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Innehåll

Shedding a Light on Sensory Pollution in Road and Railway Ecology

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A growing topic of investigation in road and rail ecology is the impact of light, noise and vibrations (i.e. sensory pollution) on wildlife. I will present the results from a systematic review of the current literature on the impacts of sensory pollution from roads and railways on wildlife.

I searched SCOPUS for articles pertaining to the impacts of light, noise and vibration from roads and railways on vertebrates. I limited my search to empirical, peer-reviewed journal articles, written in English. To be included, articles must have been on the ecology, behaviour or physiology of wildlife, so I removed any articles on humans, plants, and invertebrates. Finally, I excluded articles that suggested sensory pollution was a potential mechanism of the trends described, without directly investigating said sensory pollution (for example, studies that described a decrease of abundance of a species with proximity to a road and suggested such impact was due to a traffic noise, but did not measure noise levels). My search was limited to all of the available literature published by the end of 2019. I read through abstracts, and removed any article that did not meet the above criteria. In the end, I collected 161 articles. 2 articles were removed, since I could not get the full-text for those articles. So a total of 159 articles were used in this systematic review.

From each article, I extracted: the sensory pollution and transportation corridor investigated; the year, location and study taxa; the style of study (observational or experimental), whether or not the authors investigated the impact directly or if they tested a mitigation strategy, and also a summary of the main findings.

Preliminary analysis of the 159 articles shows 153 studies were at roads, and only 4 were at railways. 2 articles investigated both road and railway impacts. Furthermore, a majority of articles were on the impact of noise from roads. 95 articles were on noise impacts (90 at roads, 3 at railways, and 2 at both), 56 on light impacts (all at roads), and 7 articles on both, light and noise (6 at roads and 1 at railways). Only 1 article was on the impact of vibrations from roads on wildlife.

Finally, the majority of articles were on birds (n = 69; 52 on noise from roads, 11 on light from roads, 4 on light and noise from roads, and 2 on noise from railways), mammals (n = 60 articles, 34 on bats; 37 on light from roads, 22 on noise from roads, and 1 on noise and light from railways), and amphibians (n = 21, 16 on noise from roads, 4 of light from roads, and 1 from light and noise from roads). Thus, there is a clear bias in the literature towards the sensory impact of roads on wildlife, particularly noise from roads on birds, light from roads on bats, and noise from roads on amphibians.

Results from this study can be used to inspire future direction in linear road and railway ecology research.

Are railways really detrimental to bird populations? The case of the new Bothnia Line Railway in northern Sweden

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Common sense tells us that railways and trains should be detrimental to bird faunas. Birds lose their habitat, are killed in collisions, and survivors scared away by sonic, visual and human disturbances. Even scientists tend to embrace this negative effect opinion. Is their evidence solid? I tested potential effects of the construction of a 180 km long new railway on birds in agricultural landscapes in a before-during-after control-impact (BDACI) study with 13 impact and 6 control sites. The design had an additional phase when the railway was physically ready but train traffic had not yet started. In 2002-2015, I monitored species richness, numbers of breeding territories and estimated positions of territory midpoints. Species richness at large was stable in control sites and increased in impact sites. Trends were negative in one impact site (8%) and positive in three (23%). In a mixed effect model, numbers of observed bird species during the successive phases were not significantly different from the Before phase. In line with the widespread negative trend in farmland bird numbers, numbers of territories decreased in very similar ways in impact and control sites. Overall numbers for impact sites showed negative trends in four cases (31%) and a positive trend in one (8%). In this latter site, a massive compensation program was carried out over the course of the study. At species level, the trend analyses revealed a fuzzy pattern of possible winners and losers, e.g. Meadow Pipit and Northern Lapwing, respectively. Median distances from territory midpoints to an arbitrary baseline increased in control sites but distances to the railway line decreased in impact sites. This contradicts a general "scaring off" effect by construction activities and train traffic. This lack of repelling effect was also found in the mixed model analyses. Overall, this BDACI study provides no evidence for a widespread negative impact on bird populations caused by the introduction of a new railway on agricultural land in boreal landscapes, rather the opposite. Time to re-evaluate common sense and previous science?

