses

Bridges that are not intensively used, can be adjusted for shared use by animals. To this end an unpaved, overgrown strip is created. On this strip and, as a guide to the strip, a stub wall can be created, which can also provide cover. Guiding vegetation can also be used as cover, and to guide the animals to the passageway. If reptiles and amphibians are among the target species, a screen as a partition between paved and unpaved parts is required. A sound and sight screen is placed on the overpass to provide cover to the animals, mute noise and shield light. For inspection and maintenance of connecting fences see section 3.10.

Natural Strip	
What to check?	**What to do?**
Ability to pass.	Remove obstacles.
Drainage.	Improve.
Litter.	Remove litter.
Extent of vegetation (also regarding traffic safety).	Prune and remove cuttings.
Composition and structure of the vegetation (is there a maintenance plan?)	Adjust the composition and structure of the vegetation according to the requirements of the target species.
Erosion.	Add soil.
Disturbance and misuse by traffic (e.g. horse riders, Moto crossers), vandalism and activities of poachers.	Report to enforcers.
Efficacy (check for animal tracks).	Register and archive.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

Target species

Large mammals (deer, wolf and wild boar), small mammals (foxes, martens, hares, rabbits, hedgehogs, mice, bats, etc.), reptiles, amphibians and insects.

(a) (b)

Figure 37 (a) Strip clear and passable (b) Too little space for larger animals (den Ouden & Piepers, 2008)

Viaduct – Sound and Sight Screen	
What to check?	**What to do?**
Damage.	Repair or replace.
Stability and position.	Stabilise and erect.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Once every 3 months in February, May, August and November.

(a) (b)

Figure 38 (a) Screen provides complete protection (b) Screen is not fully complete (den Ouden & Piepers, 2008)

4 Conclusions

Road designs increasingly incorporate features for promoting biodiversity and for reducing the impact of roads on wildlife. To be effective, these features need to be maintained. This document provides insights on what to look out for when maintaining wildlife mitigation measures and how to address maintenance issues. It is presented in the form of a practical handbook, offering guidance that can be easily understood.

Maintenance needs vary considerably due to different habitats and topology and target species with very different behaviours and needs. Nevertheless there are many common maintenance issues that arise in mitigation measures. This handbook lists a wide range of mitigation measures and proposes practical maintenance guidance that is expected to form the basis for more site-specific guidance documents.

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Annex A: Year Table for Inspection

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