The conservation value of sandy highway verges for arthropods – implications for management

Jinze Noordijk, Karlè V. Sýkora & André P. Schaffers
Wageningen University, Nature Conservation and Plant Ecology Group, PO Box 47, 6700 AA Wageningen, The Netherlands, E-mail: jinze.noordijk@wur.nl

Sandy highway verges in the Veluwe region can be of importance to light demanding, pioneer grassland and heathland communities, characteristic of nutrient-poor sandy soils. The last decade however, the open character of these road verges is negatively influenced by encroaching trees and shrubs. The responsible authorities are now considering restoring the open and low vegetation. Although ample knowledge exists about the botanical aspects, information on the importance of these road verges for arthropod species and the management needed is insufficient. We surveyed reference sites in these verges, especially for ground beetles, ants and spiders, and found many specialized, rare, protected, and red list species. It is apparent that management changes are required, and the reference sites are to be taken as the target situation for the rest of the verges. We formulated a set of management recommendations focused on arthropods. We advise to restore open situations in highway verges by removing trees and shrubs. The nutrient-poor zone with mosaics of low vegetation types should be maximized. If applied along the overall length, verges can potentially become suitable habitat corridors connecting different nature reserves. When large scale removal of the top soil is performed, high quality vegetation refugia should be left intact as a source from which arthropods can spread again. Subsequent management should consist of fine scale and phased mowing and removal of encroachment; yearly a fraction of the verges should be managed so that in approximately ten years time all sites have been managed and the cycle can be repeated.

Keywords: Araneae, Carabidae, corridors, ecology of infrastructure, Formicidae

The Netherlands are covered by an extensive network of highways. Despite many detrimental effects of roads themselves (Spellerberg 2002), the accompanying verges may contribute to the diversity of flora and fauna (Sýkora *et al.* 1993, Noordijk *et al.* 2005). When compared to the surrounding agricultural or urban areas, many plant and animal species can be found to live in the unfertil-

ized semi-natural plant communities in verges. For traffic safety and for vegetation management most highway verges are yearly mown. This way, encroachment by shrubs and trees and succession to productive tall plant communities is prevented. Plant communities with a low standing biomass, like hay meadows, often bear relatively high biodiversity (Parr & Way 1988, Schaffers 2002). These communities declined considerably in the Netherlands and have become quite rare. From a conservation point of view, nutrient-poor situations merit particular attention, as they harbour relatively many threatened and/or rare species (Kleukers *et al.* 1997, Turin & Heijerman 1997, Mabelis 2004).

In the Veluwe region, four highways (the A1, A12, A28 and A50) were constructed between 1950 en 1980. As these roads and accompanying verges were constructed on the original nutrient-poor sandy soils it was assumed that little management was needed. Consequently, in general a mosaic of nutrient-poor grasslands, heathlands, grey hair-grass vegetation, trees and shrubs developed. These sites are usually bordered by a strip of nutrient-rich soil with grassy vegetation right next to the asphalt and by forest on the other side (Fig. 1). These verges became a suitable habitat for organisms like reptiles and lichens (Lemmens 1984, Zuiderwijk 1989). As such, they provided welcome extensions of a threatened open landscape type. Heathlands and drift sands are of high conservation concern (European Community 1992), but they are declining severely in surface and are highly fragmented in the Netherlands (Van Duuren *et al.* 2003). It has often been suggested that these particular highway verges could function as movement or habitat corridor (Bekker & De Vries 1992, Vermeulen 1994, Smeenge *et al.* 2005, Keizer *et al.* 2006). When un-interrupted suitable vegetation is provided between separate nature reserves, the corridor function seems very plausible and recommendable (Beier & Noss 1998, Ries *et al.* 2001, Anderson & Jenkins 2006).