Environmental monitoring of reptiles across a wildlife overpass

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Our objective is to evaluate the functional connectivity for reptiles after establishment of a wildlife passage. We evaluated the distribution of reptiles across a major highway and ecoduct located 20 km south of Gothenburg, Sweden.

We used Artificial Cover Objects (ACOs) for inventory and monitoring of reptile diversity. The ACOs were comprised of plywood coverboards placed in a system of positions along transects parallel with the highway. We monitored the ACOs 6 times during spring and 5 times during autumn between the years 2018 and 2019. We positioned 14 ACOs on or at the base of the ecoduct, whereas 66 ACOs were placed along transects between 50 and 250 m away from the highway. Monitoring of reptile counts underneath ACOs were combined with data on vegetation cover and shadiness and of ambient temperature from the Swedish Meteorological and Hydrological Institute. Our study design generated 308 ACO monitoring events within the ecoduct area, 792 monitoring events within the reference area west of the highway, and 660 monitoring events within the reference area east of the highway.

We used Generalized Linear Mixed Effects Models (GLMM) to analyze reptile counts in relation to the ecoduct while controlling for percent vegetation cover, shadiness and ambient air temperature. We used the ACOs as independent unit and, thus, included ACO identity as a random effect. Our data is dominated by zero counts of reptiles and the variance is lower than the mean. Therefore, we applied a negative binomial Poisson distribution.

"Barrier effect hypothesis" – the reptile distribution is different around the ecoduct area compared to the surrounding landscape, while controlling for vegetation cover, shadiness and ambient air temperature."Connectivity hypothesis" – the reptile distribution is the same between the ecoduct area and the surrounding landscape, while controlling for vegetation cover, shadiness and ambient air temperature.

We constructed three *a priori* candidate GLMMs, reflecting our two hypotheses; "Barrier effect" and "Connectivity" and an intercept (null model) in order to analyze overall performance of our models. Model selection was based on Akaike's Information Criteria (ΔAIC_c and AIC_c weights).

On 163 occurrences did we detect reptiles of six species; 10 grass snakes (*Natrix natrix*), 17 smooth snakes (*Coronella austriaca*), 2 sand lizards (*Lacerta agilis*), 7 viviparous lizards (*Zootoca vivipara*), 126 slowworms (*Anguis fragilis*) and 1 adder (*Vipera berus*).

The most parsimonious of our models supported the "Connectivity hypothesis", i.e. variation in reptile counts was best explained without discriminating between ecoduct and surrounding reference areas, while controlling for vegetation cover, shadiness, and ambient temperature (ΔAICc=0.00 and AICc weights=63%). Reptile counts was higher at AOCs with lower degree shadiness (β=-0.012 ±0.006 (SE), z=-2.1, P=0.039) and increasing ambient temperature (β=0.073 ±0.0346 (SE), z=2.1, P=0.036). The highly endangered sand lizard (*Lacerta agilis*) was identified under ACO on the ecoduct only one year after its establishment. Our results stress that management of suitable habitats is crucial across wildlife passages, in order to function for reptiles.

The monitoring program is financed by the Swedish Transport Administration.

Effectiveness of road and railway bridges for reindeer and wildlife movements – an ongoing project

