Triekol III

Applied Road and Rail Ecology

Project plan 2017–2022

2017-07-12

Översikt (bakgrund och innehåll)

Trafikverket kommer framöver att behöva satsa större belopp på åtgärder för att anpassa infrastrukturen till omgivande landskap. Detta drivs bland annat av att den nuvarande strategin med ett fokus på områdesskydd inte visat sig leda till att miljöpolitikens landskapsmål nås. Trafikverket har ett viktigt bidrag till både bevarande och främjande av biologisk mångfald i det större samhällsperspektivet. Landskapsanpassningen är också av betydelse för att stävja det ökande antalet viltolyckor.

Inom EU och i Sverige har frågor som rör konnektivitet (grön infrastruktur[1]) och landskapsanpassning kommit allt mera i fokus. Det har också uttryckts som ett direkt uppdrag till Trafikverket i Regeringens regleringsbrev 2016[2] följt av en uppmaning i regleringsbrevet för 2017 att vidta förberedelser för att öka takten i anpassningsåtgärder från och med år 2018[3]. Direktiven till inriktningsplaneringen och i den planerade ökande volymen till riktade miljöåtgärder för landskap ger konkret utryck för denna utveckling. Trafikverket har i sitt svar till regeringen bland annat redovisat det stora behovet av anpassningsåtgärder i infrastrukturanläggningen[4].

Landskapsanpassningen innebär å ena sidan att minimera barriäreffekter, viltolyckor, buller och annan negativ påverkan på biologisk mångfald, å andra sidan att maximera de positiva effekterna på biologisk mångfald genom att skapa och sköta biologiskt rika biotoper i väg- och järnvägsmiljöerna.

Kunskapsläget inom infrastrukturekologi (road and rail ecology) har förbättrats markant under senare år, både internationellt och i ett svenskt perspektiv. Riktlinjer för utformning av åtgärder som faunapassager, stängsel, trummor, anläggande av livsmiljöer, vägkantsskötsel etc har beskrivits i den europeiska handboken COST341[5], i den svenska *Vilda djur och infrastruktur*[6]

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[1] https://www.naturvardsverket.se/gron-infrastruktur

[2] http://www.esv.se/statsliggaren/regleringsbrev/?RBID=17013

[3] http://www.esv.se/statsliggaren/regleringsbrev/?RBID=17719

[4] https://trafikverket.ineko.se/en/anpassning-av-transportinfrastrukturen-som-ett-bidrag-till-en-fungerande-gr%C3%B6n-infrastruktur-planera-bygga-och-sk%C3%B6ta

[5] http://www.iene.info/wp-content/uploads/COST341_Handbook.pdf

samt i Trafikverkets serie Temablad Natur[7]. Flera kritiska kunskapsluckor har fyllts inom den tidigare Triekol-forskningen[8] (2010-2015), och även lett fram till planeringsverktyg som nu är i användning. Trafikverket har parallellt deltagit i CEDR-projektet Roads and Wildlife[9] (2014-2016) som också tagit det internationella kunskapsläget flera steg framåt.

Men trots dessa satsningar finns fortfarande avgörande kunskapsluckor, bland annat vad gäller behov av anpassning av olika underhålls- och investeringsåtgärder och deras kostnadseffektivitet. Kunskapsläget bygger i huvudsak på uppföljningsprogram med fokus på användning, och ofta med vitt skilda och svårjämförbara upplägg. Det behövs mer vetenskapligt upplagda empiriska studier, så långt som möjligt med före-efterstudier i kombination med parallella nollstudier (referensområden, där inga åtgärder görs). Det behövs också strukturerade analyser av hur olika åtgärder i pågående underhåll och investering påverkar biologisk mångfald, positivt och negativt.

Trafikverket har inom sitt ansvar för FoU, planering och genomförande samverkat med forskare inom Triekol, och på det viset tillsammans avgränsat och strukturerat frågan om transportinfrastrukturens påverkan på biologisk mångfald[10]. I planeringen för Triekol III (under 2016) har också ett arbete gjorts i samverkan mellan forskare och Trafikverkets miljöspecialister (ekologer inom arbetsgrupper för djur resp. infrastrukturbiotoper), och med input från Triekol III:s vetenskapliga panel, för att identifiera återstående kunskapsluckor av kritisk betydelse för Trafikverkets arbete med åtgärder för biologisk mångfald. Från en ”bruttolista” av forskningsområden prioriterades nedanstående delprojekt att ingå i Triekol III, då dessa bedömdes som de mest praktiskt och vetenskapligt relevanta som kunde rymmas inom den angivna budgeten:

Område Djur (sex delprojekt)

1. Viltanpassning av existerande broar (Wildlife adaptation of existing bridges; sid. 5 nedan)
2. Viltövergångsställen och aktiva viltvarningssystem (Level crossings and wildlife warning systems; sid. 7)
3. Planskilda passager för större viltarter (Over- and underpasses for larger wildlife; sid. 9)
4. Mindre projekt: Modellering av permeabilitet och mortalitet i viltpopulationer (Modeling of permeability and mortality effects on wildlife populations; sid. 11)
5. Effekt av bulleråtgärder för fåglar (Effect of noise measures for birds; sid. 12)
6. Mindre projekt: Groddjursåtgärder (Amphibian passages; sid. 13)

Område Infrastrukturbiotoper (tre delprojekt)

7. Ekologiska nyckelfaktorer och skötsel i artrika vägkanter (Management and construction of road infrastructure habitats for biodiversity; sid. 16)
8. Ekologiska nyckelfaktorer och skötsel i artrika järnvägsmiljöer (Management and construction of rail infrastructure habitats for biodiversity; sid. 19)
9. Mindre projekt: Infrastruktur-biotopernas värden för biologisk mångfald (Ecological functions of infrastructure habitats; sid. 22)

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[6] https://trafikverket.ineko.se/Files/sv-SE/12025/RelatedFiles/2005_72_vilda_djur_och_infrastruktur_en_handbok_for_atgarder.pdf