Recently, the increasing dominance of trees and shrubs has become a major problem for the open and nutrient-poor vegetation in the highway verges of the Veluwe (Noordijk *et al.* 2005; Fig. 1). The Road and Hydraulic Engineering Division (at present: Centre for Traffic and Navigation) from the Ministry of Transport, Public Works and Water Management aims to restore the open and heathy conditions of the verges on a large scale. In this scope it is important to obtain more insight in:

1) the importance of remaining high quality verges for specialized arthropod species, which therefore act as target situations for the verges to be restored;

2) the presence of protected or red list species. As large scale management is possibly needed, it is important to know about the presence and location of species from the national Flora and Fauna legislation and red lists in order to avoid their disturbance;

3) the need for a management specifically aiming at arthropod conservation;

4) the species most suitable for monitoring the success of the restoration measurements.

Figure 1. Example of a sandy highway verge with open vegetation on the Veluwe. Sand lizards, the spider *Eresus sandaliatus*, the red list ants *Anergates atratulus*, *Formicoxenus nitidulus*, *Formica pratensis* and *F. rufa/polyctena*, and the highly characteristic carabid beetles *Amara equestris*, *Olisthopus rotundatus* and *Harpalus smaragdinus* are abundant here. Photo: J. Noordijk.

In this contribution we present the main results of our arthropod surveys in these particular highway verges and propose some easily recognisable species to be used for monitoring restoration or management success. We conclude with a restoration plan followed by recommendations for a consequent management scheme.

MATERIAL AND METHODS

Study areas – reference sites

We selected six relatively high quality sites with nutrient-poor and low vegetation patches alongside highways on the Veluwe to determine species composition of ground beetles, ants and spiders (Noordijk 2005, Noordijk & Boer 2007, Noordijk *et al.* in press a). These sites were located close to nature reserves, and were almost the only locations where open and low vegetation of good quality could still be found in the verges. These sites act as references for other verges, indicating the potential arthropod communities after restoration.

Sampling methods

In the high quality patches arthropods were sampled in different ways. Most spiders, ants and ground beetles were collected using pitfall traps (ø 100 mm, half filled with a 3% formalin solution, a sample is collected during five months per year, Noordijk *et al.* in press a). Three sites were sampled for four consecutive years, while the three other sites were sampled only one year. In total, this constitutes of 99 pitfall trap samples being collected. In three of these sites we also placed four window traps for one year (window 80-by-60 cm, positioned at 1 m above the ground, gutter under window 18 cm broad and filled with salt solution, sampling for six months) to collect flying ground beetles and winged sexuals of ants. Some additional sight observations were done on ant species. For each observed species we noted whether we found it occasionally (only at one location or at two locations but in low numbers) or frequently (at two locations in quite high numbers, or at more than two locations).

Species of conservation concern

It is very difficult to make reliable and well funded statements on the conservation status of arthropods, due to the many species, the relatively few data, the influences of observational biases and the lack of monitoring programs (New 1999, Stewart & New 2007, Conrad *et al.* 2007). No national conservation policy exists for spiders and ground beetles, and insufficiently so for ants. Therefore – from the pool of collected species in the highway verges – we ourselves designated arthropods of *conservation concern* in the Veluwe region to illustrate the *conservation value* of the studied sites.

For ants we used three criteria, each of which indicates a significant conservation concern: species from the international red list of threatened species of the IUCN (2006), species that are protected by national law (Flora and Fauna Act, Ministry of Agriculture, Nature and Food Quality 2002), or specialized species which are highly characteristic of nutrient-poor and open plant communities (pers. comm. P. Boer). For the ground beetles we used two criteria: species highly characteristic of heath/drift sand areas or other low nutrient-poor vegetations on sand (Turin 2000), or species from habitats with low vegetation showing a declining trend in the Netherlands (Desender & Turin 1989). For the spiders we used two criteria: species restricted to heath/drift sand areas or other low nutrient-poor vegetations (according to Bauchhenss 1990, Hängi *et al.* 1995, Roberts 1998, Bonte *et al.* 2003), or species from habitats with low vegetation, which are rare in the Netherlands (Roberts 1998).

