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EPICroads – Ecology in practice: Improving infrastructure habitats along roads

Development of a classification system that evaluates roadside habitats in Europe

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Abstract

Roadside habitats have great potential to reduce ongoing losses in European biodiversity and ecosystem services. Thus, as part of the EPICroads project a classification system was developed to deliver a hands-on approach for fast ecological evaluation of roadsides in contrasting European environments. In the EPICroads Classification System, easy-to-use categories translate the complexity of varying abiotic and biotic conditions into a simple qualitative three-staged point evaluation. The main categories *Landscape (A)*, *Ecotone (B)* and *Habitat (C)* contain 14 subcategories including *ecological contrast (A1)*, *habitat quality (A2)*, *connectivity (A3)*, *regional species pool (A4)*, *longitudinal (B1)* and *lateral (B2) extent*, *steepness (B3)*, *human influence (B4)*, *light (C1)*, *water (C2)*, *nutrient availability (C3)*, *soil pH (C4)*, *contamination (C5)* and *management (C6)*. Each subcategory of the system is justified by sound ecological reasoning. When the scores of all subcategories are summed up (14–42 points), three overall grades indicate the ecological value of the respective roadside. The system is flexible, since local road authorities may exclude some categories, for example due to insufficient data, while still obtaining a conclusive (relative) grading. The suggested system for an ecological roadside evaluation can be used to monitor management measures that should follow the EPICroads Guidelines. However, the EPICroads Classification System is not meant as a substitute for future conservation programmes that should include species-rich roadsides habitats.

1 Introduction

1.1 Ecological significance of roadsides

The existing European road network is a primary driver of habitat fragmentation, and this conservation challenge is ongoing due to the addition of new roads (Meijer et al. 2018). Regions with low road density maintain higher landscape connectivity, allowing individuals and genes to spread across the landscape, which has positive effects on nature and thus benefits biodiversity. The road network of the eastern European countries, for example, is still less dense, and these countries thus contain areas with extensive unfragmented habitats (Ibisch et al. 2016). Yet, they are increasingly converging with the western countries through EU-supported road construction projects (Angelstam et al. 2017). This leads to further habitat fragmentation and additional losses in biodiversity.

However, road construction has a variety of further effects with high ecological significance. Foremost to name is the direct loss of habitat area through the road itself, but also a severe alteration of the roadside corridor (Laurance et al. 2014). The abiotic conditions of newly created roadside habitats differ in soil humidity and hydrology (especially enforced by lateral drainage ditches), shade, temperature, and wind, while traffic noise, artificial light and contamination are novel abiotic factors that lead to adverse conditions of the roadside habitats (Van Bohemen & Van De Laak 2003). Furthermore, the resulting roadsides can act as habitat for invasive alien plant species and as a corridor for their dispersal (Hansen & Clevenger 2005). Thus, the main negative consequences of roads are a reduced total area and patch form of high-quality habitats, restricted gene flow between remaining patches, and increased mortality due to roadkill (EPICroads Review 2019[1]). These changes have considerable impacts on organisms, their interactions, and the resulting ecosystem functions and services of roadsides (Truscott et al. 2005, Kroeger et al., in prep.).

Interestingly, the existing and planned roadsides also provide an opportunity to partly counteract habitat degradation and species extinction. Habitats along roads may function as corridors for movement of plants and animals (Fischer et al., in prep.), the resulting dispersal of genes can contribute to slow down biodiversity loss at the landscape scale (Major et al. 1999), and roadsides may even become refugia for endangered species (Eversham & Telfer 1994, Vermeulen 1993). Thus, a valuable contribution to biodiversity can be obtained by

[1] Unpublished information

appropriate planning and management of roadside habitats. To achieve this goal, road authorities require a proper classification of roadside habitats with different ecological qualities.

1.2 Challenges of roadside classification

To assess the possible ecological value of habitats related to transport infrastructure, knowledge of the factors that determine their ecological value is needed for local administrators to classify and manage those areas. Required is an objective and quantitative assessment of the factors that indicate levels of biodiversity and multiple ecosystem services, and the factors shall also include spatio-temporal scaling. The multifactorial challenge of integrating all requirements, also in consideration of Europe's highly variable landscapes, must result in a standardised classification system with European-wide compatibility. In summary, an assessment and classification system is needed, that can be communicated in simple and reliable ecological categories of roadside maps and habitat statistics; it should fit all European regions, has to reflect the actual site conditions, must integrate negative and positive effects of roads, and should be applicable in practice.

Table 1: Challenges in developing a European classification system of roadsides due to potential trade-offs of scientific and applied requirements during habitat evaluation and classification.

Scientifically handling uncertainty	←→	Applicability in practice
Ecological realism	←→	Avoiding excessive or redundant details
Local conditions with high resolution	←→	Producing informative maps
Species-specific assessment	←→	Integrative ecological evaluation
Tailored to individual countries	←→	Enabling international comparisons

The challenge of a mixed qualitative, half-quantitative or quantitative classification system for roadside habitats has some further dimensions due to potentially contradicting requirements of the scientists and practitioners involved (Table 1). For example, enough species specificity shall be provided for each country, yet the over-focus on local specialties may lead to excessive detail and finally to impracticability. After a proper classification of a given roadside the focus on regional specificity can later be integrated into best practice guidelines such as Bromley et al. (2019). Comparisons between regions should be possible, which calls for both transferable and robust habitat measures that do not end up in excessive details. Furthermore, the aim of the EPICroads Classification System is a reasonable spatial resolution that is reproducible in maps, and compatible with the literature review and guidelines of the EPICroads project.

1.3 European country-specific available classifications

For developing a European system of roadside habitat classification, it is useful to study examples from individual countries. For example, in Norway and Sweden roadside classifications already exist in different forms, and thus they will be presented and analysed for applicability in a European context.

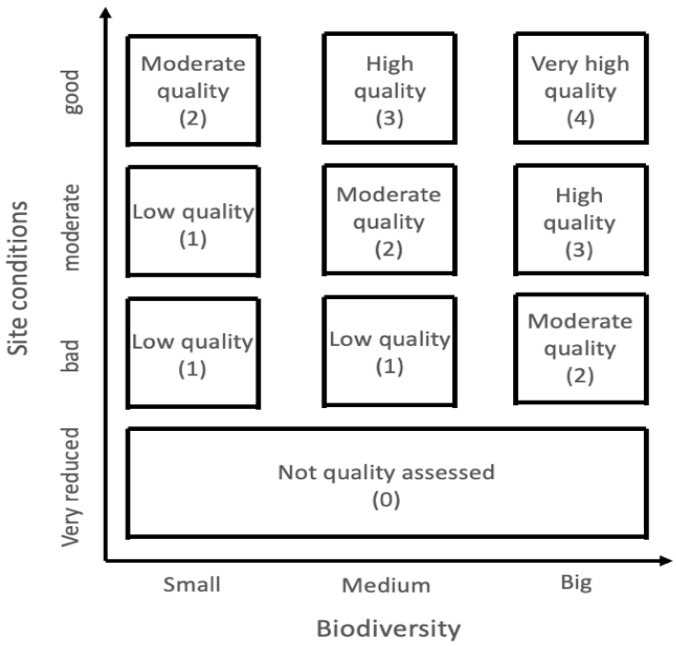

Figure 1: Norwegian Roadside Evaluation System (translated from Evju et al. 2017).

