IENE 2018

International Conference

Crossing borders for a greener and sustainable transport infrastructure

ABSTRACT BOOK

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"Crossing borders for a greener and sustainable transport infrastructure"

The Organization Committee chose for "Crossing borders…" as a central theme of IENE 2018, because this is what habitat defragmentation is all about, both literally and figuratively. It is impossible to establish and maintain sustainable populations of flora and fauna without crossing any borders, particularly where these populations are divided by transport infrastructure.

Cross-sectoral cooperation and collaboration between experts of different disciplines is also essential in this respect and an example of crossing borders. This often means leaving behind one's own familiar way of working and thinking. The IENE 2018 International Conference aims to take a step in this direction by giving more attention to ecological engineering and providing architects, engineers, contractors, and designers the opportunity to present their vision and expertise.

It all comes down to connectivity. The IENE international conferences are a perfect platform to get connected, to exchange the current state of research, knowledge and practical experience between the sectors of environment and transport, between scientists and practitioners to gain new insights and learn new ways of working.

In a world that is changing faster than ever, using a platform like the IENE international conferences is only natural. By connecting research and practical experiences we are better able to prevent, mitigate and compensate the impacts of the fast growing networks of transport infrastructure, and in such a way that it can contribute to halt the decline of biodiversity worldwide. Economics and ecology should not paralyze each other, but find their synergy.

As the chairmen of the IENE Steering Committee, IENE 2018 Organization Committee and IENE 2018 Program Committee we are very proud with the state of the art input of so many professionals working on transportation ecology from all over the world. We are happy to welcome participants from literally all corners of the globe; from Canada to Australia and from Brazil to Japan.

It is hopeful to see so many borders are already crossed so far. We sincerely hope that you will have an inspiring time during the IENE 2018 International Conference and that you will add lots of people to both your professional and personal network. Not only people in your own field of expertise but especially professionals in other disciplines who can provide you with new insights that will help you make your own work more effective.

Be inspired, be connected!
Enjoy IENE 2018!

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Edgar van der Grift
Wageningen University and Research
Chair Program Committee

Anders Sjölund
Swedish Transport Administration
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PART 1
ABSTRACTS
KEYNOTES

Connecting the dots to re-connect ourselves

Ignace Schops

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For thousands of years, we have depended on the vital services of the ecosystems of our planet. Since we entered the era of the Anthropocene our increasing ecological footprint is causing severe problems. The effects of Climate Change and loos of Biodiversity are daily reminders that the diversity and the variety of life are falling apart. We are losing our comfort zone! So we need to change the system. We need to reflect, rethink and harmonise our behaviour and our relationship with the planetary boundaries and translate them into a language everybody can understand to join the essential change. Following nature's design. In a densely populated region like North-western Europe, we face many problems due to fragmentation. We lack real connectivity: for men as well as for species. The way we harmonise transportation and nature can direct us towards a sustainable future. Is it possible to connect the dots and re-connect us? Yes, we can!

The impact of infrastructure lighting: Spectrum dependent effects on behaviour and density of species in natural habitat

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The presence of light along infrastructure is a significant challenge for ecosystems. The illumination of roads has shown a dramatic increase over the last decades and will continue to increase. Evidence showing the negative impact of artificial light at night on species and ecosystems is accumulating: effects vary from direct mortality to the disruption of species' natural behaviour. The impact of light may be particularly severe for insects, rodents, bats, and amphibians as these species strongly depend on darkness. Illumination along roads potentially amplifies effects as linear lighting structures may block corridors in the landscape. Until recently, knowledge on the impact of light on species and ecosystems was limited to the short-term effects, often observed near existing illumination. In addition, little information was available on the impact of different light spectra. Such knowledge is particularly necessary as the current transition from traditional light sources to LED lighting allows for custom spectral adaptation, which opens up the possibility to mitigate the impact of light by colour. In a collective effort to assess the long-term impact of different light colours, we have set up several experimental studies including a unique long-term monitoring project. We experiment with illuminating a natural forest edge habitat with white, green (bluer with less red) and red (with more red and less blue) light at eight different locations in the Netherlands. The setup is a lifelike representation of countryside road illumination, with the intensity of the three spectra normalized to lux. Therefore, it is equally bright for the human eye. During six consecutive years, the presence of birds, bats, mice, other mammals, insects, and plants has been monitored according to standardised protocols; in a citizen science approach combined with highly automated data collection systems. In parallel, in-depth studies were done both in the field and in the lab. Our results show a substantial variation in responses of species and species groups to the presence of artificial light. Birds show strong individual responses, with no detectable density effects over several years. Bats show strong responses to light: common species directly react with a significant increase in foraging activity in white and green light. This response is significantly dependent on insect density around lamps with these colours. Less frequent, forest-dwelling bats respond with an apparent decrease in activity around white and green light, but not red light. Wood mice and mustelid species are strongly affected, irrespective of light colour, and other mammal species show various responses. Insects are strongly affected. However, we only observed consequences on local moth populations after three years of exposure to light at night, illustrating the importance of long-term measurements. Our results are the first available on the impact of light on many species, and the first for most species on the effects of different spectra. Generally, the outcome indicates a reduced impact of red light compared with white and green light. The use of red light, or light with a low colour temperature – alongside with other mitigating measures – is preferable when illuminating infrastructure in or near sensitive ecosystems.

Through the lens of time: Long-term research integrating behavior, landscape ecology and conservation along the Trans-Canada Highway

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Canada's Rocky Mountain front harbours the richest diversity of large mammals remaining in North America. This landscape is among the continent's last remaining undisturbed natural areas and provides a critical trans-boundary linkage with the United States. Maintaining landscape connectivity throughout the eco-region has been a fundamental conservation strategy. Regional scale connectivity is the primary objective. However, securing local-scale connections across highways are equally important and necessary for landscape connectivity to be achieved. Banff National Park and its environs represent one of the best testing sites of innovative highway mitigation in the world. The Trans-Canada Highway (TCH) bisects Banff and Yoho National Parks and has been identified as a significant landscape stressor. Beginning in 1982, Banff National Park embarked on a phased-mitigation program that would span 30 years and result in 44 crossing structures built on 82 km of highway bisecting a UNESCO World Heritage Site. From 1996 to 2014, I directed long-term research assessing the impact of highways and performance of mitigation measures designed to reduce fragmentation of wildlife populations and increase landscape connectivity. Our research evolved from the fundamental questions of, 'do wildlife use the crossing structures and what attributes facilitate passage?'. And, 'do the measures reduce road-related mortality of wildlife?'. Our non-invasive genetic approach to whether the Banff crossings have restored demographic and genetic connectivity was a logical and necessary next step. From that work, we demonstrated that crossings are capable of restoring movements, gene flow, and demographic connectivity. Thus, they are functional at a higher ecosystem level. Recently, we identified a fundamental mechanism of demographic and genetic connectivity; that is, how to move breeding females across road barriers. By ensuring that key ecological processes are connected, Banff's highway mitigation is arguably one of Canada's greatest conservation success stories. The Banff mitigation has become recognized as a model for transportation planning. The overpasses inspired the ARC International Wildlife Crossing Design Competition. They are a model of what can be done and what works. Therefore, they continue to motivate and inspire other highway projects in the Americas and throughout the world.

PART 2
ABSTRACTS
FULL PRESENTATIONS

MJPO: The founding and future of a national defragmentation programme

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In the past few decades, the construction of roads, waterways, and railways has left the natural areas in the Netherlands more or less fragmented. Wildlife has increasingly become trapped in unnaturally small habitats. In 2004, a national defragmentation programme was founded to reconnect natural areas that were fragmented by the leading networks of roads, railways, and canals. This programme, also called MJPO (abbreviated from Dutch: MeerJarenProgramma Ontsnippering), will take care of defragmenting nature by installing structures such as ecoducts, ecoculverts, wildlife tunnels, and banks along existing infra-structures that are easy to pass for wildlife. These structures allow safe crossing for wild boars, otters, deer, badgers, salamanders, frogs, and even bats. These efforts will expand the habitat of wildlife while increasing their access to food and shelter, and improve their chances of finding suitable mates. At the same time, these structures will reduce the number of wildlife casualties due to traffic movement or because of drowning. Rijkswaterstaat and ProRail, the Directorate-Generals for Public Works and Water Management and Railways, are in charge of the Multi-Year Programme for Defragmentation. This was instructed by the Central Govern-ment and was approved under the auspices of the provincial authorities. The programme delivers a significant contribution to the Netherlands Nature Network, the Dutch network of current and new wildlife conservation plans. At the launch of the Multi-Year Programme for Defragmentation in 2004, the locations in need of defragmentation were identified. The bulk of the total number of 178 problem areas has been resolved in recent years by installing a variety of wildlife crossings and structures. In total, more than 550 structures throughout the country have been completed. Many of these structures already have been intensively used by wildlife. After almost 15 years, the defragmentation programme is about to finish. This presentation will not be about the contribution of all those structures to Dutch wildlife. This presentation will demonstrate the organisational successes and risks that come up when founding, managing and executing a massive programme such as the MJPO and its future. The presentation will focus on the following topics: (1) A brief history: setting up the program and finding funds; (2) Dealing with political changes and parliamentary as well as media attention; (3) Success factors and risks of program management; (4) The start of a network: cooperation between the government, universities, and contractors. Therefore, this presentation will be interesting for participants working for governmental organisations, responsible for the management of road, railway, and canal networks. Moreover, the last topic will focus on the so-called Golden Triangle of the government, commercial parties, and scientific institutions. The end of the MJPO program will be a start of a network. This is a network where the Golden Triangle affiliated with the topic of defragmentation will continue to meet and discuss the realisation and maintenance of defragmentation measures, knowledge development, and gaining public support.

Monitoring the progress of execution of the Dutch National Defragmentation Program within the Dutch railways: A multi-annual analysis of the amount of planned, changed and laid out measures

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ProRail, the Dutch railroad authority, has been involved in the Dutch National Defragmentation Program (MJPO) since the start. It is unique for a railroad authority to be so intimately involved in this type of initiative. Railroad agencies primarily focus on technical systems; ecological issues are in general not something they are familiar with. Because the defragmentation program will be finished this year, it is interesting to see what it has done for ProRail: with which task have we started within ProRail and how did it develop? What are the causes of these changes? In this broad analysis, we analyse the number of measures we started with. We also examine the amount of measures we ended with. We started with 77 designated bottleneck-locations, meaning locations where the railroad infrastructure splits existing natural areas in two. Within these bottleneck-locations, 145 measures were programmed. These measures vary: from big eco-ducts or underpasses to small eco-culverts or new walking ledges on existing watercourse underpasses. In the end, 116 will be carried out, solving or partially solving 69 of the 77 bottleneck-locations. Especially within the range of the small measures, we discovered most locations where it was impossible to build the intended fauna-passage. This meant reducing the cross-section of the passage or even the total non-execution of the project on that location. The most critical technical reason was, for example, the lack of space needed beneath the railroad tracks and above the local (ground)water levels. This issue was mainly foreseen for the lower (wet) areas in the Netherlands but also appeared elsewhere. Local groundwater levels vary enormously. Additionally, the presence of objects in the subsoil made building eco-culverts difficult. A non-technical reason, for example, is the absence of permission from private landowners and their essential cooperation. A reason that applies to both large and small measures is that promised (co-)financing is sometimes withdrawn.

Many roads to cross - Evaluating the economic costs and ecological benefits of the habitat defragmentation programme for Dutch infrastructure

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In this paper, we evaluate the Dutch habitat defragmentation programme (MJPO). In the MJPO programme, 300 million Euro was spent in the period 2004-2018 to make various roads easier to cross by animals. MJPO is a nation-wide programme in which the central and provincial governments work together with municipalities, water boards and nature conservation organisations to resolve bottlenecks between the existing national infrastructure and the main ecological network. In this paper, we analyse social costs and benefits of the programme using the method of Multi-Criteria Cost-Benefit Analysis. In our analysis, the focus is on economic and monetary costs of the different defragmentation measures around the 178 bottlenecks on the one hand and developing a standardised method for the measurement of biodiversity benefits on the other. Strengthening biodiversity is the primary goal of the MJPO, but biodiversity impacts are notoriously difficult to measure and value. To make progress on the measurement of biodiversity effects in this study of the defragmentation measures, we used a triangulation approach. Via various methods involving ecological model calculations, ecological expert estimations and detailed database-supported case studies, we measure and assess changes in the quality of nature areas due to defragmentation efforts. This multimethod approach assures a rich and reliable assessment of biodiversity effects at the defragmentation areas, but it also requires an analytical focal point. Therefore we use the output from the triangulation as input for the so-called T-EQA calculator, a software tool in which changes in biodiversity are brought together and calculated in a systematically structured way. This software application, developed by The University of Groningen, attempts to make calculations of changes in the quality of nature areas, those made by experts or external models, more simple and standardised for practice. The research will show how much biodiversity gains have been achieved for how many economic costs. It will specify which biodiversity gains, i.e. which species and ecosystems, and what economic costs different defragmentation measures have. We will distinguish between ecoducts, viaducts with shared wildlife use, and large and small wildlife tunnels. To interpret the outcomes of this research, a comparison will be made with existing policy studies that also have studied biodiversity effects. To what extent do defragmentation measures weigh up against policy alternatives such as financing nature restoration and increasing natural areas? The above may lead to new insights and advancements in the field of greener transport infrastructure and nature policy evaluations. Especially concerning which defragmentation measures are more cost-effective. Both the evaluation method and the T-EQA calculator will be made available online.

Restoring biodiversity and tackling defragmentation in the Province of Noord-Brabant

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In The Netherlands, nature policy is virtually entirely delegated to regional authorities (i.e., provinces). These days, the provincial authorities are altogether responsible for restoring biodiversity. This has been formalised in new legislation (Wet Natuurbescherming) in effect since January 1st, 2017. There are approximately 1,100 threatened species recognised in the Province of Noord-Brabant. It is a tremendous challenge to provide all these species with suitable habitats to let them survive. To achieve this goal the Province of Noord-Brabant developed a three-way strategy: (1) Defining and developing a nature network in Noord-Brabant, which is part of the national nature network; (2) Restoring threatened species by taking measures for their habitats in the provincial nature network; (3) Restoring threatened species of rural areas by stimulating farmers to take adequate measures for protecting these species. The provincial nature network is around 1,300 km^2 of which 100 km^2 is still agricultural land that will be transformed into nature. The network includes natural areas connected by ecological zones. However, half of these zones need to be remodelled. The parts of the provincial network that are crucial for restoring the habitats of threatened species have been recognised. Virtually, these areas have been drained of water in the past, and they suffer from a deposition of nitrogen compounds emanating from farms and traffic. Species on the brink of extinction often do not produce any offspring because of genetic depletion. Around 2,600 measures have to be taken in these areas to solve the identified problems. About 90 threatened species occur in rural areas of Noord-Brabant. Many birds in fields and meadows are on this list such as black-tailed godwit, meadowlark, and grey partridge. In Noord-Brabant's best areas for these species, farmers are entitled to financial assistance to customise land use to benefit certain species. For instance, one of the measures farmers can choose from is postponing the mowing of meadows to protect breeding birds. In this case, the subsidy compensates the economic loss for farmers. Provincial authorities are legally responsible for making policy for the restoration of biodiversity. The Province of Noord-Brabant has initiated research based on population biology for which threatened species ecological connecting zones and defragmentation measures are at least essential to ensure recovery of all endangered species. Around 20 endangered species in the province of Noord-Brabant need ecological connecting zones and defragmentation measures to ensure healthy populations. The Provincial Executive has executed a defragmentation programme for the provincial road network. Around 385 measures were taken for 205 identified bottlenecks most of which before 2008. Additionally, the Dutch government has composed a defragmentation programme for the disintegration caused by the national road system, carrying out almost 100 measures solving 25 bottlenecks. These days, species such as beavers and badgers are spreading across the Province of Noord-Brabant, as a result of nature policy and defragmentation. Reintroduced species in other provinces such as the otter are also expected to spread. Therefore, new defragmentation programmes are inevitable.

The Green Connection ('De Groene Schakel'), a solution for infrastructure and nature

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The Dutch central government and provinces are working on the policy goal to realize the Nature Network of the Netherlands (NNN) and have jointly drawn up a Multi-year Defragmentation Program (MJPO) to, in consultation with municipalities and nature conservation organization, eliminate the barrier effect for animals and plants of roads and railway lines in the Netherlands. The MJPO provides the realisation of the nature link 'Groene Schakel', to connect nature reserves 'Gooi' and 'Utrechtse Heuvelrug'. How does such an integrated approach work? In the area east of Hilversum the central government and the province of North Holland are working to realise two major infrastructural projects: the widening of the A27 (highway) and the construction of 'HOV in 't Gooi', a fast, high-quality bus connection between Hilversum and Huizen. Both projects serve as a 'motor' for reconnecting the nature reserves 'Gooi' and 'Utrechtse Heuvelrug'. At an earlier stage, the necessary ecological measures were included in the MJPO: a fauna tunnel under the A27 (included in the government's project), an ecoduct above the railway and the yet to be constructed fast bus lane (included in the project of the province). By taking these measures, the nature link is not complete. North of the planned ecoduct there is a busy road for local traffic. That is why it was decided to move this road ('Weg over Anna's Hoeve') right next to the railway and the planned bus lane, which results in the ecoduct also passing over there. To have a properly functioning nature connection, the area surrounding this nature connection must also be set up ecologically. An important condition here is that species not only pass the connection but also have the possibility to stay there. Furthermore, there appears to be a clear need to integrate the bundle of infrastructure (railway, bus lane and road) in the landscape. This is done with ground walls that are built up from the soil. The quality of recreational areas north ('Anna's Hoeve') and south ('Monnikenberg') of the bundle of infrastructure will also be improved. This integrated approach is a result of the coordination of three programs: the MJPO for the two major defragmentation measures, the PMI -provincial multi-year infrastructural program for the construction of the bus lane and the PMG -provincial multi-year green program - for the relocation of 'Weg over Anna's Hoeve'. Programming infrastructure in the province of North Holland includes good ecological analyses (in an early stage of the project) of possibilities for defragmentation measures of all kind; huge constructions like ecoducts, fauna-pipes underneath road-constructions, ecological roadsides etc. As a result of a combination of good programming and good cooperation with nature organisation the 'Nature Reserve Gooi', the 'HOV in 't Gooi' project organisation has succeeded in offering an integrated solution for infrastructure and nature for the area to the east of Hilversum. This includes a safer traffic flow on the 'Weg over Anna's Hoeve', a high-speed bus connection between Hilversum and Huizen and a well-functioning natural connection between nature reserves 'Gooi' and 'Utrechtse Heuvelrug'.

Understanding the population effects and individual behavioural response of Barn Owls *Tyto alba* to major road networks to inform mitigation requirements

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Barn Owls (*Tyto alba*), due to their low flight and hunting behaviour, are especially susceptible to collisions with vehicles. Mortality on roads is a significant cause of death and contributing factor in the decline of Barn Owl populations in Europe. Despite knowledge on the extent of road mortality and the route and landscape characteristics which influence collision, the implementation of effective and evaluated mitigation solutions to minimise negative effects of roads on Barn Owl populations remains a critical challenge. In addition to a more profound knowledge on the nature and effects of road mortality, an understanding of the individual behavioural response and interactions of Barn Owls to road networks is necessary to identify the potential for, and direction of, evidence-based mitigation solutions. In this context, to determine Barn Owl interactions with roads concerning mortality patterns, we investigated a couple of things: (1) the extent of and factors which influence vehicle collision; (2) the suitability of roadside verges for foraging Barn Owls; (3) the foraging behaviour and movement patterns of individual birds concerning roads; (4) the spatial distribution, occupancy and breeding performance of breeding Barn Owls in relation to road networks in Ireland. We employed a citizen science approach to collate data on a national scale on Barn Owl mortality incidents. Of 423 recorded mortalities (2008-2017), 312 (73.7%) were attributed to vehicle collisions, of which the majority were on motorways (60.2%). Juveniles were killed on roads with higher frequency than adults, with peaks in mortality during the post-breeding dispersal period. A systematic road casualty survey on a section of a motorway (94 km) and bypass (13.5 km), done once per day over 100 weeks and once weekly over respectively 144 weeks (2014-2017), provided estimates of 55 to 75 Barn Owls per 100 km/year when the number of carcasses recovered were adjusted for search and removal bias. Road mortality locations on the motorway were clustered and significantly influenced by the proportion of grassland in roadside verges ($p=0.006$), verge width ($p=0.035$) and distance to rivers ($p=0.024$), whereas mortalities on the bypass occurred at random. Motorway verges supported a similar overall abundance and higher species richness ($p<0.001$) of small mammals compared to the surrounding landscape. The movements and foraging behaviour of 13 breeding Barn Owls assessed using GPS dataloggers (one fix/10 seconds over an average of 9.5 nights) indicated that roadsides are an important foraging resource within the context of the wider landscape. Barn Owls spent more time than expected interacting with roads, frequently crossing and foraging in proximity to or along roadside verges. We assessed the spatial distribution of breeding Barn Owl pairs within a 5 km buffer of the bypass (195 km^2) and motorway (800 km^2), and on a national scale and investigated the influence of roads on occupancy of nest sites and breeding performance. This study provides new insights on Barn Owl behaviour and movements in relation to road networks which in combination with data on road mortality patterns should be used to inform a new approach to road management and mitigation requirements.

Multi-species gene flow across several large-scale transportation infrastructures

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Barrier effects of Large-scale Transportation Infrastructures (LTIs; roads, railways, etc.) are among the primary factors contributing to habitat fragmentation. Dispersal reduction across LTIs can drive small, local populations to extinction. Barrier effects detection is now facilitated by the use of the landscape genetics framework. However, a primary limitation in genetic studies is the focus on a single species. Multi-species approaches are required when trying to understand how landscape features in general and LTIs, in particular, affect biodiversity. Accordingly, we followed two vertebrates species (the grass snake *Natrix helvetica* and the midwife toad *Alytes obstetricans*) and two invertebrate species (the butterfly *Maniola jurtina* and the ground beetle *Abax parallelepipedus*) in a landscape fragmented by six types of infrastructures: a secondary road network, a country road, a motorway, a railway, a gas pipeline, and a power line. Using multiple linear regressions and commonality analyses on two types of genetic distances (classical and hierarchical genetic distances), we demonstrated that LTIs accounted for 47% of the explained variance in *A. obsetricans* genetic distances, 100% in *N. helvetica*, 0% in *M. jurtina* and 49% in *A. parallelepipedus*. More precisely, we determined that roads (country road and secondary road network) were acting as significant barriers to gene flow in *A. obsetricans* and *A. parallelepipedus*. However, the secondary road network was enhancing gene flow in the snake *N. helvetica*. The motorway limited *N. helvetica* dispersal but promoted gene flow in *A. obstetricans*. The railway impeded gene flow in *A. obsetricans* but enhanced *N. helvetica* dispersal. The gas pipeline reduced gene flow in *A. parallelepipedus*, and the power line did not affect gene flow in any species. Our results revealed that infrastructures were mostly acting as barriers to gene flow in terrestrial species (85% of the averaged unique contributions across data sets). However, they could also somehow promote it because of alternative favourable landscape features provided by right-of-ways. Considering these results, we indicate that species-specific mitigation measures on infrastructures are required. We also confirm that roads are acting as a significant threat to biodiversity. Specific efforts are needed for current and planned roads to offset their harmful effects on gene flow.

Life trait-based predictions of road-kill risk for birds and mammals in Brazil

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Empirical estimates of road mortality show that some species are more likely to be killed than others and this variation can be explained by some species' traits (e.g. abundance, diet and habitat, movement ability). However, little is known about the role of multiple ecological, behavioural and life-history characteristics of species on mortality risk. With a fast expanding global road network, there is an urgent need to develop better approaches to estimate and predict road-related impacts. Trait-based models are powerful tools to assess the mechanisms underlying the response of species to impacts and predict risks for unstudied or difficult-to-detect organisms. This study aims to identify general patterns associated with road mortality and generate predictions to understand spatial and species-level risks. We used trait-based random forest regression models to explain 783 empirical road mortality rates from Brazil including 170 bird and 74 mammalian species. Fitted models were then used to make a spatial and species-level prediction of road mortality risk in Brazil considering all 1693 birds and 653 mammals which happen within the country's continental boundaries. Our findings show that higher road mortality rates in birds are associated with larger body mass (>2 kg), earlier maturity ages, shorter lifespans, ground foraging behaviour, and habitat and diet generalism. Higher mammal road-kill rates were associated with scavenging behaviour, early maturity, smaller home range sizes, average body masses (3-50 kg), and habitat generalism. Spatial predictions identified high potential road mortality risk in Amazonia for both birds and mammals, and additionally high risk in Southern Brazil for mammals. We also found potential vulnerability to road mortality of several understudied species currently listed as threatened by the IUCN. This study illustrates the potential of trait-based models as assessment tools to understand correlates of vulnerability to road mortality across species better, and as predictive tools for difficult to sample or understudied species and areas.

Assessing the contribution of road traffic to declines in British bird populations

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In the last forty years, many common bird species have suffered severe declines across Great Britain, thought to be primarily a result of agricultural intensification. However, there is a strong correlation between these declines and increases in road traffic levels. Many studies have identified negative effects of roads on birds, via mechanisms such as avoidance of noise and light pollution, and mortality from collisions. However, no island-wide quantification of impacts on populations has been attempted for Great Britain yet. This research is using a series of models to estimate the proportion of bird population declines over the last forty years that have been caused by increased traffic flow in Britain. Additionally, it will identify species that are especially sensitive to roads and estimate the impact of planned new roads and future changes in traffic levels. The results of this will allow better planning and mitigation of the road network in Great Britain, as well as other countries with dense road networks, and contribute to current and planned conservation projects that are situated near to roads. We present the preliminary results of a spatial analysis of the variation in bird population densities across Great Britain in relation to the distribution of roads and their traffic flows.

Road and edge effects on a small mammal community in tropical forest fragments in the Brazilian Atlantic Forest

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Roads negatively affect many vertebrate species, mostly due to animal-vehicle collisions. Some studies evaluate barrier effect and avoidance behaviour in small mammals, considering traffic volume and road density. This study aims to: (1) evaluate the effect of roads on small mammal abundance, considering roads around the studied forest fragment; and, (2) evaluate which is more relevant in explaining small mammal abundance in forest fragments: road effect, edge effect, or habitat area. The study area was a 10,000 hectares human-modified landscape with 30% forest cover, situated in the Plateau of Ibiúna, a region of the Atlantic Forest biome, 50 km far from the city of São Paulo, southeastern Brazil. Twenty forest fragments were sampled to collect small mammals in a 100 m transect with eleven pitfall traps. Small mammals, including rodents and marsupials, were classified as forest specialists and habitat generalists. All roads near the twenty forest fragments are unpaved dirt roads with little traffic. Road and edge effects were represented by new metrics: Line Integral Effect (LIE) and Average Integral Effect (AVLIE), calculated using Line Integral from Differential Calculus of Several Variables through new software developed by us. LIE_road and LIE_edge measure the total sum of the effect of roads (represented by lines) and edges (polygons), respectively, in relation to the forest fragment (point). AVLIE_road and AVLIE_ edge measure the average of road and edge effect, respectively, concerning the same sampling points. We used generalised linear regression models with Poisson errors to explore the relationships between the abundance of the two groups of small mammals (forest specialists and habitat generalists) and the independent variables representing road, edge, and habitat effects. LIE_road, AVLIE_road, nearest road distance, mesh size, and road density represented road effect. Edge effect was represented by LIE_edge and AVLIE_edge, whereas habitat area was represented by fragment size and forest cover. We used simple models and multiple regression models (with two independent variables combining road effects plus edge or habitat effects). We also used one reference model (which only contained the intercept). For the abundance of both forest specialist and habitat generalist small mammals, the best model in the candidate set was that containing a road effect variable and an edge effect variable. Edge effect metrics showed a low correlation with road effect metrics. For forest specialists, the best model included AVLIE_road (negatively associated with abundance) and AVLIE_ edge (also negatively associated), while for habitat generalists, the best model included AVLIE_road (negatively associated) and LIE_edge (positively associated). Thus, there are more small mammals where road effect is lower. Forest fragments with higher edge effect showed more habitat generalists and less forest specialists. Road and edge effects were more relevant to explain the abundance of small mammals than habitat area. Because of the low traffic in the study site, we believe that barrier effect is the main road effect associated with small mammal abundance. Studies on road ecology should consider edge effect, mainly in tropical forest fragments, because edge effect can also cause a barrier effect.