Finally, for each of the three arthropod groups we propose some species which can easily be used for monitoring the success of restoration or management. The selection was done according to guidelines presented by Noss (1990): the species to be monitored should be vulnerable and indicative (*i.e.* largely restricted to the habitat to be monitored and therefore vulnerable to changes in this habitat), easily recognisable, and preferably an umbrella species (*i.e.* requires

a relatively large area or is a poor disperser, and therefore is expected to indicate the presence of other species).

RESULTS

Ants (Hymenoptera: Formicidae)

A total of thirty-five ant species was observed in the highway verges (Noordijk & Boer 2007). Among these, eighteen species (or twenty if *Formica lusatica* and *F. rufibarbis*, and *F. rufa* and *F. polyctena* are considered separate species) of conservation concern could be recognized (Appendix I), including *Myrmica schenckioides*; a new species found in a highway verge (Boer & Noordijk 2005). Together these species form a very rich species pool, highly characteristic of heathland and drift sand. We actually found most of the ant species known to occur elsewhere in the Veluwe region; only six ant species could not be found in any of the studied verges. Some sampled species are rarely observed in the Veluwe, like the thermophilous species *Tapinoma ambiguum* and *Strongylognathus testaceus* (Van Loon 2004), but were quite frequently collected in the highway verges.

Formica pratensis, *F. rufa/polyctena* and *F. truncorum* are protected by the national Flora and Fauna act. This means that it is not permitted to disturb both the nests and the surrounding habitat without legal exemption. We found no less than five ant species mentioned on the international red list of threatened species of the IUCN; *i.e. Formicoxenus nitidulus*, *Myrmica hirsuta*, *Anergates atratulus*, *Formica pratensis*, and *F. rufa/polyctena*. Three of these, *F. nitidulus*, *M. hirsuta* and *A. atratulus*, are socially-parasitic species. They have small colonies situated in the nests of other ant species.

To monitor the effects of restoration and management measures, the focus should be on the protected and red list species. The protected species – the *Formica*'s or red wood ants – are easy to find, this is however not the case for the threatened socially parasitic ants. These socially parasitic species live in the nests of other ants, and an appropriate practise to protect these species is to promote high densities of the host species (Boer & Noordijk 2004, Mabelis 2007). The nests of *Tetramorium caespitum* (Fig. 2) can host small colonies of the threat-

Figure 2. Tetramorium caespitum, the host species of two rare socially parasitic ant species. Photo: Th. Heijerman.

ened *A. atratulus*, but also of the rare *Strongylognathus testaceus*. *Formicoxenus nitidulus* makes small colonies in nest mounds of red wood ant species. Both the nest mounds of red wood ant species and the dug up sand of *T. caespitum* nests – often deposited in circular way around the entrance – are easy to find (Fig. 3). These two species offer suitable monitoring targets. Before management practices are applied, the nests of red wood ant species and of *T. caespitum* should be inventoried and located. The persistence of red wood ant nest mounds indicates the caution taken during previous management activities, but says not much on the xero-thermic habitats. The un-interrupted presence of *T. caespitum* nests