The **Norwegian approach** of an evaluation of roadsides in a classification system (Fig. 1) is embedded in a mapping guide for generally important ecosystem types based on their biodiversity (Miljødirektoratet 2018, 2020), and according to the Norwegian *Red List for Ecosystem and Habitat Types* (Lindgaard & Henriksen 2011). Roadsides are hereby only included when the vegetation is kept down by mowing and/or treading, and the habitat type is identified through the presence of stable, species-rich grasslands that constitute a certain degree of ecosystem services. The evaluation of a roadside is then done in two steps, first assessing the current state of the locality by the two primary factors of *succession speed* (good → grade 1, moderate → 2, bad → 3, very reduced → 4) and *current management intensity* (management intensity: good → 3+4, moderate → 2+5, bad → 1+6, very reduced → 7+8). Three secondary factors are the *use of fertilizers*, the *presence of alien species* and *wear and tear* of the habitat. In a second step, the species diversity and natural variation are assessed, but only if the condition of the site is evaluated higher than ‘very reduced’ in the first step. The second step also contains a differentiation in primary and secondary factors. Here the two primary factors are *size* (big >500 m → >5, moderate 100–500 m → 2–5, small 30–100 m → <2) and *habitat specific species* (no limit values defined). The secondary factor contains only the presence of *red list species* and similar to the first step it can only cause an overall upgrade by one step in the resulting evaluation. Finally, the roadside is classified by its overall biodiversity on the x-axis and the evaluated site conditions on the y-axis, resulting in five classes of roadside value (0–4), whereby from 1 to 5 a certain degree of ecological quality of a roadside is designated, ascending from low to high.

There exists an additional Norwegian system to identify, map and assess species-rich roadsides based on initial screening of geology and superficial deposits, and existing information on biodiversity and ecological qualities (Larsen & Gaarder 2012). However, this system is targeted towards locating high-value roadsides and is not a platform to classify ecological qualities along roadsides in general.

The **Swedish approach** of an evaluation of roadsides was developed by the Swedish Transport Administration (*Trafikverket*) in the course of the project *Artrika vägkanter* (species-rich roadsides) by Lindqvist et al. (2012). Here, different regions are chosen, and an inventory of the so-called species-rich roadsides is conducted. The system is relatively simplistic, since it evaluates a roadside as ‘species-rich’, when at least one of the following points is fulfilled. The first category is focused on the sheer occurrence of either *red-listed species* and *species of responsibility* and/or *indicator species*. The second category contains the factors of *special species composition* based on complex soil and structural properties and/or has a *particularly high species richness or frequency of indicator species*. The third category focuses on the properties of the given ecotone in *providing a substantial ecological resource*, for example reproduction, life cycle, protection or food. The fourth category focuses on the habitat function of *providing an important environment* that has geological and ecological conditions for *species dispersion* or *connectivity* in the landscape.

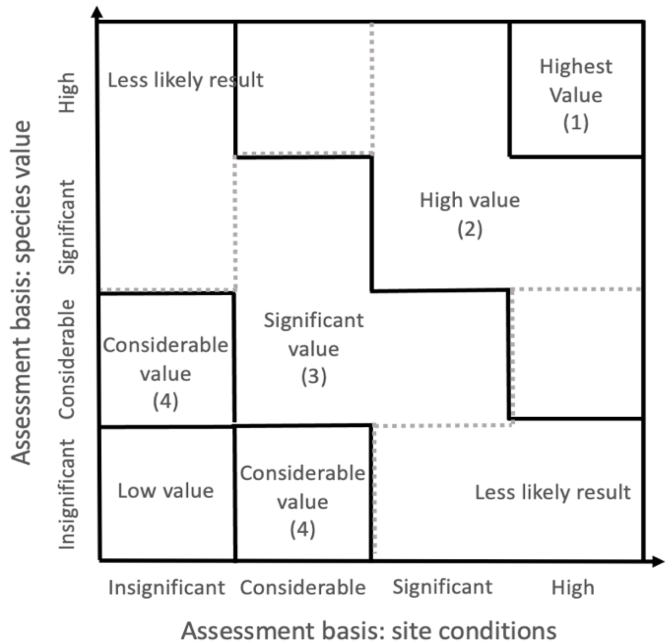

Figure 2: Swedish NVI Classification System (translated from SIS 199000.2014).

After establishing a roadside as species-rich, the qualifying components of the given roadside are recorded in a field protocol (see Appendix 1) with additional help of lists of indicator and signal species. The assessment and classification are made with the help of the evaluation matrix in Appendix 2. Three main categories of *interesting indicator/nature conservation species*, *flower wealth* and *biotope qualities* are rated in ascending quality from 1 to 4, according to the descriptions in the matrix. The overall results are then summed up and finally classified (Fig. 2) according to the Swedish Nature Value Class System (NVI) that designates the natural value of an area according to the SIS (Swedish Standards Institute) Standard SS 199000:2014.

The NVI system classifies any habitat through the overall site conditions on the x-axis and the evaluated species value on the y-axis, resulting in four classes ascending in quality from 4 (lowest) to 1 (highest). Outcomes that are close to the diagonal from the highest natural value (top right) to low natural value (bottom left) are most likely. Beside the Norwegian and Swedish examples, we are not aware of any other comprehensive national system of roadside classification that is already used in European practice, although similar solutions are expected from more countries.

1.4 European Red Lists of Endangered Habitats

Although roadsides find some consideration as potential valuable habitats in country-specific conservation systems as the Norwegian mapping guide or the Swedish project *Artrika vägkanter* (as shown above), they have not explicitly been included in national or European Red Lists of Endangered Habitats. The German Red List of Endangered Habitats (BfN 2017) was recently updated and contains a detailed differentiation of road types and their vegetation, mainly based on the properties of the differing road surfaces, yet an inclusion of roadsides or a mentioning of the edges of a road and its adjacent vegetation is still also absent in the German system. The European Red List of Habitats estimates the endangerment status of habitats of the EU28 plus Iceland, Norway, Switzerland, and the Balkan countries, and it is available as fact sheets in pdf and database format[2], yet it also does not include roadsides.

1.5 Limitations of presented country-specific systems

So, could the Norwegian and Swedish systems be used as a blueprint for a European classification system? – Unfortunately, it is not that simple. A limitation of both national systems

[2] https://ec.europa.eu/environment/nature/knowledge/redlist_en.htm

is that they evaluate roadsides only based on plant species and vegetation types. The Swedish system, for example, focusses mostly on species richness but also includes habitat quality and functions like species dispersion or connectivity, while this approach does not consider abiotic factors, disturbance through traffic and management, nor the extent and configuration of the roadside. The Norwegian system adds the current management of the roadside (mowing, treading, use of fertilizers etc.) to the species approach and also includes an evaluation of the size of a site, but again does not cover ecological factors like differences in shading, temperature, soil moisture and nutrients, and disturbance or stress by traffic.