Life and death along the highway: A study of badgers using GPS-collars and wildlife cameras

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The most important enemy of the badger is traffic. Badgers cross roads and railways without paying attention. In the Netherlands, with its large human population and dense network of roads and railways, the badger can only survive thanks to protective measures. To help protect badgers during the reconstruction of highway A27 near Hilversum, the Netherlands, the badger population along a 13 km stretch of the highway was studied using GPS-collars and wildlife cameras in the years preceding the works (2012-2015). Mortality was high on the unfenced part of the highway and negatively affected the population density. Mortality was low on the fenced part; it was always linked to temporary gaps in the fence. A total of 16 badgers were followed with GPS-collars, which collected detailed information on their ranging behaviour, collecting altogether almost 50,000 fixes. Badger group territories were lined up on both sides of the highway. A new green bridge over the highway was explored by the neighbouring badger, but was, like the highway itself, still treated as a territorial boundary. Badger tunnels (diameter 40 cm) in the study area were monitored for long periods, sometimes years, with rapidly reacting wildlife cameras. Those under the highway were intensively used in spring and less in late summer and autumn, mainly for social reasons: to contact neighbouring badger groups. These tunnels were important for dispersal and gene flow. Badger tunnels under local roads and under railway tracks, in combination with badger fences, were used by badgers throughout the year for daily commuting. In the Netherlands a wide range of technical measures has been applied to prevent mortality of badgers and other wildlife species on roads, on railways and in canals. Without these measures co-living of humans and wildlife would be impossible in the long run.

Road mortality mitigation: The effectiveness of Animex fencing versus mesh fencing

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Fencing is one of the most effective mitigation measures used to reduce roadkill however, little research is known about what materials work best to exclude herpetofauna from roads and there are a lot of concerns surrounding the safety and effectiveness of mesh fencing. This research attempts to fill this gap of knowledge and evaluates the effectiveness of mesh and solid plastic fencing (Animex) by investigating their suitability to be used as solutions to protect wildlife near roads. This behavioural study explores the reactions of various herpetofauna when placed in an enclosure comprising two sides of steel mesh fencing (1/4 inch), and two sides of solid plastic fencing (Animex). The animals observed during the study were: 15 Eastern garter snakes (*Thamnophis sirtalis*), 1 Red-bellied snake (*Storeria occipitomaculata*), 18 Green frogs (*Lithobates clamitans*), 2 Northern leopard frogs (Lithobates pipiens), 7 Midland painted turtles (*Chrysemys picta*) and 7 Snapping turtles (*Chelydra serpentina*). The activity that was recorded and compared during the observations included: (1) Time spent within each fence zone; (2) Physical interactions with the fencing; (3) Climbing or escape attempts. The results showed that the animal groups spent 42% more time near the mesh fencing than Animex, and all the animal groups attempted to escape the mesh fencing considerably more times than the Animex: 370 vs. 45 respectively. All species except Midland Painted Turtles successfully escaped the mesh fencing; however, none escaped the Animex. Based on other behaviours exhibited by animals during the trials such as clawing, poking and jumping, mesh fencing could result in injury to herpetofauna. As the goal of exclusion fencing is not only to keep animals off the road but also to funnel animals safely to wildlife crossing structures, this study recommends plastic solid barrier fencing such as Animex is the most appropriate material to be used as exclusion or drift fencing for the species studied. This study shows that mesh fencing will hinder the funnelling of animals towards wildlife crossings or into adjacent habitat due to additional risk of injury, delay or escape created by the type material.

Effect of artificial light on wildlife use of underpasses

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Road infrastructures negatively affect wild animal populations, as they are responsible for barrier-to-movement effects, loss of habitat connectivity, and mortality due to wildlife-vehicle collisions. Mitigation measures such as crossing structures (for example, underpasses and road bridges) have been implemented. However, due to the high cost, road agencies have recently been exploring the possibility of co-using the same structures by both humans and wildlife. This could present new challenges, such as the need to introduce artificial lights at the structure itself to meet people's demand for comfort and safety. The negative effects of artificial light at night have been investigated in numerous studies. However, general patterns of their impact on wildlife use of crossing structures are still unclear.
To our knowledge, only two studies have focused on this issue so far. This study examines the immediate response of terrestrial wildlife to artificial lighting at four underpasses in southeast Australia, according to a Before-After (BA) study design. Artificial lights were temporarily added to the structures on two occasions, and the animals' response was monitored with camera traps before, during and after treatment. Artificial light reduced the mean crossing frequency of the non-native red fox (*Vulpes vulpes*) at one of the three sites where they were active. We did not find an immediate, negative effect of light treatment on eastern grey kangaroos (*Macropus giganteus*) or swamp wallabies (*Wallabia bicolor*), although their average crossing frequency decreased during the last stage of the experiment following the second light treatment. While encouraging a careful evaluation of the introduction of artificial lighting at new or existing crossing structures, this study also suggests that the variation in wildlife response to nocturnal illumination should always be taken into consideration. Because high variation among species and sites is common in studies about wildlife crossing structures, long-term research with larger sample sizes could support researchers more confidently detecting trends and addressing the risk of a long-term negative effect of artificial lighting, which might affect the effectiveness of the crossing structure.

Traffic noise and light as potential explanations for suppressed use of wildlife crossing structures

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Wildlife crossing structures (WCS) over or under highways are proposed as a solution for road-related habitat fragmentation and wildlife collisions. To test the efficacy of WCS, road-related negative impacts that could cause animals to avoid WCS, such as noise, need to be considered. Human-sourced noise can affect habitat occupancy, and a suite of animal behaviours such as vigilance, communication and predation efficiency. To test whether traffic noise impacts species' use of WCS, we quantified overnight (8pm – 12am) road traffic noise, measured as dB(A), at twenty WCS positioned along four central California highways (I-5, I-80, I-680, and I-280), as well as historical WCS mammal use for twenty recorded days during the summer of 2012, 2015 or 2016. To further examine the impact of noise on WCS use, noise levels (dB(A)) and species richness at eight WCS and adjacent habitats (>800 m from the highway) were monitored over a twenty-day period. A range of variables was considered: highway, openness ratio, length of underpass, AADT (traffic volume, obtained for the month and year that species visitations were recorded), maximum noise recorded, mean noise recorded, year and month of the species visitation, species richness, number of sensitive species recorded, sensitive species as a ratio to total species recorded. We used a generalised linear mixed-effects model with Poisson error and site, year, month, and highway used as random effects. Using species richness as the response variable, after model simplification the only significant variable was AADT ($p < 0.001$). However, when using disturbance-sensitive species richness as the response variable, we found that sensitive species richness was negatively correlated with maximum noise ($p < 0.05$) and AADT ($p < 0.01$). Within the eight WCS and their corresponding adjacent habitat sites, species richness was significantly greater ($p < 0.01$) in adjacent habitats (mean 11.2) with low/no traffic noise than recorded at the WCS (mean 8.2) with high traffic noise levels, and sites with higher mean and maximum noise showed lower species richness. We also measured light intensity as total luminescence at eight WCS in the Sierra Nevada and San Francisco Bay Area. We used a novel approach employing a camera with a very wide angle lens to capture low light levels, combined with software that estimates total illumination and light wavelength. Although there was a negative relationship between species richness and total luminescence, it was not significant for these eight sites. Lower wildlife species numbers at WCS than the surrounding landscape means that these structures may not be functioning to maintain wildlife connectivity across landscapes. The effects of traffic noise and light on wildlife presence, movement and use of WCS could be mitigated by screening the highway to reduce noise and light levels below critical levels. This could be experimentally carried out and effectiveness evaluated to test these ideas.

Why wildlife-warning reflectors do not work and how they can still be useful

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Collisions with large animals are not only a significant economic problem but also an animal welfare issue and, in some situations, even an ecological dilemma. A significant proportion of wildlife-vehicle-collisions occur on rural roads during dawn and night. The objective of wildlife-warning reflectors (WWR) is to reduce this type of accidents. These devices have been available in many types and shapes for decades, and their common operating principle is to reflect the headlight of approaching cars into the adjacent verge to prevent nearby animals from entering or crossing the road. Today, most of the reflectors are designed to alter the colour of light or to flash or twinkle for an additional stimulus. While some studies show a reduction of collisions, others are not demonstrating a significant accident reduction. Therefore, we decided to address the topic by validating the functional principles of WWR's concerning the eyesight of commonly affected wildlife species. For that reason, the reflection characteristics of nine commercially available WWR's were measured in a lighting lab, and a literature review on animal vision and colour perception was conducted. The collected data were used to simulate the WWR's visibility for wildlife animals in about 3,000 patterns of approaching vehicles and approaching or observing animals. The simulations were performed concerning German legal regulations on road design and headlight characteristics. Depending on the observer's position, the amount of reflected light differed considerably. Some WWR's showed limited lighting effectiveness for each WWR, which had to do with the different combinations of the approaching vehicles distances, and the observer's position, when only under active high beam headlight. Nevertheless, none of the tested WWR's was able to generate enough optical reflection to create stimuli, regarding differences in a complicated situation of an approaching vehicle by wild mammals. As a consequence, possible explanations of the observed reduction of wildlife collisions after the installation of WWR's in some long-term studies may be a much differentiated and by far unknown system of visual perception in wild ungulates. It could also be increased alertness of the vehicle's driver, stimulated by the WWR.

Managing the timing and speed of vehicles reduces wildlife-train collision risk

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Understanding wildlife-vehicle collision risk is critical to mitigating its negative impacts on wildlife conservation, human health and economy. Research often focuses on collisions between wildlife and road vehicles, but collision risk factors for other types of vehicles that are less examined in the literature, may be informative. We studied spatial and temporal variation in wildlife-train collision risk in the State of Victoria, Australia. We quantified train movements in space and time and mapped species occurrence likelihood, across the railway network. Using spatially- and temporally-resolved collision data, we fitted a model to analyse collisions between trains and kangaroos; accounting for time of day, train frequency, train speed and kangaroo occurrence. We then predicted collision rates on the passenger railway network under three management scenarios relating to train speed and presence of kangaroos near the railway lines. Temporal variation in animal activity was the strongest predictor of collision risk. Train speed was the second most influential variable, followed by spatial variation in the likelihood of species occurrence. Reducing speeds in areas of high predicted species occurrence and during periods of peak animal activity (early morning and evening for kangaroos) was predicted to reduce collision risk the most. Our results suggest mechanisms that might improve existing wildlife-transport collision analyses. The model can help managers decide where, when and how best to mitigate collisions between animals and transport. It can also be used to predict high-risk locations or times for (a) timetable/schedule changes (b) proposals for new routes or (c) disused routes considered for re-opening. Furthermore, it utilises existing sources of data and is transferable/scalable to other transportation networks and species. Other potential uses of the framework may include an ongoing implementation where the model is updated based on new information and reports risk to operators in real-time.

Influence of lunar cycle on amphibian roadkill

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Roads are responsible for thousands of roadkill per year worldwide. Different taxonomic groups are vulnerable to this mortality source, but amphibians are especially vulnerable. In fact, very high mortality rates can occur during time concentrated periods when individuals migrate to and from reproduction areas (e.g., ponds). In addition, the activity of this taxonomic group is dependent on weather conditions, also influencing roadkill patterns. In this study we aim to assess the influence of the lunar cycle on the number of six species of amphibians killed on the road each night and total number of amphibian roadkill, while accounting for weather conditions of each night (minimum temperature, precipitation in previous hours, relative humidity, wind). Amphibian roadkill were monitored daily by car (30-40 km/h) for two years (from March 2010 to May 2012) along 37 km of National and Municipal roads in Southern Portugal (Évora district). The data here presented concern the species with higher roadkill rates in the study area (two urodeles and four anurans): Sharp-ribbed Salamander (*Pleurodeles waltl*), Fire Salamander (*Salamandra salamandra*), Iberian Painted Frog (*Discoglossus galganoi*), Western Spadefoot toad (*Pelobates cultripes*), Spiny Common Toad (*Bufo spinosus*), and Natterjack Toad (Epidalea *calamita*). We performed Generalized Linear Mixed Models for zero inflated and over dispersed data, in order to evaluate the importance of the lunar cycle and weather variables in each species and total mortality. We excluded the period of June to August after data exploration, as those months corresponded to minimum values of amphibian roadkill. We assumed that roadkill events are a result of both breeding and non-breeding movements. Overall, the increase in minimum temperature, relative air humidity and rainfall in the previous hours (8-24 h) to road surveys increases the probability of higher roadkill numbers for all studied species. However, the lunar cycle also influenced roadkill numbers of some species. Darker nights had higher numbers of roadkill of *Pleurodeles waltl*, while moonlit nights had higher numbers of *Salamandra salamandra*. There were higher roadkill numbers for *Pelobates cultripes* in Last Quarter nights when compared with First Quarter. Higher total roadkill numbers were mainly determined by a combination of wet and relatively warm nights: higher maximum and cumulative rainfall, relative air humidity and minimum temperature in previous hours of road surveys. Additional lunar effects on number of roadkill were detected for three species, although these effects were species-specific. Animals that are more active in moonlight may be at an advantage if their visual acuity is better than that of their predators. So, differences between species in the response to moonlight may be due to species' ecology, physiology or differences perceived in predation risk. Temporary mitigation actions, such as amphibian catches by volunteers, warning signs or temporary road closures, can be more successful if conducted at the right time (i.e., at periods with higher movement rates). Our work provides information to improve the timing of these actions.

Animal-vehicle collision hotspots and assessment of mitigation measures in Lithuania

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Identification of animal-vehicle collision (AVC) hotspots is a most essential step for the effective application of mitigation measures. Approximately 2000 AVC are recorded each year in Lithuania. In 2002-2016, large mammals (roe deer, red deer, moose, bison, wild boar and fallow deer) accounted for about 55% of all AVC every year, with Roe deer alone accounting for about 43% of all AVC. In order to identify AVC hotspots (short significant road sections) involving large mammals, we applied the Kernel Density Estimation (KDE) based method for the entire road network of the country. We identified AVC hotspots for each year from 2002 to 2016 and ranked them according to their risk severity for the drivers. We identified that number of hotspots increased each year from five in 2002 to 192 in 2016. In total, we found 674 unique hotspot locations, with the average length of one hotspot being 212 metres (range 150-582 metres). The total length of AVC hotspots increased by approximately 1.5 times per year and in 2016 hotspots covered 41.5 km of the 21,471 km of Lithuanian road network. There were only 7.5% of roads (excepting cities) where no AVC were recorded during the period. The maximum risk for the driver's index (measured from 0 to 1) within the hotspots increased by one-third (from 0.50 to 0.72) over the years. In order to assess where crossing mitigation measures are most important, we conducted spatial intersection of all hotspots and identified that 9% of all hotspots are recurring and appear in the same location over the years. We found that about one-third of all recurring hotspots were noted annually, while the other two-thirds recurred, but not every year. Even if their risk for the driver's index is low, recurring hotspots are important since they appear at the same location constantly. Wildlife fences (800 km in 2016) are the most common AVC mitigation measure in Lithuania. We identified that 10% of hotspots occurred within fenced road sections, but only 0.3% of hotspots within the fenced road sections were recurring. Thus, we confirm that properly set wildlife fences are quite an effective long-term AVC mitigation measure. Our study results suggest that in order to identify the most important locations for mitigation measures, we need to apply information on the yearly hotspot recurrence in line with already existing fencing data. Location-based hotspot recurrence analysis will provide more stability to AVC mitigation measures.

Animal-vehicle collisions: Improvement of regression models with the use of cluster analysis

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The identification of important environmental and transport engineering factors for animal-vehicle collisions (AVC) and their effect on the occurrence of AVC are widely investigated topics at present. The factors are usually collected at places where AVC occurred and at other places with no crash evidence. Regression modelling is performed afterwards for both groups of factors simultaneously to identify their contributions to AVC occurrence. This approach is widely used today, but it has several known drawbacks (road segmentation, time and money consumption of the data collection process, handling the missing data and the fact that similar attributes do not represent similar roads). Therefore, we introduced its significant improvement solving these issues. The suggested improvement to the approach utilizes a well-known fact of AVC clustering along roads. Significant clusters are places where AVC occur more frequently than expected due to certain local factors, whereas at other places along roads AVC occurrence is spatially random. Not every cluster, however, represents a hazardous location. Clusters may emerge as part of a random process which follows uniform random distribution. The existence of these patterns naturally implies that commonly used methods of identification of hazardous road sections "as a whole" are inaccurate. It means that the (environmental, engineering, etc.) factors should be collected for randomly chosen AVC from places within the significant clusters as cases and out of the clusters as controls. Afterwards, a logistic regression was applied to explain differences between clusters of AVC and places of random AVC occurrence. We illustrate this new approach with a case study from the Czech road network. The achieved results demonstrate that a cluster analysis performed prior to the regression analysis solves the drawbacks of the original approach and produces understandable patterns from the data.

Wildlife-vehicle collisions: What do we know and what should we aim for?

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In many countries, wildlife-vehicle collisions have been on the rise for decades. Numerous studies have addressed the issue, mapping accident locations, analyzing trends and patterns and developing predictive models that can aid in mitigation plans. Various measures were tested to prevent accidents, many roads were fenced to exclude wildlife from traffic, green bridges were built to provide safe passage for animals, and information campaigns were conducted to raise awareness. However, accident statistics still increase, even though wildlife populations may appear stable or decreasing. So, what are we doing wrong? Why can't we, despite all efforts, remedy the problem? Do we expect too much or are do statistics mislead us? What else can we attempt and what should we focus on to accomplish realistic mitigation? Wildlife-vehicle collisions are the product of many confounding factors and must be addressed at several scales and levels simultaneously. There is no single cure, and stakeholders share the responsibility for success. In addition, future technology such as driverless cars and auto-piloted assistant systems offer new challenges and opportunities or further mitigation. However, we may need to accept that we can only ease the problem but never overcome it entirely. In this presentation, I discuss these questions, provide some answers and highlight new aspects that may open the path for further research and development. In my discussion, I rely on international literature and draw empirical support from almost 50 years of wildlife-vehicle collision statistics in Sweden.

How road mitigation can reduce road kill: a meta-analysis

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Road traffic kills hundreds of millions of animals every year, posing a critical threat to the populations of many wildlife species. To address this problem, there are more than forty types of road mitigation measures available that aim to reduce wildlife mortality on roads (road kill). For road planners, deciding on what mitigation method to use has been problematic because there is not a lot of useful information about the relative effectiveness of these measures in reducing road kill. Additionally, the cost of these measures varies greatly. We present the first comprehensive analytical review of the effectiveness of road mitigation measures in reducing road kill using well-described meta-analysis methods. We conducted a meta-analysis using data from fifty studies that quantified the relationship between road kill and a mitigation measure designed to reduce road kill to ask: (1) to what extent does the effectiveness of road kill mitigation differ among measures? For example, are fences with crossing structures more effective than fences or crossing structures alone? Are less expensive measures such as reflectors as effective as fencing or crossing structures? (2) To what extent do taxa differ in the effectiveness of particular road mitigation measures? And: (3) to what extent does study design influence the estimated effectiveness of road mitigation measures? Overall, mitigation measures reduce road-kill by approximately 40% compared to controls. Fences, with or without crossing structures, reduce road-kill by 54%. Interestingly, when analysed separately, fencing alone reduced road kill by 86% while crossing structures combined with fencing reduced road kill by 51%. We found no detectable effect on road kill of crossing structures without fencing. We found that relatively expensive mitigation measures reduce large mammal road kill much more than inexpensive measures. For example, the combination of fencing and crossing structures led to an 83% reduction in road kill of large mammals, compared to a 57% reduction for animal detection systems, and only a 1% for wildlife reflectors. We suggest that inexpensive measures such as reflectors should not be used until and unless their effectiveness is tested using a high-quality experimental approach. Our meta-analysis also highlights the fact that there are insufficient data to answer many of the most urgent questions that road planners ask about the effectiveness of road mitigation measures, such as whether other less common mitigation measures (e.g., measures to reduce traffic volume or speed, temporary road closures, etc.) reduce road mortality. Another question that road planners ask is to what extent the attributes of crossing structures and fences influence their effectiveness (e.g., the presence of dig barriers, fence-end treatments, mesh size, height, numbers, and spacing of crossing structures and fenced sections, etc.). To improve evaluations of mitigation effectiveness, studies should incorporate data collection before the mitigation is applied, and we recommend study duration of at least four years for Before-After, and at least four years or four sites for Before-After- Control-Impact designs. The complete paper available in *PLoS One* 2016 11(11): e0166941, doi:10.1371/journal.pone.0166941.

How effectively can we mitigate the barrier impacts of roads on wildlife movement? A global assessment and meta-analysis

Millions of dollars are spent around the world in an attempt to reduce the impacts of roads and linear infrastructure on wildlife movement. Evaluating the effectiveness of these measures is critical if we are to ensure that conservation goals are met, and financial investments have been worthwhile. Hundreds of research projects have focused on evaluating road mitigation, however there has been no quantitative synthesis of their findings. What have we learned so far? To what extent do mitigation measures reduce barrier effects for wildlife? We assessed the global evidence for the effectiveness of mitigation intended to reduce the barrier effect of roads on wildlife using meta-analysis. We searched the literature for research that quantified the effect on wildlife movement and considered any action that was intended to lessen a potential barrier effect as mitigation (including crossing structures, modified drainage, roadside management or crosswalks). For a study to demonstrate 'effectiveness', it had to compare mitigation to an unmitigated situation (i.e. compare taking action to taking no action). More than 400 studies evaluated the use or effectiveness of barrier mitigation. Wildlife crossing structures were the most common measure evaluated. However, fewer than 50 studies evaluated effectiveness. Instead, most research efforts focused on: 1) documenting the use of crossing structures by wildlife; 2) evaluating the willingness of wildlife to use mitigation (e.g. 'acceptance'); or, 3) identifying factors affecting wildlife use of crossing structures. The lack of comparison with 'unmitigated' data is a key factor limiting our ability to evaluate the effectiveness of wildlife mitigation, leaving us unable to answer some of the most pressing questions that road planners and agencies ask. We will discuss what this means for our ability to guide effective on-ground actions and suggest how future research can address this critical gap.

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Fences and beyond: The importance of addressing fence-end effects in road-kill reduction studies

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Roads may result in increased mortality of wildlife through vehicle-wildlife collisions. Fencing appears to be one of the more effective ways to reduce road-kill in wildlife. A recent review study showed through meta-analysis that fencing, combined with crossing structures, led to an 83% reduction in road-kill of large mammals. It was also noted, however, that most studies did not address possible fence-end effects, i.e. elevated road-kill immediately adjacent to fence-ends. If such effects occur the effectiveness of fences in reducing road-kill may be overestimated. The objective of this study is to evaluate the effectiveness of fencing, combined with a wildlife overpass, in reducing roe deer (*Capreolus capreolus*) road-kill on a two-lane highway in the Netherlands. We used a BACI design and collected road-kill data both before (2006-2008) and after (2009-2016) the road mitigation measures were installed, at the mitigation site (fenced, with overpass), two fence-end sites (unfenced road stretches just beyond the fence-ends) and two control sites. The construction of the fences and overpass resulted in a 90% reduction in road-kill numbers (two-sample Poisson test, $p<0.01$) among roe deer at the road stretch where fences were erected on both sides of the highway. However, the reduction in road-kill was partly cancelled out by an increase in road-kill beyond one of the fence-ends. If we include the fence-end effects, the reduction in road-kill after mitigation is only 49% and not statistically significant (two-sample Poisson test, $p=0.216$). The study shows the importance of data collection at fence-ends in evaluation studies to make correct inferences about road mitigation effectiveness.

Prioritizing road sections for wildlife fencing: Lengths, thresholds, and trade-offs

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Roads have many negative effects on wildlife populations, the most visible of which is wildlife mortality due to vehicle collisions. Fences and wildlife passages have been applied to reduce roadkill. However, wildlife passages without fencing, in general, have been shown to not reduce roadkill. Therefore, fencing is the most important component for mitigating roadkill. Understanding where and why wildlife-vehicle collisions occur can inform planners about where mitigation measures would be most effectively placed. However, it has not been discussed how the choice of scales and confidence levels influence the results and how the locations of the warm- and cold spots should be included in the decision-making. We used roadkill data of reptiles and medium-sized mammals from three roads and applied multiple scales of analysis and several confidence levels to answer: (1) Are there thresholds in the effect of the extent of fencing (total fence length) on the expected reduction in road mortality? (2) What are the effects of varying scales and varying confidence levels on the road section prioritization results for fencing? We used the software *Siriema* to identify hotspots, warm spots, and cold spots of road mortality at multiple scales. Our results show that the choice of confidence intervals and scales affects the amount of hot-, warm-, and cold spots identified. At lower confidence levels, there are more hotspots and cold spots than at higher confidence levels. When roadkill data are analysed at a smaller scale (e.g. 100 m), there are more hotspots identified, but combined they cover a shorter overall length of the road than hotspots at larger scales. Our study shows how identifying hotspots, warm spots, and cold spots at multiple scales allows for a more comprehensive approach for locating and prioritizing road sections for wildlife fencing. We discuss the existence of thresholds in the amount of total fencing needed, the importance of considering the fence-end effect when defining the length of the fences to be installed, and the FLOMS trade-off: "Few-Long-Or-Many-Short fences". Based on these results, we propose an Adaptive Fence Implementation Plan with steps to prioritize road sections for wildlife fencing. The steps of this plan consist of collecting roadkill data to maintaining the installed wildlife fences, integrating hot-, warm-, and cold spots as well as multiple scales and confidence intervals.