[7] http://www.trafikverket.se/for-dig-i-branschen/miljo/natur/temablad-miljo/

[8] Se publikationslista: http://triekol.se/publikationer/

[9] Bestående av tre delprojekt: Saferoad (http://www.saferoad-cedr.org/en/saferoad.htm), Harmony (http://www.harmony-project.net) och SafeBatPaths (http://bios.au.dk/om-instituttet/organisation/faunaoekologi/projekter/safe-bat-paths/)

[10] Trafikverket publikation 2015:210

Som kunskapsluckor av kritisk betydelse för Trafikverkets åtgärder för biologisk mångfald identifierades också följande forskningsområden. De ingår dock inte i planen för Triekol III, utan behöver adresseras i Trafikverkets kommande forskningssatsningar:

- Viltstängsel (effektivitet vid olika utformning, funktion hos olika utformningsdetaljer)
- Andra viltolycksåtgärder (jämförelse av effektivitet kontra kostnader)
- Populationsstudier (infrastrukturens påverkan på populationsnivån särskilt för klövvilt och groddjur)
- Passager för vattenlevande fauna (trimningsåtgärder, särskilt effektivitet kontra kostnader)
- Fladdermusåtgärder
- Ekologiska värden och skötsel av artrika väg-/jvgmiljöer i landskapsperspektiv (landskapsanalys för prioritering och planering av åtgärder, och för samverkan över sektorsgränser)
- Ekologiska fällor (risken att locka arter till infrastrukturmiljön som sedan fungerar som ”sänka”)
- Hantering av invasiva arter (metoder för kartläggning, modellering av framtidscenarios, spridningsrisker i nuvarande skötsel, nya bekämpningsmetoder, konsekvenser för prioritering och planering)

Project plan with subproject descriptions

Topical structure

The research in Triekol III is structured in nine subprojects (see below), each derived from a particular question of importance to preserve and enhance biodiversity when constructing and managing roads and railways in Sweden. Despite linkages between subprojects, they are intended to function as work packages, i.e. each producing scientific publication and recommendations that can be implemented in Swedish Transport Agency´s (STA) steering documents and guidelines, and each with its given budget. Subprojects will as far as possible make use of data available from previous and ongoing monitoring projects, and relate these to the international knowledge level. Some minor subprojects are focused on completing previous studies, where smaller additional research is expected to provide important knowledge.

The project is divided in two major parts: *Animals*, dealing with the impacts on vertebrate population such as wildlife accidents, barrier to movement and noise disturbance, and *Infrastructure habitats*, dealing with the biodiversity directly related to the vegetation, such as plants, insect and other invertebrates, and pollen/nectar resources.

Subprojects and on Animals

1. Wildlife adaptation of existing bridges
2. Level crossings and wildlife warning systems
3. Over- and underpasses for larger wildlife
4. Minor project: Modeling of permeability and mortality effects on wildlife populations
5. Effect of noise measures for birds
6. Minor project: Amphibian passages

Subprojects on Infrastructure habitats

7. Management and construction of road infrastructure habitats for biodiversity
8. Management and construction of rail infrastructure habitats for biodiversity
9. Minor project: Ecological functions of infrastructure habitats

Animals

Introduction

Limiting the risk of wildlife accidents, the number of roadkilled animals and barrier effects from traffic are fundamental for landscape adaptation of transport infrastructure. The present landscape guidelines for STA (TDOK 2015:0323) state that wildlife should have the opportunity to safely pass roads and railways. However, with regard to fauna passages/bridges knowledge is lacking in particular on cost-effectiveness of measures. Wildlife passages are cost driving components in most investment projects, with a potential to affect socio-economic calculations, and in order to make the right decisions cost-effectiveness need to be better known. Wildlife passages are also probably necessary to handle traffic safety long-term.

Research is needed to identify the relative effect of different design attributes and whether there are limit values that must be matched in a minimal design. Of particular economic importance is to identify to what extent safe passage for wildlife can be provided by existing bridges or level crossings, i.e. without new costly over-/underpasses constructed specifically for wildlife. Such knowledge will help developing standardized crossing designs, making trade-offs between number and size/cost of crossings, and between new wildlife passages and retrofitting of existing non-wildlife bridges. Population modeling further support decision making regarding trade-offs in passage and fencing design.

Another environmental impact with strong cost-driving potential in investment projects and landscape adaptation is noise disturbance in natural areas. Traffic noise reaches critical levels in many important bird habitats and may therefore compromize environmental targets, and noise in natural areas are also considered a serious issue for human recreation. While the impact of noise on birds and other wildlife is well proven, cost-effectiveness of noise prevention in natural areas is virtually unknown.

The here proposed subprojects address these topics. In addition, one minor subproject is proposed to wrap up and summarize the results from the monitoring of a number of amphibian passages, as amphibian mitigation is expected to be an important future activity to minimize the impacts of new and existing transport infrastructure.

Subproject 1

Wildlife adaptation of existing bridges

Background: Conventional (non-wildlife) bridges are used by wildlife to various extent, and these bridges could with relatively small efforts be adapted to further facilitate wildlife use. Examples of improvements are:

- screening of traffic noise and visual impacts,
- vegetation or other natural structures that cover and guide animals to the passage,
- feeding stations that attract animals to the passage,
- adapted fencing to funnel animals to the passage,
- daytime illumination in underpasses,
- limiting human disturbance (traffic, pedestrians etc) in and near the passage.

Adaptation of non-wildlife bridges could potentially be a very cost-efficient way to minimize barrier effects compared to construction of new passages particularly for wildlife. However, the effect of these different improvement opportunities are not known, so currently it can only be considered a promising potential, that cannot yet substitute true wildlife passages. Also it is not known to what degree these types of improvements can increase the functionality of true wildlife passages lacking them.

Adaptation of a number of bridges is currently under planning (see below), and these mitigation measures provide an opportunity to learn more about how they can improve wildlife use of conventional bridges. Upcoming road upgrading or construction projects provides further opportunities for wildlife adaptation and, accordingly, for studying the expected increase in wildlife use.

