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Environmental Evidence

SYSTEMATIC REVIEW PROTOCOL

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How does roadside vegetation management affect the diversity of vascular plants and invertebrates? A systematic review protocol

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Abstract

Background: Roadsides have been acknowledged as potential substitutes for semi-natural grasslands and other open habitats with high biodiversity, many of which are now declining. Current recommendations for roadside management to promote conservation of biodiversity are largely based on studies of plants in meadows or pastures, although such areas often differ from roadsides in terms of environmental conditions and disturbance regimes. Stakeholders in Sweden have emphasised the need for more targeted guidelines for roadside management, based on actual roadside studies. We recently performed a systematic mapping of the evidence on how roadside management affects biodiversity and the dispersal of species. Through this process, we found 98 studies on how the richness or abundance of species on roadsides is affected by management such as regular mowing, burning, grazing or selective mechanical removal of plants. Since all of these interventions entail removal of plant biomass, they are comparable. Most of the studies recorded management effects on vascular plants, but there were 14 investigations of insects and other invertebrates. We now intend to proceed with a full systematic review of how maintenance or restoration of roadsides based on non-chemical vegetation removal affects the diversity of vascular plants and invertebrates.

Methods: Most of the evidence on which the proposed systematic review is to be based will be selected from the systematic map. To identify more recently published literature on the topic of the review, we will perform a search update using a subset of the search terms applied for the systematic map. The criteria for inclusion of studies will be the same as for the map, except that interventions and outcomes will be restricted to those relevant to the review. Relevant studies will be subject to critical appraisal and categorised as having high or low validity for the review. Studies with low validity will be excluded from the review. Utilisable data on outcomes, interventions and other potential effect modifiers will be extracted from included articles. A narrative synthesis will describe the validity and findings of all studies in the review. Where a sufficient number of studies report similar outcome types, meta-analysis will be conducted.

Keywords: Biodiversity, Roadside management, Mowing, Grazing, Burning, Plant removal, Insects, Invertebrates

Background

Roadside management has come to be regarded as an important part of overall landscape management for biological conservation [1]. Marginal habitats like roadsides may sustain biodiversity by functioning as refugia [2, 3] or by facilitating dispersal [4, 5]. By contributing to dispersal within a landscape (e.g. as corridors) they may mitigate negative effects of fragmentation and isolation of habitats even in highly-modified agricultural or urban landscapes [6].

Roadsides have also been acknowledged as potential substitutes for open habitats like grasslands [3], which

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are currently declining globally [7, 8]. In particular, semi-natural grasslands (created by low-intensity, traditional management) are well known for their high biodiversity [9, 10] but have declined rapidly during the last century, especially in Europe [11]. Many species that historically were mainly associated with meadows and pastures now thrive along roads instead [12]. In Sweden, some 190,000 hectares of managed grasslands occur along infrastructure, 164,000 hectares of which constitute roadsides [13]. This equals more than a third of the total amount of meadows and pastures in Sweden (ca. 450,000 hectares) [14].

With appropriate management, many roadsides might harbour a rich flora and fauna. In general, roadsides are presented as offering opportunities for grassland species [1, 15]. Managing grassland habitats for biodiversity usually requires removing vegetation and reversing late-successional vegetation stages, e.g. by mowing, grazing, burning, harrowing or scraping [16]. Differences in mowing regimes may affect both animal and plant populations. For instance, mowing after flowering and seed production will enhance the link between pollinators and flowering plants, as many plants need assistance by pollinators to produce seeds and pollinators need the flowers for nectar resources [17]. Disturbance-tolerant species are particularly favoured, while species representing early-successional stages will eventually disappear.

The management regimes and abiotic conditions of roadsides may be quite similar to those of mown or grazed semi-natural grasslands [18]. Current recommendations for roadside management to promote conservation values are largely based on botanical research on meadows, pastures and other semi-natural grasslands [1]. The effects on biodiversity of grazing and mowing of such grasslands are well studied [19]. However, management particular to roadsides, like ditching and reinforcement activities, use of salt for de-icing, sowing of exotic plant material and other measures for infrastructure maintenance will likely impact species and communities differently to traditional management of open grasslands. Management effects on biodiversity are less well studied along roadsides than in meadows and pastures, and much of the existing evidence on roadsides is comprised of grey literature not assessed by external reviewers. For these reasons, key stakeholders in Sweden have emphasised the need for more targeted guidelines for roadside management, based on actual studies of roadsides [20].