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Large roads and railways act as barriers for ungulates, with potential impact on individual fitness, population demography, and genetic diversity. Such barriers to movements are particularly problematic in areas where ungulates conduct seasonal migrations, such as in northern Scandinavia. For semi-domestic reindeer, as for wild migratory ungulates, fenced roads and railways may effectively block animals from reaching crucial seasonal areas and resources. For the reindeer husbandry, roads and railways with fences or high traffic volumes tend to create severe obstacles during driving of large herds, require extra efforts to retrieve animals from the “wrong” side, and result in loss of odd individual animals to neighbor districts or unknown fates. In order to minimize the barrier effects, the Swedish Transport Administration (STA) aims at providing safe passages for reindeer and other large mammals where major transport infrastructures intersect with important animal migration routes and movement corridors – i.e., at conflict points between grey and green infrastructure. However, it remains unknown how such passages should be designed to fulfil the ecological and practical requirements in the most cost-efficient way. Therefore, we have started a project to monitor how reindeer and wildlife use existing bridges over and under roads and railways. The bridges monitored vary in dimensions and design; some are constructed specifically for reindeer while others are bridges for roads or streams. The data collection includes camera trapping within and around the bridges, and camera images are analyzed for number, behavior and categories of animals. The project includes the development of effectiveness criteria towards which the use of individual bridges can be evaluated. The project is planned to run 2018-2020, and to work in close cooperation between university, STA and five reindeer husbandry districts ranging from mountain to forest and lowland (concession) districts, within Norrbotten county, Sweden. Some preliminary results will be presented.

The SLOSS dilemma of road ecology – Single Large Or Several Small fauna passages?

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Road ecologists are often asked by planners "How wide does a fauna passage have to be?", and however appealing, "The larger the better" is only rarely the wisest answer. The width tend to be one of the most cost driving factors for fauna passages at linear infrastructures, and in the planning reality cost—efficiency have to be considered.

In this presentation I address the SLOSS dilemma of road ecology, i.e., the discussion whether a Single Large Or Several Small fauna passages would produce the most benefit for wildlife. I point out risks (ecological as well as practical) with investing in one large passage, and list a number of situations where it may be more beneficial to distribute the conservation efforts in the landscape by constructing several smaller passages rather than a single large:

- In relatively intact or homogenous landscapes where animal movements are dispersed.
- In situations where the animal movement routes are expected to change over time due to landscape changes.
- In situations where animal movement habits simply are not known.
- When fauna passages are constructed for multiple species with different habitat choice, and therefore no ideal site can be appointed.
- When target species are territorial and there is a risk that individual animals monopolize the area in and around the passage.
- When target species are sensitive to hunting, poaching or predation; enemies (human or natural predators) may ambush at sites where movements of prey are pinched.
- In areas where future human development (housing, mining, forestry etc.) cannot be controlled, and natural habitats surrounding passages may suddenly disappear.

I argue that such situations are in fact what infrastructure planning normally faces, and that the default strategy therefore should be to distribute rather than to concentrate passage opportunities along major transport infrastructures. With this strategy follows an increased focus on how to make also narrower passages functional, e.g., by adapting vegetation and limiting human disturbance in and around passages. Single large fauna passages should be selected in sites where it is likely that they can serve a large proportion of target animals (species and individuals), and where their long-term functionality can be guaranteed, for example in areas that are legally protected or when agreements can be made with adjacent landusers to protect the passage and its surroundings from significant impacts.

The SLOSS issue calls for partly new directions in road ecology research, e.g., studies of the effectiveness of narrow passages and non-wildlife passages, animal behavior and interactions in and around passages, population biology of focal species, and the importance of co-management with surrounding land owners.

Condition of amphibian road mitigation constructions in Sweden

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In efforts to reduce barrier effects and road mortality of amphibians, the Swedish Transport Administration has installed tunnels and/or guiding fences at 35 different road sections identified as high-risk sites for amphibians. These constructions were built between 2000 and 2017. Until now, an overview of the different designs and materials used has not been readily available and, more importantly, the technical condition of the constructions has been largely unknown. To remedy this, we visited all 35 objects during the summer of 2018 and evaluated them using a standardized protocol. We used existing guidelines for construction and maintenance as well as previous registrations of possible problems as a foundation for the evaluation. We developed a protocol with focus on quantitative measurements of flaws in the structure or materials. For example, we measured the gap size between different segments of the fences, the amount of material blocking the tunnels and the height of vegetation growing near the fences. Additionally, we assessed the permeability of fences qualitatively. Four objects were in very poor condition. We judged the remaining objects to be largely functional although few were in perfect condition. We conclude that there are three main types of flaws, based on a combination of frequency and severity: 1) Large gaps between fence and tunnels. 2) Damage to the top of the fence. 3) Vegetation near the fence. The problems we identified with the condition of mitigation constructions for amphibians were varied and seemed to occur with all types of materials and irrespective of the age of the structure. Many of the more severe structural flaws seemed to be the result of site-specific events, such as flooding or ground movement. Overgrowth or otherwise poorly maintained vegetation and damage caused by machinery was, on the other hand, common. For some of these problems there may be underlying causes, such as flaws in the construction that could have been detected already in the building phase. We conclude that thorough inspection during building and regular and proper maintenance is vital for ensuring long term functionality. Although this may appear obvious, our study reveals that it is not always put into practice.