A strength of both approaches is that they use various species lists to evaluate plant biodiversity, including country-specific red lists. The Norwegian approach encompasses an app to directly evaluate a site, what at first glance supports the notion that this system is an attempt of user-friendliness to make it easier and faster to evaluate a roadside, and maybe enabling elements of citizen science. The Swedish approach needs good planning before evaluating a roadside on site, being equipped with different species lists and the evaluation matrix shown in Appendix 2.

All in all, the Swedish system is more complex and therefore more complicated to apply. Both approaches finally end up in creating maps in simple 4-level quality assigned colour systems, to classify roadsides by their ecologic quality. Both approaches are country-specific, being based on regional species lists, what makes them difficult to transfer to other European countries. Moreover, the evaluation of a roadside based on regional species rarity causes the problem of non-transferability to an overall European system, and also just represents one single indicator of ecological value.

1.6 Lessons learned for a new classification

A European-wide ecological classification for roadsides can use country-specific evaluation systems for roadsides only to a limited extent due to differences among regional species catalogues. It should also include abiotic measures of roadside quality. Setting qualitative thresholds in a clear and user-friendly way is another main objective that is not covered by the existing systems. However, the use of a simple evaluation matrix, as demonstrated in the Swedish system (Appendix 2), allows a fast overview over the main categories, and may be a viable path to provide the mapper with an efficient tool for a qualitative classification of a roadside in the respective category. Thus, the final classification in both the Swedish and the

Norwegian system allows for a qualitative 4- or 5- level scoring to designate a roadside's ecological quality in a final map. This looks like a suitable approach.

1.7 Ecological background of a European roadside classification

The innovative goal of the EPICroads consortium is to deliver a scientifically sound and practically useful classification system of roadside habitats that integrates biodiversity, ecological functions, and ecosystem services. Objectivity in this type of ecological evaluation can only be achieved if the descriptions of the evaluation categories are as operational as possible with reliable thresholds for mapping. Yet, the ecological evaluation of categories may be complicated through multifactorial influences. In many cases an objectively measured number may not be feasible, and thus has to be replaced by an expert estimate. Thus, many categories will be semi-quantitative estimates, while the categories and subcategories should make ecological sense and must be comparable to other regions. To avoid unnecessary complications, the EPICroads Classification consists of a three-level system with categories and subcategories based on sound ecological reasoning.

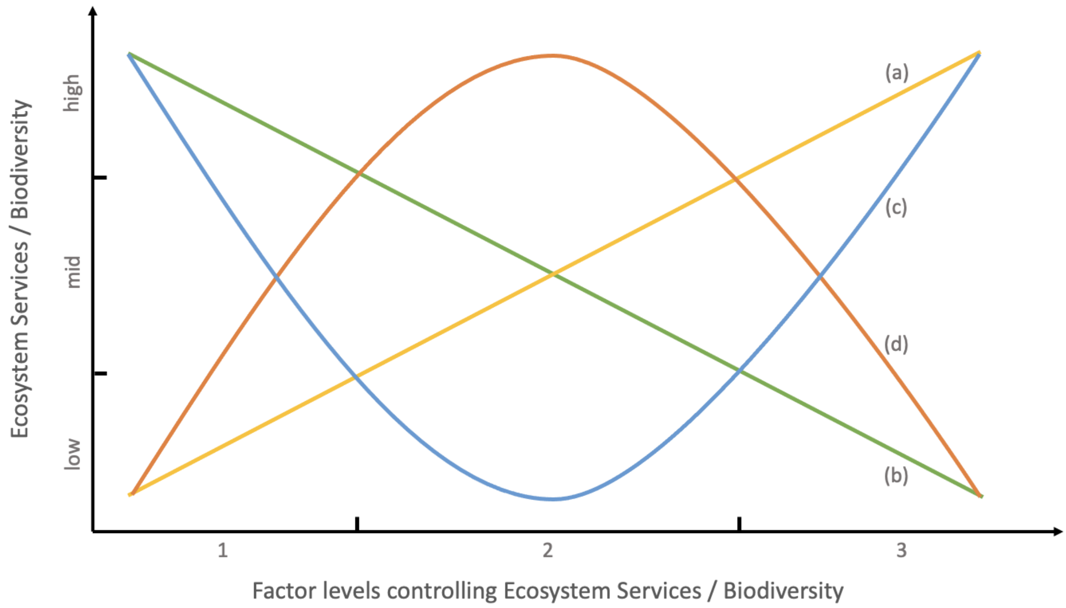

Figure 3: Conceptual figure on potential relationships between biodiversity (or ecosystem services) and abiotic ecological factors that determine roadside habitat quality. While some abiotic factors show (a) a simple linear positive relationship to biodiversity (e.g., soil pH), there might (b) also be negative linear relations (soil nutrients), (c) maximal biodiversity for both low and high values (soil moisture) or (d) quadratic correlations (mowing frequency).

On a very basic level, theoretical ecological considerations suggest four contrasting relationships between ecological factors and biodiversity in roadside habitats (Fig. 3). Linear relationships are expected for abiotic factors without positive or negative feedbacks, e.g., increasing soil nutrient concentrations leading to a declining biodiversity of plants via light limitation (Borer et al. 2014), or soil pH being positively correlated with plant biodiversity in most European regions (Pärtel 2002, Ewald 2003). In some other roadside factors very low and very high values will reduce biodiversity, as often reported for disturbance by mowing, grazing, harrowing or fire; for mowing see Bernhardt-Römermann et al. (2011). This has been formulated as the 'intermediate disturbance hypothesis' as reviewed by Shea et al. (2004). Finally, there are ecological factors that in their extremes create suitable conditions for high biodiversity, for example, in very dry or very wet roadside habitats (Walter 2020). As described in Fig. 3 these ecological relationships will be stratified for each abiotic factor in three levels that have to be estimated by experts for the respective roadside habitat, and then can be used to generate cumulative scoring points for an integrative evaluation.

Furthermore, a roadside classification should not only focus on species-richness or diversity, but also include endangered specialists and assess the occurrence of suitable habitats. This is covered by the (sub)categories suggested below in the EPICroads Classification System. It also needs to be weighed up where and where not quantitative road characteristics should be taken into account, e.g., road size and traffic volume, but so far it looks like these categories would in itself not add much to ecosystem performance and diversity at roadsides, and are actually covered by the selected combination of subcategories, for example on connectivity, contamination or disturbance.

2 Classification system of roadside habitats

2.1 Scope and approach of the classification system

Based on the concept explained in Fig. 3, the main ecological factors that determine ecological quality of roadsides are included in the EPICroads Classification System. Within that system, three spatial categories are used, namely *Landscape*, *Ecotone* and *Habitat,* as explained to some more details within the EPICroads Guidelines (2021[1]). The system of categories and subcategories is based on the extensive work of the EPICroads Consortium. However, in contrast to these documents, the information is condensed to a less detailed and more general system that can be easily applied by practitioners that classify roadside habitats based on (aerial) photos, maps, inventories, or simple records of habitat physiognomy, and that eventually could be implemented in a smartphone app. Detailed species mapping or monitoring of interactions is beyond the scope of this classification system. We do also refrain from defining quantitative thresholds for most of the 14 subcategories, e.g., regional species pool, soil moisture or intensity of management (Table 2), since this has to be developed in region-specific classification tools for the respective European country or region. Thus, we would expect that road authorities and ecological consultancies, for example in Austria, Norway, Spain or The Netherlands, adapt the EPICroads Classification to their regional settings.