Activities: In this subproject we will monitor wildlife´s use of existing bridges before and after wildlife adaptation. Improvement types tested are dependent on what is most likely to be applied in full scale on bridges, but will as a minimum include screening and vegetation/natural structures. One special option is to use simple temporary screens (dense fabric) particularly for visual purposes, that could easily be mounted/demounted along fences and bridge railings. As far as possible, each improvement type will be studied in separation, with control and test trials on selected pairs of passages (BACI approach). Field methods will include studies of animal movements and behaviour near and through the passages as indexed by a combination of photo traps, sand beds, track stations and snow tracking. Effect sizes are compared with the cost of each improvement type. The results will be published scientifically.

Output: This subproject gives values of the increased efficacy for wildlife of different bridge improvement types. Efficacy is separated between species and categories of animals (age and gender) to put light on population level impacts. The most important outcome is that the results enables cost-efficiency comparisons between different improvement types and with true wildlife passages. In addition, the subproject contributes to the knowledge about wildlife passages on more general levels, e.g.:

- better estimates of wildlife use of conventional bridges (by the studies of un-improved control sites), and
- better knowledge of the relative contribution of different design components in true wildlife passages (such as screening, vegetation etc.).

Study objects/sites: STAs bridge data base (BaTMan) contains hundreds of bridges with dimensions and siting allowing wildlife use, and that also are suitable for wildlife adaptation. The following bridges are candidates for study objects.

1) In the current plan for landscape adaptation (PA023; 2016-2019) – the planned adaptations can be adjusted if motivated by the research (contacts are established with STA environment specialists Annelie Rossander and Frida Kumb):

- Bridge over river Lagan at motorway E4 in Småland (vid rastplats Sjöboda; knr 7-564). Planned adaptation: screens along the motorway, adjusted fencing, widened land passage on one side of river, human recreation (fishing) directed to other side.
- Bridge over minor road at motorway E4 in Småland (knr 7-587). Planned adaptation: screens along the motorway, guiding structures.
- Bridge over minor road at motorway E22 at Gualöv (knr 11-964). Planned adaptation: vegetation around entrance, possibly improved screening along the motorway.
- Bridge over minor road at E6 Hallandsås (knr 11-546). Planned adaptation: screening along the motorway, vegetation around entrance.

2) Proposed improvements at fauna bridges for which wildlife use has previously been monitored (hence before-data are available):

- Reindeer bridge over E4 at Harrioja (Haparanda). Planned improvements: adapted fencing (closing of nearby fence openings), limitation traffic over the bridge.

- Four moose underpasses at national road 31 near Tenhult. Proposed improvement: temporary visual screening along the road.
- Red deer underpass at national road 11 near Vomb. Proposed improvement: temporary visual screening along the road.

3) Part of proposed mitigation measures in ”Pilotprojekt Vilt” (research will be conducted in cooperation with project leader Mattias Olsson):

- Bridge over minor road at road 23/34 at Brokind. Planned adaptation: adapted fencing and cattle grid to guide animals particularly fallow deer.

4) Numerous bridges at motorway E4 between Järna and Linköping for which adaptation can be motivated by the adjacent new highspeed railway Ostlänken (ongoing inquiry by Kajsa Nilsson/Anna Hansson):

- Knr 2-736, 4-506, 4-137, 4-536, 5-884, 2-745, 4-337, 4-588, 5-793, 5-882, 2-1168, 4-386, 4-544, 5-574, 5-647, 2-1163, 4-384, 4-637, 5-535, 5-639, 4-398, 4-378, 4-540, 5-537, 5-646, 4-396, 4-377, 4-539, 5-536, 4-394, 4-341, 4-538, 5-526

Other bridges/sites can be selected for research, depending on where new adaptations will be planned. The research budget assumes that the technical measures as such are financed from other sources (STA investments). The number of adapted bridges available for research may therefore be a limiting factor for this subproject.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Planning and initiation of field studies	2017-2019	90
Field studies	2018-2021	720
Data analysis	2018-2022	150
Project coordination	Continuos	135
Reporting (annual and final)	2019-2022	108
Scientific publication (1-2 manuscripts)	2022	270
Expenses (travel, per diem, equipment)		100
	Sum	**1.573**

Subproject 2

Level crossings and wildlife warning systems

Background: Level crossings (“viltövergångsställen” in Swedish VGU terminology) may provide a cost-efficient alternative to under- and overpasses, even if only for larger species and under certain conditions. The idea with such passages is that the animals should be directed to certain shorter sections of a road, where the drivers are alerted for animals on or near the road. Level crossings combine three main components: i) an opening in the fence, constructed to guide animals over the road, ii) an electronic system for detection of animals near to the road, and iii) a system for alerting drivers of the presence of animals and to reduce vehicle speed. Still not many level crossings are built, and results from available studies are contradictory, so uncertainties remain whether this type of wildlife passage can be made functional at all, at if so to what degree the functionality depend on technical details of the different all three components.

Despite the uncertainties, for economic reasons there is a big interest in constructing level crossings, and if made functional they can be used on many roads with intermediate traffic flow. Therefore, it is crucial that the performance of new level crossings is monitored and that the results are properly analysed and published. The performance of level crossings depend on both animal and human behaviour, and must be measured in terms of both wildlife connectivity and traffic safety.

Activities: In this subproject we will monitor the performance of level crossings in terms of wildlife use and connectivity between road sides, and effect on wildlife accidents and drivers behaviour. Field methods should include studies of animal movements and behaviour near and through the crossing (photo traps, snow tracking), and the effect of driver alert systems on vehicle speed. Effect on wildlife accidents will be studied with a BACI approach on larger geographical scale. Also the technical functionality of the detection and warning systems will be assessed. As far as possible, data should be gathered from (and in cooperation with) monitoring studies conducted within the respective investment project, but in certain cases the field work need to be conducted by and financed within Triekol (see below). Effect sizes will be compared with the investment costs. The results will be published scientifically. In addition, the results will be summarized in a report for practitioners, where also the international knowledge level regarding efficiency of level crossings will be described and recommendations for construction will be given.