We recently performed systematic mapping of the available evidence on how roadside management affects biodiversity and the dispersal of species [21]. In the protocol for the systematic map [20], we provided a general background on biodiversity effects of roadside management, presented the rationale for the mapping initiative, and described the methods that we intended to use.

The results of our mapping exercise show that much of the literature on ecological effects of roadside management describes attempts to revegetate recently constructed roadsides, or the use of herbicides for controlling roadside vegetation in general and invasive/nuisance plants in particular. Chemical management of roadsides is nowadays largely restricted in many countries, and the literature that we have found on such management is dominated by older American studies (many of them dating from the 1970s or earlier) of substances that are now obsolete there.

However, we found more than a hundred studies with more obvious relevance to the conservation or restoration of biodiversity in roadsides, including their role as substitutes for grasslands and other habitats under threat in intensively managed landscapes. More specifically, we identified 98 studies of how the richness or abundance of various taxonomic or functional groups of species in roadsides is affected by vegetation disturbance by managers, such as regular mowing, burning, grazing or selective mechanical removal of plants. Since all of these interventions entail removal of plant biomass, they are comparable in the sense that they all follow Grime's [22] classic definition of disturbance as the partial or total destruction of biomass. A review of their impact on biodiversity should therefore permit some generalisable conclusions. Most of the studies have recorded management effects on vascular plants, but there are also 14 potentially relevant investigations of insects or other invertebrates.

We focus on non-chemical interventions that may aid the conservation or restoration of roadside biodiversity. These studies should be of considerable interest to roadside managers, including, e.g. transportation and conservation agencies, park authorities, municipalities, and farmers and other private landowners. This has been confirmed by our contacts with Swedish stakeholders. For instance, according to a representative of the Swedish Transport Administration, it is of central importance to clarify precisely how mowing and similar kinds of roadside management should be carried out to give the desired results under various biotic and abiotic circumstances. Effects of different timing of such management and of management regimes based on various combinations of interventions were mentioned as being of particular interest (Anders Sjölund, pers. comm.). A representative of the Swedish Biodiversity Centre also underlined the importance of considering potential effect modifiers such as soil type, nutrient status, shading, management history and presence/absence of invasive species (Tommy Lennartsson, pers. comm.).

Encouraged by the input from stakeholders, we intend to proceed with a full systematic review of how disturbance-based maintenance or restoration of roadsides affects the diversity of vascular plants and invertebrates. The review will follow the guidelines for systematic reviews in environmental management issued by the Collaboration for Environmental Evidence [23].

Objectives

The primary aim of the proposed systematic review is to clarify how the diversity of vascular plants and invertebrates is affected by roadside maintenance or restoration using various forms of non-chemical vegetation removal. Since current recommendations for roadside management to promote diversity largely draw on studies of semi-natural grasslands, we will also investigate whether our findings differ from those on semi-natural grasslands. Our review will largely be based on studies selected from a systematic map of the evidence on how roadside management affects biodiversity and the dispersal of species along roadsides [21]. We will apply no geographical restrictions when collecting and analysing the evidence.

Primary question: *How does roadside maintenance and restoration implementing non-chemical vegetation removal affect the diversity of vascular plants and invertebrates?*

Components of the primary question:

Population	Roadside habitats and the species of vascular plants and invertebrates found within them.
Intervention	Maintenance or restoration of roadside habitats based on non-chemical vegetation removal such as mowing, grazing, burning, clearance of shrubs and saplings, coppicing, pruning, or mechanical removal of invasive plants.
Comparator	Non-intervention or alternative forms of the interventions.
Outcomes	Measures of functional/taxonomic diversity (including abundance) of vascular plants or invertebrates.