Moreover, the evaluation of a given road must be done separately for each side of the road, since roadsides may have different properties and thus contrasting ecological value. Reasons for this can be differing abiotic conditions, individual development because of deviating management practices, or adjacent landscapes that influenced a roadside to develop differently.

Table 2: Summary of the 14 ecological subcategories within the categories Landscape, Ecotone and Habitat, employed by the EPICroads Classification System for evaluation of roadside habitats.

Subcategories	**Score**	**1**	**2**	**3**
Landscape				
A1	Ecological contrast habitat–landscape	low or high	-	intermediate
A2	Habitat quality in the surrounding landscape	low	intermediate	high
A3	Connectivity to adjacent habitats (lateral, longitudinal and/or across the road)	one realised	two	three
A4	The regional species pool	low	intermediate	high
Ecotone				
B1	Longitudinal extent	<1 km	1–5 km	>5 km
B2	Lateral extent	<5 m	5–20 m	>20 m
B3	Steepness of slope	<5%	5–20%	>20%
B4	Human influence	high	intermediate	low
Habitat				
C1	Light intensity	0–40%	40–80%	80–100%
C2	Water availability	mesic	-	dry or wet
C3	Nutrient availability	high	intermediate	low
C4	Soil pH	<5.0	5.0–7.0	>7.0

C5	Degree of contamination	high	intermediate	low
C6	Management	low or high	-	intermediate

2.2 Category Landscape

Landscape (A) contains the subcategories (A1) *ecological contrast* (based on vegetation and site characteristics) between road corridor and adjacent landscape, (A2) *habitat quality* in the surrounding landscape, (A3) *connectivity* to the adjacent habitat, and (A4) the *regional species pool* as source of biodiversity along roadsides.

Ecological contrast (A1) stands for the amount of contrasting site conditions of the roadside compared to the surrounding landscape. The ecological conditions on a roadside can contrast from the adjacent landscape in plant and animal diversity, habitat composition and configuration. If there is only a minor difference of the ecological conditions at a roadside to the adjacent landscape, the roadside supports a certain amount of biodiversity and ecosystem services and will be awarded 1 point. If the roadside shows an extreme difference in ecological conditions, it cannot connect well to the adjacent landscape and therefore cannot support populations in the surrounding landscape, although it adds to some amount to the overall biodiversity. Thus, the roadside is again awarded 1 point. If the roadside shows an intermediate ecological contrast to the surrounding landscape, it still provides enough connectivity to benefit adjacent populations and can contribute to achieve an increased biodiversity and amount of ecosystem services in total. Thus, intermediate roadside–landscape contrasts will be awarded the highest evaluation with 3 points.

Habitat quality in the landscape (A2) will also affect the ecological value of a roadside, since the adjacent landscape can accelerate the plant compositional changes towards late-successional stages at the roadside, providing it with a diverse propagule pressure (García-Palacios et al. 2001) and different degrees of landscape resistance (Fischer et al., in prep.). The nearby presence of designated NATURA 2000 protected areas also can positively influence the ecologic development of a roadside via plant and animal dispersal, and therefore shall also be considered. Thus, the levels 1–3 are assigned to the increasing numbers of habitats of good ecological quality and protected habitats in the vicinity of roadside habitats. Then, since in ascending order positively correlated with biodiversity and ecosystem services, these levels are awarded 1–3 points, respectively.

Connectivity to the adjacent habitat (A3) is negatively affected by fences, rail tracks, paths, powerlines, or any other barriers. Existing connectivity from one roadside to the other through wildlife crossing structures over or under the road are considered as positive landscape-connecting elements. Increased structural connectivity (e.g., via steppingstones) is positively correlated with biodiversity and ecosystem services, since roadsides then may function as corridors for movement of plants and animals longitudinal and lateral to the road (Van Bohemen 1998). The more lateral connectivity on a roadside is present (a) along the road, (b) from the adjacent landscape to the roadside, and (c) from one roadside to the other side of the road through wildlife crossing structures over and under the road, the higher the connectivity of a roadside. If present, each factor (a, b, c) is awarded one point, resulting in a connectivity score of 1–3 points.

The regional species pool (A4) of the roadside habitats reflects the *potential* biodiversity at roadsides that for most species are both site- and dispersal-limited (García-Palacios et al. 2011). The more regional species there are compared to the area available at the roadside, the higher its ecological value. Therefore, the higher the regional species pool, the higher a roadside is given points accordingly from 1–3. Yet the occurrence of invasive species is considered as an indicator of reduced ecological value of roadsides, and thus should be considered in the evaluation of the regional species pool as a negative factor.

2.3 Category ecotone

Ecotone (B) contains the subcategories of (B1) *longitudinal* and (B2) *lateral* extent of the roadside, (B3) *steepness* across and along roadsides, and (B4) degree of *human influence* within the road corridor.

Longitudinal extent (B1) stands for the length of a roadside habitat (type?) without any interruption by crossroads, bridges, or water bodies (not excluding human settlements, because city roadsides shall be included if possible). It will be measured in kilometres and divided into three levels (<1, 1–5, >5 km). The positive evaluation hereby correlates to the length, ascending from low to intermediate to high, since the longitudinal connectivity of a roadside as an ecotone positively impacts pollinator diversity (Holzschuh et al. 2010), enables pollinator movement (Cranmer et al. 2012), and thus presumably increases pollination in general (Hoehn et al. 2008, Townsend & Levey 2005). Similar patterns may be seen in other ecosystem services, that are positively correlated with length of a roadside. Thus, since increasing longitudinal extent is positively correlated with biodiversity and ecosystem services, the levels 1–3 will be awarded with respective points.

Lateral extent (B2) stands for the width of a roadside until its adjacent habitats (e.g. crop fields), urban boundary (e.g. parallel underlying road network, separation ditches on boundary property, separation fences, buildings, sidewalks) or any natural boundary (e.g. rivers, lakes, forests) outside the road corridor. It will be measured in metres and divided into three levels (<5, 5–20, >20 m). The positive evaluation hereby correlates to the width, ascending from low to intermediate to high. Plant biodiversity can be significantly increased by management methods that implement planting or preservation of different heights of vegetation. Yet, this has to be in accordance with existing safety restrictions for visibility for drivers (for roadkill see D'Amico et al. 2015), and therefore taller vegetation should only be established in ascending order further from the road (Keken at al. 2019). Thus, the wider the roadside is, the taller and more differentiated the vegetation can be. The more differentiated the roadside vegetation is, the more differentiated not only the plant biodiversity will be, but also its animal biodiversity (for small mammals see Ascensão et al. 2012). Since increasing lateral extent is positively correlated with biodiversity and ecosystem services the levels of 1–3 will be given the respective points.

The *steepness* (B3) stands for the lateral or longitudinal difference between the maximum and minimum height versus the total width of the roadside. This estimate of the slope inclination within a road corridor needs not to distinguish between raised or lowered roads. Some steepness is considered as positive, because a steeper roadside increases abiotic gradients and thus the potential for habitat diversity, while habitat area and distance to the road are reduced. So, very steep roadsides may actually lead to increased contamination and higher road mortality. Moreover, these slopes have to be stabilised by engineering measures with metal nets or concrete constructions that reduce ecological habitat quality. Therefore, the positive evaluation ascends from level to intermediate slopes, while very steep slopes have reduced ecological value (<5, 5–20, >20%), resulting in 1 point for flat roadsides, 3 points for intermediate slopes, and 1 point for very steep slopes.