A large scale plan for ungulate passages and fencing along two highways in northern Scandinavia

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Large roads and railways in the far north tend to be important mortality factors for ungulates, and to create severe barriers not least to seasonal ungulate migrations. In northern Scandinavia, moose (*Alces alces*) and reindeer (*Rangifer tarandus*) migrate up to hundreds of kilometers between summer and winter ranges. Reindeer in this area are semi-domestic and herded by the indigenous Sami people, but are still free-ranging and largely follow their natural migratory patterns. The Swedish Transport Administration (STA) aims at minimizing the number of ungulate—wildlife accidents, and providing safe passages for ungulates where major transport infrastructures intersect with important animal migration routes and movement corridors.

Two of the major highways in northern Sweden are the E4 Nordmaling-Haparanda (450 km along the coast) and the E10 Töre-Kiruna (290 km inland). While the E4 is 3-4 lane and fenced in most part, the E10 is yet to be upgraded with fencing and road widening. A small number of designated fauna bridges are already in place along the two roads, but both roads are in most part currently a serious source of mortality or barrier for ungulates.

We developed a large scale plan for ungulate mitigation (passages and fencing) at these two highways, based on information on ungulate movements collected from reindeer herders and local hunters, on wildlife accident recordings, and a simplified landscape analysis (based on habitat and topography). For simplicity, we assumed that fauna passages to be built will be of any of 4 standard types: i) ca 50 m wide overpass, ii) ca 25 m wide overpass, iii) ca 20 m wide underpass, or iv) at-grade crossing designed to provide safe passage for ungulates. We further assumed fences designed to keep ungulates out of the road as good as possible, meaning 2.5 m height, angled at openings, with minor roads gated, escape opportunities for animals, and well maintained. We identified a total requirement of 89 new fauna passages, an immediate need of 150 km new fencing, and >100 locations where current fencing needs improvement. We estimated the total cost for the passages in the plan to 100-120 million EUR.

We notice that the frequency of passages required is roughly in line with the criteria defined in STAs national guidelines for fauna passages, stating that ungulates should have a passage opportunity every 4-6 km along larger roads. We further notice that the needs for reindeer and wild ungulates correspond well, despite their slightly different habitat preferences, and that most passages proposed could serve both species. This should however depend on the passage construction, and we stress the importance of monitoring the function of fauna passages that are to be built. Upcoming case-by-case planning for fauna passages must further elaborate passage siting and design, in dialogue with local stakeholders, not least the Sami reindeer herding districts. We also point out the need for more research on fencing, not least the design of fence openings at road intersections, which may be critical to limit ungulate roadkill.

Temporal patterns of humans and ungulates at bridges - Co-existence or disturbance?