Output: This subproject produces values of the efficacy of level crossings in connecting wildlife between roadsides and in decreasing the number of wildlife accident. Efficacy is separated between species and categories of animals (age and gender) to put light on population level impacts. The most important outcome is that the results enables cost-efficiency comparisons between level crossings and over-/underpasses.

Study objects/sites: Few level crossings will be available for study, and accordingly all these are candidates for study objects.

1) Already established:

- At highway E22 Haraldsmåla

2) In the current plan for landscape adaptation (PA023; 2016-2019):

- Two crossings alongs county road 108 north of Svedala (Bökeberg + Sjödiken)
- At highway E22 south of Brömsebro (early planning, unclear)
- At national road 27 Tranemo-Borås

3) Other proposed sites for level crossings (but unclear to what extent these will include warning systems):

- At E45 Högvalta-Bonäs (N of Fagerås)
- Several crossings along E18 Årjäng-Töcksfors and Knöstad-Valnäs
- At national road 42 Koberg
- At national road 56 Dingtuna
- At road E10 between Töre and Kiruna

List of activities and costs

Activity	**Year**	**Budget**

		(kSEK)
Field studies (incl. planning)	2017-2021	600
Data analysis	2018-2021	150
Project coordination and cooperation with external monitoring projects	continuos	135
Reporting (annual and final)	2018-2022	108
Scientific publication (1 manuscript)	2022	135
Expenses (travel, per diem, equipment)		100
	Sum	**1.228**

Subproject 3

Over- and underpasses for larger wildlife

Background: Several over- and underpasses targeted particularly for larger wildlife has been built or are currently in construction in Sweden. These varies in design, for example dimensions, fencing/screening, and vegetation and other habitat components in and around passages. Some design parameters, most notably size, are highly cost driving, and better knowledge of design details is needed to make future constructions more cost-efficient. There is generally a lack of rigid scientific support (also internationally) for the available construction guidelines, and there is an obvious risk that wildlife passages are built too small to fulfil their intended function, or conversely that they are built too large for precautionary reason. In either case, money may be wasted.

Monitoring of wildlife passages is largely neglected in Sweden and abroad, or conducted at a very basic level, not allowing to relate to set targets or making cost-efficiency comparisons. Also monitoring results from different passages cannot be easily compared or scientifically reported. Accordingly opportunities to gain important knowledge are missed. Trafikverket have however now agreed on a standardized monitoring method, that allow the joint analysis of different passages that is necessary to produce new, scientifically founded construction guidelines.

Activities: In this subproject we will monitor wildlife´s use of a number of over- and underpasses and compare performance depending on size and design, and to a degree on siting and landscape type/geographical region. Monitoring method will be similar between passages to facilitate direct comparison. As far as possible, data should be gathered from (and in cooperation with) monitoring studies conducted within the respective investment project, but field work may need to be conducted by and financed within Triekol for selected passages for which performance data is of particular interest but where no monitoring data are already at hand. Field methods should include studies of animal movements and behaviour near and through the crossing (photo traps, snow tracking), following standardized methods described in a STA report[11]. Effect sizes will be compared with the cost of each improvement type. The results will be published scientifically.

Output: This subproject produces values of the efficacy of wildlife over- and underpasses in connecting wildlife between roadsides. Efficacy is separated between species and categories of

[11] https://trafikverket.ineko.se/Files/sv-SE/12125/RelatedFiles/2015_173_ekologisk_uppfoljning_av_planskilda_passager_for_landlevande_daggdjur.pdf

animals (age and gender) to put light on population level impacts. The most important outcome is that the results enables cost-efficiency comparisons between different crossing types and designs, and ideally (together with previous subprojects) to point out the optimal design for a ”standard” wildlife passage.

Study objects/sites: The following wildlife passages are candidates for study objects.

1) Already constructed wildlife passages, with on-going monitoring (research will be conducted in cooperation with project leader Mattias Olsson):

- Large moose underpass at national road 31 near Tenhult.
- Other, minor passages at national road 31 near Tenhult.
- Red deer underpass at national road 11 near Vomb.

2) Already constructed wildlife passages, where monitoring can be conducted and has been strongly requested by STA:s regional environmental experts*:

- Four combined fauna/road overpasses at national road 45 between Kungälv and Trollhättan (*Mats Lindqvist)
- Moose bridge at national road 73 Älby, Nynäshamn (*Kerstin Gustavsson)
- Reindeer/wildlife bridge over Haparandabanan railway at Sangis (*Niklas Kemi/Malin Delvenne)
- Reindeer/wildlife bridge over road E10 at Mertainen (*Katarina Andersson/Malin Delvenne)
- Reindeer bridge over Malmbanan railway at Råtsi (*Katarina Andersson/Malin Delvenne)
- Reindeer bridge over railway at Aitik mine (*Katarina Andersson/Malin Delvenne)

3) Already constructed tunnels, where the roof can be expected to function as wildlife passage, thereby motivating monitoring. Examples are Ullbro and Frösvi tunnels at E18, Jeriko tunnel at E20, Löttinge tunnel at väg 265, but numerous other candidates exists.