Methods

Searches for literature

Most of the evidence on which the proposed systematic review is to be based will be selected from the recently compiled systematic map of biodiversity impacts of roadside management [21]. The systematic map is based on literature searches using 13 publication databases, four search engines and about 40 specialist websites and literature reviews. The majority of these searches were performed in October–December 2015.

When deciding whether an article included in the systematic map is also eligible for inclusion in the proposed review, we will use the criteria described in the next section. This set of inclusion criteria is a more restrictive version of that used for the systematic map.

To identify more recently-published literature on the specific topic of the systematic review, we will also perform a search update, using the following subset of the search terms used for the systematic map:

Population	roadside*, "road side*", (road* AND (verge* OR edge*)), roundabout*, "traffic island*", "median strip*", "central reservation*", boulevard*, parkway*, (avenue* AND tree*)
Outcomes	*diversity, species, abundance, vegetation

The terms within the 'population' and 'outcomes' categories will be combined using the Boolean operator 'OR'. The two categories will then be combined using the Boolean operator 'AND'. An asterisk (*) is a 'wildcard' that represents any group of characters, including no character.

The search update will cover literature published in 2015 or later, which means that we expect it to add a fairly limited number of articles. When making literature searches for the systematic map, moreover, we found that about 90% of recent studies eventually included as relevant had been identified through Scopus and/or Transport Research International Documentation (TRID). Therefore, we consider it sufficient to base the search update on these two resources, with a complementary search in Google Scholar. When searching in Google Scholar, we will examine the first 200 hits (based on relevance) for appropriate data. No language or document type restrictions will be applied.

Article screening and study inclusion criteria

Articles identified during the search update will be evaluated for inclusion at three successive levels. First, they will be assessed by title. Next, each article found to be potentially relevant on the basis of title will be judged for inclusion on the basis of abstract. Finally, each article found to be potentially relevant on the basis of abstract will be judged for inclusion based on the full text. At all stages of this screening process, the reviewer will tend towards inclusion in cases of uncertainty. The screening will be performed by reviewers who participated in the main screening of studies for the systematic map and

who are therefore well acquainted with the relevant literature and with the criteria for inclusion. The screening of articles from the search update can be seen as a continuation of the main screening, for which detailed, multi-level consistency checking was performed. Articles identified by the primary reviewer as potentially utilisable based on the full text will also be assessed by a second reviewer, and reviewers will not assess studies authored by themselves. Final decisions on whether to include doubtful cases will be taken by the review team as a whole.

A list of studies rejected on the basis of full-text assessment will be provided in an appendix together with the reasons for exclusion.

In order to be included in the review, studies included in the systematic map or identified during the search update must pass each of the following criteria:

- Relevant subjects: Roadsides anywhere in the world. A roadside is defined as the unpaved zone of a road that is exposed to roadside management.
- Relevant types of intervention: Maintenance or restoration of roadsides based on non-chemical vegetation removal such as mowing, grazing, burning, clearance of shrubs and saplings, coppicing, pruning, or mechanical removal of invasive plants.
- Relevant type of comparator: Non-intervention or alternative forms of the interventions.
- Relevant types of outcome: Measures of functional/taxonomic diversity of vascular plants or invertebrates (including abundance of assemblages and single species). Ratings of intervention effects based on visual assessments of vegetation vitality will not considered to be relevant.
- Relevant type of study: Primary field studies (reviews and other secondary compilations will not be included). Comparisons can in principle be made both temporally and spatially. Studies with a 'BA' (Before/After) design compare data collected at the same site prior to and following an intervention. Other studies may be based on comparison of different parts of a roadside, some that have been subject to a certain kind of management and some that have not. These may be termed as 'CI' (Comparator/Intervention) studies, or 'BACI' (Before/After/Comparator/Intervention) if they present data collected both before and after the intervention.
- Language: Full text written in English, Danish, Dutch, French, German, Norwegian, Spanish or Swedish.

Study quality assessment

Studies that have passed the relevance criteria described above will be subject to critical appraisal: Based on assessments of their clarity and susceptibility to bias, they will be categorised as having high or low validity (with regard to our review question).