Effectiveness of wildlife fencing and crossing structures in reducing collisions with large mammals and providing habitat connectivity for deer and black bear along US Hwy 93 North, Montana, USA

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The US Highway 93 North reconstruction project on the Flathead Indian Reservation in Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56-mile-long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.71 miles of road with wildlife exclusion fences on both sides of the highway. We investigated the effectiveness of the mitigation measures in reducing collisions with large mammals and providing habitat connectivity for deer and black bear in three road sections with relatively long sections of wildlife fencing and crossing structures. Based on a Before-After-Control-Impact (BACI) study design, large-mammal vehicle collisions were reduced by 71-80% ($P<0.05$). For the unmitigated road sections, large mammal-vehicle collisions did not remain the same before (2002-2005) and after (2011-2015) highway reconstruction, but they increased by 91-232%. We also investigated connectivity for deer and black bear in the three road sections before (2003-2005) and after highway (2008-2015) reconstruction and the associated implementation of the mitigation measures. Deer highway crossings remained similar or increased after highway reconstruction ($P=0.065$). Black bear highway crossings remained similar after highway reconstruction ($P=0.197$). There was no indication of an increase in deer population size after reconstruction compared to pre-construction. We conclude that the highway reconstruction, and the associated mitigation measures, did not reduce habitat connectivity for deer or black bear in the three areas. The results have the following practical implications: (1) Historical wildlife-vehicle collision data are not a good predictor for collisions after the reconstruction of a rural highway. They underestimate the number of collisions after reconstruction, and a correction factor should be applied during the decision process on whether to include wildlife mitigation as an integral part of highway reconstruction. (2) Whereas the primary function of wildlife fences is to function as a barrier to wildlife movements, keep wildlife off the highway and reduce collisions, wildlife fences in combination with wildlife crossing structures can also reduce the barrier effect of transportation corridor for wildlife. This last point should mitigate potential resistance against the implementation of wildlife fences in combination with wildlife crossing structures with wildlife managers who may be concerned about these measures reducing habitat connectivity for wildlife.

Influencing international transportation policy and practice for more wildlife-friendly roads

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Road and rail systems provide important connections for the movement of goods and people that can improve the quality of people's lives; at the same time these transportation systems can disconnect ecosystem functions, sever wildlife movement and increase wildlife and human injury and mortality. A new global opportunity has arrived to influence transport policies and practices that result in infrastructure that is more sensitive to the needs of wildlife and ecological processes. In 2016, the International Union for Conservation of Nature (IUCN) launched the Connectivity Conservation Specialist Group (CCSG) under its World Commission on Protected Areas. The CCSG has been charged with developing a new type of conservation area that the world's governments can adopt – Connectivity Conservation Area (CCA). Draft CCA guidelines are being developed that include such items as criteria for establishment, typology, governance, and management. These guidelines will enter a consultation process with the world's governments in 2018. After emerging from consultation, it is hoped the CCAs will be adopted to link protected areas, such as national parks and wilderness areas, into ecological networks. There was a need identified to assure CCAs will be sensitive to the adverse impacts of roads and rails. Thus, a Transport Working Group (TWG) has been formed to advise and provide direction regarding transportation infrastructure so it avoids, minimizes and/or mitigates impacts to wildlife movement and mortality within CCAs. The TWG is seeking interested individuals to help develop practical transport system guidance so CCAs accommodate natural, political, and cultural variation in both developing and developed countries. The TWG will build on existing relevant documents advanced by countries or other entities regarding wildlife sensitive infrastructure and create specific guidance useful for protecting CCAs. This presentation will discuss the CCSG's and TWG's progress along with a call for interested individuals to join.

Environmental impact assessments: When to monitor the effects of implemented plans and programs?

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Environmental impact assessments (EIA) are an essential tool for maintaining biodiversity and sustainable road development. EIA's ability to do so rests on elucidating and understanding the environmental effects of implemented plans and programs (e.g., road development) through monitoring. This requires high-quality monitoring studies, measure relevant parameters, and indicators. To meet this goal, it needs taking into account several different interlinked factors (e.g., types of road projects, natural variation, available resources) together (i.e., holistically). This is often not the case, with low-quality results as a consequence. For example, because of selecting indicators that are environmentally important but that are impossible to measure given the road projects premises. The objective of the study was to develop a method for evaluating the possible types of monitoring in a road development project, and where to conduct the monitoring as an extension of this. Our study has developed a criterion-based method that determines if a road development project is suited for simple or complex monitoring studies (or non) based on the information from the projects' EIA. The criteria can be used for all habitats and species. Examples of simple and complex monitoring studies of vegetation change would respectively be repeating pictures of the same place, or repeated detailed vegetation analyses within one or more observational units in a place by detailed study design. We believe that determining the possible complexity of a monitoring study in a project gives a solid foundation to: (1) Select appropriate parameters and indicators to measure, by excluding those parameters and indicators that are impossible to measure given the project's premises; (2) Select applicable methods; (3) Communicate the degree of information that the results are likely to give. This approach ensures a high quality within the scope of the study and eliminates the cases where complicated studies are conducted on projects only suited for simple monitoring studies. This is a worst-case scenario that wastes both time and money. In this presentation, we will present and discuss the criteria for simple and complex studies and their integration in the Norwegian road development process. This includes the reasoning and scientific background and their practical use in current projects. The criteria are based on and assess the different factors that a monitoring study must take into account. The criteria can be divided into three distinct areas: Nature, Road, and Premises. The criteria in the nature area assess the ecological factors; the criteria in the road area assess the different aspects of the road project such as placement, mitigation factors, etc. Lastly, the criteria in the premises area assess the premises of the project such as available resources and the goals of the research. We conclude that using clear and understandable criteria for selecting suitable road development projects are fundamental factors to obtaining high-quality results, which may explain the effects of road development on the environment.

Frontiers for conservation: Targeting European borders as conservation areas

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It is widely known that political borders should not hamper wildlife. Conservation actions involving several countries are perceived to bring large-scale benefits to nature while helping to resolve social and political conflicts. While many neighbouring countries have lived peacefully for a considerably long time, namely the western European countries, several eastern countries were isolated from the western regions due to the so-called "iron curtain". More recently, in the former Yugoslavia and currently along the border of Ukraine-Russia, devastating conflicts are also isolating regions and countries. On the other hand, human developments, and particularly transportation networks, are severely threatening biodiversity. For example, roads inflict severe mortality rates due to animal-vehicle collisions, can obstruct the animal movement, or represent essential pathways for the spread of invasive species. It is common for conflict zones to have a lower density of roads and populations. We suggest that former isolation and conflict areas should be recognised as opportunities for biodiversity conservation to strengthen cross-country relations. In fact, border areas can become important areas for conservation due to higher habitat quality, namely forest cover and reduced density of infrastructures. The German Green Belt project is an excellent example of this. We provide an assessment of the potential for European political borders to function as fundamental conservation and connectivity areas by evaluating and comparing the number and size of roadless areas, distribution of top predator species and human appropriation of net primary productivity within countries and along their borders. We detected several opportunities that could be taken into account to improve our network of protected areas. For example, borders of eastern countries have a significantly higher cover of roadless areas, from Belarus down to Croatia and Greece. We further discuss how focusing on conservation action at borders can form a 'win-win' situation with advantages for both biodiversity and human peace. Conservation of flag species such as bear and lynx at borders of main geopolitical blocks can be used to increase the cooperation between such regions and with that ensure a long-lasting peaceful coexistence.

Integrating road ecology into wind-turbine ecology in Ontario, Canada

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In 2012, the Ontario Government gave Gilead Power approval to build an industrial wind farm development that included nine forty-story high wind turbines, 5.4 km (6 m wide at 15 km/hour) of access roads and collector lines, and municipal road upgrades. The problem is that Ostrander Point is a globally rare alvar habitat, International Bird Area, and supports 19 Species at Risk including the globally Threatened Blanding's Turtle. This remote beachhead jutting out into Lake Ontario is situated within one of North America's most important migratory bird routes. The Prince Edward County Field Naturalists (PECFN), appealed the decision in the belief that the wind turbines will cause severe and irreversible harm to habitat and wildlife. The appeal procedure retained experts to argue the case for 'will cause' to an Environmental Review Tribunal. Among other bird, bat, turtle, and butterfly experts a road ecologist was retained to argue the case for serious and irreversible harm to the Blanding's Turtle due to road upgrades and construction. A plethora of road ecology and turtle science exists to back up this claim. First Blanding's Turtles are globally threatened across their range, and in Ontario only small, localised populations still occur. Their life history strategy is characterized by long life spans, delayed maturity, and very high adult survivorship. This means that any acute or sudden increase in adult mortality will likely result in population declines and recovery is slow. At this particular site, the increased threat of road-kill, predation of eggs along newly built gravel roads, the threat of pet-collection and poaching, and destruction of alvar-wetland habitat would collectively cause severe and irreversible harm to the Blanding's turtle population. The tribunal agreed. The fact that PECFN won this case on road ecology science alone, is a testament to the lack of science for wind ecological impacts on wildlife. It also exposes flaws in the current legislative process. Severe and irreversible harm is a tall order, and the fact that the process did not account for cumulative impacts of turbine development to imperiled species such as birds along the Great Lakes is concerning. Presently, each case is heard on a project-by-project basis. Like roads, large-scale wind turbine development and its associated infrastructure (road and collector lines) must be subject to a placement where environmental impacts are minimal. These criteria need to be carefully selected and are subject to a rigorous environmental, social and economic analysis. Alongside, direct impacts from construction, new and improved road access in existing road-less areas prepares for exploitation of natural resources and secondary development. Drawing from road ecology science, environmental impacts must first be understood to design and install mitigation measures adequately. Once implemented, these measures have varying success and can only partially mitigate impacts. There is a great need to better understand the impact, design, and effectiveness of mitigation measures for wind farms on a species by species basis. This case underscores the need to apply lessons learned from road ecology science to a new field of wind-turbine ecology.

Road networks in Latin America: Research efforts, mitigation and policy towards better governance

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Managing the environmental and social impacts of new infrastructure in Latin America will be a challenge, given the unprecedented scale of planned investments in the next decade. Anticipated growth and ongoing highway investments have generated increasing interest in research and the formation of national road planning networks. Our aim is to show the research efforts, different collaborative partnerships working towards road mitigation and better governance. We conducted a literature review (n=209 peer-review articles) on the ecological effects of roads in Latin America to identify research gaps and define future directions. Compared to developed countries, research in Latin America has been slow to address the ecological effects of roads and design science-based solutions. Of these 88% of studies were from South America, while only 12% were from Central America. Studies focused on mammals (36%), birds (12%), reptiles (9%) and amphibians (4%). More than half reported on mortality, while 27% habitat fragmentation. There was a gap in information on barrier effects and mitigation efficacy. National networks have been formed to leverage public policies for a more sustainable transportation structure. In Brazil, BIOINFRA consists of varying stakeholders with the aim of developing actions in areas of research, public policies, environmental education, training and communication. Mexico's efforts consist of workshops between government agencies, academics and conservation NGOs. Wildlands Mexico and Anima Efferus are actively working with government to mitigate roads in critical landscapes. The World Bank and National Parks supported the first road ecology workshop in Argentina. RECOFSA in Colombia works with public and private road agencies at a national level to evaluate transportation impacts and create mitigation strategies. Vias Amigables con la Vida Silvestre (VAVS; Costa Rica) has organized multi-stakeholder workshops and training courses for agency and consultancy staff in Central America. Highway mitigation projects are growing exponentially with many case studies. Mexico's Nuevo Xcan-Playa del Carmen Highway has 28 wildlife underpasses and 22 canopy bridges. Jaguars have been documented using the underpasses. Two Federal Highways are Mexico's signature projects mitigating impacts for a range of wildlife. Bridge underpass/culvert retrofits make up the majority of mitigation in Colombia in addition to canopy crossings. Nine mitigation projects have been implemented in key protected areas and corridors in Argentina. These projects include the first wildlife overpass in Latin America and many underpasses and canopy crossings. Several key highways in Costa Rica have incorporated wildlife crossings by using research data collected by VAVS and Panthera. Planning and design processes and lessons learned from these model projects will be presented. Although Latin America has lagged behind developed countries in creating sustainable transportation networks in their regions, there has been high interest and political engagement in training, changing practices and policies, working with financial lending institutions. Many of these efforts are conducted at the national level and have not crossed borders and taken

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a transboundary approach. We conclude by identifying the future challenges and needs for improving national and transboundary planning, policies and frameworks for creating ecologically sustainable infrastructure networks in a rapidly changing Latin American landscape.

Can linear transportation infrastructure verges constitute a corridor and/or a habitat for insects in temperate landscapes?

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The role of linear transportation infrastructures (roads, railways, oil and gas pipelines, power lines, rivers and canals) in fragmenting natural habitats is a fully acknowledged fact. Up to now, the potential of habitats and corridors for biodiversity of linear transportation infrastructure (LTI) verges (road/railway embankments, strips under powerlines or above-buried pipelines, waterway banks) for biodiversity remains controversial. This work presents the results of the first synthesis of evidence about the potential of linear transportation infrastructure verges as a corridor and/or habitat for insects in temperate landscapes. Our searches identified almost 65,000 articles, which concerned all compartments of biodiversity. The screening stages were restricted to articles about insects. After critical appraisal, 91 articles that reported 104 studies were included. Meta-analyses were performed on studies comparing biodiversity in verges vs other habitats, and we conducted narrative syntheses for the other aspects addressed. We used specific questions to categorise the retained studies and to appraise them critically. These questions incorporated the potential of boundaries as habitats and corridors for insects, and the effects of management and landscape context on these potentialities. A user-friendly database was created to map the studies with low and medium susceptibility to bias. In some cases, artificialisation of transportation infrastructures lowered insect biodiversity while vegetation restoration had a modest positive effect; the trend remained unclear for mowing/grazing practices. Urbanization and agriculture in the surroundings tended to lower the biodiversity hosted by verges, while natural and forested areas tended to promote it. No study dealt with the influence of management or surrounding landscape on insect dispersal along the verge. However, only a small number of studies compared the dispersal along verges and in habitats away from transportation infrastructures. Meta-analyses revealed that insect abundance was similar in LTI verges than in compared habitats, and sometimes even higher (pollinators and primary consumers in non-highway road verges). In addition, the characteristics of the surrounding landscape seemed to influence on the LTI verge biodiversity. Finally, a significant knowledge gap regarding the potential of linear transportation infrastructure verges as corridors for insects has been identified. Thus, we encourage more research on this topic. Infrastructure practitioners could benefit from our research results for certain taxa and about the impact of their management practices on insect abundance and species richness.

Rare and endangered species in railway station dry grassland areas

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Among the 1,400 Swedish railway stations, a majority has been surveyed for biodiversity potential. The results include a list of more than 2,000 species of insects and vascular plants having their habitat in dry grassland patches in railway areas. The list includes approximately 100 red-listed species, mainly bees, beetles, butterflies, and vascular plants. The survey has also included a method identifying and ranking sites based on nature conservation values. High-ranked railway stations are subject to specific biodiversity management plants. By focusing conservation efforts on specific habitats on high-ranked stations, the most valuable railway environment will be preserved and developed. An example is dry and sunny patches with dense patches of the herb *Herniaria glabra*. This herb species is common in sandy and gravelly grounds, but sun-exposed spots are unusual. Much of the railway environment with *Herniaria glabra* is indeed sun-exposed. As a consequence, the red-listed moth *Coleophora scabrida*, of which the larvae are monophagous on *Herniaria glabra*, is frequently documented in railway station areas in some regions. Outside railway areas, this moth species is scarce in Northern Europe. The field visits register the overall classification (1-5). The class 4 (low capacity) and 5 (lack of capacity) will not be considered for management plans. The railway station areas classified to 1 (very high conservation values), 2 (high conservation values) and 3 (moderate conservation value) are proposed to be the subject of a specific management plan. Such management plans are developed to secure and develop the identified conservation values. Currently, 1,300 railway sites have been classified throughout Sweden. The remaining 110 railway stations will be ranked in 2018. We hope that this methodology will trigger a long-term valuation of the natural assets of railway environments. Furthermore, we believe that this national survey will push biodiversity issues to be part of the regular management of railways. For example, training seminars, biodiversity brochures, and web information can be necessary steps to raise awareness for these endangered species and habitats in relevant authorities and management companies.

Effects of management regimes associated with maintenance mowing along Hungarian roadside verges on ground-dwelling snails, slugs (Gastropoda), and arthropods (Osiscidea: Isopods, Araneae, Carabidae)

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The establishment and maintenance of linear infrastructure contribute to the reduction and the degradation of natural habitats. Primarily, the aim of our research was to study how a change in maintenance intensity (number of mowing periods) impacts the different ground-dwelling species diversity of roadside verges. Then, we determined how verge types and seasons affects snail, arthropod, and beetle diversity. Data collection was conducted in four sampling sites in Pest-county representing the main types of verge habitats along the Hungarian roads between 2014 and 2015. One sampling area included arid grassland with some small bushes. The second sampling area was situated in the lowland and hilly landscape of Hungary and bordered by two roads. The opposite sides of the roads were used for agriculture. The third sampling area was situated next to a forest, and the fourth sampling area crosses a wetland in the west section of Lake Velence. All localities include three sections representing without maintenance (not mown), normal maintenance (mown once or twice a year), and enhanced maintenance (mown three or four times a year). The distance between two sections was a hundred metres. In each section, five pitfall traps were established which were five metres from each other and located 1,5 metres from the road edges. Double glass pitfall traps filled with ethylene glycol were used which were deployed in the field for three weeks and three times a year in different seasons (spring, summer, and autumn). Our results do not support the intermediate disturbance hypothesis. Without maintenance, it caused a significant positive effect on arthropod and slugs assemblages concerning arid grassland verges in 2014 spring. The abundance of snails, slugs, carabid and isopod, and the density of *A. vulgare* varied strongly depending on maintenance. The density of all slug and one isopod species, *A. vulgare* decreased with the increasing intensity of maintenance in almost all verge types. While in the forested verge type the normal maintenance led to the lowest density of the slug and isopod species. Regardless of their generalist features, two isopod species, and several slug, snail, and carabid species responded to maintenance intensity in different ways. Spider diversity did not vary significantly with the change in maintenance intensity. In all verge types, normal maintenance resulted in the highest variety of spiders, except for agricultural habitats, where enhanced maintenance positively affected the spider diversity. The highest spider diversity was observed in spring. Consequently, the effect of maintenance on arthropods depends mainly on verge type and season. Thus, the sufficient intensity, timing, and location of mowing maintenance may contribute to an increase in biodiversity along roads. Roadside verges may be important habitats for biodiversity conservation, and we should consider the beneficial effects of maintenance on biodiversity. The research program was funded by CEDR-Harmony (http://www.harmony-project.net/) project. We thank the National Road Authority and the directory of the Duna-Ipoly National Park for the permission to do our research in the field.

Expansion of alien invasive plants along the roadside: A remote sensing approach

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Invasions by alien species are among the most important threats to biodiversity, ecosystems and human well-being. The extent of their negative impacts demands a considerable effort to monitor the invasion status and territorial susceptibility to implement prevention and mitigation measures. Remote sensing (RS) is an important tool for large-scale ecological studies, gathering information in a constant, consistent and repeatable manner over large areas. Therefore, in recent years RS has been applied as an efficient approach to assess and monitor the dynamics of invasive plant species, including their expansion along the roadside. This study aims to describe the spatiotemporal distribution patterns of several invasive plant species (*Acacia dealbata, A. melanoxylon, Robinia pseudoacacia, Ailanthus altissima, and Arundo donax*) along the roadside, in one of the main transport/energy corridors that links Portugal to Spain. Our goal is to develop a methodology that can support preventive protocols and invasion control measures to be adopted in this kind of infrastructures. We analysed a set of multi-temporal aerial photos from 1995, 2010 and 2016. Aerial photos for 2016 were acquired in the framework of the project Life LINES - "Linear Infrastructure Networks with Ecological Solutions". We conducted a field survey to obtain training data of the invasive plant species along the roadsides of the study area with the aid of a real-time kinematic (RTK) GPS receiver. The aerial photos were segmented using the multiresolution algorithm and an object-oriented classification (Nearest Neighbour classifier) in eCognition Developer software. We conducted two sequential classifications. The first classification was used to eliminate the objects of the image without interest for the study of the invasive plants. The second classification was performed to identify invasive plant species. The classification accuracy was assessed using a confusion matrix and the overall accuracy (OA) and Kappa Index of Agreement (KIA) metrics. To analyse the expansion of the invasive species along the roadside, we built a model based on the maximum entropy approach (MAXENT). Finally, we identified areas that are more susceptible to invasion to assist prevention, detection and early intervention directed to control/elimination, as well as to produce an updated distribution of these invasive species. In general, the cover of invasive species increased in the study sites between 1995 and 2016. In the last six years (2010-2016), *A. donax* expanded more than the other invasive species. During this period, some invasive trees were cut along the roadside, suggesting localised management. The probability of expansion of invasive species along the roadside is reduced when there is control of the ditches, with an exception for *A. donax*. In conclusion, in this study, we could observe how invasive species expanded along the roadside between 1995 and 2016. The use of species distribution modelling will help to assess the susceptibility of a territory to invasion. In the light of maintenance effectiveness, RS is a good approach to help in the development of well-planned management of invasive species that spans from anticipation/prevention to control/confinement and even local eradication.

Estimating the invasion risk to the German railway system for 123 invasive alien species

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In 2016, the German Federal Ministry of Transport and Digital Infrastructure (BMVI) established a ´Network of Experts´ addressing urgent questions of the future within the transportation system. Traffic routes and infrastructure are considered as major drivers for the introduction and spread of invasive alien species (IAS) which have been suggested as a serious threat to biodiversity, economy and human health. However, it is not well known which species are most relevant for the transportation system nor how to manage these species. Within the BMVI network, we developed a risk assessment methodology based on five different criteria to estimate the potential of a given IAS to invade the German railway system. These criteria are: (1) occurrence and distribution in Germany and adjacent countries; (2) current and predicted expansion in Central Europe; (3) occurrence in railway specific habitats; (4) reproductive potential; (5) relevant dispersal pathways and vectors. For each criterion, we developed and applied a point-based system ranging from -2 to +2. We calculated the final invasion risk for all IAS as the sum of points assigned to each of the five criteria. We classified the final invasion risk into one of five categories ranging from ´very low invasion risk´ to ´very high invasion risk´. Combining this methodology with performing a comprehensive literature and database survey, we determined the invasion risk for 85 plants and 38 animal IAS. For each species, a datasheet was created providing the risk assessment, underlying data and cited literature. For species with a very high invasion risk, we gathered additional information on potential health risks, possible damage to the railway system, and prospective management actions. We found that 98% of the 123 IAS used dispersal pathways and vectors highly relevant for railway systems. Overall, unintentional dispersal with soil, plant material or wood was the most frequent pathway. The risk assessment indicated that 7% of the IAS has a very high and 38% a high invasion risk. Moreover, 42% exhibited an average invasion risk, and for only 2%, the invasion risk was assessed to be low. None of the 123 IAS had a very low invasion risk. A much larger proportion of plant species were classified as very high or high risk, whereas none of the animal IAS was evaluated as having a very high invasion risk to the railway system. The risk assessment methodology can easily be adapted to other modes of transport and provides essential information for defining management priorities and for identifying prospective measures for preventing and mitigating the introduction and spread of IAS via and within the transportation system.

An evidence-based approach to road mitigation for small vertebrate species

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Roads represent substantial negative factors for natural habitats and wildlife populations worldwide and their impacts are particularly obvious in Europe, where the road network is exceptionally dense. Ecological mitigation using tunnels and green bridges has made significant progress in recent decades yet, most such structures remain insufficiently monitored and their effectiveness is poorly understood for smaller-bodied species, including amphibians, reptiles and small mammals. We undertake a large review of multiple projects undertaken in the UK since 2013 and discuss the results in relation to an evidence-based approach in order to highlight success stories, knowledge gaps and areas of concern, in particular related to species ecology and chemical pollution. We developed and deployed a custom-made automated system for monitoring road mitigation tunnels and investigated multiple sites in the UK across several seasons and years. We combined this approach with large-scale modelling of mitigation prioritization sites across the UK and a complex scheme for monitoring comparative habitat usage on both sides of the roads by species of conservation concern, such as hedgehogs (*Erinaceus europaeus*) and water voles (A*rvicola amphibius*). Hedgehog usage of road mitigation sites showed strong positive selection, but overall numbers were small. A large percentage of all amphibian and reptile observations did not result in full crossings of the mitigation measure but rather in U-turn movements and this percentage varied significantly with species, age class, site and season. We comparatively assess the rejection rates for different species and road mitigation designs and present opportunities for research and practical improvements of future schemes. Additionally, we present and discuss negative consequence of ecological mitigation projects in relation to the facilitation of habitat access by human-associated predatory species, such as brown rats (*Rattus norvegicus*) and house cats. We highlight key remaining questions and argue that a combined, evidence-based approach could substantially progress and improve the effectiveness of road mitigation measures for a variety of species, in Europe and further afield.

Effectiveness of road mitigation for common toads (*Bufo bufo*) in the Netherlands

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The impact of roads and traffic on amphibian populations is primarily the result of amphibian road mortality. This is particularly obvious in species, such as the common toad (*Bufo bufo*), that migrate between its wintering and breeding habitat and often crosses roads. A variety of measures have been developed to prevent road mortality. For example, the construction of fences and amphibian tunnels. Although such measures are frequently applied across the world, only a few studies have evaluated their effectiveness in reducing road kill and facilitating safe movements across roads. This study focuses on the effectiveness of mitigation measures taken for a population of common toads on a local road in the central part of the Netherlands. In 2013, 2014, and 2015 we carried out a capture-mark-recapture study. Immediately after the start of spring migration, toad surveys were conducted along the drift fence on the south side of the road, on the road and at the northern tunnel exits. A crossing index (CI) was calculated by dividing the number of marked toads that did use the tunnels by the number of marked toads that did not use the tunnels. During the years of studying, we marked a total of 722 toads, either individually (43%) or as part of an amplexus (57%). 61% of the marked toads were males, 38% were females, and 1% the sex was not identified. Of the marked toads, 31% used the tunnels to cross the road, 68% failed to use the tunnels to cross the road, and 1% ended up on the road. During the years of studying, we marked a total of 504 toads. Of these toads, 118 used the tunnels, and 386 did not. Migrating population numbers decreased by about 75% after the mitigation measures were installed. Before mitigation, the migrating population was estimated at about 3,000 individuals. After mitigation, the migrating population size is rated at 800 individuals. We found that a relatively small proportion of the toads that approached the road managed to get across via the two amphibian tunnels. The main reason seems to be the low tunnel density, which means the distances are too big to cover for most toads. Most toads do not manage to get through the tunnels and consequently take no part in breeding. Additionally, toads frequently end up on the road where they run the risk of being killed by passing cars. This all seems to have severely affected the population numbers and may even form a threat to the survival of the population. Our research emphasises that the following measures are vital for mitigating road impacts adequately and maintaining viable toad populations: for example, better baseline studies on where toads cross and what distances they move before mitigation, tunnel densities that are based on the mean movement distance of the most critical toads, and drift fences that go well beyond the location where toads cross the road. But also tailor-made measures that prevent toads from entering the road corridor and wandering between the fences, alternative mitigation measures, and well-designed evaluations of mitigation effectiveness.