4) Wildlife passages in planning and to be constructed during the project period, and where also monitoring is planned (contacts are established with STA environment specialists Annelie Rossander and Thomas Grönlund):

- Fauna underpass under E6 at Hallandsås
- Red deer bridge over motorway E65 at Lemmeströtorp
- Fauna bridge over national road 21 at Ekeberg (between Kristianstad and Hässleholm)
- Fauna passage at road E22 Norra Binga (east Blekinge)
- Two fauna underpasses at road E20 Kristineholm-Bälinge
- Fauna passage at intersection at E20 Tollered-Ingared
- E20 Hova
- Smaller fauna passage under national road 23/34 at Hamra (Åtvidaberg)

Further bridges/sites can be added to the research, depending on where new adaptations will be planned.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Field studies (incl. planning)	2017-2021	700
Data analysis	2018-2022	150
Project coordination and cooperation with external	Continuos	135

monitoring projects		
Reporting (annual and final)	2018-2022	150
Scientific publication (1-3 manuscripts)	2020-2022	270
Expenses (travel, per diem, equipment)		100
	Sum	**1.505**

Subproject 4 (minor)

Modeling of permeability and mortality effects on wildlife populations

Background: A meta-population model that evaluates the effects of infrastructure permeability and traffic mortality on population viability criteria has been developed in the previous Include and SafeRoad projects. The model is a potentially influencial tool to identify critical impacts on populations, and its strength lies in the analysis of the relative effects of mitigation options (fences or passages) that reduce mortality and/or barrier effects. The most recent step in the model development have given new and potentially very important results with regard to the need of fencing for population viability. The model can serve as a decision support tool, by helping infrastructure planners to locate and identify cost-effective measures. If combined with cost-estimates for individual measures, cost-benefit calculations can be employed. So far, the model has only been applied to generalized, simplified landscapes.

Activities: The current model is applied to selected Swedish landscapes, thereby validating the previous results by running the model in real-world landscapes. Digital data on wildlife, road network and landcover are compiled and digital maps developed to provide tabular input into the model. The model will be run with adjusted coding to simulate several different mitigation scenarios. The functionality of the model in real-world mitigation planning will be assessed. The results will be published scientifically.

Output: The model predicts probabilities for local population survival and extinction in dependence to the different mitigation scenarios. If the application proves to be useful to real-world mitigation planning, the results can be used to develop a user-friendly interface that will allow end-users (planners, consultants) to run the model freely to test different scenarios.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Computer modelling	2017-2019	200
Writing of scientific manuscript	2020-2021	135
Writing of practitioners report	2020-2021	30
	Sum	**365**

Subproject 5

Effect of noise measures for birds

Background: The impacts of noise on birdlife are well proven, and dose-effect relationships and critical levels are described in scientific literature. In a previous Triekol-project, a method was developed that points out road stretches where the traffic noise exceeds critical levels and impacts species of conservation concern, and accordingly where noise prevention is needed. While a number of measures to reduce noise for people are used (e.g. screens, berms, adapted paving, traffic calming), their performance for birds have not been tested. Mitigating traffic noise in important bird areas is expected to add significantly to the cost of road/railway construction and maintenance. To enable cost-effectiveness analyses of noise reduction in important bird areas, the reduction effect of different measures need to better known, and combined with available cost estimates for the different types of measures. Acoustic ecology is an emerging field, and to our knowledge, similar studies as these here proposed has not been conducted, so the results are expected to gain international attention.

Activities: In this subproject we will study the effects of noise mitigation along existing road/railway stretches near important bird habitats. Birds are censused in areas where noise screens are installed along an impacting road/railway and in comparable but unmitigated reference habitats, both before and after mitigation (i.e. BACI design).

In addition to these new studies, available data from the previous studies on birds along the Botniabanan railway will be compiled, (re-)analyzed and published scientifically, to produce a final insight in the main results regarding the railway´s impact on birds. These studies have been following a BACI setup (at least in part), but no wrapping-up of many years of studies has been funded. The publication will also contain an overview of the international knowledge level regarding the impact of railway disturbance on birds (particularly wetland birds).

Output: This subproject gives an insight in to what degree available noise mitigation measures are at all functional for birdlife. In addition it produces more insight into the impacts of railways on birds, where the knowledge today is particularly meagre.

Study objects/sites:

- Västkustbanan railway near Getterön N2000 area; potential noise mitigation along existing railway (contact established with STA environment specialist Katinka Klingberg)
- Agricultural fields around Botniabanan railway and Umeå; publication of available data from several studies (research will be conducted in cooperation with project leader Adriaan de Jong at SLU)

Further objects/sites can be added to the research, if noise mitigation will be conducted in other important bird habitat during the study period. The present budget however only covers one site of new field studies.

A secondary option for study sites are areas where noise mitigation is conducted for people/housing areas but the measures also impacts bird habitats such as parks or other green areas.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Field studies (incl. planning)	2017-2021	450

Data analysis of new field studies	2018-2022	120
Compilation and analysis of old data (Botniabanan)	2018-2019	120
Project coordination	Continuous	30
Scientific publication (2-3 manuscripts)	2018-2022	360
Expenses (travel, per diem, equipment)		100
	Summa	**1180**

Subproject 6 (minor)

Amphibian passages

Background: Tunnels in combination with guiding fences are standard mitigation measures for roads near amphibian habitats, designed to lower the number of road-killed amphibians while still allowing them to pass the road. However, the monitoring of such measures often fails to answer whether the both goals (lowered roadkill and barrier effect) are reached, and accordingly available design guidelines for amphibian tunnels and guiding fences stand on a weak foundation.

In the last years, three amphibian mitigation sites near Stockholm were monitored, in part as BACI-studies of roadkills and animal movements. The monitoring derived valuable results regarding design attributes. However, the monitoring project budgets did not allow full data analysis nor publication of the results to a broader audience.

Activities: This subproject aims at publishing the results from the monitoring of the three amphibian mitigation sites. Hence, in this subproject available data will be (re-)analyzed and published scientifically. In addition, the results will be summarized in a report for practitioners, where also the international knowledge level regarding efficiency of amphibian mitigation will be described and recommendations for construction will be given (the latter will be guided by a European overview soon to be published).

Output: The subproject derives recommendations for construction design of amphibian mitigation measures. Recommendations can be implemented in available guidelines such as VGU and fact sheets (Temablad Natur).

Study objects/sites:

- Skeppdalsström (Värmdö) – BACI study, STA:s project
- Kyrksjölöten (Bromma) – BACI study, Stockholm municipalitys project
- Skårbydammen (Botkyrka) – BA study, STA:s project

Further objects/sites can be added to the research, if monitoring have been conducted deriving comparable data (search of such cases is ongoing).