Human influence (B4) within and beyond the road corridor stands for all human-made disturbance to wildlife through traffic noise, collision and artificial light (e.g., vehicle headlights, street lighting). It is an estimation parameter according to the predominantly negative effect of roads to animal abundance (Fahrig & Rytwinski 2009). Road noise intensity and frequency cause disturbance of animals (McClure et al. 2013), and streetlights not only artificially illuminate the street, but often the roadsides as well, and therefore interfere with the nocturnal life of animals (Russart & Nelson 2018, Dupont et al. 2019). The negative evaluation correlates to the overall intensity of the human interference, ascending from low to intermediate to high. Since increasing human influence is negatively correlated with biodiversity and ecosystem services, the levels 1–3 will be used in descending point order from 3–1.

2.4 Category habitat

Habitat (C) comprises the subcategories of (C1) *light* intensity (aspect, angle and shadowing vegetation or other structures), (C2) *water* and (C3) *nutrient availability*, (C4) *soil pH*, (C5) *degree of contamination* and (C6) *management* intensity. These categories can be estimated based on in-situ measurements or indicator species.

Light intensity (C1): Since light is a limiting factor in most plant species (and high light is beneficial to many ectothermic animals as well!) the amount of shade caused by shadowing vegetation or any other shading structures on a roadside negatively correlates with biodiversity and ecosystem services. The shading levels are set from level 1 = high light (0–20% shading), level 2 = intermediate light (20–60% shading) and level 3 = low light (60–100% shading). Thus, increasing shade levels are awarded descending points from 3–1.

Water availability (C2): Highest plant competition is expected at mesic sites with an intermediate amount of water supply and thus in those conditions many subdominant and transient species are suppressed by fast and tall growing grasses, forbs and woody species. On the other hand, extreme hydric conditions (dry or wet) create suitable habitats for stress-tolerating plants, for amphibia (very wet) or bees and wasps (very dry and warm; Heneberg et al. 2017). Thus, the negative quadric relation of water availability to biodiversity and ecosystem functions are awarded accordingly the highest points in the extremes: 3 points for low water availability, 1 point for intermediate water availability, and 3 points for high water availability on a given roadside, while there are close interactions with nutrient availability.

Nutrient availability (C3): Based on the classical humped-back relationship of Grime's understanding of plant competition, an increasing nutrient supply that drive productivity is expected to be negatively correlated with biodiversity of plants and ecosystem services also in any given roadside. Through the abundance of nutrients some plants will be able to use them to increase their growing speed and will suppress many competitors via light limitation by growing faster and taller than them (Borer et al. 2014). Thus, increasing nutrient supply is awarded in decreasing point order from low = 3 points to intermediate = 2 points, and high = 1 point.

Soil pH value (C4) is positively correlated to vascular plant richness in most parts of Europe, as explained through eco-evolutionary history (Pärtel 2002) and normally only subdivided into low (≤5.5) and high pH (>5.5). However, we aim at a slightly more differentiated evaluation with acidic (pH < 5.0), near-neutral (5.0–7.0) and alkaline soil reaction (>7.0). Thus, the positive linear relationship between plant species density throughout the temperate zone (Ewald 2003) results in 1 point for acidic, 2 points for neutral, and 3 points for alkaline roadside habitats. Experts can either measure soil pH or use indicator plants and animals to evaluate a given roadside.

Degree of contamination (C5) is often expensive to measure, but closely correlates with traffic volume and road width, since an increased amount of traffic is accompanied by an increased production of exhaust gases, rubber abrasion, heavy metal pollution, noise, and traffic light. Representing a negative linear correlation to biodiversity and ecosystem services, increasing contamination estimated through traffic volume is awarded in descending order 3 points for a low level of contamination, 2 points for an intermediate level of contamination, and 1 point for a high level of contamination.

Management (C6): Connell's classical 'intermediate disturbance theory' suggests highest species density of herbaceous plant communities at an intermediate level of disturbance, and in most cases the evidence in empirical studies is consistent with that prediction (Grace 1999). Mowing, grazing, pruning, coppicing, fire, herbicides, harrowing, soil disturbance (compaction by road maintenance vehicles), or any other management disturbance represent examples of these ecological disturbances that affect plants and animals in roadside habitats. Representing a quadric relation to biodiversity and ecosystem services, the three ascending levels of management are awarded accordingly 1 point for low intensity, 3 points for intermediate intensity, and 1 point for high management intensity.

3 Category evaluation

The goal of the EPICroads Classification System is an easy-to-read evaluation of roadside biodiversity, ecological functions and ecosystem services (Table 2), that can be translated into an overall point score (Fig. 4), and that can be expressed via a colour-coded system (Fig. 5), as for example done in the European river assessment reports. The subcategories of the classification system are rated in three levels as seen above, i.e., low, intermediate, and high. Each level is assigned points, as specified for each subcategory in Section 2. As the suggested system has 14 subcategories it results in 14–42 possible points per road section of 100–1000 m.

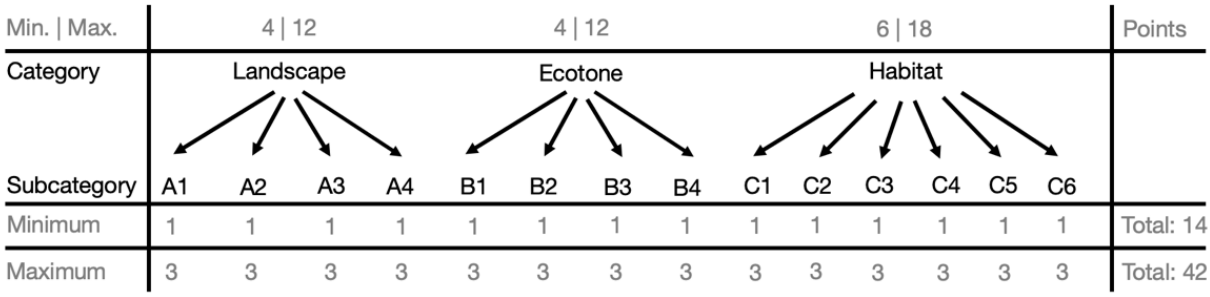

Figure 4: Roadside habitat point score overview of the EPICroads Classification System (for details of the scoring system see Table 2; examples in Fig. 6, 7).

These scores are synthesised in five classes of ecological quality of roadside habitats as shown in Fig. 5, i.e., *very poor* (14–19), *poor* (20–25), *moderate* (26–31), *good* (32–37) and *very good* (38–42). However, in many roadside surveys it might not be possible to get reliable estimates for all 14 subcategories. In that case the sum of points can be transformed in percentage values based on the highest possible score with the categories used, i.e., *very poor* (33–45%), *poor* (46–58%), *moderate* (59–71%), *good* (72–84%) and *very good* (85–100%). The potential ecological value of a roadside can then be presented as a colour-coded system (red, orange, yellow, light green, dark green) in maps and used for regional and European statistics.