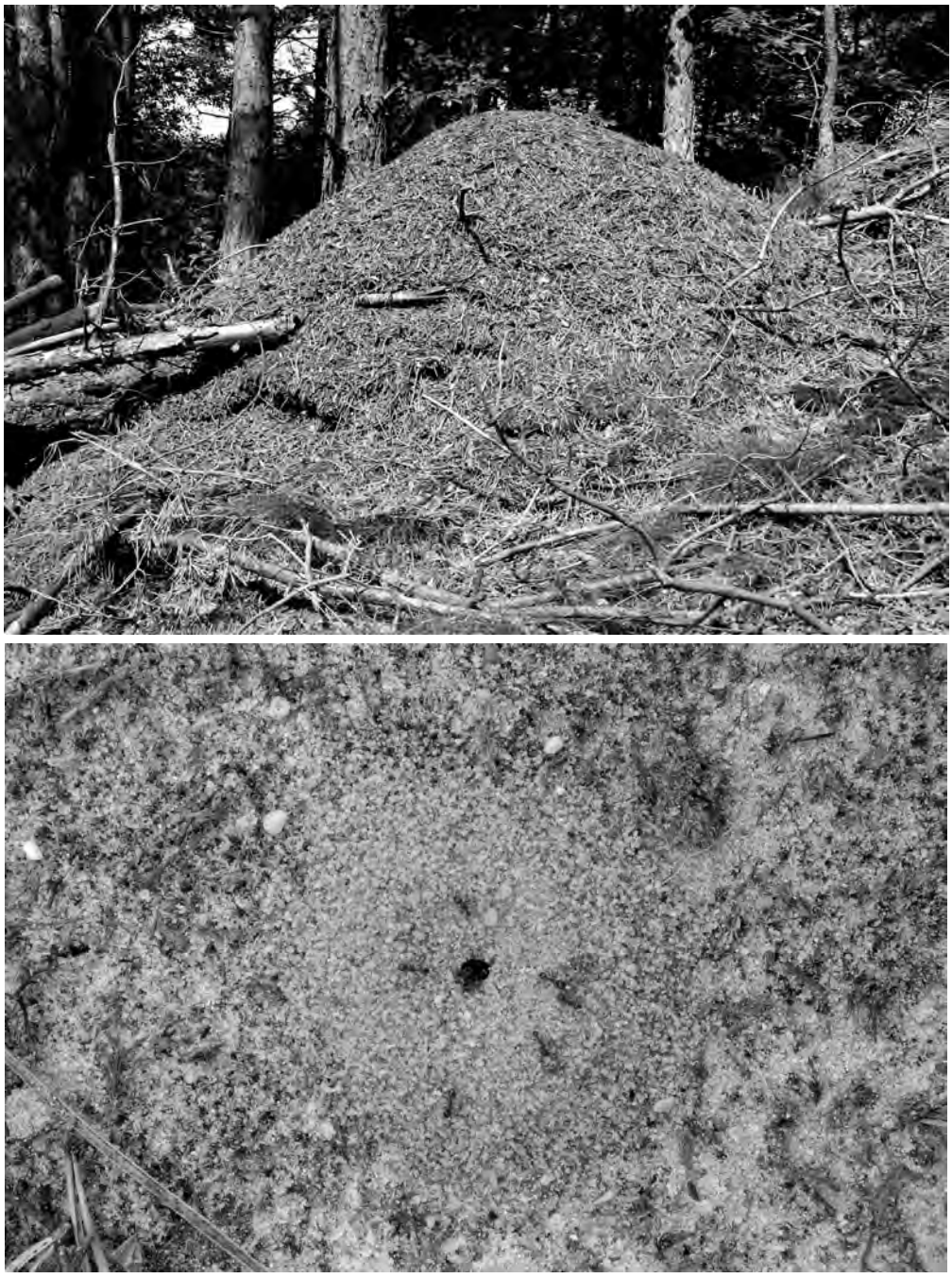

Figure 3. Nest mounds of *Formica*-species (in this case *F. rufa*) and nest entrances of *Tetramorium caespitum* colonies are easy to find. Photos: J. Noordijk.

alongside the highway indicates the existence of a – nutrient-poor and open – corridor for two rare socially parasitic ant species. Unfortunately, the nests of the host species of *Myrmica hirsuta* – *M. sabuleti* and *M. lonae* – are difficult to find.

Ground beetles (Coleoptera: Carabidae)

In total, seventy-nine ground beetle species were sampled in the studied verges. Many species, thirty-two, could be labelled as of conservation concern (Appendix II). These include habitat specialists, for example *Amara equestris*, *Calathus ambiguus*, *Bradycellus ruficollis* and *Harpalus servus*, and beetles that are in decline in the Netherlands, for example *Harpalus neglectus*, *H. anxius* (Fig. 4), *H. solitaris* and *Laemostenus terricola* (Turin 2000). The species rich carabid composition of the verges clearly characterises the mosaics of heathland, nutrient-poor grasslands and forest edges (see also Vermeulen 1993). For many species, recently emerged adults (so-called tenerals) were collected, indicating the importance of verges for their reproduction; verges appear not only to be temporary refugia but also reproduction sites.