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The effectiveness of fauna passages depends on a number of factors, one of which being human disturbances in and around passages. There is an increasing demand to allow humans to use fauna passages, and even to construct passages with a combined function for fauna, recreational use and local traffic. Yet the impact of human co-use on fauna use of crossing structures is not well understood. We are studying temporal patterns of humans and ungulates at six road or railway bridges in Sweden; four constructed mainly for fauna and two for other purposes (road or stream), but all accessible to people and traffic. We have collected data over 6 consecutive months, using trail cameras to record the activity of humans, wild ungulates (moose and roe deer) and semi-domestic free-ranging reindeer at the passages. Human activity at individual bridges ranged from approximately 0.07 to 2.8 events per day, while ungulate use ranged from approximately 0.2 to 1.3 events per day. Overall, human activities were primarily snowmobiles, secondarily cars and pedestrians. Human activity events occurred mainly in daytime or evening, leaving most of night and dawn without human interference. Moose and roe deer used the bridges mainly at night, which coincides with the period they are assumed to be most active. Reindeer, on the other hand, used the bridges mainly in daytime. At three bridges, humans were more active on weekends than weekdays, but at one bridge the trend was opposite. Ungulate use of bridges tended to be higher on weekdays than weekends, though these results were inconsistent. Human activity increased throughout the winter, which is likely associated with the gradual increase in daylight and improved conditions for snowmobiling. Ungulate use was higher in early winter, possibly due to natural seasonal migrations. The time elapsed between a human event and the subsequent moose event was generally longer than the time elapsed between two moose events, indicating a disturbance effect of human activity on moose use. There was no similar effect on reindeer, while that aspect could not be analyzed for roe deer. We conclude that i) human activity at bridges varied over time (in general lower at night and dawn, at weekends and in early winter), and accordingly that time-sharing between humans and wild ungulates occurred to a degree, and ii) there were some indications of human disturbance effects, but yet no consistent reverse temporal patterns between human and ungulate use of the bridges. These conclusions are however preliminary; the study is ongoing (including all year and additional bridges) and we hope to better understand the nuances of these relationship and the implication of the results to fauna passage construction.

Road sides as ecological traps – challenges and solutions: changed biotic interactions due to non-native seed mixtures and invasive alien plants

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Roadsides offer habitats for many species, and they act as a habitat network in numerous landscapes. Therefore, in many countries, efforts are made to improve roadside quality for biodiversity. However, there is widespread evidence that these habitats may attract animals and allow establishment of plant populations that end up having lower fitness. This is caused by slower growth, higher mortality and reduced reproduction. In the most extreme cases sink populations develop that depend on constant colonisation by individuals from adjacent source populations. In those cases, roadsides act as so-called ecological traps with overall negative effects. One key question for the work with roadside biodiversity, is to evaluate under which conditions roadside habitats act as traps and when they improve conservation status, respectively.

The intensity of the trap effect depends on the quality of the roadside in relation to the surrounding habitats, and on the degree of stress and disturbance caused by traffic. Some of these effects are moderated by the width of the roadside, and negative effects can be mitigated by improved planting and adapted management schemes. A less well understood effect is the quality of the plant material used. In some regions non-native (and sometimes invasive) plants are still planted along roadsides, and often species-poor commercial seed mixtures that disrupt trophic interactions with native pollinators and herbivores are sown. These problems are exacerbated if invasive alien plants colonise roadside habitats, because they outcompete native plant species and require hard management.

Most likely, the unwanted trap effects depend on the size and the traffic volume of the road, as well as on roadside maintenance and adjacent land use. However, they may increase under climate change due to low reproduction and increased mortality of species adapted to current conditions. Moreover, phenological mismatches might occur between primary producers, consumers and decomposers. This can cause reduced pollination and increased herbivory, which would jeopardise the ecosystem services roadsides provide.

It is still debated whether or not roadside design should encourage species establishment, and we largely lack methods for evaluating risks of trap effects for different species groups. Also methods for mitigating such effects are scarce, although, more recently, some solutions have been developed to address these problems. One measure is to use local plant material and to ban the use of cultivars or (potentially) invasive plant species. Seed mixtures, seeding methods and maintenance strategies that reduce the establishment of unwanted species and benefit biodiversity of associated animals are available.