Standardized methods for amphibians at roads: Identifying critical road sections and evaluating mitigation measures

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Amphibians can be seriously impacted by mortality and barrier effects of roads, and road owners and managers need to mitigate these impacts on critical road sections. We developed standardized method protocols to: 1) identify road sections where current impacts on amphibians are critical and need to be mitigated, and 2) evaluate the effectiveness of amphibian mitigation measures taken. The protocols were developed based on experiences from work conducted in Sweden in the last decade, and on the advice from a national expert group. While generic in nature, and therefore no detailed manuals, the protocols describe method frameworks that should be followed by anyone engaged for the tasks, thereby securing that the results from projects conducted under different contracts are comparable on a national level, and that results reach the required quality. The protocols state the following: (1) Critical road sections should be identified based on: i) available reports on road killed amphibians (large numbers of common species or any number of rarer species); ii) citizen data on amphibian observations or important habitats (primarily breeding ponds) near roads, and iii) counting of dead and alive amphibians on the road (this counting should be used as a 'zero measurement' if the road is later mitigated). The protocol could in principal be applied also for railway, with adapted methodology. (2) Evaluation of amphibian mitigation measures (tunnels and fences) should include: i) counts of road killed amphibians; ii) counts of amphibians passing the road through tunnels and over the road surface, and iii) a basic inspection of the technical construction. Counts should be done before and after mitigation (BA design), extend outside of the mitigated section (to cover any edge effects), and be comparable before and after mitigation so that effectiveness rates can be calculated for both survival and connectivity. The Swedish Transport Administration will commission future amphibian projects according to these protocols. To our knowledge, these are the first national method standards for amphibians on roads, and though the protocols are adapted to the Swedish situation and in addition could certainly be developed after further experiences build up, we hope that they can serve as inspiration to others.

The suitability and use of green bridges by herpetofauna within the Veluwe district, The Netherlands

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Ecological traits make herpetofauna highly responsive to the harmful effects of habitat fragmentation by roads. Wildlife crossing structures like "green bridges" theoretically facilitate gene flow between formerly isolated populations, reduce road kills and enable species to colonise previously isolated habitats. Basic monitoring has shown a limited presence of herpetofauna on and nearby the green bridges. Successful crossings of individual reptiles or amphibians have not been recorded in the Veluwe district to date. Sparse research efforts is a major cause for the gap in knowledge though green bridge 'suitability' could be a limiting factor as well. To test the suitability hypothesis we researched on between June and September 2017. Five green bridges within the Veluwe district were selected, targeting six reptile and one amphibian species. To determine the suitability of the green bridges, reptile densities of two transects located on each green bridge were compared with four reference transects in suitable habitat on either side of the green bridges. Reference transects were situated outside the Road Effect Zone (100 m) but within a 500 m radius from the bridge. To differentiate between open, less-structured zones and well-structured zone with tree stumps on green bridges, the two transects were established in each of such zones. Data were collected utilising a standardised monitoring protocol and analysed with a Generalized Linear Mixed Model. Due to the small sample sizes of individual reptile species, data were grouped before statistical analyses. Species-specific markings were photographed, and GPS-data recorded to employ capture-mark-recapture techniques so individual movements could be described. Photos were not only collected from within the transects, but also in run-up area (100 m radius) on both sides of green bridges. Photos were compared manually or with the CMR-software Wild-ID. Significant differences between reptile densities on green bridges and surrounding habitat could not be found: indicating that green bridge suitability is comparable to their natural habitat. The number of reptiles encountered on rows of tree stumps was 4.63 times higher than those in open areas (p=0,016). This shows that these structures are indeed interesting to reptiles and are likely to facilitate guidance over and towards the green bridges. Based on 1,037 photographed specimens, individual movements have been detected on all green bridges. Although movements of *Lacerta agilis, Anguis fragilis, Natrix helvetica, Coronella austriaca* and *Epidalea calamita* on green bridges have been recorded, only single full crossings for *N. helvetica* and *E. calamita* could be detected. Knowledge of green bridge habitat suitability is an important tool for understanding the effectiveness. It enables managers to optimise the landscaping. Long-term monitoring will often be necessary to be able to calculate suitability on the individual species level. Tree stumps are of great importance for herpetofauna, and it is strongly recommended to apply such wall form structures on and near larger crossing structures but also to ensure replacement when such structures start decaying. The crossing data as presented in this study are of importance in the interpretation of genetic effectiveness studies of green bridges, as was the case in four of the green bridges involved in this study.

Amphibian and reptile highway crossings worldwide: A state of the practice review and gap analysis

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A programme is underway to develop a Best Management Practice Guidelines for sensitive (rare, declining and most 'at risk' or impacted by roads) herpetofauna crossings for the State Road Authority; CALTRANS in California, USA. We examined 52 English language studies concerning road impact mitigation passage and barrier systems, concerning 125 individual taxa (75 reptile and 50 amphibian species or sub-species) from mainly Europe and North America but also South American and Australasia. Snakes, lizards, and frogs were the most studied of the seven discrete species-groups, each representing about 20-25% of taxa, with 13 salamander and newt taxa, five turtle and two of tortoise studies. Information was assessed in categories; *passage construction and use, passage environmental variables and barrier construction and use*. There was a little over twice the number of publications for amphibians as for reptiles. However, the level of information was not that different overall. Crossing structures were divided into five categories, mainly reflecting the width of passage over or under roads. Very few of the studies represented massive overpasses and other more prominent crossing types with almost all considering passages of fewer than 3.0 metres span. Results suggest that, in most cases, road impact mitigation planning has not been set against a quantitative objective but mainly to try to reduce direct road mortality. Monitoring of passage use has been generally weak and inconclusive. However, more recent results show that this has improved. Some controlled experiments manipulating key variables are indicative in showing effects and trends. Nonetheless, studies often have small sample sizes and low confidence inferences. Use of general purpose passages under highways that are created by river bridges and drainage culverts have mostly not been evaluated for their role in helping to maintain genetic and population connectivity for herpetofauna. Going forward there is both a need for appropriately designed studies to evaluate the effectiveness of purpose-built (engineered) and non-engineered road structures that provide passages and barriers. There is also a need for conducting studies (controlled experimental or field settings) to directly measure, test and compare existing and potential road and passage permeability, how systems contribute or fail and the relationship between construction cost and benefits. Information on system use in respect of passage qualities, including size (diameter and length), light levels (by day and night), moisture and substrate (passage floor) will inform future approaches. Most important for immediate need is defining what kind of passage use is necessary for each situation (habitat, land use type, community and population needs) and the measurable success criteria for the passage outcome. The results of this review have informed small-scale field research projects in California that are underway at experimental and existing mitigation sites before finalising the BMP guidelines for 2020.

Integrating wildlife into Europe's national road network

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The European road network does not only provide an extensive and vital transport system, but it also results in impacts on the surrounding environment. Biodiversity is a priority area for the European Union (EU). In 2011, the EU Commission announced a new strategy to halt biodiversity loss within ten years. This strategy emphasises the severity of habitat degradation caused by fragmentation and the importance of incorporating ecological connectivity and green infrastructure into spatial planning. In 2010, the United Nations (UN) and the parties of the Convention on Biological Diversity adopted a new Strategic Plan for Biodiversity 2011–2020. This plan also stresses the need to integrate biodiversity values into planning processes, and for all stakeholders to maintain the impacts on natural resources within safe limits. The UN General Assembly declared 2011–2020 the Decade of Biodiversity. Consequently, maintaining a green infrastructure network in Europe is of equally great importance to the EU as maintaining and developing a transport infrastructure. Therefore, methods of combining these two goals should be investigated, and best practice should be identified. Road investment is subjected to extensive discussions between the road and environmental authorities, with often long planning periods and occasionally resulting in demands for expensive mitigating actions. Therefore, it is essential that the mitigating strategies are cost-efficient. The Conference of the European Directors of Roads (CEDR) undertook a transnational research call in 2013 to ensure the latest best practice related to wildlife was adopted during the development of road infrastructure. In this way, a more cost-efficient approach complying with environmental demands, including demands from the various EU Directives could be achieved. The research call, known as 'Roads and Wildlife', focused on subjects requiring international cooperation. It also focused on the practicalities of implementation by the National Road Administrations (NRAs) so that the new information proves beneficial to their needs. The 2013 Call focused on the following issues: (1) Cost-efficient road management for compliance with the demands from wildlife: (a) Compliance with EU legislation; (b) Procurement; (c) Maintenance. (2) Cost-efficient mitigating strategies for roads and wildlife: (a) Effects on populations of mitigating strategies; (b) Determining what would be good enough; (c) Strategies for safeguarding the effect of mitigating actions; (d) Mitigating strategies for bats. Three projects, known as SAFEROAD, HARMONY, and SafeBatPaths were successfully procured and completed under this call. The findings of these projects were then used to produce some new ecology chapters to extend the COST 341 handbook, which was initially published in 2003. This presentation will cover the output of the three research projects as well as the development of the new wildlife handbook for NRAs. Areas under discussion include legal issues associated with wildlife, procurement and performance indicators, maintenance strategies, bats, etc.

Procurement – The relevance of the CEDR Roads and Wildlife Manual for road engineering

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Road authorities across Europe aim to minimise costs while ensuring quality outcomes for the protection of nature. At the same time, there is a broad interest in transitioning to outcome-based specifications in construction and maintenance contracts. The Conference of European Directors of Road (CEDR) identified the need to gain insight in how the various procurement practices across Europe considered ecological mitigation measures and recognised the need to understand better how outcome-based procurement might influence the results for nature in their 2013 Roads and Wildlife Call. Initially, funding the projects *Harmony* (Procedures for the Design of Roads in Harmony with Wildlife), *SAFEROAD* (Safe Roads for Wildlife and People) and *SafeBatPaths* (Fumbling in the dark – effectiveness of bat mitigation measures on roads)', CEDR have since commissioned the 'CEDR Roads and Wildlife Manual' to bring together the distilled, essential, outputs of the original projects. This presentation will describe the content of Chapter 4 of the CEDR Roads and Wildlife Manual, 'Procurement and Performance Indicators'. There will first be a review of the relevant *Harmony* and *SAFEROAD* results, including a survey on procurement practices across nine countries. These results form the basis for the work presented in the Manual. The presentation will then outline approaches to the procurement of road mitigation measures, describing the various types of procurement and how the choice of contract type can affect the ecological outcomes. Contracts that engage the contractor before planning, those that focus solely on maintenance and those that provide for maintenance after construction all have advantages. Regardless of the contract type, it is essential that parties with ecological expertise are involved at all contract stages. Incorporating suitability assessments and making their ecological aspects a pass and fail criterion should ensure improved engagement and better outcomes for nature. The language used in the procurement of mitigation measures should be standardised to help contractors. Methods to achieve effective, measurable outcomes that facilitate wildlife crossings are then discussed. Follow-up studies need to be an integral part of all mitigation aspects of projects. Follow-up studies establish the performance of a contract, certifying delivery, and can also be used to establish best practice. The development and use of performance indicators to judge the products and services delivered by contractors can help ensure that the road authority gets maximum delivery from procurement.

Road mitigation for bats

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The impact of infrastructures on bats is an increasing conservation issue. Although bats will fly across roads, they often do so at traffic height, which puts them at risk of collisions. Furthermore, roads and other traffic infrastructures may also degrade and destroy habitats and act as barriers reducing the overall ecological functionality of the landscape. Consequently, interventions are needed to maintain the favourable conservation status of bat populations when constructing new transport infrastructures or upgrading existing ones. All bat species have a relatively long life span and low reproductive rates, which renders them very susceptible to increased mortality rates and limits their ability to recover if populations are depleted. A variety of interventions has been developed which may mitigate the potential impacts of roads on bats. For example, green bridges, viaduct bridges, and culverts, providing safe crossing sites and maintaining landscape permeability. Or screens and hedgerows, diverting commuting bats to secure crossing sites, and habitat improvement and artificial roost sites to compensate for habitat degradation and destruction. Unfortunately, the effectiveness of many mitigating measures has not been documented or evaluated in quantitative terms. The different bat species have different behaviours and flight patterns. That is why the effectiveness of a mitigation strategy depends on species composition, habitats, and the topography at a site. Thus, we need detailed pre-construction surveys at a site. The mitigation measures should be carefully selected, designed, constructed, and subsequently monitored to ensure high effectiveness. Special consideration should be given to rare species, small vulnerable populations, or species with a fragmented distribution. The CEDR Manual provides recommendations on the different types of mitigation measures and their effectiveness for bat species with varying characteristics of flight. Furthermore, the manual outlines vital points to consider for the different types of mitigation measures.

Road maintenance guidelines to improve wildlife conservation and traffic safety

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In recent decades, significant efforts have been made, and a considerable amount of money has been invested in designing and constructing wildlife measures on road networks. These measures help to reduce habitat fragmentation and to prevent road kill of wildlife due to transportation infrastructure. Such measures may be limited in their effectiveness by the lack of appropriate maintenance. Moreover, road verges and other green areas linked to roads and railways have been highlighted as wildlife habitats that could play a role in enhancing biodiversity conservation and ecological connectivity, particularly in densely populated areas. In this regard, maintenance practices emerge as a fundamental factor in reducing long-term road impacts. The aim of our study was: i) to provide an overview of current road maintenance practices regarding wildlife in Europe, ii) to identify opportunities and best practices that enable adaptive management of wildlife-related issues, and iii) to provide guidelines for road maintenance to reduce hazards for road users and wildlife, enhance biodiversity, and strengthen the European Green Infrastructure. We interviewed 24 professionals involved in road maintenance from 11 European countries, carried out a literature review, and organised a workshop that brought together road and wildlife experts. The final output was a set of guidelines for the maintenance of roads and their surroundings from an ecological perspective. Most relevant ones have been included in the Roads and Wildlife Manual, published by the Conference of European Directors of Roads (CEDR) in 2018. Road managers are recommended to adopt a flexible strategy and a lifecycle approach to guarantee the long-term effectiveness of wildlife mitigation measures, to identify better cost-efficient strategies and to use wildlife conservation opportunities. Appropriate road–wildlife maintenance strategies should include: i) standards for wildlife mitigation measures to be met according to both the instructions provided by designers and constructors, and the road safety and operational requirements; ii) scheduling inspection and maintenance tasks adapted to the local conditions of wildlife and habitats; iii) establishing procedures for identifying conflicts or deviations and how to solve them; iv) defining proper training programmes for maintenance crews; v) defining methods for monitoring and reporting in compliance with standards, and disseminating this information to road planners and other stakeholders involved. Instructions for the inspection and maintenance of wildlife fencing and screens, wildlife crossing structures and wildlife awareness devices are provided to improve traffic safety, and to funnel animals to safe crossing points. Additionally, a number of Best Management Practices (BMPs) on maintenance of road verges, landscaped areas, retention ponds, and other aquatic habitats associated with drainage systems are described. Attention must be paid to avoid the risk of creating ecological traps, i.e., habitats that attract animals to areas with a high mortality risk. Early detection and removal of alien invasive species, that could damage local habitats or species, is also envisaged as a critical factor to be applied to road maintenance procedures. An overall strategy that considers and integrates information on the maintenance of wildlife mitigation measures and roadside habitat management will provide appropriate risk assessment and identify the BMPs that have to be applied.

CEDR Roads and Wildlife Manual: Road mitigation strategies and monitoring

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Roads and traffic may increase mortality of wildlife due to wildlife-vehicle collisions, act as barriers to animal movement and migration, and affect both the amount and quality of wildlife habitat. Over the last four decades, concern for the impacts of roads on wildlife has resulted in efforts to mitigate these effects. Road agencies and conservation organisations are currently investing large amounts of money in developing and implementing numerous mitigation strategies and techniques. However, what is the most efficient mitigation strategy? Should we focus on reducing wildlife mortality due to vehicle-wildlife collisions? Is increasing road permeability for wildlife the better option, or should we consider doing both? If mitigation measures have been installed, additional questions arise. Do they work? Are they effective in reducing road impacts? We have to carefully evaluate the performance of current and future road mitigation measures to answer these questions. Nevertheless, what is the best way to do this? Which performance indicators should be selected? What would be the best study design to assess whether the desired outcome is achieved? And how can we be assured that the measured outcome is not biased by factors that do not directly relate to the road mitigation works? All these questions are addressed in the 'Roads and Wildlife Manual', recently published by the Conference of European Directors of Roads (CEDR). The handbook provides seven guidelines for preparing an effective road mitigation plan: (1) Identify and quantify the road impacts; (2) Identify clear goals of mitigation; (3) Involve stakeholders early on in the process and aim to let all stakeholders agree on the goals; (4) Select road mitigation measures for which effectiveness is proven; (5) Combining fences with wildlife crossing structures is best practice; (6) Select mitigation measures that have proven to be sustainable; (7) Explore the economic benefits of road mitigation. The set of guidelines is not a step-by-step guidance document, but should be merely seen as a checklist that helps to address all relevant issues in the preparation of a scientifically sound mitigation plan. The handbook also provides a framework to assist the evaluation of the road mitigation performance. A set of guidelines is presented for the preparation of a scientifically sound plan to evaluate whether the desired outcome for road mitigation has been achieved or not: (1) Identify the target species and goals of mitigation; (2) Select appropriate performance indicators; (3) Use reference values and controls; (4) Select appropriate survey methods; (5) Select an appropriate spatial scale for data collection; (6) Time data collection carefully; (7) Take sufficient time for performance evaluations; (8) Use a sampling frequency that provides sufficient data; and (9) Measure explanatory variables. The new handbook updates and complements the COST 341 handbook, which was published in 2003. It provides a strong foundation for considering the effects on wildlife throughout the various stages of the roadway's life and aims at solving conflicts between roads and wildlife.

What drives the spatial distribution and temporal persistence of bat road kill hotspots?

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Road kill hotspots are frequently used to identify priority locations for mitigation measures. However, understanding the landscape context and temporal dynamics of these hotspots is a challenge. We investigate the factors that drive the spatio-temporal variation of bat mortality hotspots in a Mediterranean landscape. We hypothesise that hotspot locations occur at places where bat activity is higher. Additionally, we hypothesise that this activity is related to vegetation density and productivity because this is related to insect prey abundance. We used a combination of spatiotemporal analysis and generalised mixed models to evaluate the effect of the local spatial variation of vegetation productivity (as measured by the Normalized Vegetation Index -NDVI) on bats space use. Then, we combined this information with bat road kill locations to predict and validate spatial and temporal variation on road kill hotspot locations. During three years (2009, 2010, and 2011) we conducted daily surveys (n=690) along a 51 km long transect that incorporates different types of roads in southern Portugal, searching for bat casualties. Overall, we found 474 bat casualties during the sampling period. Then, to conduct the bat mortality analyses we assigned each road kill to the corresponding 500 m-road segment. We identified mortality hotspots for each year; segments where the number of casualties exceeded the upper 80% confidence limit of the mean, assuming a Poisson distribution of road kill per road segment, and analysed if they changed their location over the years. Overall, only 10% of segments were identified as hotspots during the whole year. 37% of road segments are intermittent road kill hotspots, i.e., they are classified as hotspots only in one or two years. 53% of road segments had very few bat casualties and were not identified as hotspots. For 20% of the road segments, we did not find any bat casualties. Thus, the non-persistent hotspots were the most frequent category. Further analysis of this type of hotspots showed that the spatiotemporal congruence of hotspots locations declined with decreasing vegetation production and the associated reduced bat activity on the proximity of road segments. This supports our hypothesis showing that a decline in overall vegetation productivity, and the presumed lower abundance of prey have a significant effect on the decrease of bat road kill. In this study, we show for the first time that using readily available series remote sensing data, and the indices that can be calculated based on this information, such as the NDVI, can be a powerful tool to predict bat road kill hotspots and their persistence in time. Thus, NDVI can be used in road planning, to prioritise location of mitigation measures or to identify essential road habitats for conservation.

Predicting bat diversity, abundance and movements in road projects: Evaluation of a habitat suitability model

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Large road projects are expensive and require long-term planning. Information about conservation values in the landscape as early as possible in the process will save time and money, and when the environmental impact assessment is started, it is good to know what kind of surveys should be conducted and where conflicts with conservation values might occur. Roads have a significant impact on bat populations. Both mitigation and compensation measures based on available population data is possible. To create an "early-warning" system for potential conflicts with bats, a habitat network model was developed, based on publicly available geographical data. The model takes several important aspects of bat population ecology into account, aspects as temporal variation in habitat quality, spring migration and foraging behaviour around breeding colonies. The model predicts bat distribution based on landscape specific connectivity parameters and the distribution of habitat patches of different quality, which a model of population dynamics can be built on. First of all, it can be used to make predictions on where in the landscape bats are most likely to search during spring and autumn. Secondly, it can be used to specify when insects are restricted to specific combinations of habitats. Thirdly, it can be used to determine where summer colonies are most likely to be established. And fourthly, the model can predict where bats are expected to cross infrastructure or which routes bats are most likely to take through the landscape when moving from one place to another. The model was constructed using a set of ArcGIS methods linked together in a workflow. The model was evaluated in the field by a bat survey using stationary ultrasound detectors (during summer 2017), and based on this result it was possible to develop the model further. The model is now ready to use, but to improve the model, more data about habitat selection of some bat species will be collected during following years.

Ecological effectiveness and implementation of hop-overs for bats: a case study on the N356

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In 2006 the provincial board of Friesland decided on the construction of the N356 road 'De Centrale As' (DCA) in the northern part of the Netherlands. This new road crosses the small-scaled bocage land-scape of the northern part of Friesland as well as some parts of the main ecological structure. The area is known as important for bats. In the design, much effort was put on the mitigation of the possible impact on the bat populations in the region. This lead to the imple-mentation of so-called 'hop-overs' to maintain commuting and foraging routes, as well as to reduce mortality of bats. An important process-based objective was to design effective ecological constructions, being feasible regarding planning and construction. This was realised through a system engineering approach. Ecologists were involved at an early stage in the construction process. Before the design, commuting and foraging routes of bats were mapped. Based on this spatial inventory, potential hop-over spots were chosen, and the ecological requirements were specified as SMART as possible. This allowed to use them as input for the design, together with and at the same priority level as technical requirements. The framework of the design was further set by legislation and environmental and social aspects. From the moment the alignment of the N356 was confirmed (2006), the hop-over locations have regularly been monitored for the presence of bat species. Currently (2018), long-term agreements on opera-tion and maintenance are being made with the engaged stakeholders, to ensure functionality of the hop-overs in the long term. Fifteen natural and five artificial hop-overs were constructed. Additional-ly, six watercourses were made passable for bats. Both hop-overs and watercourses passages were built according to plan. This was verified, monitored and evaluated during the construction phase using the system engineering approach. This facilitated the process and communication between ecologists and the contractor and additionally was helpful to test for ecological functionality. The monitoring shows a lot of variation in the number of passing bats per location before the construc-tion started. This may be explained by the presence or absence of nearby colonies and weather condi-tions. After the preparatory activities (cutting wooded banks) we detected no outliers due to the lack of suitable foraging habitat. Two years after the road had been put into use (2015), the hop-overs are frequently used by bats. The number of passages at natural hop-over sites, with well-developed trees, are at the same level as before the preparatory activities. Artificial hop-overs and hop-over sites with newly planted trees are not (yet) at the level before construction, but nevertheless frequently func-tion as a passage for bats. We recommend that ecologists should be involved at an early stage of the process and monitoring should continue throughout the construction process. Additionally, agree-ments on operation and maintenance are essential to ensure functionality in the long term. Finally, the specification and translation of ecological requirements in a system engineering approach help to communicate effectively and additionally facilitates to test hop-overs on ecological functionality.

A road-effect zone for insectivorous bats not caused by lack of insects

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The effects of roads and traffic can be detected hundreds of metres from the road. Known as the road-effect zone (REZ), this phenomenon effectively reduces the quality of habitat along roads, resulting in significant impacts than those typically acknowledged by road agencies. A number of different factors can cause the REZ. Identifying which one(s) is essential to develop effective mitigation strategies. Wildlife may respond to the primary effects of the road (such as traffic disturbance, habitat loss or the gap in the canopy), or to secondary impacts, such as prey availability. For example, insectivores may be less abundant where there are fewer insects, thus a REZ for insects may be correlated to a REZ in insectivores. However, few studies explore this relationship between predators, prey, and the road-effect zone. In this research, we have quantified the REZ for insectivorous bats and nocturnal flying insects, their primary prey. We surveyed bat call activity and collected insect samples along eighteen transects that were perpendicular to three freeways in southeast Australia. We found that nine out of ten insectivorous bat species, evaluated in this study, showed reduced activity within the first 200 metres of the freeway compared to 2,000 metres away from the freeway. However, we found no change in insect biomass with distance from the freeway, except for the Orthoptera, in which biomass increased with increasing distance from the freeway. Therefore, we suggest that the road-effect zone for insectivorous bats is close to the freeway, , likely due to degraded habitat quality (i.e. from traffic noise spill, and unsuitable or lack of vegetation), rather than a reduction in prey availability. Further exploration of the role of these factors on the presence of bats near freeways is essential to mitigate the road-effect zone for insectivorous bats.

Recent innovations in threatened microbat mitigation on road projects in New South Wales, Australia

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Roads and Maritime Services are responsible for maintaining over 18,000 kilometres of road network in New South Wales (NSW), Australia. Along the east coast of NSW, a roosting and breeding habitat for threatened microbats occurs in a variety of Roads and Maritime assets. This includes structures such as historical timber truss bridges, concrete pipe, and box-cell concrete culverts, and concrete bridges. When these structures are removed or upgraded for maintenance or safety reasons, impacts on threatened bats such as the Large-footed Myotis (Myotis macropus) and Bent-wing bats (Miniopterus spp) can be significant enough to cause the extinction of local populations. Our agency aims to restore roosting and breeding habitats, to minimise impacts of road projects on threatened microbats. We do this by providing mitigation measures such as bat boxes, which are subsequently monitored for use. However, results from ecological monitoring indicate that wooden or recycled plastic bat boxes should only be considered as temporary construction mitigation measures. Most microbat boxes are sure to deteriorate over time and are sometimes not utilised by the target microbat species. For the past six years, Roads and Maritime Services have investigated and documented the features of known roosting and breeding habitat for threatened microbats in a variety of concrete and wooden structures within the Northern Rivers of NSW, Australia. Based on these known features, ecologists, bridge designers, biodiversity specialists, environment staff, and project managers have worked together to include permanent roosting and breeding habitats in the design and construction of new concrete bridges and box-cell culverts. These designs have also been applied to the retrofitting of existing concrete culverts, and new ecological monitoring has recorded successful uptake and breeding events. This presentation provides details of the evolution of microbat mitigation in NSW and the project that resulted in an Australian first-inclusion of permanent microbat roosting and breeding habitat in the design and construction of a new concrete bridge. It also highlights the lessons learned during construction and illustrates how the culture of a road agency is changing to design and incorporate permanent roosting and breeding habitats for threatened microbats into new concrete structures.

Restoration and optimising ecological connectivity in the North Sea Canal Region

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As almost 30% of the Netherlands is below sea level, flood prevention has always been a significant topic. In time, various anti-flood measures have been taken. One important measure is the continuous pumping of surplus water. Especially since the production of smaller pumping stations has become less expensive in the seventies, pumping stations has grown to a number of more than 5,000 stations. Unfortunately, this resulted in a consequent reduction in connectivity between different water systems. In the Netherlands, sixteen diadromous fish species occur naturally. Apart from two species, they all are threatened to become extinct. Habitat fragmentation is likely to be one of the leading causes of this decline. The North Sea Canal was constructed mainly by reclaiming land from a large, brackish inland lake where migratory species were widespread. Today, the canal still features the salinity transition zone of an estuary. This allows diadromous species to adapt gradually to changes in the physical environment. The water authorities around the North Sea Canal have realised that a joined cooperation and a combined approach is necessary to sustainably improve fish stocks. Therefore, a program has started providing a framework. In this framework, eight partners can work more effectively, concerning approaches and the collaboration of partners. This program so far has resulted in combined measures and gaining and sharing new knowledge. Since last year, a joint large-scale monitoring project has started with an emphasis on species that used to be common in the local water systems. The program will take three years. In 2017, telemetry experiments were carried out. Over 300 silver eels were surgically implanted with VEMCO-transponders, and over 2,100 silver eels were tagged with passive integrated transponders. In total 63 receivers were distributed throughout the region to collect data. In this way, it was possible to establish the migration routes of silver eels and learn about their activity patterns. In 2018, the research program focuses on glass eels and three-spined sticklebacks. By release and catch experiments, we aim to find out more about the total number of fish, dispersion rate, and swimming speed. In order to do so, 4,000 glass eels will be collected, marked with Visible Implant Elastomers and will be released afterward. Sticklebacks will be tagged with PIT-tags. Finally, in 2019, the focus will be on the migration of non(obligate)-migratory species. Effects of habitat fragmentation on these species so far have been poorly explored and might be crucial in population structure, diversity, and stability of the ecosystem. The results of the monitoring program will contribute to achieving the objectives of the European Framework Directive, more sustainable water management, an increase in species diversity, and more stable ecosystems.