Almost every location harbours ground beetles. Many species are very rapid colonisers of newly created sites (Haeck 1971). Quick colonisation will almost certainly take place at restoration sites in the highway verges as well. However, the carabid species that really need ecological corridors in fragmented landscapes

Figure 4. The ground beetle *Harpalus anxius* shows a decreasing trend in the Netherlands. Photo: Th. Heijerman.

are habitat specialists which are incapable of dispersal by flight (De Vries *et al.* 1996, Den Boer 1990). During our inventories we found several of these species: *Carabus arvensis*, *Poecilus lepidus*, *Notiophilus germinyi*, *Olisthopus rotundatus* and *Masoreus wetterhallii*. These non-flying specialist species of heathy vegetations are good indicators of site quality and accessibility for carabids. Their appearance will therefore reflect the success of restoration or management practises. Pitfall trapping during spring and summer is an appropriate method to establish the presence of these species before and after the practises. Their identification, however, asks for some entomological expertise.

Spiders (Araneae)

We found seventy-four spider species at the six highway verge sites (only non-webbuilding spiders belonging to the families Atypidae, Eresidae, Gnaphosidae, Liocranidae, Corinnidae, Clubionidae, Miturgidae Zoridae, Thomisidae, Philodromidae, Salticidae, Lycosidae, Pisauridae, Agelenidae, Mimetidae and Theridiidae were identified). Thirty-seven species can be regarded as of conservation concern (Appendix III, Fig. 5), since they are very characteristic of nutrient-poor situations or rare in the Netherlands. These include the spectacular *Eresus sandaliatus*, which in the Netherlands is restricted to the southern part of the Veluwe (Van Helsdingen 2005). In addition, some very rare species were collected like *Micaria silesiaca*, *Kishidaia conspicua*, *Phaeocedus braccatus* and *Ozyptila scabricula* (see also Noordijk 2005).

Figure 5. The spider *Aelurillus v-insignitus*; a common but highly characteristic species in the studied verges. Photo J. Lissner.

Figure 6. The spider *Atypus affinis* is an appropriate species to monitor restoration and management success. Photo Th. Heijerman.

Spider species are relatively difficult to identify, due to the high number of closely resembling species (Van Helsdingen 1999). However, one species seems to fulfil all requirements that would make it suitable for monitoring purposes: *Atypus affinis*. This mygalomorph spider is characteristic of largely undisturbed, mosaics of nutrient-poor vegetations. It is a large species (females up to 18 mm) and probably has a relatively low dispersal capacity (Pedersen & Loeschcke 2001). Therefore, the presence of this spider most likely indicates the accessibility of the site for spiders and that it is large enough to harbour many other species as well. In addition, it is easily recognisable (Fig. 6) and widespread on the Veluwe (Noordijk 2005, Tutelaers 2008). Inventory of this species – directly in the field or using pitfall traps – should take place in late summer, when the males leave their underground tubular webs in search of females. Another suitable spider to be monitored is *Pardosa monticola*. This species is restricted to xerothermic nutrient poor vegetation, a relatively poor disperser (Bonte *et al.* 2001), and during the early summer easy to find because of its conspicuous hunting behaviour. This spider knows, however, some closely resembling species and is therefore not as easily identifiable.

DISCUSSION

The observed species and their *conservation concern* indicate that entomological values of the selected sites in highway verges are very high and should not be neglected. The habitat characteristics of the studied verges indicate that potentially all highway verges on the Veluwe can be restored into suitable habitat areas as well. To stimulate the presence of species with high conservation concern, open and nutrient-poor vegetation should be restored and the complete area of highway verge should be managed.