This workshop will address these topics with an interdisciplinary perspective. We have assembled a group of plant and animal ecologists, vegetation scientists, restoration ecologists, conservation experts and roadside ecologists that have agreed to support the workshop. Some of these scientists have already reviewed the literature on the workshop topic. The expert knowledge shared and discussed in this workshop should later be exchanged with roadside engineers, construction experts, landscape planners and roadside authorities to identify potential solutions to the challenges described above. The results of the workshop will be incorporated in a manuscript that is under preparation and should be submitted in summer 2020. The practical implications will be communicated to road authorities.

The workshop will have the following structure and content:

1) Welcome and introduction – J. Kollmann (Munich)

2) Keynote 1 "Roadsides as ecological traps" – J.C. Habel (Salzburg)

3) Keynote 2 "Significance of local adaptation for biotic interactions" – A. Bucharova (Münster)

4) Keynote 3 "Engineering biotic resistance of plant communities against unwanted species" – F.A. Yannelli (Berlin)

5) Small discussion groups on trap effects, regional plant material, invasive alien plants and adaptation to climate change

6) Plenary discussion (H.M. Hanslin)

7) Conclusions and practical implications (S. Kroeger)

Permeability modelling of infrastructure networks for wildlife - towards a decision support tool for mitigation planning

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Roads and railroads impose a network of movement barriers and sources of mortality on terrestrial wildlife that may impact meta-population dynamics and lead to local declines in population abundance and ultimately to the disappearance of a species. Road agencies have been attempting to mitigate these impacts, commonly through strategies of facilitating safe-crossing, while reducing access to transportation corridors (e.g. using crossing structures and fencing). The interplay between the existing threats and mitigations produce a complex landscape-wide pattern that is difficult to address in conventional impact assessments, particularly when infrastructure planners are attempting to provide large-scale mitigation. In order to assist in this task,, we developed a simulation tool that assesses the cumulative barrier and mortality effects of roads within existing infrastructure networks on populations.

We used the existing road network of southern Sweden to build a meta-population model, where primary and secondary roads delineated local populations within the areas of the meshes of the road network. As inter-population boundaries, these roads were a barrier and/or a source of mortality, parameterized by traffic volume, traffic avoidance, presence of fences and crossing structures. For example, where a road was fenced, we assumed it to be fully effective as barrier and thus in preventing accidents. On the other hand, crossing structures were attributed with variable efficacies for wildlife depending on passage design and dimensions. These efficacies were translated into the mitigated proportion of each boundary road. Local areas or meshes were assumed to differ in carrying capacity depending on size and relative forest cover, while initial parameters such as fecundity, sex ratio and age distribution were considered being a common trait for the entire meta-population. Local mortality was assessed from hunting regime and traffic accidents on minor roads within each area. No concern was given to habitat distribution or type of non-forest habitat included. We further assumed that reproduction and dispersal events happened once per year and that the proportion of individuals that encounter a given boundary road was a function of the size of the local area and the relative length of the boundary road.

With this model, we can demonstrate how changes in barrier and mortality effects of individual roads, as may result from a mitigation program, can affect the entire meta-population. This will help planners to anticipate the outcome of construction and mitigation plans. We also discuss how these effects relate to species specific traits such as home range size, dispersal range, population density as well as to the species specific responses to traffic.