Ecological value of constructed shallow water zones along a navigable canal: A case study from the canal Ghent-Bruges

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In navigable canals space is often limited and a depth-width ratio is required for navigation. As a consequence, strong hydraulic disturbances, generated by vessel movement, affects the canal banks. Until some decades ago, banks of navigable canals were steep and often stabilized with hard-armoured materials, such as concrete revetments or metal sheet-piles. Hence, a sharp transition between water and land was created and marginal riparian habitat was limited. Furthermore, navigation-induced hydraulic forces cause difficulties for vegetation establishment or hamper vegetation growth. In this way, conditions for marginal riparian vegetation along navigable canals are unsuitable. Nowadays there is a growing practice to employ ecologically friendly bank stabilisation methods. Ecologically friendly bank stabilizations use vegetation for construction and promote the continuum between the terrestrial and aquatic environment. A case study of artificial shallow water zones (700 m length at the northern bank and 300 m length at the southern bank) along the canal Ghent-Bruges is presented. The shallow water zones were constructed by building a dam of riprap parallel and in front of the actual canal bank. No planting or seeding was performed. It is expected that the dam inhibits the navigation-induced hydraulic forces. As a result, a sheltered zone between the actual bank and the dam with suitable condition for vegetation development is supposed. The vegetation in the shallow water zones was examined by means of 10x1 m plots in 2006 (8 years after construction), 2009, 2013 and 2017. Water quality was measured in terms of temperature, conductivity, pH and dissolved oxygen concentration and oxygen saturation and took place in 2013, 2014 and 2016. The following research questions are addressed: (1) can helophyte and rooted aquatic vegetation establish and develop in the shallow water zone? (2) which plant species are involved? (3) did vegetation succession happen? (4) is there a difference in water quality between the shallow water zone and the fairway? The studied shallow water zones provide appropriate conditions for establishment of native herbaceous helophyte vegetation. Cover of willows shows strong differences at both canal sides. The shallow water zones are of little importance for rooted aquatic plant species. A lower dissolved oxygen concentration and oxygen saturation were measured during summer and autumn in the shallow water zones compared to the fairway. Mitigation measures for navigation impact can increase biodiversity and ecological processes in navigable canals. The key findings of the case study can be useful for waterway managers, policy-makers and technicians in future bank engineering projects.

Adjusted tidal sluice management, an easy way to improve the upstream migration of glass eels in Flemish waterways (Belgium)

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For centuries, tidal barriers have been erected all around Europe to safeguard the hinterland from flooding and to better manage the local hydrology for agriculture and transportation purposes. Besides the benefits for human's prosperity, such barriers resulted in the deterioration and disappearance of typical brackish habitats and species. Often, they constitute a significant threat to fish species, especially migrating ones, such as the catadromous European eel (*Anguilla anguilla* L.). Due to a multitude of anthropogenic impacts, this enigmatic species has recently endured a population collapse, without signs of recovery. Nowadays, it is considered to be *Critically Endangered*. An uninterrupted migration route between the spawning area in the Sargasso Sea and the freshwater growth habitats in Europe's lakes and rivers is crucial for the European eel's long-term survival. However, every spring, millions of glass eels arrive at the European coast to see their inland migration route blocked after which many succumb and die. In the frame of the Belgian Eel Management Plan, we investigated the possibilities of adjusted tidal sluice management (ATSM) to enhance the eels' upstream migration. During the glass eel season (March-May), sluices are slightly opened at flood tide, allowing seawater to flow into the upstream part of the river, enabling glass eels to pass. During three consecutive years (2016, 2017, and 2018), glass eel numbers and biometric variables (length, weight, pigmentation, stomach content) were weekly monitored. This monitoring was done by artificial substrates and two eel ladders installed on both sides of a pumping station located in the upstream part of a small drainage canal connecting a 20,000 hectares polder area to the Yser estuary (Nieuwpoort, Belgium). By comparing the number of incoming glass eels with and without applying ATSM in this canal, we could demonstrate that glass eels indeed use this free passage opportunity. Moreover, the upstream migration capacities of these migrants, which are confronted with dramatically shifting conditions (e.g., salinity, water movements) upon intake, seemed to be unaffected. By continuously monitoring the salinity, we could demonstrate that ATSM did not result in salinization of the polder area, which is otherwise prevented by temporarily stopping ATSM (mainly during dry periods) as soon as a salinity threshold is reached. Our study clearly shows the potential of ATSM techniques as a valuable tool for the management and restoration of migrating species such as the endangered European eel. As such, a more comprehensive application of this cheap and easy applicable technique should be considered as one of the measures to implement within the national Eel Management Plans across Europe.

Pumping stations and the 'migration road' towards safer pumps for the critically endangered European eel

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Water managers use pumping stations (PSs) for numerous applications on rivers, canals, and other water bodies. They play a significant role in wetland drainage, irrigation, water diversion, agriculture, drinking water provision, flood protection, water level control, and the conservation of polder areas. The increasing pressure on water resources and flood protection, for example, due to climate change, will also boost the need for controlled water provision and evacuation in future decades. The worldwide distribution of PSs is poorly quantified. However, in the lowland countries Belgium and the Netherlands alone, more than a hundred to thousands of PSs, respectively, are needed to evacuate water towards the sea. Despite the obvious benefits of PSs, their impact on fish populations is poorly understood. From the different migrating fish species impacted by PSs, the critically endangered European eel (*Anguilla anguilla* L.) may be one of the most vulnerable. These eels migrate downstream and must pass PSs to reach their spawning grounds in the Sargasso Sea. For the Belgian Eel Management Plan, eel mortality was studied after downstream passage through four different types of pumps and pump sizes on three lowland canals in Belgium. A propeller pump (2008), a larger and smaller Archimedes screw pump (2009), a larger and smaller de Wit Archimedes screw pump (2012-2013), and a sizeable fish-friendly screw pump (2016-2017). The two types mentioned last were innovative designs that should minimise physical impact and ensure safe fish passage. Nets were mounted permanently on the outflow of the pumps to monitor downstream eel passage. Based on the condition of the fish and injuries sustained, the assessed maximum mortality rates ranged from 97 ± 5% for the propeller pump, over 17 ± 7% for the large, and 19 ± 11% for the small Archimedes screw pump, to 19 ± 4% for the large, and 14 ± 8% for the small de Wit Archimedes screw pump. Mortality rates for the fish-friendly screw will also be presented (this is a work in progress). According to pump types, striking or grinding caused most injuries. To achieve escapement targets set in the eel management plan, we need fish-safer pump designs and effective PS bypass solutions.

Crossing borders between roads agencies and building companies, for a greener and sustainable transport infrastructure

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The construction of Dutch national infrastructure has a history of increasing use of outcome-based procurement methodologies. This is shown in the frequent use of Design & Build and Design, Build, Finance & Maintain contract types, where functional requirements are the basis for building companies' design processes. However, procurement methods were still based on conventional roles of government agencies to conduct landscape-level analyses to decide which ecological measures are required, and of building companies to limit the design process to a pre-defined scope. This approach has several disadvantages: (1) ecological measures may mismatch efficient construction approaches desired by building companies; (2) building companies may be late to fully integrate ecological aspects in project organisations and designs, i.e. after the tender; (3) scope-expanding opportunities during the design process are usually missed or ignored. Since 2012, two Dutch highway expansions have been commissioned that attempted to cross the border between the traditional roles of government agencies and building companies. This was done by tendering with an, in part, open scope, and by challenging building companies throughout the tender to develop measures to add ecological value to the project. The incentive for building companies was a more significant chance to win the tender when more ecological value was added to the project, although the winner of the tender was selected based on a combination of value and costs. The two projects led a total of five tendering building companies to recruit senior ecologists and researchers who undertook landscape-level analyses to identify a wide range of measures to mitigate and compensate adverse effects, defragment habitats and develop new habitats. Because ecologists and civil engineers collaborated from an early stage, opportunities and innovations arose, and mutual understanding and respect contributed to overall sensitivity and support for ecology throughout all project phases. The proposals submitted by the tendering building companies varied in ecological value offered, but the overall value was high. An important advantage of the incentive used was that building companies pursued measures that offered large ecological benefits at reasonable costs. It was not possible to shift the entire identification and selection process for ecological measures in the highway expansions to the tender phase, because tenders require a project approval with associated actions. Nevertheless, we found that shifting part of the process to the tender significantly improved the conservation, robustness and connectivity of natural areas near the highway expansions. Consequently, several future highway constructions will follow a similar methodology.

'Structure-Permeability-Index' to assess highway alignments

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Although Swiss motorways are fenced in, the alignment leaves some connectivity for wildlife species thanks to the existence of numerous crossing structures such as bridges, underpasses, water outlets, viaducts and tunnels. A user-friendly Structure Permeability-Index (SPI) to analyse crossing structures was developed for fenced highways in Switzerland in order to rank priorities during upgrading projects. Crossing structures identified with potential for connectivity can then be improved by measures such as planting around the edges, noise screens or other simple adaptations. The SPI considers structure type and dimensions, the surrounding land-use (forest, agriculture, settlement, water bodies), traffic noise emissions in the surroundings and night-time motorised traffic on the structure. The SPI index has a value between 0 and 1, offering a comparison of the connectivity offered by different crossing structures and therefore an analysis of the overall permeability of a highway section. The SPI was tested using linear regression analyses comparing the relationship between the SPI and the number of measured (camera survey) animal crossings of 98 crossing structures. Results show a strong statistical relationship between SPI and number of animal crossings ($R2=0.45$, $p<0.001$). The tests used the field data for two motorway stretches: (1) 27 km of A7 through a farmland landscape with a relatively low average daily traffic volume of 47,000 vehicles/day; (2) 22 km of the A1 through a more densely populated area with a high average daily traffic volume of 81,800 vehicles/day. The number of wild animals using the crossing structures along each stretch was recorded with the aid of self-triggering cameras equipped with infrared flash devices over a period of three weeks. Only those animals were counted that actually crossed over the motorway via the respective structures. Due to the methodology chosen only medium-large mammals were recorded going from martens to red deer. On the A7 stretch, 16 culverts, 25 overpasses, 13 underpasses and three specific "green bridges" were monitored, and on the A1 stretch, 8 culverts, 18 overpasses and 16 underpasses. On the A7, a total of 1,802 animals, including foxes, hares, badgers, roe deer, martens, wild boar and beavers, crossed the motorway via the various available structures during the observation period. Foxes used around 85% of the structures, while martens and badgers used 30%, roe deer and hares 20%, and wild boars used three of the corridors. On the A1, a total of 876 animals, including foxes, badgers, martens and roe deer crossed the motorway via the available structures. Here, foxes used 85% of the structures, martens 37%, badgers 13% and roe deer just one. If we take the average number of wildlife crossing via each structure, we find that the crossing structures along the stretch of the A7 were used twice as frequently (n=34) as those along the A1 stretch (n=17). The index expresses these differences and should allow to identify more easily crossing structures which are suitable for retrofitting to optimize connectivity.

A user-friendly computer platform to assess the impact of transport infrastructure on wildlife: a case study with the Eurasian lynx in France

Large carnivores are wide-ranging species, highly mobile and live in human-dominated landscapes where habitat destruction and fragmentation are important threats. In parallel, the terrestrial transportation network is getting denser and acts as a barrier for the movement of these animals as well as it increases the risk of collisions. In this contribution, we focused on the Eurasian lynx (Lynx lynx) and its populations in the Vosges and Jura mountains in France and Switzerland, for which vehicle collision is the main source of mortality. Our main goal was to develop and provide an operational tool upon which the managers would rely on in the decision-making process to predict the potential impacts on lynx viability of future land-use planning. To do so, we gathered a group of various stakeholders (public and private; researchers, wildlife managers and carnivore experts; infrastructure managers and road/transport planning experts) with the two following objectives: (1) Maintaining functional connectivity between favorable lynx habitats and elaborating strategies for avoiding and reducing collision risks; (2) Building a tool to reinforce and facilitate the implementation of land-use planning public policies. We used data on lynx-vehicle collisions and transport infrastructures to identify the areas with high probability of collision risks. We developed a spatially-explicit individual-based viability model (IBM) to predict lynx extinction risks and assess the impact of transport infrastructures using different scenarios, such as the creation of a new road segment, the reduction of collisions in an area using fences, or the creation of a road overpass. We implemented this decision-making approach in a user-friendly computer platform that allows building interactive management reports and intuitive visualizations. Our individual-based model correctly identified corridors that were preferentially used by lynx and also identified relevant areas with high risks of collisions between lynx and cars/trains. Besides, by following a participatory approach, the software platform was smoothly adopted by the stakeholders. The modelling approach was particularly relevant for lynx conservation in fragmented landscapes because it combines a population dynamics model and a habitat model through explicit dispersal. Overall, our participative approach fills a gap between the academic research, the stakes of land planning, the lynx conservation and the needs of transport infrastructures managers/operators.

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On-Board cameras reveal wildlife responses to approaching trains

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Collisions between wildlife, especially ungulates, and trains (UTC), are of increasing concern to railway traffic in Sweden. Train drivers report thousands of incidents per year. The actual number is probably substantially larger. High corporative expenses for train repairs and consequences of train delays suggest that the problem has previously been underestimated. In fact, on average, UTC occurs more frequently per km railway than per km public road. In response, the Swedish Transport Administration (STA), the Swedish Railway Company (SJ), the Swedish University of Agricultural Sciences (SLU) and EnviroPlanning AB initiated a project to develop new and customized measures to counteract UTC. As one of the first steps in this endeavour, we studied the behaviour of animals towards approaching trains. This was done with onboard video recording made by train drivers during April 2015 through January 2018 and is still continuing. Train drivers were instructed to capture all incidents whenever they detected wildlife within or near the railway corridor. The video recordings were then analysed with respect to the animals' flight responses and flight initiation distances (FID) in relation to distance to and speed of approaching trains. A total of 454 recordings (in January 2018) could be included in further analysis, including 279 cases with roe deer, 99 observations of moose, and the remaining observations with wild boar, red, and fallow deer. In most cases, animals were able to escape from the train in time. 16 collisions were documented. Although the recordings do not represent a systematic survey, they appear to match the diurnal and seasonal variation of reported collisions. Most of the accidents occur in late winter and during dawn or dusk. On average, animals were visible on the video recording at a distance of about 150 m. A first response by the animal, suggesting that they detected the train, was visible when the train had approached to approximately 105 m. In about half of all the observations, the animals were already in flight mode when they were detectable on video. In most other cases, animals initiated flight when the distance to the train had decreased to less than 90 m. FID were slightly longer when animals were initially on the railway track, as opposed to those who were near the track. However, when animals collided with trains they appeared to be unaware of the approaching train at all, or they initiated their flight response too late and in the wrong direction. Our preliminary results suggest that animals can, to some degree, habituate to train traffic and respond appropriately. In general, the response time is short, indicating that it is difficult for animals to detect approaching trains. We conclude that measures that would help to increase FID could be useful in reducing ungulate-train collisions.

Changing driver behaviour in Protected Areas of South Africa

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The Endangered Wildlife Trust has strived to raise public awareness of the impacts of roads on biodiversity through media campaigns, extensive social media platforms and by engaging with relevant stakeholders. Initially our attention was focused on road impacts on wildlife outside of protected areas, since traffic volume is higher and collisions are often more visible and more threatening to human life. However, reports from various social media platforms have indicated huge public concern for wildlife-vehicle collisions (WVC) inside protected areas. Consequently, in 2017 we initiated an assessment of driver behaviour within Pilanesberg National Park in South Africa. To investigate the factors affecting WVCs, we laid a plastic, dummy snake approximately two meters from the road's edge across four combinations of habitat (dense/open) and road shape (straight/curved). For each vehicle passing the dummy snake, we recorded 10 different variables. We then investigated the effectiveness of roadside signage in modifying driver behaviour. We did so by erecting wildlife-warning signage of four variations, depicting either a snake or a cheetah, and in either photographic or silhouette form. We repeated the above WVC experiment using the dummy snake placed either 100 m or 1 km after the awareness sign and recording our ten driver-related variables as described above. An interaction between speeding and driver occupation (staff/visitor) was the best indicator for wildlife collision, explaining 98% of the variation. When driving below the speed limit, visitors were almost three times more likely to hit the dummy snake than were staff, with a collision probability of 0.19 for visitors and 0.07 for staff. However, when speeding, visitors and staff had a similar probability of wildlife collision (0.33 and 0.26 respectively) that was also much higher than when driving within the speed limit. The presence of a wildlife-warning sign significantly changed driver behaviour in response to the dummy snake where 61% drivers who had passed an awareness sign changed their behaviour when they saw the dummy snake. Further, changing behaviour in response to the dummy snake significantly reduced collisions, where 67% of drivers who changed their behaviour, missed the dummy snake. There were no significant differences across the four combinations of habitat (dense/open) and road shape (straight/curved) variables that helped explain mortality rates. An interaction between the animal depicted and distance before the dummy snake affected collisions, explaining 91% of the variation. A photographic wildlife-warning sign (as opposed to a silhouette) depicting a snake (as opposed to a cheetah), and placed 100 m before the dummy snake, was most effective at reducing collisions than a sign placed at 1 km. Our results suggest that drivers adapt their behaviour to signage that portrays smaller animals rather than larger, and are placed closer to potential roadkill hotspots.

PART 3
ABSTRACTS
LIGHTNING TALKS

Wildlife collisions on Dutch railways: Improving decision making and strategic planning of mitigation measures using machine learning techniques and data visualization tools

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Every year there are approximately 1,500 reported animal related interferences on the Dutch railways. These disturbances are often caused by collision with trains or the catenary system. Collisions results most of the time in a delay in travel time for passengers and is mostly fatal for animals. Preventing collisions is not easy due to sparse data, and the data is scattered over multiple data sources. Combining these scattered data sources in an organization is challenging but will result in better insights of the problem. The primary focus of this project was to improve strategic decision making using advanced data processing and analysing techniques and make them accessible using data visualization tools. For this project, multiple data analyses tools were used for both gathering and combining data. Essential for the project was to create equal segments of railway with a length of 500 meters. Creating equal railway segments make it easier to combine these segments with infrastructure, geographical and collision information. Collision data has been gathered from notifications made by the train operator using text mining techniques in Python (Python 3). QGIS (QGIS2.18.13) has been used for a better understanding of geographic data and has been used to transform shapefiles to comma separated files (.csv). More Advanced geographical analyses have been accomplished using Esri ArcGIS. After combining the multiple data sources, a dashboard in Qlik (QlikView 12) was created to visualize the data. Using the Scikit-learn package (Scikit-learn 0.191.1) a random forest classification model has been created to predict segments where there is a high risk of animal related collisions for the upcoming month. Also, the best predictors of the model were used to create a better insight of these collisions using the best predicting futures of the model. The results of this project/research are an operational working dashboard which provide insights in historical data of segments with a high amount of animal-collisions and time dependent patterns. The dashboard also provides insights in what type of infrastructure (e.g. fences, overpasses) is present around the railway for each railway segment. It is also possible to get a prediction on which segments there is high risk of an animal related interference for the upcoming month. Translating outcomes of advanced analytics tools in more accessible dashboards stimulates knowledge and can eventually result in more effective decisions making to prevent wildlife collisions. Despite the promising outcomes there are still some factors that interfere with the data. This project/research focusses on the notifications of Train operators, which results in lot of useless data due to missing information or data that has to be combined due to uncertainties. Also, another major issue is the lack of knowledge of contributing data that at the moment is in possession by other organizations (road-, forest – and wildlife authorities), and thus not available.

Validation of the ecological connectivity model Circuitscape using GPS-data

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Habitat fragmentation is considered to be one of the fundamental pressures on biodiversity, causing ecosystem decay and population fragmentation. Infrastructure is one source of habitat fragmentation, which also causes barriers for animals. For conservation purposes, it is essential to analyse animal movement patterns in fragmented landscapes. To do this, we used an ecological connectivity model to map animal movements on a larger scale. However, this tool needs to be validated to be reliable. In this project, we used positioning GPS-data from different species to validate simulated animal movements. Additionally, we used the validated movement patterns to calibrate how to use the model regarding settings and modelling approaches. Another aim of the project was to evaluate empirical friction values from GPS-data by calculating home ranges and utilization recourses and using a biotope map. Finally, we used the statistical method logistic regression to estimate coefficients for the different species.

Multi-level wildlife distribution models in the planning of green infrastructure

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It is well known that green infrastructure planning is a very complex, time consuming and often-complicated procedure. A critical part of good practice is the utilisation of science-based practical information of biodiversity placement. In the last decade, demand for precise species distribution mappings and predictions of future trends have increased. Our recent studies show that different processes in wildlife populations occur at multiple hierarchical spatiotemporal levels. For example, large-scale landscape characteristics with extent up to tens of kilometres that can predict the placement of population patches twice as better as single site attributes. Still, there is little knowledge of the scale effects at patterns of species distribution and space use. There is even less experience in using such knowledge in practical landscape and infrastructure planning. In recent academic research, we have developed a novel approach to separate the site, landscape, and regional level effects in models of species occupancy. Our next goal is development and integration of the spatially explicit multi-level models of wildlife species landscape and habitat use in procedures of spatial planning and infrastructure development. The intention is to cross the border between basic science and real-life implementations. This means transferring knowledge between ecologists, engineers, decision makers, interest groups, and the general public. From 2013 to 2018, the biodiversity mapping approach has been applied in the planning of more than 350 km of roads and railways in Estonia (often with strong public interest). Among other things, we have identified wildlife accident hotspots on roads, mapped optimal sites for wildlife passages, and contributed to the selection of alignment of new infrastructure. The results support the view that landscape composition has a good predictive power on the occurrence of different species, including terrestrial mammals, bats, birds, and amphibians. As a result, the planning of population connectivity measures could be faster and more efficient. This has given better opportunities for cross-border collaboration and public communication. We conclude that knowledge of regional variation in landscape utilisation and knowledge-based planning procedures are essential for a functional green network, successful conservation, and the sustainability of populations. While separating the effects of site, landscape, and regional scale processes we have a highly effective approach for spatial planning of green network components. In the presentation, we will demonstrate last years' experience of planning wildlife mitigation measures for Estonian roads and railways, and discuss future perspectives.

The harmonisation of 'Grey' and 'Green' Infrastructure in South-East Europe: Introducing the GreenWeb platform

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The harmonisation of 'Grey' and 'Green' Infrastructure in a dynamic world such as South-East Europe is tremendously important. This is especially true when it comes to conserving the earth's living environment for future generations and for achieving the United Nations' Sustainable Development Goals. A network of professionals from a variety of sectors is developing the GreenWeb Platform, aiming for proactive engagement and dialogue with all stakeholders. In this way, they can secure ecological connectivity ensuring the coherence and ecological functionality of areas with high biodiversity value while developing linear transportation in South-East Europe. By encouraging international collaboration in policy, research, and practice, GreenWeb will enhance the exchange of knowledge and develop harmonised standards and procedures for all parties involved. GreenWeb will work towards: (1) Promoting environmental sustainability at a policy level: To promote the political will and support decision-making for a sustainable policy in Grey Infrastructure sectors with an emphasis on transportation. (2) Supporting a Strategic approach: (a) To establish basic principles for guiding the overall sustainable approach, from outlining necessary actions at national central governance and policy levels to concrete measures in practice at a local level. (b) To facilitate active involvement of politicians, specialists, and stakeholders through the development of a specialists network of interdisciplinary expertise supporting a strategic science-policy dialogue. (3) Promoting integrated planning: To promote and apply integrated planning of transportation projects at the ecosystem and landscape level, supporting multidisciplinary cooperation of specialists from the entire spectrum of transportation and ecology sectors. This will lead to the establishment of an environmental supervisory body that advises on the design, construction, and operationalisation of linear transportation projects. (4) Improving scientific knowledge: (a) To support the research and the production of scientific knowledge. (b) To create a Green & Grey infrastructure repository where methodological tools, policy recommendations, and background information is compiled. This includes existing databases and best use or practice examples of available resources and scientific approaches, which are readily available and accessible. (5) Optimising and adapting technical solutions: (a) To use scientific knowledge and applied research to act proactively to produce best practice solutions for, and effective management of, linear transportation infrastructure projects to maintain, restore, and enhance connectivity at the landscape level. (b) To support an exchange of best practices and information in the field by sharing examples of good practices and learning from less successful approaches, and applying optimal and appropriately adapted technical solutions. (6) Communication and dissemination: (a) To advance and integrate our understanding of the impacts of linear transportation infrastructure on biodiversity and ecosystem services. (b) To facilitate effective communication and rising awareness of coexistence of Grey and Green Infrastructures in South-East Europe. (7) Raising funds to support concrete action: To facilitate effective cooperation and planning towards identifying fundraising opportunities and proposal development, to support the activities of the Platform to achieve its goals.

Implementation of the Wildlife Friendly Roads Toolbox for Central America

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For developing countries in Central America, it is essential to harmonize the relationship between infrastructure development and biodiversity conservation. Roads are used as an indicator for development growth, so an accelerated increase on road construction projects in the region is expected. The impact of roads on wildlife has been extensively studied in North America and Europe. Significantly, research on this topic and measures to reduce traffic impact on wildlife are scarce in the central region of America. In Costa Rica, Road Ecology research started in 1996. Since then, valuable data and the evidence of road impact on the biodiversity of Protected Areas was collected. Even with this amount of information generated, few measures have been implemented in road development projects. Therefore, it is essential to find a tool to decrease the impact on environmentally vulnerable areas because of the growing road development. To address this need, an Environmental Guide "Wildlife Friendly Roads" was elaborated. Previous initiatives of research and mitigation actions were valuable but disperse and isolated. With this tool, the identification of the impact and measures to decrease it would be a requisite for roads projects to obtain their Environmental Viability. We provide these tools to government agencies and other entities involved, to improve the road planning, construction, and operation on behalf of wildlife respect, protection and conservation. This toolbox with adjustments to the characterization of each Central American country can become the basis for each of them. It will help them to build their path to the decrease of roads impact on the biodiversity in this region. This guide was developed based on the review of Road Ecology literature at national and international levels, expert consultation and the study of the Costa Rican environmental legal system. As a validation process, a workshop was developed with representatives of government agencies and other sectors involved. Twenty-three national and international (Spain, USA, and México) professionals (road ecology-road construction, planning and financing, wildlife management, biology, government agencies, legal) reviewed this document. Technical Guidelines are at the core of this toolbox. The first guideline is the identification of Environmentally Fragile Areas and Wildlife Vulnerable to Road Impact. This serves as a basis to determine if the road project requires continuing fulfilling the guidelines. If this is the case, the next step is the identification of Wildlife Crossing sites in the project area as a basis for the implementation of specific measures to reduce the local impact of road development. We have identified that the planning phase of a road project is the most important. It is where scientific information from Wildlife Crossing sites in the project and suggested mitigation actions should be mentioned and included in the design of the road project. The costs of these measures should be included in the budget. Currently, the Guide is used as a reference on the scientific study of different roads that are going to be improved, hired by the Ministry of Transportation. Together with the Environment Ministry, they are collaborating to transform the Guide in an Official Environmental Manual on Roads and Wildlife.