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Data (re-)analysis	2018	20
Writing of scientific manuscript	2018-2019	100

Writing of practitioners report	2018-2019	30
	Sum	**150**

Infrastructure habitats (IH)

Introduction

A growing body of research has shown that infrastructure habitats (IH) are of critical importance for a number of red-listed species[12], and that collaboration between road/rail holders and nature conservation can significantly improve the conservation status of species[13]. IH has also been suggested to contribute in several other ways to important conservation issues, for example by providing nectar/pollen resources and dispersal corridors in the landscape.

There are, however, several critical knowledge gaps regarding which ecological functions and biodiversity values of IH to prioritize, and how these values can be maintained and enhanced by infrastructure maintenance. The need for better knowledge about IH management is emphasized by preliminary results of STA:s monitoring of species-rich road and rail habitats, showing reduced biodiversity values over 1-2 decades. Below we describe the need for practically applicable knowledge in more detail.

During earlier phases of Triekol, researchers and STA practitioners have together identified a number of particularly critical knowledge gaps regarding road and rail IH, some of which were addressed in Triekol 1-2, some of which remain to be dealt with. In general, for the management of IH we need knowledge of specific methods for maintenance and creation, but in order to develop this knowledge, we also need more basic knowledge of the ecology of different IH and of the values they contribute with in the landscape. The basic questions and the more applied ones can be regarded as links in a knowledge chain, in which different pieces of knowledge are attached to each other.

In the chain below, links 1-2 are about the values and functions of IH in the landscape, 3-5 about the management-related ecology of IH, and 6-8 about implementation in field practice and organisational planning.

1. Which are the most important ecological values from the IH, such as habitat for threatened species, nectar resource for butterflies, and dispersal corridors? How can such values contribute to biodiversity conservation and other societal goals, such as cultural heritage and ecosystem services?
2. How important are different types of values in a landscape perspective, e.g., for ecosystem functionality, for priority conservation problems, for other societal goals for biodiversity and ecosystem services? This also includes the possibility that IH act as ecological traps in a landscape perspective.
3. Which are the ecological key factors responsible for forming the values in different IH, and how can IH be classified into groups based on values and ecology (ecological key factors)? Examples of key factors are different maintenance activities, soil, sun exposure, vegetation dynamics/successional stage, and biogeographic region.
4. Which are the main threats to different values in IH ("key threats"), such as invasive species?
5. How are the key factors related to IH management, that is, how can the key factors of each group of IH be achieved (and the threats be avoided) by applying the correct package of biodiversity management activities in road and rail maintenance and construction?

[12] See references in Helldin et al. (2015) Nature Conservation 11:143–158.

[13] http://media.triekol.se/2013/10/Triekol-CBM-skrift-80.pdf

6. How can the groups of IH, each requiring different packages of management activities, be identified in practice, based on identification criteria?
7. How can identification, planning, and performance of management activities be implemented in the organisation of the STA?
8. How can the values of IH in a landscape perspective be enhanced by landscape planning across administrative societal sectors?

During 2016, this knowledge chain, and a gross list of research projects addressing all its links, have been discussed in a group of researchers (at the Swedish Agricultural University and Calluna) and practitioners (the STA Biotope group), and with input from the Triekol III scientific advisory panel, in order to design the most practically and scientifically relevant research for the given budget. This process has resulted in subprojects that will focus on link 3-6, i.e. on how to preserve, improve, and construct biodiversity-rich IH. It also makes a brief analysis of link 1, the biodiversity values of IH. The main motives for the choice of links is the urgent need for a refined "toolbox" for preserving and enhancing biodiversity values in road and rail maintenance and construction, and the great opportunity of studying ongoing and evaluating past maintenance and construction activities. Furthermore, activities, which are part of the normal maintenance and construction, have a large potential to contribute to biodiversity conservation at no or little extra cost.

In link 4, we will not specifically study invasive species as a threat in road infrastructure, because this question is too large to be fitted in the available budget.

Subproject 7

Management and construction of road infrastructure habitats for biodiversity

Background: Considerable efforts are put into monitoring and management of so-called species-rich road verges (SRV). The SRV denotes a well-developed concept in Sweden, in which certain road sides are designated as SRV based on flora composition, and managed with certain management activities. Monitoring of SRV however points at declining species richness in many areas, in spite of presumably adapted management.

In order to enable proper measures for maintaining and forming of biodiversity-rich road IH we need better knowledge about the ecology and threats of different SRV in relation to different management methods. With such knowledge we can evaluate the limitations of the present management and suggest changes.

Activities: This subproject will use field data to analyse which environmental conditions, including management, that constitute ecological key factors for different biodiversity values (e.g. species groups) in road IH. The ongoing management will be regarded a large-scale experiment and evaluated in order to discern effects of different maintenance and construction activities on those key factors. A number of modifications of management and new management methods will be tested as new experiments.

The subproject has two aims: (A) to analyse why some, but not other, road verges have high biodiversity values, and why some have remained species-rich over time while others have become deteriorated; (B) to analyse how biodiversity-rich road habitats can be assigned to different habitats in terms of species composition and ecology, and how habitats can be grouped according to their needs for biodiversity management activities.

Data for both A and B will be derived from STA's databases on SRV, and from new field surveys, in which we compare (1) SRV and ordinary road verges (or road verges along a gradient in species richness), (2) SRV that have lost *vs.* not lost their values over time (10+ years), and (3) SRV that have been subject to different management activities (including activities specifically aiming at biodiversity). These studies (1-3) can be regarded a use of the ongoing STA activities as a large "living" field experiment. In addition, a number of particularly important management activities will be identified early in the subproject and tested in specific experiments throughout the project period. Vegetation data will be sampled, but in order to obtain results faster than the slow vegetation responses can provide, we will also study some indicator species in a life-cycle perspective. Some SRV habitats are important for different insect groups, for example bees, weevils, and leaf beetles. Data on some insects of conservation concern will be collected during the field surveys, together with data on their habitats (in Swedish *livsmiljö*), such as host plants, nesting sites, and pollen/nectar resources.