Our results do not suggest that highway verges bear some intrinsic characteristics that make them unsuitable for a wide array of specialized species of heathland and drift sand situations. However – as could be shown in a previous study (Noordijk *et al.* in press a) – arthropod species composition in selected grey hair-grass vegetation patches (Violo-Corynephoretum; pioneer vegetation on acidic sand) in highway verges differs from nearby nature reserves, and some carabids and spiders occurring in the reserves are lacking in the verges. In particular, some characteristic species preferring sites with bare sand were missing. Also, characteristic carabid species with large body-size were less numerous in verges than in the nature reserves, probably indicating the patches in the verges to be too small for some species. Also the vegetation in the verges, even when of the same type, differed from the vegetation in the nature reserves. In the pioneer vegetation of the verges the proportion of bare sand appeared to be lower, while the cover of herbs and trees was higher. Concluding from the prevailing species and the vegetation characteristics, the last remaining grey hair-grass patches in the verges are already of lower quality than in the nature reserves (see also Angold 1997). Likely key factors capable of increasing the presence of specialist species in the verges are the increase of openness of the sward, the prevention of encroachment by tall herbs, grass, trees and/or shrubs, and extension of the total surface of suitable open vegetation (see also Morris *et al.* 1994).

Many species will benefit quickly from restoration practises. Mostly this concerns the good disperses – *e.g.* small ballooning spiders and insects with good flight capacities – and species which are not so much habitat specialists (Tscharntke *et al.* 2002). An example of a quickly colonising species is *Oedipoda coerulescence* (Fig. 7), a red list grasshopper which can fly over considerable distances. This grasshopper was found in a verge one year after sod-cutting and in another verge one week after the burning away of the vegetation. Most winged sexuals of ant species probably also fly considerable distances to start new colonies (Duelli *et al.* 1989). For example, we found *Lasius psammophilus* – a species that shows a decreasing trend in the Netherlands – in suitable habitat in the middle of a highway junction, a site completely isolated from other habitats by asphalt.

However, many other species might have more problems to reach (far-away) highway verge sites, for example flightless species or habitat specialists.

Figure 7. The red-list grasshopper *Oedipoda coerulescence* is a fast immigrant of newly created sites with bare sand. Photo: J. Noordijk.

Although most spiders can disperse quite well as spiderlings, there are indications that specialist species tend to balloon to a lesser extent, since their risk to land in unsuitable habitat is higher than for generalist species (Bonte *et al.* 2003). Sensitive and poorly dispersing ants are likely to be found under the socially parasitic species. These species often have few winged sexually active individuals per year, and need high densities of the host ant species to start new populations, while the chance of starting a new colony is likely to be lower than in other species. Among the carabids, stenotopic species unable to fly are poor dispersers. Species like these would benefit greatly from connections consisting of appropriate vegetation – and the appropriate host ant species for the socially parasitic ants – to reach suitable sites.

Possibly, our dataset is biased towards higher species diversity. The sampled highway verges were quite close to nature reserves; this possibly had a positive effect on species diversity (Vermeulen 1994, Koivula 2005). On the other hand, in the Veluwe region almost all verges are close to natural heathland/drift sand areas. A landscape design where many connections are created between nature reserves and close-by verges is feasible, and may therefore very well contribute to the realisation of local ecological networks (Keizer *et al.* 2006). Since highways are one of the main causes of fragmentation of the landscape, it seems logic to construct and manage the accompanying verges in such a way that they can

counteract fragmentation. Such ecological compensation seems well possible because verges form an extensive network, stretch over long distances and after restoration and under right management can harbour many characteristic species – as shown in the current study. However, two conditions should be met in order to function as a corridor. First, connections with nature reserves should facilitate species to reach the verges. A second – important – condition is that the verges should be managed as habitat corridor. This means that the entire stretch of the road (up to the next nature reserve) should consist of high quality habitat for xero- and thermophilic arthropod species. Sites with high vegetation or large areas with closed swards are probably already barriers for some habitat specialist (Vermeulen 1994).