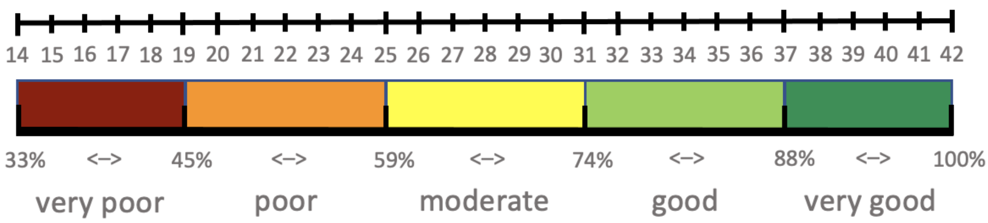

Figure 5: Roadside habitats point bar including the suggested colour code of the EPICroads Classification System.

Figure 6: Two examples of applying the EPICroads Classification System at roadside habitats (a) near Copenhagen Airport (E Denmark), and (b) near Weinsberg (S Germany; photos J. Kollmann and J.C. Habel). Evaluation scores: **Landscape** *ecological contrast* (3 vs 3 points), *habitat quality* within the landscape (1 vs 2), *connectivity* to habitats outside the road corridor (1 vs 2), and regional *species pool* (2 vs 2); **ecotone** *longitudinal* (2 vs 3) and *lateral* extent (3 vs 3), *steepness* (3 vs 3), and *human influence* (1 vs 2); and **habitat** *light* (3 vs 3), *water* (1 vs 3), *nutrients* (1 vs 3), *soil* pH (2 vs 3), *contamination* (1 vs 3), and *management* (3 vs 3). This results in 27 of 42 possible points for the Copenhagen case (=64%: ‘moderate value’), and 38 in the Weinsberg case (90%: ‘very high value’). For further description of the (sub)categories and scores see Table 2 and Section 2.

Figure 7: Another two examples of applying the EPICroads Classification System at roadside habitats (c, d) near Krakow (S Poland; photos M. Drąg). Evaluation scores: **Landscape** *ecological contrast* (1 vs 3 points), *habitat quality* within the landscape (1 vs 2), *connectivity* to habitats outside the road corridor (2 vs 2), and regional *species pool* (1 vs 2); **ecotone** *longitudinal* (2 vs 1) and *lateral* extent (1 vs 2), *steepness* (1 vs 3), and *human influence* (2 vs 2); and **habitat** *light* (3 vs 3), *water* (1 vs 1), *nutrients* (1 vs 2), *soil* pH (2 vs 3), *contamination* (2 vs 2), and *management* (3 vs 3). This results in 23 of 42 possible points for the c case (=55%: ‘poor value’), and 31 in the d case (74%: ‘moderate value’). For further description of the (sub)categories and scores see Table 2 and Section 2.

4 Discussion and application

4.1 Habitat conservation in Europe

Most countries in Europe do habitat conservation along two or three parallel tracks. These include both conservation-based on habitat types (biotopes) and conservation-based on areas of value not based on defined habitat types. This may be also considered for roadsides.

First, there is the *Natura 2000-system*, which is formally in common for all EU countries, but which also clearly includes national specialties, brought into the system together with new member states. Western taiga and wooded pastures of Fennoscandian type are two examples introduced when Sweden and Finland became members. This system is thought to cover most of the biodiversity within EU, and thus includes most identifiable habitats of high or moderate importance for biodiversity, or that for some other reason is seen as important for European (or national) nature. The different habitats fall into two classes of priority for budget and measures. Apart from those two priority classes, there is no value ranking of the habitats. A certain proportion of the national area of each habitat type should be identified and protected as N2000 sites. There is no value ranking of sites within each habitat type, but the conservation status of each site is assessed regularly based on a set of habitat-specific criteria, mainly structure/value elements, key processes and typical species. The total conservation status of a habitat type in a country is assessed by combining all site assessments with the habitat area (checked against a desired reference area), by producing six-yearly statutory reports within the member states to the EU.

Secondly, *national systems for habitat classification* complement the Nature 2000 system in many countries. This is mainly for applied purposes, for example a system set up for a certain type of land-use, such as for biodiversity landscape planning in forestry, or for an inventory, such as the Swedish national survey of semi-natural grassland. Such national classification is normally more detailed than the N2000 system and also serves to cover nature outside of the N2000 sites. Some national classification also remains from earlier traditions, such as phytosociological systems still being common in some countries. In some countries, e.g., Germany and Austria, national classification systems are made for the purpose of red-listing of habitats.

Thirdly, the mere *biodiversity value of sites*, irrespective of habitat class, is the basis for much conservation. For example, outside of the N2000 sites, most nature reserves in Sweden are identified based on biodiversity value of a certain place, linked to the national conservation policy, national red lists etc. Some parts, or all, of an identified site of value may be assigned to a N2000 habitat, while this habitat type is not the primary reason for protecting the site. Consequently, the sites are also managed based on local conditions, best practice etc., not primarily on, for example, the conservation status criteria of the N2000 system.

This kind of conservation, not being based on habitat types, is essential for biodiversity conservation, for several reasons. One is that nature is more complicated than any system for habitat classification, and therefore, more detailed information on a site is needed to manage it properly. Similarly, if habitat classes are rather broad, it is frequently not desirable to assign a patch of nature to a certain habitat type and manage it according to a fixed habitat-specific scheme, but to use a more flexible and pragmatic management approach.

Roadsides are not included in the N2000 system and not part of the official national systems, and the suggested EPICroads Classification System thus fills a major gap in conservation and restoration planning of European roadside habitats.

4.2 Introductory problems of the N2000-system

The introduction of the N2000-system in Europe’s countries caused a lot of complications in existing nature reserves, since often it has to be chosen a habitat type for nature that was something in between two types, and that had been managed accordingly. Another reason is that most classification systems contain bugs that may have severe effects on conservation. One example is a collaboration of the Swedish Biodiversity Centre (SLU) with the Norwegian Institute of Bioeconomy Research (NIBIO) around high-value meadows. The finest meadows had been identified and management plans were set up for each. However, most meadows appeared to have a history of occasional plowing – probably that has contributed to their species richness. The problem was that at the time, the Norwegian system for habitat classification early in the decision tree differentiated between cultivated and non-cultivated habitats, where the meadows could only occur in the latter group. Thus, the high-value meadows were not ‘meadows’ according to the classification system, which would be deleterious if conservation had been based entirely on the habitat classification.

Similar issues can occur when evaluating roadside habitats. Thus, these types of complications were deliberately avoided when developing the flexible EPICroads Classification System.

4.3 Swedish roadside program vs EPICroads Classification System

In Sweden, the identification of high-value road verges is not based on habitat classification, but on measuring several value criteria. This works fine but is time-consuming (see Appendices 1 & 2), and there is a need for complementing the survey method with a classification system that makes it easier to do a fast survey of the road network. Habitat classes would also be valuable for assigning proper management for each road verge, since a number of habitats could be linked to specific packages of management measures, such as cutting regime. There is, in other words, a need for understanding the ecology behind the value criteria in the existing survey system and to assemble that knowledge into habitat classes together with descriptions of each habitat's ecology.