Data will be analysed in order to identify which environmental variables that constitute ecological key factors for different biodiversity-rich IH. Examples of environmental variables are management practices (current and previous), soil, slope, sun exposure, succession, surrounding species pool, and occurrence of invasive species. We will use both quantitative and qualitative approaches, using, for example, species-habitat models developed at CBM[14]. Habitat identification and grouping will be done using structured models based on a combination of functional species groups, ecological values, ecological processes (including management), and basic conditions. The results will be published scientifically.

Output:

- Knowledge about which environmental variables that account for SRV, and for the variety of SRV (ecological key factors).
- Knowledge about how such ecological key factors can be obtained by management activities.
- Knowledge about how different types of SRV can be identified in the field, and of which packages of management activities that are required for different groups of SRV.

In total, this output will provide a necessary, but today largely lacking, knowledge base and cost-efficient toolbox for planning, prioritizing, performance, and monitoring, to be used in activities for maintenance and construction of IH. The results will significantly help in halting the loss of SRV at the landscape level, both through the preservation of existing SRV, and through better use of the potentials for creating SRV at road construction and rebuilding. From a theoretical perspective, the results will considerably enhance the knowledge of the ecology of IH and their species.

Study areas: The subproject will be performed in two larger geographic areas and four smaller areas with special values and ecological conditions. The larger areas are south-western Sweden (the STA Region west having 22 management areas; DO:s) and eastern Sweden (including some DO:s in STA Region East and some in Region Stockholm). The smaller areas are DO Öland (STA region South), and limestone-rich areas in DO Rättvik, DO Krokom, and DO Sveg (all in STA Region Mitt). All study areas are rich in known SRV of several types, such as limestone types and sand types, occurring in both agricultural and forest landscapes. In both areas, IH are important for a number of red-listed species and other species of conservation concern. Several DO:s in both areas provide a potential for comparing SRV that have lost their values with those that have not, and to link differences to management activities and other environmental conditions. A large number of SRV will be evaluated using both STA:s own data and new field data, in order to identify ecological key factors for habitat quality in different types of SRV.

[14] Swedish Biodiversity Centre

There is also a great potential for evaluating biodiversity effects of different recent and ongoing construction and rebuilding activities. On initiative of the STA ecologists, some biodiversity inventories have been performed in connection with construction, re-building, and maintenance, and there have also been some experimental establishment of new vegetation. Such sites provide an opportunity for evaluating effects of specific biodiversity-related management activities over time. Initially in the project, potential study sites with such activities will be searched for, be evaluated and the most suitable ones be chosen. For example, we will pay special attention to the following, promising sites:

- Skövde. New road stretches with large slopes (and adjacent stretches that have not been rebuilt). Experimental sowing of species-rich vegetation, and transplantation of particular species, are initiated.
- The Kattarp area, Halland. New road (national road 15) since 10-15 yrs. Bare sand and thin re-spread top soil in north and south facing slopes. Experimental sowing on different substrates initiated, with some vegetation data.
- Mellbystrand. Large area mown with agricultural equipment. May be suitable for experiments on mowing techniques and measures for vegetation succession.
- The transversal main roads on Öland. Some parts have been rebuilt, and it is also possible to study effects of top soil removal.
- The Åminnen area, Dalsland. Experiments have been performed with leaving islands of vegetation at top soil removal.
- Långeskogen, Filipstad. A coming case of how to move and favour red-listed species (Gentianella) when rebuilding.
- Glimminge, Uddevalla. Various measures for improving species-richness of road slopes: seeding, planting, removal of nutrient rich soil, and root pulling of shrubs.
- Roasjö, Borås. Various measures for preserving SRV when rebuilding.
- Osdal, Borås. Road through a sandy area at an old military training field; hotspot for plants and wild bees. Some measures for creating sand habitats have been performed, some areas are still to be vegetated.
- Road Uppsala-Östhammar. Rebuilt and new road (recent and ongoing), through a mosaic of soil and landscape types (of which sandy types and lime-rich types are particularly interesting), and adjacent to known SRV.
- Motorway E4 North of Uppsala, following the Uppsala esker. Large sandy slopes and several more recent soil disturbances, adjacent to areas with species-rich vegetation and high values for sand insects.
- Stingtorpet-Tärnsjö, Heby. Ongoing experiments with vegetation establishment, including re-spreading of top soil.
- Söderön, Östhammar. Surveys of host plants for redlisted insects have been performed, which can be linked to timing of mowing.
- Funäsdalen-Fjällnäs. Surveys of sub-alpine meadow plants have been performed, which can be linked to timing of mowing.

In DO Norra Roslagen (Region Stockholm), there is detailed information on biodiversity in grasslands in the surrounding landscape, which can be compared with IH in later landscape analyses.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Fieldwork setup. Choice of relevant environmental variables and methods for field sampling, and choice of study areas.	2017-2018	250
Sampling of field data on vegetation, habitat elements, and environmental conditions	2018-2020	650
Collecting of complementary information on past (at least recent) management, road age etc.	2017-2019	125
Experiment setup: Identification of methods to test and design of experiments and methods for monitoring	2018-2019	250
Experiments and data sampling	2019-2022	800
Data analysis: Identification of key factors for species richness and threatened species	2018-2020	300
Data analysis: Management experiments	2020-2022	250
Data analysis: Habitat classification	2019-2022	250
Scientific publication (4-5 manuscripts)	2020-2022	600
Reporting, coordination	continuous	125
Conference travels and fees		100
	Sum	**3.700**

Subproject 8

Management and construction of rail infrastructure habitats for biodiversity

Background: Recently, it has been shown that many parts of the railway system, in particular at stations, are surprisingly species-rich and constitute important refugias for threatened insects of several groups. As for SRV there are indications of declining biodiversity values also in railway IH. In order to enable proper measures for maintaining and forming of biodiversity-rich rail IH we need better knowledge about the ecology and threats of different IH in relation to different management methods. With such knowledge we can evaluate the limitations of the present management and suggest changes.

Activities: This subproject will use field data to analyse which environmental conditions, including management, that constitute ecological key factors for different biodiversity values (e.g. species groups) in rail IH. The ongoing management will be regarded a large-scale experiment and evaluated in order to discern effects of different maintenance and construction activities on those key factors. A number of modifications of management and new management methods will be tested as new experiments.