Automating Wildlife-Vehicle Conflict Tracking

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Wildlife-vehicle conflicts (WVC) impact motorists, transportation agencies, emergency responders, individual wildlife, wildlife populations, and ecological communities. They are among the most observable and spatially extensive of ecological and safety impacts. WVC data are critical for planning WVC-reduction projects, but most agencies do not effectively collect WVC data, both as crashes and as wildlife carcasses. When data collection occurs, it is geographically and taxonomically incomplete, inconsistently collected, and often lacks metadata and images for species verification. To address this problem, we developed two automated approaches for collecting crash and carcass data: (1) The California Highway Incident Processing system (CHIPs) periodically accesses and retrieves crash data from an online incident reporting system maintained by the California Highway Patrol (CHP). Records are given a unique identifier and all attributes found in the native record are stored in a relational database and viewed through a web-based interactive graphic user interface (GIU). To find all deer incidents, a text-based query was built to select records containing keywords such as "deer", "buck", or "fawn" and to exclude false positive records containing additional terms (e.g., "Starbucks"). This query resulted in ~99% accuracy, defined as correctly identifying deer-related incidents. We found that ~90% of WVC involved deer (2015 and 2016), therefore, the query we built for deer-related incidents resulted in a live feed of WVC events involving vehicle damage and/or human injury. In addition, the rate of automated data retrieval meant that active incidents were sometimes reported as they were happening. Between February, 2015 and February 2017, we collected 1.4 million traffic incidents records, including 12,243 WVC records. We spatially analyzed combined WVC-crash and WVC- carcass records to identify high-density and spatially-clustered WVC hotspots. In addition, we used USDOT (2013) cost coefficients for accident severity to determine per-incident and per-mile costs of WVC. These "legacy" hotspots can be compared to new ones that might develop in the future and can provide a real-time data feed to drivers/vehicles of WVC incidents. (2) To complement the CHP based crash-reporting system, we also developed an easy to use smartphone app for casual users to upload images of carcasses resulting from WVC. Rather than use a form-based approach, we developed a one-click solution that automates recording of the user id, date, time, and location. The user only has to point, shoot and send. The app sends the images to a global "bucket", where the data is processed and can be "pushed" (sent) to compatible WVC reporting systems, such as the California Roadkill Observation System. 3) To manage a rapidly growing dataset of WVC-carcasses and images from camera traps, we developed a method to use the images themselves to store metadata about incidents. Specifically, we wrote incident details (e.g., species) to the Exif data associated with each image. This approach making not only makes the data easier to share across databases and platforms, it also allows the novel combination of data about WVC and safe passage of animals. These technological innovations should ease automating WVC data collection and analysis.

Agouti: A platform for processing and archiving imagery from road crossing

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Camera traps and video surveillance systems have become standard tools for measuring the use of road-crossing structures by wildlife. In combination with information on the characteristics of the structure and the wildlife community on either side of the road, the images and data collected have great potential value for comparative analysis of effectiveness. In turn, this can be used to optimize designs. Furthermore, as crossing structures sometimes form the only opportunity for wildlife to pass infrastructure, these cameras have a relatively high likelihood of capturing instances in which wildlife species migrate into new areas. However, the material that is currently collected by thousands of cameras is tough to compile, because organizations involved in the measurements tend to have their protocol, their approach to image analysis, and their data management system if any. Original images and data tend not be securely archived and are often lost or deleted. This hampers data compilation for larger-scale analyses and makes it nearly impossible to revisit images for verification or additional observations. Web-based platforms such as Agouti provide a solution to this problem. These platforms allow researchers to manage camera-trap surveys, process images with collaborators, and archive images and data in a standardized and efficient manner. The software combines images into events that can easily be annotated in a standardized way, stores images and data in a secure server, and allows for archiving the material in a secure repository that can be queried from GBIF. We show how the platform Agouti was used for monitoring wildlife use of overpasses and underpasses in the Province of Gelderland in the Netherlands, and the OZON Life+ project in Belgium. We urge organizations to adopt standard protocols for monitoring the use of crossing structures by wildlife. Additionally, we invite them to use systems such as Agouti to manage their monitoring efforts more sustainably so that the information can be used to support road ecology.

Impact of road-infrastructure on the environment. A question of participation and cooperation?

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The A11 highway was a missing link in the high-structure of Flanders, connecting the port of Zeebrugge with the highways E40/A10 and N49/A11. The A11 highway (approximately 12 km) is also the first highway, constructed in Flanders, that is realized by a DBFM-contract (design-build-finance-maintain) with a private partner. Realisation of the A11 took several years, but crucial steps where: (1) Reference design of the A11, finished in 2008; (2) Environmental impact analysis, finished in 2009; (3) Spatial planning, finished in 2009; (4) DBFM procedure, finished in 2013; (5) Environmental permit and building permit, obtained in 2014; (6) Start construction in March 2014; (7) Construction finished in September 2017. The environmental impact analysis was the driving motor in the design of the A11: the exact routing of the A11, the choices in technical solutions for crossings with local roads, railroads and canals (bridges, tunnels, viaducts, etc.), and the connections between A11 and other roads. The environmental impact analysis gave the arguments for the choices made. In the planning phase of the A11-highway, the participatory process was vital in the reference design-environmental impact assessment. Local partners such as environmental organizations, farmers organizations, local municipalities and water boards were partners in the trajectory to the design choices. This had the consequence that design choices were driven by minimalization of the impact of the design on the environment and driven by opportunities for improvement of the surroundings of the A11. Improvements like tunnels instead of bridges for crossings, a trajectory and design which minimalizes the sound impact on inhabitants, a clear quantification of realisation of compensation of nature and landscape-losses, eco-passages for every crossing, minimal use of lighting, visual quality of design elements, choices for visual buffers, choices for new bicycle-routes, land consolidation for farmers, and more. In the realisation phase of the A11-highway cooperation was necessary so that the consensus achieved in the planning phase could result in an effective realisation of every aspect of the consensus. The private partner for the realisation of the highway was responsible for highway construction, but not responsible for the realisation of all measures to be realized in the surroundings of the highway. A land consolidation project realized a basis for the future use of agriculture; a land development project realized bicycle-routes, collective buffer zones, landscape restoration, plantation of individual buffers; a nature compensation project realized 30 hectares of new nature in the surroundings. This process of long-term participation and cooperation lead to a project that was more than the construction of a highway. The construction of the A11 became a program of improvement of the quality of life in the whole area surrounding the A11.

Environmental possibilities and challenges in early-stage transport planning in a Swedish metropolitan context

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This study examines the dynamics of early-stage transport planning in a Swedish metropolitan context regarding environmental aspects. We are specifically interested in the interplay between the multiple actors involved with the planning process and how this affects implementation and design of environmental measures. Previous studies show that transport planning have difficulties with paving the way for sustainable societies in terms of environmental aspects. Planning engage multiple actors, possibly with conflicting interests. The complex planning context may lead to de-prioritization of environmental perspectives in early stage transport planning. This research project aims to identify key issues contributing to the development of strategies for integrating environmental measure in transport planning. We hypothesise that transport planning lack effective strategies in order to meet environmental objectives and climate goals. Two Strategic Choice of Measure (SCM) studies were analysed through document studies, interviews and interactive research within the context of the final outcome and how various actors address environmental issues. SCM studies are conducted by the Swedish Transport Agency in order to solve transport related problems and it is based on the so-called four step principle, meaning that measures affecting the need for transport and choice of transport mode (step 1) and that leads to more efficient use of existing infrastructure (step 2) should be considered before large reconstruction measures (step 3) and investments in new infrastructure (step 4). Preliminary results show that a major issue was to define system boundaries of the investigated area. The city regions were continuously interlinked in terms of e.g. mobility and natural systems but also divided by administrative borders. The mandate and knowledge of involved actors appeared to affect the extent and effectiveness of the process and thus the outcome. Further, implementation of step 1 and 2 measures was found to be particularly difficult. Such measures are highly relevant for environmental aspects, as they demand for cross-boundary collaboration. Our findings call for flexible strategies in order to meet the governance challenges of environmental issues in transport planning, which would contribute to valuable opportunities for smart infrastructural solutions.

Redesign from an ecological perspective

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The ring road around Brussels - the Belgian and European capital - needs to be redesigned. Daily traffic jams and accidents, dangerous crossings under and over the ring road, show that the existing ring road no longer meets today's standards. The ring road is coping with three essential types of traffic; circulation to and from the capital city, interregional traffic, and international traffic flows. It interconnects the E40 in the west (direction Ghent/Calais) to the east (direction Liege/Cologne) and has 180,000 vehicle passages a day. Within the redesign of the Brussels Ring Road, separating the local and the international traffic is one of the primary objectives. Furthermore, the redesign gives the opportunity to erase mistakes from the 'car minded' past: by creating bicycle lanes, tram and bus lanes, park and rides, park and bikes, and by promoting a mental shift towards greener mobility in this heavily congested area. Throughout the redesign process, infrastructural works will be integrated into the environment, taking into account several regulations such as the impact on water as well as the ecological impact. The redesign process restarted in 2017 (after making a predesign in 2014). A multi-disciplinary team tried to reconcile different and opposite aspects and views by mingling legal professionals, architects, landscape designers, ecologists, financial experts, and communication experts. An environmental impact assessment is also feeding the redesign, making it more solid and future-proof. Unlike the predesign in 2014, which was handled in a strictly engineering way, the team now invited and contacted external partners, governmental organisations, and field experts to give input by mail and during workshops. They believed that gathering input on the possible impact on woodland, water (quality and quantity), grassland, (protected) plant, and animal species would lead to a stronger design. Listening to experts while walking along the ring road, several 'fundamental species' were identified within the specific boundaries of - or nearby - the project, such as the European Grass Snake, Common Lizard, Garden Dormouse, Brown Hairstreak, Stag Beetle, Pyramidal Orchid, and Yarrow Broomrape. By creating an interaction between the actual road design and the ecological findings in the area, improvements on the actual road design have been made: searching for solutions to relocate the mentioned fundamental species, choosing adopted working periods during the breeding season, locating new potential ecological passages, and upgrading existing passages. Through this, they could sustain and improve new and existing ecotopes, migration corridors, foraging habitats, and species crossing borders: (1) Crossing borders by integrating bunkers for bats, an ecobridge for animals and humans, upgrading several tunnels to ecotunnels; (2) Crossing borders by implementing different habitats into the design of the landscape, such as hedgerows, flower meadows, ponds, reed beds, and forest restoration; (3) Crossing borders between the redesign and the environment.

Otter road mortality in the Netherlands: population impact and effective mitigation measures

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The Eurasian otter (Lutra lutra) is one of the wildlife species in the Netherlands which highly suffers from traffic collision. Due to their high mobility and a territory of various square kilometres, individuals need to cross roads on a daily basis. The number of otter road casualties shows a distinct seasonal pattern, with the highest number found between August and December, most likely related to a peak in mobility during that period. Since the start of the reintroduction in 2002, the yearly number of traffic victims proportionally increases with the increase in population size. Population size is yearly estimated by genetic monitoring of the population, using a non-invasive fingerprint technique based on DNA from fresh spraints (otter droppings) and from the tissue of dead-found otters. Traffic mortality amounts to 20-25% of total population size, which is substantial. It is by far the most important mortality cause. By consequence, the migration to new territories is significantly impeded. Over the last years, a variety of mitigation measures has been taken at many locations to reduce road mortality. At certain hot spots, a substantial reduction in road mortality was achieved by improving the design of road crossings and watercourses, or by creating fauna tunnels with guiding barriers on important migration routes. However, as the growing population is gradually spreading to new territories, new risk zones arise. Places, where traffic victims are found, are registered and added to a database. The national list of high-risk zones is periodically updated after field inspection of sites where fatalities have been registered. This list is communicated to the responsible road managers with the request to take protective measures.

Steps towards an integrated mitigation strategy for a large carnivore roadkill hotspot in Northwestern Greece

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Although linear transportation infrastructures are linked to economic development, the impacts of roads on the surrounding landscape can be detrimental. Roads act as barriers to animal movement with negative impacts on foraging routines and dispersal, especially for wide-ranging mammal species, while reduced connectivity consequently affects demography and genetic fitness of local subpopulations. Moreover, wild-life-vehicle collisions may seriously increase mortality rates and have severe implications related to human safety. When major linear infrastructures are constructed in areas of high ecological importance, negative effects can be particularly profound and severe. Such a case is the "Kleidi" area, in northwestern Greece (region of W. Macedonia-Florina), where segments of two major highways, the old and the recently upgrad-ed one, both circa 10 km long, encircle the Kara-Duru hill. This double highway system with traffic volumes ranging from medium to high values has become a critical roadkill hotspot. Road casualties include numer-ous medium and small-sized mammals, i.e. foxes, badgers and martens, as well as large mammals, i.e. brown bears, grey wolves, roe deer and wild boar. In this study, we attempt to evaluate the significance of this area for brown bears and assess the need for further mitigation measures. For this purpose, we: a) performed a cost distance analysis to identify important areas for brown bear; b) collected data on brown bear roadkills in Kleidi; c) carried out systematic surveys to assess the highway crossing frequency for large mammals; d) discuss the need for enhanced road mitigation. First, we performed a cost distance analysis utilising IR cam-era trap data (ca. 600 trap-nights) and bear signs (n=369) and tested three different scenarios in terms of environmental factors scoring. The results evidenced that this sector is a critical linkage area for brown bears and a vital corridor for gene flow between two bear sub-populations occupying Voras and Vitsi-Varnoudas mountain massifs. We then found that road mortality over these two short highway segments is especially high for the protected brown bear population, with at least 14 roadkills, of which three during 2017. It is worth mentioning that most collisions occurred on the upgraded highway. Lastly, the systematic field surveys along the two highways revealed high crossing frequency for large mammal species (i.e. brown bear, wolf and wild boar), with a minimum number of 50 crossing locations. Despite the above, both road segments remain fenceless, while the effectiveness of installed wildlife warning signs and existing under-passes is poor. The need for additional mitigation measures will be partially met through the ongoing LIFE "AmyBear" project, which entails the installation of Wildlife Warning Reflectors and new wildlife warning signs along these road segments. However, the need for more effective mitigation measures (i.e. bear proof fence and construction or improvement of underpasses) remains. With this approach, we found that Kleidi is a critical linkage area for a protected species population, as well as a roadkill hotspot. The need for a com-prehensive mitigation strategy seems as imperative as ever to improve the safe coexistence between humans and wildlife.

Implementation of the no-net-loss approach at the project 'Outer Ring Parkstad Limburg'

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The Province of Limburg (the Netherlands) is constructing a highway including the improvement of rural roads and addition of new sections. It crosses two Natura 2000 areas and nature areas of national importance. Apart from transport-related objectives, one of the primary purposes of this road project is to establish a robust network of habitats in the region where the road is planned. This is carried out using obliged mitigation and compensation measures and an extra € 8.2 million funding on top of these measures. The no-net-loss approach with the National Ecological Network as a guiding principle has been worked out by defining and selecting areas where these measures should be realised: adjacent to existing nature reserves, in potential areas for nature development and corridors between nature reserves. The implementation of mitigation and compensation measures give affected species the opportunity to continue to live in their current or adjacent habitat taking into account the necessary abiotic conditions. Scientific research and expert-judgement have determined the habitat range of affected species. Mitigation and compensation areas have been realised along the outer ring, and thousands of animals and plants have been moved to these areas before constructing the road. On existing sections asphalt has been replaced by asphalt producing less noise, which resulted in better conditions for birds living in habitats adjacent to these sections. In current parts of the road fauna passages (such as a green bridge and an enlarged bridge crossing a river) were completed, which also led to better conditions for animals compared to the previous situation. The € 8.2 million set of measures have been purposefully used in the region to relaunch ecological projects with a financial deficit. As a result, about 45 hectares of additional nature area has been added to the already 125 hectares obliged nature compensation area. Additionally, a second green bridge will be built across another road that will lead to a connection between a Dutch and a German Natura 2000 area. We removed a spoil tip for a stream valley restoration project that led to the connection of two nature reserves. This is another example of a successful measure, which has been catalysed with this highway. In conclusion, the project provides us with the following insights and recommendations: (1) Planning a new road or upgrading a road offers opportunities for improving the ecological connection. We did this by defragmentation measures, the development of new (compensation) nature reserves and the improvement of environmental conditions crucial in nature areas, such as noise and nitrogen reduction; (2) It is essential to not only focus on the road itself but also to search for chances to catalyse ecological projects in the surroundings of the road; even on a regional or international level. In the case of this project, it appears that looking across the border (Germany) results in discovering a long-cherished desire for realising a borderless connection of two Natura2000 reserves. This way, it is possible to implement the no-net-loss approaches, to create a green (European) network.

Mitigating the ecological impacts of transportation infrastructure: A compilation of global case studies

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One of the greatest challenges in planning and designing roads, railways and other linear infrastructure is that there is no single book containing detailed mitigation knowledge and experience. While numerous texts exist, such as the Handbook of Road Ecology, they do not provide extensive or comprehensive detail of real-life examples and case-studies to guide and inspire future projects. Consequently, many engineers, planners and project managers are still unaware of the accumulated knowledge and experience that the 'road ecology' community has amassed through applied research and practical experience. To address this, I am proposing to edit an open access book that brings together case studies of mitigation from around the world in an accessible style and format. Ideally, each case study will: (1) Be co-authored by an ecologist and a designer and/or engineer who were both involved in the project to ensure both perspectives are captured; (2) Include things that worked as well as those that didn't - because failures are just as important as success! (3) Be written in a style and format for the target audience, which includes ecologists, engineers, planners, landscape architects and project managers, etc. Importantly, the book will include: (1) Case studies that are geographically and taxonomically diverse to get thorough representation from around the globe, different ecosystems and species; (2) Include mitigation for all types of linear transportation infrastructure; (3) Be widely sourced from all continents; (4) A companion website with a rich diversity of supplementary material, such as videos, photos, project plans and reports to enhance the reader experience. This book will be published as an open access E-book, so that everyone, everywhere, can access it at any time, for free! There are two invitations: (1) Content: Do you know of any mitigation projects that must be highlighted in this book? Maybe it is yours and you would like to write it, or maybe it is one you know of; (2) Funding: High-quality open-access books are free to read but are expensive to produce. There are two potential funding models I am pursuing: 1) if the chapter authors have sufficient financial support, they pay a modest publication fee; 2) Sponsorship from road agencies, development banks, private companies, NGOs or philanthropic sources to fund the whole project or in part.

Patterns of road threat on a global scale: Using large datasets in transportation ecology

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Meta-analysis of the impact of roads on animal abundance has highlighted general trends regarding which species are likely to be most negatively impacted by roads. One trend is that large-bodied species with low reproductive rates are typically more sensitive to the negative effects of roads than smaller, fecund species. Past meta-analyses have incorporated data from only a tiny fraction of the world's species, but the existence of large databases documenting life history characteristics and species status facilitates preliminary investigation to see if these trends hold on a global scale. I used two databases: The Red List of Threatened Species, which contains information on extinction risk and threats for species across the globe, and AnAge, a database of life history characteristics with a primary focus on mammals. Using all mammalian species for which there was data available in both sources, I calculated the proportion of species within a family which are identified as being threatened by roads on the Red List, and regressed it against the average adult body mass, female age at maturity, litter size, and longevity of species within the family. In total, 124 families consisting of 5,430 species were considered; for 264 species, roads were considered a threat. These species were globally distributed across Africa (n=1,234 species), Asia (n=1,537), Europe (n=44), Oceania (n=403), North America (n=195), and Central/South America (n=1,490), with some species ranging across regions (n=527). The results of this analysis confirm the trends observed in smaller-scale meta-analyses, with road threat more pronounced in families with larger-bodied, longer-lived species and slower reproduction, with the proportion of species within a given family which are threatened by roads ranging from 0-100 percent. This study highlights the exciting possibilities that can be explored by incorporating big data into transportation ecology, and how existing datasets can help explore trends identified in small-scale transportation ecology studies.

How reliable are your data? Verifying species identification of road-killed mammals recorded by road maintenance personnel in São Paulo State, Brazil

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Many wildlife roadkill studies across the world rely on data collected by road maintenance personnel or volunteers, but data quality control is rarely applied. We investigated whether maintenance personnel correctly identified the species of road-killed mammals along toll roads in São Paulo State, Brazil. We used two complementary methods. For method one we investigated 3,222 images of road-killed animals and compared the original species descrip-tions by road mainte-nance personnel ("non-experts") with our descriptions ("experts"). For method two we presented images of alive and road-killed mammals to road maintenance per-sonnel and asked them to identify the species. The results of the two methods complemented each other and strengthened our conclusions regarding the reliability of species identification by non-experts. For method one we found that the following species were typically correctly identified (>70% correct identifica-tion through their common names): maned wolf, crab-eating fox, European hare, capybara, southern tamandua, puma, ocelot, giant anteater, and the gray brocket. For method two we found that the road-killed maned wolf, capybara, south-ern tamandua, puma, ocelot, and giant anteater were typically correctly identified (>70% cor-rect identification through their common names). The data showed that non-experts regularly correctly identified specific common, large, or highly recognisable species whereas other species (e.g. small wild canids and felids) were poorly identified. To improve the reliability of spe-cies identification by non-ex-perts, we recommend training in species identification, including images with a scale to accompany all roadkill records, and verification of the roadkill records and associated images for selected species by experts.

Better intelligent systems for mapping amphibian and small bird roadkill

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Roads have multiple effects on wildlife, from animal mortality, habitat and population fragmentation, to modification of animal reproductive behaviour. Monitoring roadkill is expensive and time-consuming, and depend mainly on volunteers. Thus, cheap, easy to implement, and automatic methods for detecting roadkill over larger areas and over time are necessary. We present results from the research project Life LINES, where we developed a cheap and efficient system for detecting amphibians and small birds roadkill using computer vision techniques. We present here the Mobile Mapping System 2, an improved version of the Mobile Mapping System 1 developed during the Roadkill-project and presented in previous IENE congresses. We have successfully reduced the size and energetic consumption of the MMS, so now the device can be attached directly to the back of any car. The MMS2 is composed by several cameras (multi-spectral, visual with 3D laser technology, and high definition). The algorithms were trained with previous collected pictures of road-killed amphibians and small birds. We have tested all images using the Haar Cascade algorithm from the OpenCV library, which provided high rate classification results. We tested the MMS2 in three conditions: a control test with plastic models of amphibians and birds in a small road; a control test with collection specimens of amphibians and birds; and a real test on a 30 km road survey in Southern Portugal. The MMS2 has been developed using low cost components with the idea of saving funds, time and personal resources for wildlife preservation.

Innovative road kill monitoring with speech recognition and route registration

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In many countries, roads are monitored for the presence of road kill to study the impact of roads and traffic on wildlife. Experience gained from several large projects all over the world has shown that conducting road kill monitoring as a citizen-science project results in big and reliable data when specific criteria are met. However, two critical issues are potentially hampering data collection and its application: (1) For safety reasons, many countries put legal restrictions on the driver-use of smartphones in cars. As most drivers are alone in the car, this limits participation and data collection in a road kill registration project; (2) Most citizen-science road kill monitoring projects gather opportunistic observations of road kill. Therefore, information about search effort is missing. This poses problems for data interpretation (e.g., hotspot analysis), and calculations based on the data. A solution applied in some projects is to monitor fixed transects, but experience has shown that it is much harder to find volunteers. With technological innovations, we created solutions for both issues. We improved the existing app for wildlife and road kill observation ObsMapp: (1) ObsMapp (linked to the data portal observation.org) has a voice recognition mode, which deals with the first issue. A tap on a big button activates the microphone and automatically registers a position fix, date, and time. The user pronounces the species name followed by 'road kill' and optional information. Automatic speech recognition fills out the respective fields. This function makes it a hands-free app, allowing the user to record road kill while still driving safely; (2) Providing the app with a route registration function solved the second issue. At the start of a trip, the user opens the app and starts route registration. The travelled route is now continuously recorded. When the user stops the route registration at the end of the trip, the complete track, start and stop time, date, route length, and average speed are registered automatically. This generates detailed information about search effort, while still being very flexible. It is possible but not necessary to follow fixed transects. This flexibility lowers the threshold to join and should result in more high-quality data with complete information on search efforts for many different roads. The hands-free observation registration function allows all drivers to record road kills in a save way. Countries that allow hands-free calling in the car will probably allow this kind of road kill registration. However, country-specific regulations have to be checked by the driver before using this app. The detailed information on search effort obtained by route registration allows several analyses and applications of the data. For example, real hotspots and road sections with low animal mortality can be distinguished. With information on search effort, an estimate can be made of the total number of road kills for a given road section or network. Combined with population data, the impact of a road section or network on population survival probability will be estimated.

How to assess species crossing natural corridors through a new kind of wildlife sensors?

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Haute-Savoie Department was facing a specific hotspot concentrating a high number of collisions between vehicles and wildlife along a 1.5 km natural corridor. The PATDD – Environmental Service of the Haute-Savoie Department, in close collaboration with the Road Service, called for a project to restore the natural corridor while reducing the risks of collisions. Neavia Technologies, part of the Lacroix Group, has been awarded for its disruptive approach. In France, at the south end of Annecy lake, a natural reserve has been established in 1974 for protecting the remarkable latest wetland area of the lake. Along with a distance of 1.5 km, the southeast part of the reserve is bordered by RD1508, a road used by more than 12,800 vehicles per day, of which 5% are trucks. Around 50 collisions between vehicles and wildlife are recorded each year along the corridor. Because of the natural reserve, building fences along the road is meaningless: the land must be kept opened for wildlife free moves. Building one ecoduct as large as the width of the corridor under the road (several hundreds of meters long), would be too costly and making several smaller ecoducts not efficient. Neavia proposed a new kind of wildlife sensors and a collaborative cloud-based platform producing statistics about the wildlife species based on detections. The system combines long-range IR sensors with video cameras. Motion algorithms double check detections triggered by the sensors based on image analysis. Wildlife experts are provided with video clips to analyse the species living in the area. To protect the natural environment, the solution is designed to be energy saving. Power comes from solar panels. Designed to resist to vandalism, the solution requires reduced maintenance. Thanks to an effective partnership with the Haute-Savoie Hunting Federation, it has been possible to identify the usual paths used by animals crossing the road, thus to optimise the number of sensors and their locations. To warn the car drivers in an anticipated way, the solution includes road signs illuminated when a detection occurs. A first report issued by the Haute-Savoie Hunting Federation after three months of operations – from the beginning of December 2017 to the end of February 2018 - has positively surprised the experts: 2,248 motions detected, among which 75% are boars, 17% deers and 8% foxes. For boars, detections show groups made of 6 to 8 individuals. Recorded images showed the never yet observed behaviour of the animals along a road. A specific study is expected to be conducted by environmental experts to analyse those behaviours more deeply, based on the data that will be collected for the several years of this long-lasting project. During the observation time of this report, only four collisions have been recorded. Considering that the wildlife that moves along the corridor is concentrated over a period from September to the end of March, this means a drastic reduction by a factor 6 of the number of collisions compared to the previous years. The solution has quickly demonstrated its efficiency for the two expected challenges: restoring natural corridor and increasing protection of wildlife by reduction of risks of collisions.