Implications for management

It has already been mentioned that nutrient-poor habitats deserve much attention in Dutch nature conservation practices. The nutrient-poor vegetations in the Veluwe region are threatened and deserve most attention (Houdijk *et al.* 1993, Riksen *et al.* 2006). The heathy situations here studied are European target vegetations (European Community 1992), and Veluwe verges potentially provide extensive areas of open habitats. Our inventories make it very clear that the verges should be managed to maintain the open and nutrient-poor vegetation that can still be found occasionally, and that it is highly advisable to restore this habitat in all other densely vegetated verges. Although, a temporal and spatially phased management is more profitable for many arthropod species (Morris 2005), the initial restoration takes some extensive measures. This way, a species-rich and highly characteristic arthropod fauna, including protected and threatened species, will be preserved and extended. Obviously, there are also interesting species to be found in the forest edge and forest. However, these habitats will always be amply available; forest is abundant along the verges and the forest edge will merely be shifted further from the road. The total area of forests habitats are actually increasing and gaining in quality in the Netherlands (Reemer *et al.* 2003, Van Duuren *et al.* 2003).

To restore and maintain the highway verges as important habitat for xero- and thermophilic arthropods, we suggest (see also Bell *et al.* 2001, Van Turnhout *et al.* 2001, Noordijk *et al.* in press b):

> An extensive restoration of the open, nutrient-poor and sandy situations in highway verges in the Veluwe region. Encroaching trees and shrubs should be removed over the full width of the verges. At selected sites the topsoil should be removed.

> Leaving sites still containing nutrient-poor vegetation patches intact. From here, arthropod species can colonize other parts of the verges.

> Creating connections between nature reserves and the adjacent verges. In this way, verges can be used as an extension of existing nutrient-poor habitat and even function as ecological corridors between nature reserves.

> A periodical management scheme with relatively small scale measures to be implemented subsequently. Each year, encroaching trees and shrubs should be removed in a different part of the total area of highway verge in such a way that all sites receive this treatment once every eight to ten years. The management cycle can be restarted after this period.

> The nutrient-richer grassy vegetation close to the asphalt to be mown regularly – preferably every autumn – and the cuttings to be removed.

> During reconstructions of road verges (or construction of new ones) the original soil or soil from local sources to be used. The application of a nutrient rich top-soil – used during some previous highway reconstructions – is highly inadvisable.

> 'Red wood ant' nest mounds – which are legally protected – and the surrounding plants should be avoided during management. Before management the easily recognizable nest mounds should be inventoried.

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APPENDIX I

Ants (Formicidae) of conservation concern in highway verges on the veluwe

The reason for the conservation concern status is given: red list (IUCN), protected (FF) or characteristic (char) thermo- and xerophilic species. Indicated is whether we encountered the species frequently (freq) or occasionally (occas).

Species	Conservation concern	Frequent or occasional
Anergates atratulus (Schenck)	IUCN, char	occas
Formica cunicularia Latreille	char	freq
Formica lusatica Seifert / *rufibarbis* Fabricius	char	freq
Formica pratensis Retzius	IUCN, FF	freq
Formica rufa Linnaeus / *polyctena* Förster	IUCN, FF	freq
Formica truncorum Fabricius	FF	occas
Formicoxenus nitidulus (Nylander)	IUCN	occas
Lasius psammophilus Seifert	char	freq
Myrmica hirsuta Elmes	IUCN, char	occas
Myrmica lonae Finzi	char	freq
Myrmica rugulosa Nylander	char	occas
Myrmica sabuleti Meinert	char	freq
Myrmica schencki Viereck	char	freq
Myrmica schenckioides Boer & Noordijk	char	occas
Myrmica specioides Bondroit	char	freq
Ponera coarctata (Latreille)	char	occas
Strongylognathus testaceus (Schenck)	char	freq
Tapinoma ambiguum Emery	char	freq

APPENDIX II

Ground beetles (Carabidae) of conservation concern in highway verges on the Veluwe

The reason for the conservation concern status is given: characteristic (char) thermo- and xerophilic species or species which show a decreasing trend (decr) in the Netherlands. Indicated is whether we encountered the species frequently (freq) or occasionally (occas).