Assessing Biodiversity in Railway Dry Grassland Patches

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Infrastructure habitats are receiving increasing attention as important habitats for endangered species. In Sweden there are about 200,000 ha managed grasslands along linear infrastructure such as power lines, national road network, airports and railways. The Swedish Transport Administration has documented, through a series of years, the diversity of insects and plants in railway environments in different regions. Therefore, we know that over 2,000 species of insects and vascular plants have their habitat in a railway environment. Among these species, about 100 are included in the national red-list. In this work we present a method to assess, categorize and handle railway environments on a national basis. The method consists of three steps: remote assessment, field visits and biodiversity action plans. The remote orthophoto assessment selects railway environments to be visited in field based on a set of parameters such as visible structures and soil characteristics. The next step, field visits, focuses on recording habitats for vascular plants and insects and includes a survey of plant species. The status of 12 pre-defined habitat structures are targeted and assessed in the field. These pre-defined habitats are each represented by a unique combination of flora and fauna, containing one or more protected species. An example of a pre-defined habitat includes dry and sunny gravel with dense patches of the herb *Herniaria glabra*. This plant species is common on patches dominated by sand and gravel in urban and rural areas, but very warm and sunny patches are unusual. Much of the railway environment with *Herniaria glabra* is indeed in a warm and sunny microclimate. Therefore, the red-listed moth *Coleophora scabrida*, which larvae are monophagous on *Herniaria glabra*, is frequently documented in railway environments. Outside railway areas this moth species has become very rare in Northern Europe. The field visits conclude an overall classification (1-5) based on the biodiversity parameters. The class 4 (low capacity) and 5 (lack capacity) will not be considered for action plans. The railway environments classified to 1 (very high conservation values), 2 (high conservation values) and 3 (moderate conservation value) are subject to a specific action plan. The purpose of these action plans is to secure and develop the biodiversity along the railway environments. Currently, all Swedish 1,400 railway stations have been surveyed. The results show that 230 railway stations include dry grasslands that are high-ranked (1, 2 or 3). Action plans have been produced for a set of railway stations. In 2021 we anticipate finalizing the action plans for the remaining high-ranked stations. We hope that this methodology will trigger a valuation and ranking of the natural assets of railway environments. We further believe that this national survey will push biodiversity issues to be part of the regular management of railways.

Why do some road verges have higher biodiversity than others?

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Road verges can be rich in species of different groups of organisms and thereby contribute to biodiversity conservation. Species richness and other measures of biodiversity, however, differ between verges. Knowledge about which environmental factors, including management activities, that account for high biodiversity, is crucial for our possibilities to construct and maintain roads of high conservation value. In this talk, we summarize results of two ongoing research projects, one European CEDR-funded project that compile published information (EPIC-Roads) and one Swedish empirical project that analyze new field data (TRIEKOL). In this talk we focus on vascular plants and vegetation.

Roadside vegetation is more or less successional and different environmental factors are important for its composition during different stages during the succession. The succession starts with construction or maintenance activities that expose bare soil, and proceeds through increasing competition between species, reduced opportunities for establishment, and raising nutrient levels due to accumulation of organic matter. The rate and progression of vegetation change is influenced by, e.g., soil nutrient levels, mowing of the vegetation, and occurrence of competitive species. Dry and nutrient poor soils can maintain high species richness of drought-tolerant species for a very long time, with limited need for mowing. Somewhat richer or more moist soils can develop and for a long time maintain species-rich vegetation if they are regularly mown, and domination of tall plants thereby counteracted. Rich soils, or roadsides colonized by competitive grasses or invasive species, undergo rapid succession towards species-poor tall vegetation in spite of mowing. Roadsides through arable fields often become nutrient rich because they are affected by the spread of fertilizers in the fields.

In addition to these environmental factors, sun exposure is important, through influencing, e.g., soil moisture and thereby drought stress and soil nutrient level, and the cover of bryophytes and lichens. Highly different types of vegetation can often be seen at different sides of an east-west stretching road.

Which species that colonize, especially at an early stage, depends on the species pool in the surrounding landscape, mainly the adjacent habitats. There is great differences between areas with calciferous soils and acidic soils, the former having more species-rich vegetation. Much of the vegetation, not least the occurrence of invasive species, may also be explained by transportation of seeds via the material used for building the road.

Many old roads may have been colonized from species-rich habitats formed by pre-industrial agriculture, such as unfertilized pastures and hay-meadows. Often, these habitats are now gone and their species remain only in the road verges.