A new approach for monitoring fauna in eco-infrastructure: A win-win arrangement for an affordable continuous way of studying and evaluating

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Working with students offers a range of opportunities for studying and evaluating; this also concerns eco-infrastructure. At the level of Masters of Biology, students have to get an internship at an external organisation. Liaising closely with the university and proposing study topics makes it possible to have a win-win arrangement for an affordable continuous way of monitoring and evaluating of fauna in eco-infrastructure. Unfortunately, the duration of short internships does not allow a thorough investigation. However, many interesting findings can be registered if the required twenty internship days are divided over a more extended period. This provides more possibilities because you can monitor infrastructure such as the migration of amphibians for a longer period. This creates a bridge between science and practice. The students encounter practical problems that need to be solved in preparation for, and during, the actual monitoring. A network of professionals and volunteers becomes involved in making contributions. Results are published on a specific project page on the website waarnemingen.be to make the observations accessible. This communication tool provides the latest information about the species and frequency of animals passing through the tunnels. However, for correct numbers, we need more extensive monitoring. This exchange of information is available to all interested groups, including schools visiting these eco-infrastructures.
In this way, people gain an understanding of the purpose of the infrastructure. Additionally, practical attention can be paid to the maintenance of the tunnels, and a precise guiding structure can be set up. The goals are as follows: (1) An appreciation of the importance of suitable habitat defragmentation for the fauna for which infrastructure is built, by studying; (2) Relative continuous monitoring and evaluating of the eco-infrastructure; (3) An affordable way of monitoring the eco-infrastructure; (4) Advising concerning eco-infrastructure (e.g., maintenance, possible points for improvement); (5) A good network of professionals and volunteers who exchange information concerning eco-infrastructure; (6) Open access to observations. DMN gives the opportunity to students to do an internship concerning the monitoring and evaluating of eco-infrastructure at specific locations. The work schedule of the students' internship of the 1st Master of Biology allows the splitting up of the required twenty days into separate elements suitable for the study. Each student will be guided separately. Monitoring with the wildlife cameras and fykes is organised including resolving practical issues such as finding or building the equipment. Checking the infrastructure and informing municipalities or other involved partners should be done before starting. Creating connections with professionals and volunteers involved in the monitoring shows the students the benefits of teamwork and keeps them well informed throughout the project. Reports about meteorological conditions are utilised to adapt the fieldwork to the expected weather patterns to monitor fauna (e.g., amphibians) when active. Observations with the cameras and fykes are analysed. The observations are entered on the open Internet project page waarnemingen.be. The students give a presentation of the results of their internship to all concerned with the project, demonstrating what they have learned and gained from their experience.

Assessing the effects of multiple environmental variables on aquatic biodiversity in highway stormwater ponds: Does metabarcoding improve the performance of traditional morphological methods?

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Roads are spread around the world, and most people rely on vehicles for transportation in their daily lives. However, roads could impair ecological conditions along the roads through multiple anthropogenic stressors, including chemical pollutants in runoff and disruption of connectivity. Constructed stormwater ponds have been established as green infrastructure along the roads to compensate for the adverse effects of roads. Usually, such a system is applied to flooding and pollution control. Our project aims to use stormwater ponds to maintain and promote aquatic biodiversity. However, the extent to which these systems can support biodiversity has been questioned. To answer this question, the evaluation of impacts of single and multiple stressors on the aquatic biodiversity is crucial. However, identification of organisms to the species level is a significant challenge, especially for non-specialists. Even expert taxonomists are unable to identify some freshwater species that lack morphological diagnostic characteristics at the larval and even at the adult stages. The problems arising from traditional morphological approaches are particularly true for the large-scale application of organism sampling, leading to significantly higher identification error rates for species compared to family level. DNA metabarcoding can be used to identify unknown specimens based on DNA sequence and has gained popularity in overcoming problems related to the morphological identification. It allows the rapid and cost-effective assessment and monitoring of biodiversity using massively parallel sequencing of bulk samples or potentially degraded DNA from environmental samples. Metabarcoding has been successfully applied to samples where species identification is not practical with traditional methods. Metabarcoding has been tested to address a variety of biological and environmental problems. The capacity of metabarcoding has been demonstrated in the analysis of correlative patterns between biological composition and the significant environmental variables, and the identification of taxa that show positive and negative responses to the fundamental environmental variables. The objectives of this study are to evaluate the use of metabarcoding to study aquatic biodiversity in stormwater ponds and to study the influence of traffic-related stressors and other variables (e.g., pond characteristics) on aquatic biodiversity. Metabarcoding and traditional morphological identification were applied to the samples collected from twelve highway stormwater ponds. Metabarcoding allowed the identification of 429 species, while traditional morphological methods identified 181 taxa, and some taxa were only identified to the family level. Metabarcoding provides more accurate species identification; accurate identification of organisms at the species level is essential for improving our understanding of the influences of different variables on the aquatic biodiversity. However, it is important to note that metabarcoding only provides information on species presence, whereas traditional morphological methods offer an abundance of individuals. Therefore, different statistical methods will be required to evaluate the influence of traffic-related stressors and other variables on aquatic biodiversity.

Forecasting the viability of Brazilian maned wolf populations in varying scenarios of road effects

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The expansion of Brazil's road network in the last decades presents a rising threat to biodiversity, being responsible for additional mortality, habitat loss, and fragmentation for many species due to collisions with vehicles. However, little is known about the effect of roads on the population's persistence. One example is the maned wolf (*Chrysocyon brachyurus*), a South American canid classified as Near Threatened by the IUCN, with an occurrence mainly in the Brazilian savannah. This study aims to evaluate the potential impacts of the road mortality and fragmentation on the maned wolf population size and its spreading in Brazil. Additionally, we intend to estimate where these impacts might be most substantial, thus suggesting critical areas for road mitigation. We developed a large-scale, mechanic, spatially explicit, individual-based forecasting model using the HexSim software. This way, we could generate quantitative estimates of the consequences of road mortality and fragmentation that can impose on the maned wolf population dynamics, size, and distribution. Our three-stage model linked stage-specific vital rates to habitat quality accounts for density-dependent effects on reproductive rates and allowed us to explore a range of scenarios regarding wolf behaviour toward roads (avoidance, successful road crossing, unsuccessful road crossing). Our results suggested that even low rates of road mortality result in severe population declines and might be altering the species range. We were able to identify five locations with high road-kill frequency, which can optimise future efforts for the species conservation. The novelty approach appears to be a method to evaluate road effects on the target species, prioritise research efforts, and define critical areas for road mitigation. By improving our characterisation of the effects that road kills have on maned wolf populations, we can guide managers and conservation biologists that will help prioritise mitigation efforts such as fencing roads or the placement of wildlife overpasses.

Effects of habitat encroachment by roads on space use and movement patterns of an endangered vole

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Roads are a significant cause of habitat fragmentation and a barrier to movement of several species across the world. Terrestrial species with low mobility, low abundance and specific habitat requirements could be particularly affected by this kind of barriers concerning their movements. In the present study, we aimed to assess the influence of habitat invasion by roads on space use and movements of Cabrera voles (*Microtus cabrerae*), an Iberian endemism, classified as 'near threatened' and with small and fragmented populations. We hypothesise that: (1) individuals occupying areas more densely encroached by roads have smaller home ranges and higher intrasexual spatial overlap; (2) movement paths are i) shorter; ii) more linear; and iii) more frequent along the road in areas with more encroachment; (3) movements are shorter during higher traffic periods of the day (daylight) in those areas. We radio-tracked 16 Cabrera voles (Wildlife Materials; SOM-2018) in two habitat patches along a National road in Southern Portugal (Évora district). The patches are separated by 1.4 km, with one being highly encroached by roads ("verge" patch) and the other much less impacted by these structures ("meadow" patch), with high habitat availability despite the proximity of roads. Eight voles were radio-tracked in each patch (1 male and 7 females in "Meadow"; 5 males and 3 females in "Verge"), between 7th April and 14th June 2017. Fixes were registered at 15 min-intervals in rounds of 4 hours which covered the 24h cycle. We measured home range size (biased random bridge kernel) for all individuals, the percentage of home range overlap between females (UDOI index), path length, path linearity, and path and step direction to assess space use and movement patterns in the two habitat patches. According to our predictions, animals occupying the "verge" patch showed significantly smaller home ranges when compared with animals sampled in the "meadow" patch, although female spatial overlap was not statistically different between patches. Some of the remaining predictions were not satisfied, as there were no significant differences in path length, path linearity or step direction between patches. Nevertheless, there were differences in path length between day periods but only for the "verge" patch. The paths were shorter for the period 09-21h when compared with 05-09h in verge patch (but not in meadow patch). No events of road crossing were detected in any of the radio-tracked animals. Overall, these results provide empirical support for the idea that habitat invasion by roads may significantly impact species behavioural traits related to space use and movement patterns.

Community analysis of microcrustacean in freshwater lakes adjacent a salted road in Norway

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Roads pervade the landscape, but their short- and long-term physical, chemical, and biological impacts may harm the environment. For example, in many northern and central European countries road winter conditions may be harsh and to improve driving conditions and road safety de-icing chemicals (road salt) are frequently applied. During the last 20 years the amount of salt in Norway has more than tripled. Thus, environmental concerns about the use of road salt have been raised. The aim of the present study was to reveal any biological impairments of lakes adjacent a stretch of a salted road in Norway (Norwegian National Road E134). We hypothesised that the application of road salt on E134 may have caused impairments of the lakes' water quality and subsequently that the microcrustacean communities in the lakes are altered. Seventeen lakes adjacent to the Norwegian National Road E134 in Buskerud and Telemark County and three reference lakes were included in the present study. The study area covered approximately 130 km of E134. Microcrustacean and water samples were collected three times (June, August and September 2013) from the surface of the lakes' presumed deepest point. The mean chloride concentrations in the surface and the bottom water in the lakes ranged from 0.6-20 mg/L and 0.6-60 mg/L, respectively. Nine of the lakes showed a gradient in chloride concentration (1-10 mg/L) or had elevated concentrations of chloride through the whole water body. Half of the lakes had oxygen concentrations below 1.5 mg/L, and three lakes had anoxic conditions in the hypolimnion. In addition, the chloride concentrations in lakes and the estimated road salt loading within each catchment were significantly correlated. The community analysis performed by Redundancy Analysis (RDA) showed that the first two RDA Axis significantly (p=0,01) explained 13% and 8% of the total variation in the data, respectively. In conclusion, the preliminary results of the present study indicate that some of the lakes adjacent the National Road E134 were affected by road salt. The microcrustacean community analysis revealed no apparent road salt effect on the lakes' ecology. However, we cannot exclude some minor effects, and we will conduct more in-depth analysis of the data prior to the IENE conference. The present research, together with a larger on-going national monitoring program on road salt have led to an increased awareness that road salt may damage water bodies. Thus, the Ministry of Transport and Communications has required that the Norwegian Public Roads Administration conduct mitigation actions that reduce the amount of road salt on the road network but still enough to secure safe driving conditions. In addition, the newly revised national handbook on road building require that water bodies vulnerable to road salt are protected by e.g. conveying the road runoff to a more robust water body.

Different effects of the habitat structure under road bridges in a human-modified landscape in Hungary: Conservation hotspots or barriers to crayfish, fish, amphibian, and reptile species?

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Most biological studies on linear infrastructures focus on fragmentation, road kills, and invasion by exotic species, the effect of air, noise and chemical pollution on animal behaviour or the effect of preventing measures. Although numerous streams have been modified by urbanisation, relatively little attention is given to the habitat function of different types of streams and channels under the road, motorway and railway bridges. Our study aims to investigate the impacts of linear infrastructure presence and landscape urbanisation on the stream and stream bank biota. The presentation summarises results of six research seasons between 2012 and 2017. Electrofishing surveyed crayfish, fish, larval, metamorph, and juvenile amphibian assemblages. The adult individuals of amphibians and reptiles were surveyed with visual observation at night and daytime once in each season beneath and around in fourteen bridges of four streams and one channel. Apart from the wastewater load, there are intensive anthropogenic effects on the catchment area of all streams. One of the most severe effects is the diffused contamination as a consequence of the intensive crop production, which imposes a considerable risk on the natural values of the streams and its tributaries. Samplings presented the native noble crayfish (*Astacus astacus*) only in the Koppány-stream. All of the 279 individuals could just be caught under the bridges, where the current velocity and sediment composition were optimal for them. Samplings presented the 176 individuals of non-native spiny-cheek crayfish (*Faxonius limosus*) only in the Sződrákos-stream, and they could be caught not only under the bridges, but also in neighbouring natural habitats. Six of the total 39 fish species were non-native (e.g., *Carassius gibelio, Lepomis gibbosus, Proterorhinus semilunaris*). The reophil protected cyprinid fish species (e.g., *Alburnoides bipunctatus, Romanogobio vladykovi*) were caught mostly in the sampling sites at bridges, because the current velocity and the sediment composition were optimal at different water levels at these sections of streams. The non-native and native fish species were represented equally in each section. However, during summer, in the low water level period, the abundance of each fish species was higher under the bridges than in the adjacent natural sections. The adult amphibian individuals (e.g., *Hyla arborea, Pelophylax* sp.) preferred the sampling sites at bridges because they can find more prey and sunny spots. The occurrence of larval and metamorph individuals was influenced in all streams by the annual dynamic of floods. The occurrence of three lizard species and four snake species were higher near the bridges in all streams because the number of hibernation zones and prey items was higher than in the other sections of stream banks. However, the pond turtles (*Emys orbicularis*) were observed only in the neighbouring natural, semi-natural sections. These results provide information to help understand the role of aquatic habitats in streams beneath and around bridges in a human-modified landscape. Our results presented that habitats under bridges affected aquatic, semi-aquatic and terrestrial species in different ways. They also had a fundamental role in the conservation of native reophil species in a modified stream.

An assessment of the potential impacts of China's Belt and Road Initiative in Myanmar: risks and opportunities

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The Belt and Road Initiative (BRI) is China's strategy to boost connectivity and trade between China and a wide swath of Asia, Europe and Africa, with massive investments in infrastructure envisioned across the to be connected countries. Myanmar is one country expected to be significantly impacted by the BRI, with two proposed development corridors running north-south and east-west, spanning the length and breadth of the country. WWF conducted an assessment highlighting the significant extent to which BRI road infrastructure could impact Myanmar's biodiversity, ecosystems and ecosystem services, including disaster risk reduction and clean water provisioning. We digitised proposed routes for BRI corridors in Myanmar from publicly available reports and overlaid these on ecosystem service maps produced for an earlier assessment of Myanmar's natural capital. To evaluate how the corridors could impact areas of conservation significance, we also overlaid the proposed development corridors on maps of protected areas (PAs), Key Biodiversity Areas (KBAs), Intact Forest Landscapes (IFLs) and mammal species richness. We then described multiple illustrative possible realignments of the corridors that attempt to balance better socioeconomic and environmental costs and benefits of the development corridors based on different weightings of potential costs and benefits. These cost and benefit estimates were derived from the layers mentioned above and additional spatial data on terrain, population centres, agriculture and mining. Key findings: Over 20 million people live in the watersheds potentially intersected by the corridors. Significant portions of the corridors pass through flood-prone areas, including Chin and Shan states and the Bago region. Forested areas in these watersheds are important for providing flood risk reduction and erosion control services. For the most part, the corridors do not directly overlap PAs, KBAs, IFLs or areas with high mammal species richness, except in Shan state, where the east-west corridor would pass through areas with a high number of mammals. However, expanding land use change triggered by the corridors could lead to losses in biodiversity, ecosystems and ecosystem services. Our analyses show that proactive planning before the corridors are finalised is critical to protect ecosystems and biodiversity, and to balance socioeconomic and environmental costs and benefits better. Application: We provide suggestions for government, investors and developers regarding the planning of BRI-related investments in Myanmar. WWF is using this study as part of its engagement strategy with government and other stakeholders involved in infrastructure planning and development in Myanmar.

Road network development and forest fragmentation: An inter-state analysis

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Road networks in the developing countries, including India, are expanding at an unprecedented rate. The underlying premise is that road infrastructure development promotes socio-economic development, one of the most critical Sustainable Development Goals (SDGs) as defined in Transforming Our World – the 2030 Agenda for Sustainable Development. Road networks increase connectivity. Hence, road networks may play an integral part in generating employment opportunities. However, they also open up the way for resource extraction and other human activities in previously inaccessible areas of high environmental value, potentially leading to extensive degradation and resulting in ecological imbalance. Our study aims to understand forest cover and road development nexus along road networks across the borders of the northern Indian states of Uttarakhand, Himachal Pradesh, and Uttar Pradesh from 2000 to 2016 through spatiotemporal satellite data analysis. The study site is part of the central Himalayan eco-region – a mosaic of forests, protected areas, and high population density, forming a delicate socio-ecological fabric. A spatiotemporal land cover change detection and forest fragmentation analysis was carried out to achieve this objective. Landsat 7 Enhanced Thematic Mapper (ETM+) satellite imagery was used to prepare temporal Land Use/Land Cover Maps (LULC). Road network data was acquired from Open Street Maps. A correlation trend was studied for changes in percentages of non-forest areas at intervals of 100m for a 1km wide zone on either side along the road network. Particularly landscape metrics, the number of patches, and effective mesh size were calculated to quantify the impact of road networks on forest fragmentation. The study indicates a decrease in percentages of non-forest areas in all the three states with an increase in distance from the road. Fragmentation analysis shows an increase in landscape fragmentation, majorly along the road network, in the study area from 2000 to 2016. This suggests that road networks act as drivers of land use change in fragile forested landscapes. Inter-state forest and transport policies were analysed with the quantitative analysis to support the arguments on how these shape the fragmentation patterns in different states along the road network. Such studies relating infrastructure development and forest fragmentation have not been attempted in India so far and could provide a new dimension in understanding tropical forest fragmentation in the developing countries.

Road impact assessment on the soundscape of a Costa Rican rainforest using dominant frequencies

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Soundscape evaluation through automated methods is an easy technique, which provides useful information about the characteristics of the surrounding landscape and biodiversity. Among others, soundscape includes the sound of birds, amphibians, mammals, and wind. These sounds are widely classified as biological, anthropogenic, or geophysical. In this research, we wanted to evaluate the effect of roads on the soundscape in tropical forests. We researched in Braulio Carrillo National Park, Costa Rica, where the soundscape was evaluated across the spectrum of dominant frequencies (1-11 kHz). Twelve recorders (Song Meter SM2, Wildlife Acoustics Inc.) were placed at three distances from the Ruta 32 road. These distances were 50 meters, 800 meters, and in the interior of the rainforest entirely out of the road effect. In each distance, recorders were placed 200 meters from each other. The sound was evaluated in intervals of 1-kHz, which are readily interpretable. For example, geophony occurs between 1-2 kHz and most biophony between 2-8 kHz. It is challenging to extract meaningful information from these large datasets. We used acoustic indices to describe the behaviour of the soundscape such as the acoustic complexity index (ACI), and the normalised difference soundscape index (NDSI). The importance of continuing to use this type of measurements is discussed because it seems to be possible to establish patterns of bioacoustic activity (e. g., temporal and spectral entropies). We also discussed the importance of continuing to monitor sound activity to evaluate the impact of roads on bioacoustic activity in tropical forests.

How can transport infrastructure habitats reduce habitat fragmentation in the landscape?

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Fragmentation of habitats is a significant threat to biodiversity. Fragmentation is primarily caused by loss of biodiversity-rich habitats, both natural habitats such as old-growth forest, and human-made habitats as semi-natural pastures and meadows. Transport infrastructure may enhance fragmentation by creating barriers for organisms. However, it is increasingly acknowledged that road verges, railroad corridors, and similar linear structures may also reduce fragmentation for specific groups of organisms by connecting habitat patches, in particular in the agricultural landscape. Consequently, in many countries, such transport infrastructure habitats (TIH) are essential components of the work with improving green infrastructure in the landscape. When working with the TIH's potentially positive contributions to green infrastructure, some crossing-border issues need to be handled. The apparent issue is the cross-sectoral collaboration between different actors in the landscape. Another issue is how TIH can bridge ecological borders by ecologically 'communicating' with other habitat types in the landscape. Here, we present a literature review of how TIH may reduce fragmentation of certain types of habitats and for certain species groups. We particularly aim at elucidating which ecological functions TIH can provide in the landscape and thereby enhance landscape functionality, the degree of similarity between TIH and surrounding habitats, and how ecological functions and similarity can be improved by applying appropriate methods for construction and management of TIH. We review both scientific and more practice-oriented ('grey') literature. We propose that TIH constitute a rather diverse group of habitat types, from regularly mown grassland habitats to scrubland, successional and ruderal habitats. Most studies of TIH consider them to be a type of mown grassland, but this view thus needs to be widened. TIH also provide several ecological functions that can contribute to green infrastructure in different ways. They can serve as replacement habitats for species that have lost their earlier sites in the agricultural landscape, or as complementary reproduction habitats for species that also occur in adjacent habitats. Furthermore, TIH can provide essential deficit resources such as nectar and pollen. The TIH's role as dispersal corridors rely on different dispersal mechanisms: some species disperse slowly through TIH by reproducing there, other species disperse while foraging in TIH, and some species use TIH as specific movement corridors. These different types of transport infrastructure habitats, as well as their different values, require different means of management and construction. Thus, a proper choice of management strategy, both annual and long-term management, is crucial for their ecological functions. The review emphasises that it is crucial to understand ecological functions when applying management strategies, and suggests that a more diverse array of management methods needs to be developed and applied. It is also essential to adjust the management of other habitat types in the landscape to optimise ecological similarity and contact between TIH and other habitats, and to minimise the risk of TIH becoming ecological traps.

Biodiversity potential of transport infrastructure: A reconnaissance survey in the Netherlands

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About 350,000 hectares of the properties of Rijkswaterstaat (the Netherlands National Authority for Water Management and Transport) are situated in or within a distance of 100 m of Natura 2000 sites. In the majority of cases, these assets concern linear infrastructure: roadsides, and banks of rivers and canals. In the past, these assets were mostly mono-functional. However, Rijkswaterstaat aims to increase its societal relevance by striving for multifunctional use in support of nature. This paper addresses the biodiversity potential of the terrestrial habitats concerned. A quick scan of available GIS data of the Rijkswaterstaat assets compared with various maps of nature reserves and terrains with specific biodiversity values reveals that there is considerable potential for improvement of the biodiversity values (both within the assets and in adjacent terrains). This is especially true for wet ecosystems along rivers and canals. But also the drier habitats, such as roadsides, within the Rijkswaterstaat properties, represent significant opportunities for improving coherent nature networks and corridors. We used three approaches to assess the potential for improving biodiversity values: (1) current availability of habitats; (2) contribution to robust ecosystems by development potential; (3) positive effects of changing spatial dynamics, land use planning, and management. The estimation of the biodiversity potential strongly depends on the distance assumed as a boundary condition for a (re)connection with nature reserves, and also varies with the type of habitat or species concerned. Moreover, in the Netherlands, various types of reference areas can be taken into consideration: Natura 2000, terrains of high nature value of national or provincial trusts, defragmentation sites (MJPO), etc. We illustrate the findings of this reconnaissance study with two case study areas, one in a lowland peat area south of Rotterdam (Hoeksche Waard), and one along the northern branch of the Rhine River (Grebbeberg-Wageningen-Renkum). It is concluded that there is a tremendous potential to improve the biodiversity values of the assets of Rijkswaterstaat. Priorities should be defined by taking into consideration biodiversity hotspots, an extension of specific habitats, and population growth of rare species. Additionally, the provision of ecosystem services such as biomass production of hay and cuttings or energy production through photovoltaic installations is critical.

To mow or not to mow? Public perception of urban roadside verge management

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Greenspace within urban areas plays a vital role in the provision of ecosystem services including carbon storage, drainage and aesthetic value. An often overlooked area of urban green space are road verges, which support biodiversity and a number of ecosystem services. Road verges (highly visible strips of grass next to roads) are managed by both private and public sectors. Currently, road verges are typically maintained as frequently mowed short grass, which does not maximise biodiversity or ecosystem services. With growing funding cuts being made to the public sector in the UK, there is an impetus to identify alternative management strategies which are cost-effective. A key consideration when making management decisions is public perception, as members of the public are the end users who benefit from the services/disservices that road verges provide. Nevertheless, there is little evidence assessing public perception towards alternative urban roadside verges. Using a paired design, 17 urban roads across Sheffield, UK were selected for a mowing trial in 2016, reducing the mowing frequency on one side of the road (every 6-8 weeks) and maintaining current mowing frequency on the other side of the road (every 3-4 weeks). Face to face and postal questionnaires were conducted on these roads in 2017 to assess the perception of these changes and other hypothetical scenarios. In this study, we assess public opinion of (I) the mowing trial on their road, (II) different hypothetical road verge management scenarios and (III) the ability of different road verge scenarios to support biodiversity. This study is one of the first to assess the public perception of urban road verge management by residents experiencing a management change. Road verges which were mown less frequently (every 6-8 weeks) had a significantly lower preference score than typically managed road verges (mown every 3-4 weeks). Residents preferred short, frequently mown grass over other hypothetical scenarios. Tarmacked road verges were perceived to be the worst for biodiversity, and long, wildflower-rich road verges were perceived to be the best when compared to current road verge management. While reducing the mowing frequency of road verges is a cost-effective management measure, this study shows that residents prefer frequently mown short grass, even though it is perceived by residents to be worse for biodiversity than other alternative management scenarios. This research provides an evidence base to inform decision makers considering management changes to urban roadside habitats.

Road verge maintenance: How to eradicate invasive species simultaneously to promote species-rich, pollination-friendly habitats?

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Species-rich grasslands are essential for botanical biodiversity, pollinators, and ecosystem services. The present lack of species-rich grasslands makes it vital to conserve and promote these valuable habitat types, including novel habitat variants such as road verges. A significant challenge with maintaining and developing species-rich road verges is their fine-scale spatial environmental and ecological heterogeneity. Different types of road verges demand different types of maintenance. The road authorities face a twofold challenge when developing maintenance strategies: if the maintenance plan is too detailed, it will be too expensive, or it will be too complicated for a regular procurement-process. If the idea is too general, it will harm the biodiversity. Therefore, it is important to ask the following question: what kind of practical maintenance strategy both protects existing species-rich road verges and promotes road verges dominated by agricultural weeds or invasive species to become species-rich? The solution implemented in Norway after nearly a decade of research and practical experience is as follows: road verges are divided into two main groups based on botanical criteria, high-growth or low-growth. High-growth-vegetation verges are cut twice while low-growth-vegetation verges are cut once during the season. However, these two categories are not detailed enough to promote and preserve biodiversity. Road stretches that may be negatively influenced by this cutting regime are mapped. Therefore, we developed an adjusted cutting plan. Now we start seeing results: the dispersal of invasive species decrease, and the high-growth-vegetation become more diverse and lower. In this presentation, we will illustrate how we maintain the road verges in Norway, and demonstrate the changes. We will discuss the, sometimes clashing, maintenance strategy challenges: (1) To stop invasive species and weeds, it is essential to mow early and to often mow for some years. This prohibits the flowering of all kind, which is the primary source for pollinators; (2) To enhance maximum flowering season and seeding, the verges should only be cut once a year, late in the season. This will spread weeds and invasive species; (3) Timing is everything, especially for the pollinators. We conclude that eradication of invasive species must be a priority. After this, the areas with particular importance for the pollinators need attention. However, some verges need new maintenance methods to meet the goal of promoting species-rich road verges.