Therefore, the EPICroads Classification System explains the scientific and conceptual background behind each of its value criteria. It may be applied in Europe outside of any European-wide or country-specific habitat classification system and sets the base for subsequent best management practices in a simplified manor.

4.4 Roadside habitat type vs evaluation

It is important to separate habitat classification, habitat-value ranking, and site-value ranking. Habitat-value ranking has a limited significance, since in all biomes, the habitats complement each other and together cover the biome's biodiversity. It is, for example, not relevant to say that species-rich calcareous fens are more valuable than species-poor raised bogs, since they host different sets of the total species pool. Value ranking of sites within a habitat type, however, is of course important, for example in order to prioritize conservation measures.

So, what is needed for practical conservation by road authorities is a system for classifying and evaluating roadsides as habitats, including a description of what makes the habitat ecologically functional. Through the description of each evaluation category of the EPICroads Classification System each roadside can be easily characterised and evaluated, and that description and evaluation can thus be used to assess the conservation status of roadside habitat patches or sites, and the need for appropriate management or restoration measures.

4.5 Actual vs potential habitat status of roadsides

Perhaps the most essential question when creating a classification system for roadsides is whether it should distinguish between current state and the potential for biodiversity and ecological functions after modifying site conditions, adapting management, and introducing species. A caveat is for example variation in biodiversity of roadside habitats due to landscape history, since current connectivity does not necessarily reflect past conditions. However, for many sites information on historical landscapes and past biodiversity may not be available or too difficult to trace within a rapid roadside evaluation. To cope with this challenge, our system deliberately combines indicators of actual (e.g., soil productivity) and potential (regional species pool) state. Thus, the system should be able to deliver an integrative ecological assessment with robust results, respecting and also including aspects of past and future value of roadside habitats. This delivers the foundation for choosing best management practices suitable to maintain and also to foster the potential value of a particular roadside for biodiversity and ecosystem services.

5 Acknowledgement

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Annex A: Swedish roadside protocol (p. 1–2)

***Trafikverkets inventeringsblankett** – Artrika vägkanter (AVK) och hänsynsobjekt (HÄO)*

Bilaga 1

Grundläggande information om objektet

Vägnummer ____________________ Ev. objektnr. i MWL ________

Objektnamn ____

Ev. f.d. objektnamn: ______________________________________

Driftområde:____

Sida/sidor
□ Norra
□ Södra
□ Östra
□ Västra

Inventeringen

Ev. löpnummer
(under fältarb.) _________

Datum: _____ / ____ 2020

Datum: _____ / ____ 2020

Inventering utförd av

Klassning och motivering

Typ av vägkantsobjekt
AVK
□ *befintligt* □ *nytt*
HÄO
□ *befintligt* □ *nytt*

Föreslagen åtgärd
□ Behåll tidigare klassning
□ Klassa om till HÄO
□ Klassa om till AVK
□ Stryk objektet

Bedömd värdeklass NVI
□ Klass 1: Högsta naturvärde
□ Klass 2: Högt naturvärde
□ Klass 3: Påtagligt naturvärde
□ Klass 4: Visst naturvärde

□ Se ifyllt krysschema för beslutsstöd (se bilaga 2)

Motivering

Väder
□ sol
□ mulet
□ regn

Vind
□ lugnt
□ måttligt
□ blåsigt

Temperatur _________

Kategori (arter, strukturer m.m.)

□ A) Rödlistade arter/Ansvarsarter i infrastrukturen/ÅGP-arter
□ B) Skyddade/fridlysta arter
□ C) Indikator- och signalarter
□ D) Sällsynta arter m.m.
□ E) Rikblommande sträcka/mkt substratväxter
□ F) Biotopkvaliteter
□ G) Nyckelstrukturer
  □ *sandblottor* □ *expon. skärning*
  □ *berg i dagen* □ *stenmur*
□ H) Landskapssamband
□ I) Begränsade - oklara värden/ Utvecklingsmark

Vägkanten

Fuktighetsgrad
□ torr/skarp
□ frisk
□ fuktig
□ blöt

Näringsstatus
□ näringsrika förhållanden
□ näringsfattiga förhållanden

Kalkinslag
□ ja, källa oklar
□ ja, från berggrund
□ ja, från jord
□ ja, från skalgrus
□ ja, från vägmaterial

Sandigt/grusigt
□ ja, källa oklar
□ ja, från omgivande mark, ytterslänter etc.
□ ja, från vägmaterial t.ex. i vägbank

Huvudsaklig vegetationstyp

____

____

Vägkanten (forts.)

Intressanta slänter
□ innerslänt □ ytterslänt
□ dikesbotten □ bankslänt

Omgivningen

Skogsmark m.m.
□ ädellövskog
□ triviallövskog
□ blandlövskog
□ fjällbjörkskog
□ barrskog
□ blandskog (barr och löv)
□ kalhygge

Odlingslandskap
□ naturbetesmark/äng
□ brukad/gödslad åkermark
  □ *åker* □ *vall* □ *träda*
□ övrig öppen mark
  □ *ängsmark* □ *gamla vallar*

Vatten
□ hav/kust
□ sjö/tjärn etc
□ vattendrag/större dike
□ våtmark (mosse/kärr)

Bebyggd miljö
□ gårdsmiljö
□ bostads/industriområde
□ kyrkogård/parkmiljö
□ ruderatmark

Övrigt
□ grus-/sandtag
□ stenmur
□ berg i dagen/klippmark
□ infrastrukturmiljö
□ kraftledningsgata
□ död ved
□ alvarmark
□ kalfjäll
□ övrigt: ______________

Objektets status och skötsel

1. Mark- och vegetationsstatus - faktorer
□ brist på mineraljordsblottor (om förutsättn.)
□ alltför massiv grässvål/sen succession
□ mycket knylhavre
□ mycket av andra ohävdsarter
□ privatslåtter
□ ”makadamisering”
□ upplag

2. Vedväxter (väl röjt i hela vägområdet?)
□ god □ medel □ dålig

3. Invasiva arter (frånvaro av är positivt)
□ god □ medel □ dålig

4. Annan påverkan (ledningsarbeten m.m.)

____

____

5. Skötselstatus totalt (för befintliga/nya objekt utifrån habitatets grundläggande förutsättningar m.m.)

□ god □ medel □ dålig

6. OK med tidig slåtter (1,2 m)*: ja □ nej □
OK med dikning i IS/DB: ja □ nej □

Åtgärdsbehov

____

____

____

Rätt skyltat
□ ja, alla står rätt (om AVK)
□ nej (nytt objekt)
□ nej, inga alls
□ nej, felplacerade
□ nej, vissa saknas
□ nej, flyttas p.g.a. ny avgränsning
□ nej, tas ner p.g.a. omklassning

Fältblankett version 2020-05-19

Särskilt viktiga arter

Klass 1- och 2-indikatorarter (se bilaga 3)
(ange frekvens* och position i vägområdet**)
* 1=fåtalig, 2=måttlig, 3=riklig
** IS=innerslänt, DB=dikesbotten, YS=ytterslänt

Art (markera klass 1-arter)	Frek.	Pos.
	1 2 3	
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	1 2 3	

Klass 3-arter och övriga:

Stryk under artnamn för obsar som har rapporterats in i Artportalen.