Studies will be excluded from the review due to low validity if any of the following factors apply:

- No true replication (interventions not replicated)
- Intervention and comparator sites not well-matched (sites significantly different before intervention)
- Severely confounding factors present (e.g. additional treatments carried out at the intervention sites but not at the comparator sites)

The first two of these criteria deal with susceptibility to selection bias, whereas the last one deals with performance bias, as defined by the CEE guidelines [23]. The guidelines also list two other kinds of bias: detection bias and attrition bias [23]. We will address detection bias at full-text screening by excluding studies that only report simple 'ratings' of intervention effects based on visual assessments of vegetation vitality (see above), whereas attrition bias is not relevant to our review question—the interventions considered could not lead to systematic differences in attrition between intervention and control plots.

We will also exclude studies that are unclear to such an extent that their validity cannot be judged, for instance due to absence of key information on study design. More specifically, we will categorise a study as having unclear validity if any of the following factors apply:

- Methodological description insufficient (e.g. not clear to what extent the study was actually conducted at roadsides)
- Intervention data cannot be interpreted (e.g. since they consist of post hoc records such as 'evidence of mowing')

If none of the above five factors apply, the study will be considered to have high validity.

Detailed reasoning concerning critical appraisal will be recorded in a transparent manner. The quality of each study will be assessed by one reviewer and double-checked by another one. Reviewers will not assess studies authored by themselves. Final decisions on how to judge doubtful cases will be taken by the review team as a whole.

A list of studies rejected on the basis of quality assessment will be provided in an appendix together with the reasons for exclusion.

Data extraction strategy

Mean outcomes and measures of variation and uncertainty (standard deviation, standard error, confidence intervals) will be extracted from tables and graphs, using image analysis software (WebPlotDigitizer) when necessary. Where

multi-year series of outcomes are available, we will extract all data and use either cross-year means or, if there are sufficient studies, look for time trends in responses. Data on interventions and other potential effect modifiers will also be extracted from the included articles. All extracted data will be double-checked by a second reviewer.

It may in some cases be useful to ask authors of relevant articles to supply data in digital format. This will primarily be done for articles less than 10 years old where useful data have been published in graphs from which they are difficult to extract accurately enough, or when it is known or assumed that considerable amounts of relevant but unpublished data may be available in addition to the published results. If raw data are provided, summary statistics will be calculated by us. Extracted data records will be made available as an additional file.

Potential effect modifiers and reasons for heterogeneity

To the extent that data are available, the following potential effect modifiers will be considered and recorded:

Roadside data

Type, timing and intensity/frequency of roadside management
Goals of the management (e.g. conservation/restoration of biodiversity)
Roadside manager
Width, aspect and slope of roadside
Type and structure of roadside vegetation
Soil type
Nutrient status of the soil
Shading, e.g. by trees

Road data

Road type (width, type of surface)
Time elapsed since the road (or roadside) was constructed
Traffic (no. of vehicles per day)
Road maintenance (e.g. salting, gritting, dust control, snow clearance)

Study setting

Geographical coordinates
Altitude
Mean annual temperature and precipitation
Vegetation, land use and history of land use in the surroundings of the road

Study design

Time interval between most recent roadside-management activity and data sampling
Spatial setup of interventions and sampling

Data on geographical coordinates, altitude and climate will be searched for in external sources if not available in the included articles. A final list of modifiers and causes of heterogeneity to be recorded will be established as the review proceeds.

Data synthesis and presentation

A narrative synthesis of data from all studies included in the review will describe the quality of the results along with the study findings. Tables will be produced to summarise these results. The findings in our systematic map also indicate that sufficiently many studies report similar kinds of outcome such that meta-analysis will be possible in some cases. In these cases effect sizes (mainly standardised mean differences) will be calculated, weighted appropriately and analysed using random-effects models. Meta-regressions or subgroup analysis of categories of studies will be performed where a sufficient number of studies report common sources of heterogeneity. Analysis of sensitivity and publication bias will be carried out where possible. Overall management effects will be presented visually in plots of mean effect sizes and variance. Any major knowledge gaps identified by the review will be highlighted and discussed. Details of the quantitative analysis will only be known when full texts have been assessed for their contents and validity.

Authors' contributions

The manuscript was drafted by CB. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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