Species	Conservation concern	Frequent or occasional
Amara consularis (Duftschmid)	char	occas
Amara convexior Stephens	decr	occas
Amara equestris (Duftschmid)	char	freq
Amara lucida (Duftschmid)	char, decr	occas
Amara ovata (Fabricius)	decr	occas
Bradycellus ruficollis (Stephens)	char, decr	freq
Calathus ambiguus (Paykull)	char, decr	occas
Calathus erratus (C.R. Sahlberg)	decr	freq
Calathus micropterus (Duftschmid)	char	occas
Carabus arvensis Herbst	char	occas
Cicindela campestris Linnaeus	char, decr	occas
Cicindela hybrida Linnaeus	char, decr	occas
Harpalus anxius (Duftschmid)	char, decr	freq
Harpalus griseus (Panzer)	decr	occas
Harpalus latus (Linnaeus)	char, decr	freq
Harpalus neglectus Serville	char, decr	freq
Harpalus rufipalpis Sturm	char, decr	freq
Harpalus servus (Duftschmid)	char, decr	freq
Harpalus smaragdinus (Duftschmid)	char, decr	freq
Harpalus solitaris Dejean	char, decr	freq
Harpalus tardus (Panzer)	decr	freq
Laemostenus terricola (Herbst)	char, decr	occas
Masoreus wetterhallii (Gyllenhal)	char	freq
Nebria salina Fairmaire & Laboulbene	char	freq
Notiophilus aesthuans Motschulsky	char	occas
Notiophilus germinyi Fauvel	char	freq
Olisthopus rotundatus (Paykull)	char	freq
Poecilus cupreus (Linnaeus)	decr	freq
Poecilus lepidus (Leske)	char, decr	occas
Pterostichus diligens (sturm)	char	freq
Pterostichus quadrifoveolatus Letzner	char	freq
Syntomus foveatus (Geoffroy)	decr	freq

APPENDIX III

Spiders (Araneae) of conservation concern in highway verges on the veluwe

The reason for the conservation concern status is given: characteristic (char) thermo- and xerophilic species or rare species (rare) in the Netherlands. Indicated is whether we encountered the species frequently (freq) or occasionally (occas).

Species	Conservation concern	Frequent or occasional
Aelurillus v-insignitus (Clerck)	char	freq
Agroeca proxima (O.P.-Cambridge)	char	freq
Alopecosa barbipes (Sundevall)	char	freq
Alopecosa cuneata (Clerck)	char	freq
Alopecosa fabrilis Clerck)	char	freq
Atypus affinis Eichwald	char	freq
Cheiracanthium erraticum (Walckenaer)	char	occas
Cheiracanthium virescens (Sundevall)	char	occas
Clubiona diversa O.P.-Cambridge	char	occas
Drassodes cupreus (Blackwall)	char	freq
Drassodes pubescens (Thorell)	char	occas
Drassyllus pusillus (C.L. Koch)	char	freq
Eresus sandaliatus (Martini & Goeze)	char, rare	occas
Evarcha arcuata (Clerck)	char, rare	occas
Kishidaia conspicua (L. Koch)	rare	occas
Micaria dives (Lucas)	char	freq
Micaria fulgens (Walckenaer)	char	freq
Micaria silesiaca L. Koch	char, rare	freq
Ozyptila scabricula (Westring)	char, rare	occas
Pardosa monticola (Clerck)	char	freq
Pellenes tripunctatus (Walckenaer)	char, rare	freq
Phaeocedus braccatus (L. Koch)	char, rare	freq
Phlegra fasciata (Hahn)	char	freq
Phrurolithus festivus (C.L. Koch)	char	freq
Steatoda albomaculata (De Geer)	char	occas
Steatoda phalerata (Panzer)	char	freq
Talavera petrensis (C.L. Koch)	char, rare	freq
Tegenaria agrestis (Walckenaer)	char	freq
Thanatus formicinus (Clerck)	char, rare	occas
Tibellus oblongus (Walckenaer)	char	occas
Trachyzelotes pedestris (C.L. Koch)	char, rare	occas
Xysticus erraticus (Blackwall)	char	occas
Xysticus ferrugineus Menge	char, rare	occas
Xysticus kempelini Thorell	char, rare	occas
Zelotes electus (C.L. Koch)	char	freq
Zelotes longipes (L. Koch)	char	freq
Zelotes petrensis (C.L. Koch)	char	freq