Antal arter
(klassificering i bilaga 3)

___________ st klass 1

___________ st klass 2

___________ st klass 3

Insekter (se bl.a. bilaga 5)

□ Intressant insektsobjekt
□ Intressant kryptogamobjekt

Saltgynnade arter:	Frekvens:
□ gulkämpar:	1 2 3
□ trift:	1 2 3
□ strandråg:	1 2 3

Invasiva arter:	Frekvens:
□ blomsterlupin:	1 2 3
□ jättebjörnloka:	1 2 3
□ parkslide:	1 2 3
□ jätteslide:	1 2 3
□ jättebalsamin:	1 2 3
□ vresros:	1 2 3
□ kanadensiskt gullris:	1 2 3
□ parksallat	1 2 3
□ rönnspirea	1 2 3
□ plymspirea	1 2 3

Ohävdsarter: (Ev. frekvens)

Skötselkategori (förslag till AVK-skötsel enligt gällande SBV-mall)

□ 1) 1/8–15/9, sen slåtter
□ 2) 25/8–15/9, extra sen slåtter
□ 3) 1/8–15/9, sen slåtter m. skärande redskap + uppsamling
□ 4) 25/5-21/6 – tidig slåtter (20 cm ovan mark) + sen slåtter 1/8-15/9.
□ 5) 15/5-31/5 – tidig slåtter + sen slåtter 1/9-15/9

□ Lämpligt/möjligt med naturvårdsbränning
□ Lämpligt med objektspecifik skötselbeskrivning
□ Har redan objektspecifik skötselbeskrivning

Övriga kommentarer

Fältblankett version 2020-05-19

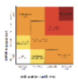
Annex B: Swedish roadside evaluation matrix

Version 2020-05-19

Krysschema - beslutsstöd vid naturvärdesbedömning (bilaga 2 till TRV 2012:149)

Datum: **Driftområde:** **Väg-nr:** **Löpnummer/objektnamn:** **Inventerare:**

Identifiering och avgränsning av AVK/HÄO vid vägkantsinventering i sidoområden. Sätt kryss i relevanta rutor och gör summerad bedömning av värdeklass och objektstyp till höger. För bedömning av AVK så räcker det att en eller enstaka rutor blir ikryssad. Styrkan i bedömningarna går från vänster till höger (d.v.s. artfynd väger tyngre). Flera "svagare boxar" kan naturligtvis ge en starkare slutsummering.

Bedömningsgrund - 1 Artfynd: Naturvårdsarter, indikatorarter m.fl.				**Bedömningsgrund - 2** Rikblommighet/mkt substratväxter	**Bedömningsgrund - 3** Biotop/habitat-kvalitet/struktur		**NVI-klass**	**Bedömt vägkants-objekt**	**Kommentarer**
Rödlistade arter (CR, EN, VU, NT, DD), **Ansvarsarter i infrastrukturen, ÅGP-arter** A	**Skyddade och fridlysta arter** (lagstiftning) B	**Indikator- och signalarter** (se bil. 3, klass 1 och 2, och bilaga 4 och 5 i manualen). C	**Sällsynta eller regionalt speciella arter (om ej i A-C)** D	**Rikblommighet - särskilt av nyckel- och substratarter för insekter** (se bil 3 i manualen, klass 3-arter) E	**Biotop-kvalitet (typ, grad)** F	**Strukturer och värdeelement (förekomst, total mängd)** G	**Naturvärdes-klass enligt NVI-systemet** 	**Naturvärdes-objekt** (AVK eller HÄO)	**Tolkning av bedömt vägkantsobjekt**
Inga rödlistade arter.	Inga eller enstaka förekomst av fridlyst art.	Enstaka klass 2-arter och i huvudsak ingen klass 1-art. Viss förekomst av klass 2-arter. Enstaka klass 1-art.	Inga eller enstaka med marginell förekomst av sällsynta eller speciella arter.	I viss omfattning: *"Den rikblommande åkervägkanten"* dominerad av klass 3-arter med visst inslag av klass 2-arter, enstaka klass 1. *"Prästkrageslänter"*, "Renfaneväg-kanter", *"Höstfibble-vägkanter"*, *"Gotland/Ölands-kalkvägkanter"*	Obetydliga till små.	Begränsad förekomst av strukturer och element.	4	**Inget** **HÄO**	Ofta noterat från bilen: "Småfint" eller "Fint" (kan ofta med rätt skötsel höjas till AVK). Kring HÄO tänk: 1. Konstaterat lägre värden 2. Ej kartlagda värden 3. Värden svåra att bedöma just nu (insekter?)
Obetydlig förekomst av hotad art eller enstaka rödlistad art i övrigt eller mkt begränsad förekomst.	Fridlyst art i mindre omfatt-ning.	God förekomst av klass 2-arter och/eller ca 5-10 klass 1-arter.	Viss förekomst och frekvens av sällsynta eller speciella arter.	I genomsnitt per 50 meter upp till 50 blommande stänglar per m^2 dvs relativt rikt blommande sträcka (ej enskilda blommor), även ofta stort inslag av klass 2-arter och ofta av utpekade nyckelsubstrat-arter. Finare *"Gråfibble/tjärblomster-slänter"*.	Viss förekomst och status på intressanta vegetations-typer.	Viss förekomst av en eller flera strukturer och element.	3		De flesta AVK-objekt bör hamna i NVI-klass 3.
Rödlistad art/arter i hyfsad eller god status. En eller flera hotade arter i hygglig status. Viktiga ansvarsarter i infrastrukturen eller ÅGP-arter.	Skyddad art i viss till god omfatt-ning eller större förekomst av fridlyst art.	God förekomst av klass 2-arter och/eller fler än 10 klass 1-arter och/eller betydande population av någon/några av dem.	En eller flera speciella och intressanta arter med god förekomst.	I genomsnitt per 50 meter fler än ca 50 blommande stänglar per m^2 dvs rikt blommande sträcka blommande exemplar (ej enskilda blommor), även ofta stort inslag av klass 1- och 2-arter och särskilt av utpekade nyckelsubstratarter.	God förekomst och status på intressanta vegetations-typer, t.ex. N2000-habi-tat.	Talrik och/eller utmärkt förekomst av strukturer och element och/eller mångformiga strukturer.	2	**AVK**	Gräns mellan 1 och 2 behöver utforskas mer. Klass 1 sällan före-kommande
							1		

AVK kan i enstaka fall väljas om värdena kan höjas med rimliga insatser, men det kräver hänsyn i skötsel som t ex sen slåtter d.v.s. kontobundna åtgärder (enligt SBV) eller extra restaurering eller säkerhet för hotad art som annars är svår att bevara. Är biotopen väl utvecklad och i gott skick, men arter saknas eller det är svårt att bedöma förekomst. Arealmässiga överväganden. Kort distinkt objekt kontra långa sträckor med spridda värden som tillsammans ger t.ex. stor individrikedom. Rikblommighet bedöms inom ramen för tänkt typsträcka av 50-100 meter. OBS att "gränsvärdena" i boxarna ännu är preliminära och ingen absolut sanning. OBS att rikblommiga vägar ofta har en "ambulerande" florarikedom, den varierar över tid och är oftast som störst några år efter störning, t.ex. en dikning.