Management of biodiverse railroad stations – experiment of preventing tree and bush encroachment

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Railroad stations in Sweden include several important habitat types e.g. for dry meadow plants and pollinators. They may constitute the last remainings of open sun exposed sandy soils that were much more common in the preindustrial agricultural landscape in Swedish. The values are in most cases linked to the conditions of the station area regarding soil, nutritional regime and sun exposed open areas. Open sand is crucial for bees that dig nests in sandy soil and bare soils creates a warm microclimate that is important for many species to survive in an otherwise relatively cold climate in Sweden. In addition, as long as stations are in operation, there are some kind of vegetation management to avoid trees and grasses from establishing. In most cases, vegetation has also been mowed or manually "weeded" on the station yard, which has resulted in positive effects on low growing plant species that otherwise are easily outcompeted by more dominant species. Thus, the values of a station for conservation is much related to the prevention of trees and grasses intruding in the open areas. Three types of management were tested on three stations in mid-Sweden over 4-5 years: 1) Scraping - removal of trees and roots with a tractor and then scraping of the soil top layer, 2) Root pulling of all trees and roots with a tractor, 3) cutting - cutting of all steams with a bruch or chain saw. The time until regrowth of trees was clearly dependent on management type. Scraping kept an open surface of sandy sun exposed soils more effectively than the other two types. In general trees established from seeds in scraped patches while they established both from seeds and from roots in root pulled and cut patches. Encroachment of grasses was dependent on both establishment from seeds and from vegetative spreading from present plants. Overgrowth of grasses was inhibited by the shade from established trees to some extent but although scraping did not have a fast establishment of trees these management still prevented overgrowth of grasses to a higher extent than root pulling and cutting. The stations were located relatively isolated in otherwise forested landscapes and therefore the established flora in experimental sites were very much dependent on the composition of the immediate local flora, thus the established flora differed a lot between sites. The number of flowers, thus the food resources for pollinators, was not different between management nor between sites. Results from this study may help managers of stations or other sandy habitats to maintain biological values over time.

Both roads and power line corridors contribute to landscape scale biodiversity of plants and insects

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Traditionally managed semi-natural grasslands, and the biodiversity associated with them is declining all over Europe. Linear infrastructure rights-of-way, such as road verges and power line corridors contain vast areas of grassland habitat managed in a way that is resembling that of traditional semi-natural grasslands, and hence they have a great potential for conservation of especially species associated with grasslands. We first conducted a review of the value of linear infrastructure habitats (LIH) for biodiversity. Similar to grasslands or heathlands, LIH often harbor high numbers of species including rare plants and animals. There is, however, a risk that LIH act as ecological traps, by attracting organisms that fail to survive or reproduce there. Second, we selected 32 forest-dominated landscapes with contrasting amounts of LIH and semi-natural grasslands. In each of these 32 landscapes we surveyed plants, butterflies and bumblebees in five different habitats: semi-natural grasslands, power line corridors surrounded by forest, road verges of big and small roads and uncultivated field margins. Then, we investigated how the amount of LIH in the landscape affected the evenness, phylogenetic diversity and species richness of the three different organism groups within the five before mentioned habitats.

Landscapes with presence of power line corridors had higher species richness of plants than landscapes without power lines, but there was no such effect for butterflies or bumblebees. At the local scale, power-line corridors had as high diversity of plants and butterflies as did grazed semi-natural grasslands. Road verges along larger roads tended to have lower diversity of all taxa than road verges along small roads. The overlap in species composition between habitats was relatively large, but with relatively distinct, sets of plant species in field margins and power line corridors compared to the other habitats. The similarity in species composition between habitats in the same landscape was higher in landscape with presence of power line corridors. For bumblebees, this was especially the case when the density of roads was high. In contrast, a high road density tended to result in less similarity in species composition. In conclusion, linear infrastructure habitats have a high diversity of plants and pollinating insects, and provide additional habitat for a large proportion of the grassland species in the landscape. Especially power line corridors contribute to higher landscape scale biodiversity and appear to provide connectivity resulting in more similar composition of communities in different grassland habitats in the landscape. Roads have less clear effects, possibly due to the dual role of road verges as habitat and roads themselves as barriers to dispersal. Future studies that assess the population level mechanisms behind the observed patterns are needed before any clear recommendations for biodiversity conservation can be given.