The subproject aims at understanding the ecology of the railway station habitats, in particular the relationships between occurrences of species of conservation concern, the micro-environmental variation within the station, and the ongoing activities for maintenance (e.g. ground vegetation control and shrub clearing) and construction (which cause soil disturbance and new vegetation successional stages).

We will investigate which environmental factors (related to management, substrate etc.) that account for the biodiversity values of rail IH, known from earlier surveys by STA. Since rail IH can be considered ruderal, highly unstable, habitats, vegetation analysis is not appropriate. Instead, we will use a species based approach, in which characteristic or threatened species, or species with key habitat or community functions, will be analysed with respect to their specific micro-environment, which can be assumed to reflect their environmental needs and threats. Vascular plants, insects, and some cryptogams have been subject to earlier STA inventories, and will be analysed in this sub-project. The micro-environment is characterised by ground substrate, successional stage, disturbance regimes, exposure etc, which implies that the overall habitat may be characterized by certain dynamics. A model for structured data collection of species' microhabitats has been developed earlier and generated some information. The model will be used to collect complementary field data on species microhabitats. In order to get as strong as possible connection to management, sites which have been subject to known management activities, including ongoing experiments in Triekol I-II, will be evaluated specifically. Such activities include alternative measures for shrub clearing (pulling instead of cutting), ground vegetation control, and soil handling. Activities also include measures for control of invasive species.

Data on species-microhabitat relationships will be derived from earlier STA inventories, and from new field surveys, in which we use earlier inventories to locate the species. Ecological effects of recent and ongoing management activities (including earlier experimental ones) will be analysed using earlier monitoring data combined with more thorough monitoring during the project period. These studies can be regarded a use of the ongoing STA activities as a large "living" field experiment. In addition, a number of particularly important management activities will be identified early in the subproject and tested in specific experiments throughout the project period.

Data will be analysed in order to identify which environmental variables that constitute ecological key factors for different groups of species of conservation concern in rail IH, and how these variables are formed by different combinations of activities for maintenance and construction. We will use methods for combined qualitative-quantitative cluster analysis and species-habitat models developed at CBM. The results will be published scientifically.

Output:

- Knowledge about which ecological conditions and processes (ecological key factors) that account for species of conservation concern, species richness, and important biological functions of rail IH.
- Knowledge about how such ecological key factors can be obtained by management activities.

In total, these results will provide a necessary, but today largely lacking, knowledge base and a cost-efficient toolbox for planning, prioritizing, performance, and monitoring, to be used in activities for maintenance and construction of rail IH. The results will significantly contribute to preserving and developing the biodiversity values of rail IH at maintenance and construction.

Study areas: Biodiversity values in broad sense are known for a large number of stations, through STA:s own inventories during the last years[15], and the data that have been used to classify the stations according to degree of conservation concern (three classes). Inventories are largely spatially explicit, for example in terms of species occurrences.

Management activities for biodiversity have been performed on 27 stations, and monitoring of the activities has been launched, which can be continued within the subproject. On five of these stations, more elaborate experiments and effect monitoring have been performed (Byvalla, Jordbro, St. Tuna, Gustafs, and Avesta-Krylbo). Altogether, this background information and planned activities provide an excellent opportunity to evaluate ongoing and previous activities, and to design new management experiments to follow from the beginning.

Beginning in 2017, a new set of stations will be subject to management activities (ca. 15 stations, tentatively). Initially in the project, suitable study sites will be selected based on existing information combined with some additional field information. We will combine in-depth studies of the ecological conditions and variability at five stations, with studies of specific microhabitats and management methods at a larger number of stations (c. 10).

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Fieldwork setup. Choice of relevant environmental variables and methods for field sampling, and choice of study areas.	2017-2018	125
Sampling of field data on vegetation, habitat elements, and environmental conditions	2018-2019	300
Collecting of complementary information on past (at least recent) management, road age etc.	2017-2019	80
Experiment setup: Identification of methods to test and design of experiments and methods for monitoring	2018-2019	125
Experiments and data sampling	2019-2021	500
Data analysis: Identification of key factors for species richness and threatened species	2018-2020	250
Data analysis: Management experiments	2019-2022	250
Scientific publication (2 manuscripts)	2020-2022	250
Reporting, coordination	continuous	See sub-proj 7
Conference travels and fees		See sub-proj 7
	Sum	**1.880**

15 http://www.trafikverket.se/contentassets/bee7e899e67b44d78612ed2594d80359/biologisk_mangfald_pa_sparen.pdf

Subproject 9

Ecological functions of infrastructure habitats

Background: The work with SRV has so far largely focused on SRV as a type of meadow vegetation. The importance of IH for red-listed species has more recently been highlighted[16]. The planned research in road and rail IH (subprojects 7 and 8) will no doubt show that IH contribute to biodiversity conservation in more ways than have so far been discussed. An overview of the different functions of IH is important for setting up of conservation goals for different types of IH, and thereby for designing management activities that give the best possible biodiversity effects.

Activities: This subproject uses information from subprojects 7 and 8 on road and rail IH to qualitatively identify different ecological functions of IH, i.e., different ways by which IH can contribute to a better biodiversity conservation status in the landscape. The result will be published as a conceptual scientific paper.

Output: Highlighting of the variety of biodiversity values of IH, as a conceptual base for planning of conservation and management, and for future, more thorough, analysis. Conservation planning of IH will be more efficient with a more diverse target-setting. For example, the value of some types of road verges may not be species richness (SRV), but rather their function as nectar/pollen resource, or as dispersal habitat. Knowledge about such functions will influence the choice of conservation target for the habitat, and of management strategy.

List of activities and costs

Activity	**Year**	**Budget (kSEK)**
Analysis of information and scientific publication (1 manuscript)	2020	180
	Sum	**180**

16 http://media.triekol.se/2013/10/Triekol-CBM-skrift-31.pdf