Control strategies for Asian knotweed

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Verges of transport infrastructures can provide a suitable habitat for many species and may serve as corridors or stepping stones. On the other hand, verges are commonly affected by various anthropogenic disturbances and edge effects. This may result in the colonization by non-native invasive plant species. Big Asian knotweeds (species complex Fallopia) are among the most invasive plant species in Northwest Europe. These plant species are able to propagate generatively by intraspecific and interspecific hybridization, and in a vegetative manner from shoot and tiny rhizome pieces. This makes eradication of these plants especially difficult. Currently, chemical control is based on phloem-mobile herbicides, such as glyphosate, imazapyr, and synthetic auxins. Other management techniques often applied in Flanders are removing topsoil, covering infected areas or zero management. The Flemish Agency for roads and traffic has to cope with the presence of the Big Asian knotweed in the road verges and during earthworks for civil engineering projects. As the Agency sets its goal in maintaining and - if possible - increasing the biodiversity in the road verges, it is also responsible for reducing the spreading of it. A cost-efficient strategy for the management of the invasive plant during road construction and operation is being developed in collaboration with the Flemish Research Institute for Nature and Forest. A decision tool will be presented at the conference. Additionally, in collaboration with Ghent University, a new method of chemical control is being tested because the use of glyphosate is more and more under discussion and the search for alternatives is imminent. In our experiment, the effect of biologically produced vinegar, vinegar in combination with triclopyr and triclopyr were compared to glyphosate and an untreated control. First results indicate that the application of triclopyr can be a good alternative to glyphosate. Furthermore, biologically produced vinegar shows to have a direct impact on the growth of Asian knotweed. However, a more intensive spraying scheme needs to be applied in order to be successful. Promising results compared with historical data will be presented at the congress.

Biological control of Japanese knotweed (*Fallopia japonica*): A pilot project for the control of the invasive weed on railway infrastructure

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For several years, the Japanese knotweed (*Fallopia japonica*), an invasive plant species originally native to East Asia, has been spreading alongside railway infrastructure of the Austrian Federal Railways Company (ÖBB). The spreading is hindering railway construction, maintenance, and operation. Since 2014, the ÖBB has implemented a pilot project, trying to fight this invasive plant species through intensive grazing by goats and sheep. In 2017, E.C.O. Institute of Ecology was commissioned to establish several monitoring research plots in the scope of this project to monitor and document the effects of grazing on *F. japonica* with scientific methods. Two testing areas were determined, where seven transects with a length of approximately 20 meters across the embankment were set up. Alongside these transects, the coverage and height of *F. japonica* were measured monthly in 1 m^2 subplots from May until October. Further plant species that are present within the plots are identified as well. One of the transects serves as a control transect; an area where no measures are taken to fight the invasive weed. A second transect, which was first intended as control transect too has been fenced and thereby added to the grazing area, so the effects of exposing *F. japonica* to grazing animals can be monitored from the outset. Interim results, both qualitative and quantitative, indicate that grazing, especially with an appropriate ratio of sheep and goats, counts as a satisfactory method in controlling the Japanese knotweed. An adequate number of grazing animals seem to be a crucial factor as well as the ratio of sheep and goats. The economic efficiency compared to other methods such as mowing still have to be evaluated, as well as the public acceptance of the project in general. The study will be running until September 2019, when final result will be delivered.

Usefulness of power line right-of-way for wild bees and butterflies in agroforestry landscapes

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Insects, in particular, pollinators, are declining worldwide with consequences on pollination of many crops and wild plants. Habitat loss and fragmentation due to agricultural intensification and anthropisation of land – which includes the development of linear transport infrastructures (LTI) – are recognised as significant causes of pollinator decline. However, paradoxically, in areas impacted by economic activities, the green verges associated to LTI are subject to less environmental pressures and can be regarded as a haven for local biodiversity and green corridors for movements and dispersal of species. When a power line crosses a wooded area, for safety and maintenance reasons, within its right-of-way (ROW) the vegetation is maintained low by means of regular clearings. This creates conditions that may be suitable for species that favour open habitats such as insect pollinators. This study aimed to assess the interest of that kind of ROW for wild bees (Hymenoptera, Anthophila) and butterflies (Lepidoptera, Rhopalocera). The study was carried out in an agroforestry landscape to allow comparison between ROW sites and reference sites for insect pollinators, such as grasslands. The study area was located in the Limousin and Dordogne hilly areas of France. A total of 31 ROW sites and 25 reference sites were investigated. Average species richness (bees and butterflies) and bee abundance appear statistically equivalent between ROWs and reference sites, with only a small proportion of bee species (35%) shared by both kinds of sites, and an opposite situation in butterflies (74%). ROW sites offered less floral diversity, but more nesting resources for bees (bare soil, dead wood, hollow stems) than reference sites (principal component analysis). Parasitic bees, significantly more numerous (abundance and richness) in ROWs, indicated the good condition of host bee populations. ROW sites were home for common bee and butterfly species, but also to several data deficient species on the IUCN Red List (15 vs 4 for reference sites), and some threatened species (4 vs 5 for reference sites), as well as a protected butterfly in France (*Euphydryas aurinia*). This demonstrated the contribution of ROWs to the regional pool of bee and butterfly species. Similarity Bray-Curtis records between bee communities in nearby ROW sites (at a distance compatible with bee flying distance) suggested possible exchanges along forest ROWs. Some bee community similarities were also noted between ROW sites and adjacent reference sites, suggesting possible exchanges with the landscape. In places where a forest is freely gaining upon abandoned open habitats, the maintenance of ROWs is a way to keep relics of important habitat for insect pollinators in the landscape (e.g. dry grassland against *Quescus pubescens*). However, on the whole, the good elements of habitat observed in ROWs were all incidental. This emphasises the potential that could be expected from the management of ROWs carried out with care for wild pollinators: control of ferns, a boost of the local flora diversity and preservation of nesting resources (below-ground and above-ground).

The achievements of the LIFE Elia-RTE project (2011-2017)

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Transmission System Operators (TSO) have to integrate green energy by renovating or extending the electrical grid. They also have to face this significant challenge by taking biodiversity into account. Vegetation management is a fundamental issue when dealing with the electrical safety of high-tension lines crossing forest areas. Most of the TSO proceed to regular vegetation elimination to avoid problems. As an alternative to this traditional vegetation management, the LIFE Elia-RTE project took place between September 2011 and December 2017. It implemented seven innovative actions in Belgium and France along 165 km of lines (i.e., more than 460 hectares) to combine electrical safety and biodiversity. These actions were carried out locally, with the involvement of local stakeholders by finding win-win solutions. The European Commission, Elia (Belgian TSO), RTE (French TSO), and the Walloon Region funded the project.
All actions aimed at enhancing biodiversity: planting forest edges and conservatory orchards, restoring Natura 2000 habitats, digging ponds, grazing or pasturing, sowing flowering meadows, or fighting invasive plants. Communication tools (website, leaflets, didactic panels) have been developed, and contacts have been created with seventeen other EU countries to raise awareness of all stakeholders and the general public. As a result, 100 hectares of habitats described in the EU Directives were improved or created, increasing the connectivity in and out of the Natura 2000 network. Some rare or patrimonial valued species have been detected or are strongly expected to appear in the future. The key to success of this innovation plan leans on agreements with local stakeholders who will now collaborate efficiently with the TSO.

Prevention of wildlife-vehicle collisions: An evaluation of odour repellent effectiveness

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Wildlife-vehicle collisions (WVC) pose a safety issue in many nations. Collisions with large mammals result in numerous deaths and severe injuries to animals, property damage and injuries to car passen-gers. Therefore, several safety measures have been recommended to decrease the number of WVC. The best results (up to 83% of WVC decrease) were accomplished by the use of fencing combined with over- or underpasses. On the other hand, fencing is only recommended for highways and primary roads due to their overall costs. Affordable measures, such as odour repellents, can be considered as an appropriate alternative for secondary roads. We examined the effectiveness of odour repellents concerning the reduction of WVC. The Before-After-Control-Impact study design was applied to con-trol both the effect of odour repellents and the expected natural variation in wildlife populations at the monitored sites over time. Eighteen places were selected on the Czech road network where WVC were frequent in previous years on the basis of traffic crash data. Control places were delimited on the same road segments to keep the exposition to the traffic the same. We compared the WVC fre-quencies before and after odour repellent installation at treated sites to the WVC frequencies at con-trol sites. Wildlife carcass gathering was carried out once per week during spring and autumn from 2014 to 2016. We also used the police crash database to supplement carcass data. In total, 201 killed mammals (roe deer, red deer and wild boar) were identified over 47 months (January 2013 – Novem-ber 2016). First, we analysed the data using a standard technique based on the comparison group method. However, this conventional approach is suitable only for sufficiently large datasets. Low frequencies usually lead to insignificant results. Therefore, we also applied an approach based on the Bayesian inference. We calculated the probability that the odour repellents have a positive effect on the number of WVC. We found out that a WVC decrease accounting for 26-43% can be expected at treated sites. The odour repellents can be used as affordable measures to reduce the number of WVC. Some specific requirements have to be met, however, to ensure that the repellents work properly (installation, rejuvenation, etc.).

Sonic devices effectiveness in keeping wildlife off the road

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Road networks represent a major disturbance for wildlife, and their continued development threat-ens biodiversity. Many mitigation measures show reliable results at reducing road mortality, alt-hough with high costs (e.g. fences and crossing structures). Inexpensive measures have been applied, but there is little proof of their effectiveness. Finding possible ways to reduce this impact should be a priority issue for road planners. Some animals may take advantage of roads as refugees (mostly small animals) or as easier hunting sites (birds of prey), which makes them vulnerable to vehicle collisions. Therefore, dissuasion measures should be implemented in such a way that prevail over these bene-fits. Here we tested the efficiency of monitoring and sound devices as an alternative method to reduce wildlife road and electrocution mortality. We hypothesised that exposing animals to these stress levels will cause them to stay away from the devices and, consequently, from the road or elec-trical line. We made four prototypes: three dissuasion prototypes that include a motion detection system based on infrared sensors and a sound device; and one monitor prototype that includes a motion detector camera. Two dissuasion prototypes aimed to discourage mice from approaching roads and were placed on the ground on a road verge in southern Portugal. The third dissuasion pro-totype aimed to dissuade large birds from landing on an electrical pole and was placed in an electrical pole in Southern Portugal. The monitoring prototype aimed to record the approaching and be-haviour of large birds on the electrical pole with the dissuasion prototype, and it was placed pointed directly to the electrical pole. Whenever motion is detected, the devices started to play ultrasound (mice dissuasion prototypes), audible sound (large birds dissuasion prototype) or start recording (monitoring prototype). We counted the presence of animals at the spot 10-days before, and 10-days after the device was switched on (Before-After study): we sampled mice with Sherman traps, and every day we observed the dissuasion prototype and the monitoring prototype of large birds. Our results showed a reduction of animal approach as soon as the dissuasion prototypes were switched on, with fewer mice captures on the road verges and greater bird avoidance or reduction of length of stay on the electrical pole. The monitor prototype was able to detect with good accuracy most of the birds that landed on the electrical line. Wildlife detectors equipped with sound devices seem to be a useful measure to reduce the approaching of these species. The next steps would be to analyse if this avoid-ance will cause a significant road and electrocution mortality reduction and if this method can be adapted to others species or locations.

Evaluating the success of wildlife crossing structures using genetic approaches and an experimental design: Lessons from a gliding mammal

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Wildlife crossing structures are an increasingly common approach to mitigating the effects of roads on wildlife movement. However, we know little about the degree to which these structures facilitate dispersal and gene flow. Our study incorporates two elements that are rarely used in the evaluation of wildlife crossing structures: an experimental design including a before and after comparison, and the use of genetic techniques to demonstrate effects on gene flow at both population and individual levels. We evaluated the effect of wildlife crossing structures (canopy bridges and glider poles) on a gliding mammal, the squirrel glider (*Petaurus norfolcensis*). We genotyped 399 individuals at eight microsatellite markers to analyse population structure, first-generation migrants and parentage relationships. We found that the freeway was not a complete genetic barrier, with a strong effect evident at only one site. We suggest that the presence of corridors alongside the freeway and throughout the surrounding landscape facilitated circuitous detours for squirrel gliders. Installing a crossing structure at the location with a strong barrier effect restored gene flow within just 5 years of mitigation. Our study highlights the importance of using genetic techniques not just to evaluate the success of road-crossing structures for wildlife, but also to guide their placement within the landscape. Managers wishing to reduce the effects of linear infrastructure on squirrel gliders and other arboreal mammals should aim to preserve and enhance vegetation along roadsides and within centre medians, as well as mitigate large gaps by implementing wildlife crossing structures.

Using eDNA metabarcoding to evaluate the effect of nature-friendly banks as mitigation measures for fish

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To prevent erosion of banks in waterways due to shipping traffic, many banks have been heavily defended over time. This has often resulted in sharp transitions between water and shore with low ecological value. Growing awareness of the ecological aspects of natural banks and shallow shores as important zones for many species has resulted in measurements like nature-friendly banks (NFBs) in different forms. In the Netherlands alone, 2,500 km of nature-friendly banks (NFBs) have been constructed since 2009. It is generally assumed that NFBs have a positive impact on fish communities by providing habitat, spawning locations, nurseries and function as stepping stones. However, surprisingly few studies researched this topic. Here we present the first results of a large study that aims to evaluate the effects of NFBs on fish in the Omval-Kolhorn Canal in the Province Noord-Holland (Netherlands). We compared the fish fauna in six NFBs, and six canal transects (250 m) with camp shedding. The six NFBs consisted of three different types: (1) dug along the entire length of the canal, providing a local widening of the canal; (2) ponds behind the camp shedding connected by narrow canals of 8 m width; (3) ponds behind camp shedding connected only to the canal by two culverts. Besides traditional methods (electrofishing and seine nets) an innovative approach to monitor the fish fauna was used: environmental DNA (eDNA). This method uses DNA-based identification, also called barcoding, to detect species from extracellular DNA, or cell debris, that species leave behind in the environment. Using a universal approach (eDNA-metabarcoding), it is possible to detect all fish species in a single eDNA sample. In this approach, universal primers are used that expand DNA off all fish species. After the increase of DNA in the PCR, the product is sequenced with a 'Next Generation Sequencer' (NGS). The amplified sequences are then matched to sequences in a reference database to generate a list of species present. We will present the results of the comparison of fish fauna in the NFBs and canal transects with a focus on Habitat Directive, Red List and limnophilic fish species. eDNA-metabarcoding detected 23 species in total compared to 21 species detected in the traditional monitoring. Traditional monitoring verified the hypotheses that the NFBs function as spawning location and nurseries. In the NFBs 81% caught fishes were juveniles (0+) compared to only 2% in the canal. This study shows the strength of the eDNA-metabarcoding in getting a broad view of fish communities with relatively low effort. The method could also be used in evaluating the effectiveness of fish passages by screening which species are present downstream and upstream of a barrier with or without a fish passage.

Wildlife crossings in Poland: A source of data for placement and effectiveness evaluation process

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Wildlife Crossing Structures have been built in Poland from the 1990s. However, since 2012, their number has rapidly increased. We prepared the questionnaire of pre- and post-investment monitoring conducted on wildlife crossings for medium and big animals built in Poland in the years 1996-2016, which was sent to managers of national and provincial public roads. Based on obtained data we analysed methods used to choose the placement of wildlife crossings and to evaluate their effectiveness. According to questionnaires, over 3,500 wildlife crossings were built in Poland in the years 1996-2016. Their placements were chosen primarily based on information from the State Forests, National and Landscape Parks or using ecological corridor maps (in total 73% of crossings). In 11 cases, the localisation of crossings was chosen based on the mortality monitoring of animals. Only in 47% of all planned crossings, the pre-investment tracking was done. Often, pre-investment monitoring was conducted for overpasses less than 35 m wide and underpasses 1.5-6 m wide (60% and 80% respectively). It was rarely performed for large crossing structures. The pre-investment monitoring was conducted mostly for six months (65% of planned crossings), using direct observations, tracking on mud, winter tracking, and others (e.g., pellet group count). For 69% of crossing structures, the post-investment monitoring was conducted. We checked if the pre- and post-investment monitoring was done for the same crossing structure. The post-investment monitoring was done in 92% of crossings, where the pre-investment monitoring had been conducted. On the contrary, for only 62% of wildlife crossings with post-investment monitoring, pre-investment tracking had been done. The post-investment monitoring lasted one to three years, with the aid of direct observations, and snow or mud tracking, but also camera traps and digital cameras. The post-investment monitoring was conducted for all massive overpasses (over 80 m wide) and most of the small underpasses (less than 6m wide). However, it was not often conducted for underpasses 6-20 m wide and underpasses along the watercourse. According to the collected data, medium animals and big animals used 95% of crossings in Poland. In detail, 100% of all overpasses were used, but underpasses 15-20 m wide and 1.5-6 m wide were used not as often (90% and 92%, respectively). We discovered that brown hare, martens, badger, red fox, wild boar, roe deer, and red deer used all types of overpasses and underpasses listed in the questionnaire. Moose used overpasses 35-80 m wide and underpasses 6-15 m, and over 20 m wide. Our results showed that both planning and evaluation processes were imperfect. Due to the lack of clear guidelines, different, often straightforward, and biased methods were used in these two stages. Moreover, pre- and post-investment monitoring was usually done for various objects. Therefore, the results that we obtained did not allow making comparisons between similar objects or results obtained in different stages. This means that despite significant costs incurred in connectivity maintenance in Poland, it is difficult to assess the effectiveness of measures taken and to improve in the future.

A journey to success: How to identify high-risk roads, plan and monitor amphibian tunnels

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We have identified potential conflict road parts, where amphibian species face the risk of being killed during road crossing. A field survey identified and classified which of these roads that are of high priority for securing a safe amphibian passage. In 2017, amphibian tunnels were established on two high-priority roads. We aim to present and get input on our method of identifying, planning and monitoring these amphibian tunnels. The Swedish Transport Administration regulations state that the effects of roads as barriers should be minimized. One method to reduce the impact of barriers is to provide safe passages, such as amphibian tunnels. In new road infrastructure, this perspective is part of almost all projects. However, in the existing infrastructure network, the fauna connectivity is to a large extent an unresolved issue. We present cases from SE Sweden including identification of road sections causing problems in fauna connectivity, setting up a solution to this problem by building amphibian tunnels and monitoring the results of the new safe passage. In 2014, we performed a study of conflict roads along the state road network in S Sweden, covering an area of over 33,000 km^2. The analysis included examining aerial photographs and species survey data, and interviewing experts. We identified several so-called conflict road parts. A comprehensive field survey was performed to relevant roads. We used the analysis and the field survey data to set site action priorities based on the ecological impact of amphibian connectivity. In 2017, we continued to survey the conflict roads that had been identified as high priority for actions. These detailed surveys included species surveys, road kill surveys and a plan for how and where to establish amphibian tunnels. By the end of 2017, amphibian tunnels were established on two of the conflict roads. On eight of the identified high priority conflict roads, no tunnels or other measures were considered relevant. We also concluded that one additional conflict road would benefit from an amphibian tunnel, but this tunnel could not be established in 2017. In 2018, we plan to monitor the success (passage frequency, species) of the two tunnels established in 2017. In 2018 we will also design and construct the tunnel at the last identified conflict road.

Green bridges in the dunes: Monitoring of wildlife bridges in Zuid-Kennemerland

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In the dunes of Zuid-Kennemerland, along the Dutch west coast, three wildlife bridges were built between early 2014 and spring 2018. The bridges connect protected dune grasslands and scrub habitats that were previously separated by two busy roads and a railway. These roads formed a barrier for many fauna species. Monitoring started in 2014 and included vegetation, mammals (with two types of cameras), herpetofauna (both with cameras and by visual assessment) and different groups of insects (both with transects and pitfall traps). Results show that 17 out of 23 assigned key animal species for the Zuid-Kennemerland region were recorded within four years. The vegetation on the bridge developed towards a pioneering stage of a dune grassland habitat, a priority Natura 2000 habitat. Furthermore, even flightless beetle species benefit from the bridge: they now cross from one side to the other. Our monitoring results suggest that these bridges provide mitigation for ecological fragmentation of dune habitats.

Comparative study of animal carcass survey methods on roads

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Linear Transport Infrastructures (LTI) have been known since the 60's as one of the significant factors involved in the global biodiversity loss. The LTI network leads to land fragmentation in smaller and more isolated zones in developed countries, and more recently in developing countries. In this con-text, animals are used to crossing LTIs to satisfy their basic living needs and then they are more or less often killed by traffic or by the LTI's structural elements. Fauna road and rail casualties then result in economic damage and even danger for users. This fact underlines the need to detect the LTI sections causing most losses (e.g., mortality hotspots). But according to previous studies' conclusions, the scien-tific knowledge is incomplete concerning methods of carcass surveys on LTIs, especially con-cerning biases, the limits in use and the efficiency in detection between different taxonomic groups. The aim of the study: each survey method counting LTI carcasses provides both advantages and limits regarding use and results. The aim of this study is to compare spatial distribution, carcass numbers and taxonomic composition of each hotspot of fauna mortality obtained with two different survey methods - a decay survey conducted by an ecologist and another one done by road patrollers (mostly used by road network managers) - in order to identify their biases, limits of use and their possible complementarity. These analyses will allow their potential adjustment and integration of these methods to evaluate the ecological permeability of an LTI, on a strengthened methodological frame-work. Thus, an evaluation of the feasibility of a survey method adapted to the railway environment will be tested. Study area - Methods: a literature review and direct contacts with German and Swiss teams carrying out comparable studies will be conducted. This study relies on datasets collected dur-ing an entire year (2016) using two different methods on two 40 km long road sections in the DIR Ouest road network (state road network in Brittany, France). An ecologist from Cerema especially surveyed each month all fauna carcasses according to a protocol drawn up by Cerema, counting from a car driven at 40 km.h-1. These data will be compared with those of road patrollers, who counted every day as one of their many activities. The patrollers then followed a protocol established by the MNHN (UMS 2006 PatriNat) for DIR Ouest. Statistical analyses will compare the different taxonomic groups (ranked by size) numbers obtained with both methods. Other comparative statistical studies will be conducted concerning the spatial distribution of mortality hotspots, taxonomic size group composition and their number of carcasses obtained with the two survey methods, analysing then the clusters of casualties with Ripley's K function or Kernel Density Estimation available in Siriema and KDE+ software respectively. Preliminary results: these two carcass survey methods show strong similarities in hotspots of mortality (all taxonomic together) localisation and intensity. It also reveals a complementarity between these both methods: patrollers carcass survey being exhaustive for large fauna (i.e. ungulates, fox, that patrollers remove for safety reason) and ecologist carcass survey being more accurate in small and medium sizes fauna. They could be used together in a new methodologi-cal framework to obtain more accurate data on LTI fauna mortality hotspots: a daily «Patroller car-cass survey» should be completed by a monthly «Ecologist carcass survey» to evaluate efficiently hotspots of fauna mortality especially on road infrastructures.

AVC data by volunteers and official crash data: a comparison based on three years of experience with reporting the application srazenazver.cz

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Several crowd-sourced applications, as well as professional databases based on police crash data, are currently used worldwide for roadkill data gathering. Underreporting of roadkill records are one of the main known issues. Both kinds of datasets inevitably differ as they usually focus on different species and also have a different spatial pattern. CDV – Transport Research Centre developed an animal-vehicle collisions (AVC) report application www.srazenazver.cz (roadkill in Czech) to combine both main data sources on AVC: data from citizens and from professionals. The application is accessible through web browsers and allows users to input, edit and browse data. The data is visualized in the form of maps, graphs or tables and analyzed online (hotspots identification, area statistics). AVC on roads, which cause damage to vehicles or injuries to vehicle passengers, are registered in an official crash database maintained by the Police. This data, always GPS located, are imported to srazenazver.cz once a month. The second source of AVC data is an online system of all traffic incidents (OSTI), including traffic crashes, road blockages, regular road maintenance, etc. Collisions with animals are identified using full-text filters to free text which is attributed as a comment to the traffic incident data. The last data source is volunteers. 550 volunteers are currently registered on srazenazver.cz. Volunteers added approximately 4,000 records between 9/2014 and 12/2017, 75% of which were roadkill of mammals. Police crash data amount to 35,000 records and approximately 30,000 records were data-mined from OSTI. The police and OSTI data are spatially homogenous, but only half of the records have roadkill species attributed. We are only using the official data for identification of crash locations (hotspots). In contrast, almost all data added by volunteers have the species identified. Volunteer data cannot still be used for a state-wide AVC analysis, but certain regions (usually hunting areas with active administrators) have sufficient AVC data coverage to allow for local statistical analyses. A combination of several data sources provides better insight into roadkill on roads, but at the same time causes issues with data duplicities. This is being partially solved by online filters, analyses and additional reporting functions for users. We will discuss similarities and differences between official and volunteer data and their strengths and weaknesses in this presentation.

Which factors are different between WVC hotspots with large mammals and randomly selected sites along roads?

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The numbers of registered traffic crashes caused by animals (wildlife-vehicle collisions; WVC) are continuously increasing in many European countries. Precise selection of high-risk locations along roads has to be performed in order to apply mitigation measures. We used the KDE+ method to identify these sites, because it allows for an objective determination of significant clusters (hotspots). In addition, the KDE+ method provides stable results with respect to both underreporting and errors in a crash database as traffic crash data are usually incomplete or contain erroneous values. We focused on determining the differences between significantly dangerous places (hotspots) and other locations along roads where WVC only randomly occur. We analysed separately crash data for roe deer and wild boar which are the most common species registered in the srazenazver.cz WVC database. We subsequently randomly chose 50 hotspots of collisions with roe deer and 25 hotspots of collisions with wild boar along with 75 control sites. Significant clusters, identified by the use of the KDE+ method, contain non-randomly distributed WVC, while other WVC did not form any significant spatial pattern. The environmental characteristics of WVC were consequently compared by the use of Wilcoxon test, odds ratio estimate, logistic regression and Bayesian inference. We found out that at least 34% of WVC form a spatial pattern in the Czech Republic. These significant clusters were only located within 1.029% of the entire road network. The results indicate that the KDE+ method, followed by the selected data mining methods is able to produce meaningful results from the data. We used a probabilistic model to predict the consequences as an association between the presence of a hotspot on a particular locality and road characteristics. In addition, we demonstrated a significant difference between the WVC hotspots and randomly chosen WVC (which do not form a spatial pattern) with respect to the environmental characteristics of the particular location. We found no significant difference in the environmental characteristics when comparing the hotspots of collisions with roe deer and hotspots of collisions with wild boar. According to achieved results, we concluded that crashes with large mammals predominantly occur at places with poor viewing conditions for drivers.

Combined use of KDE+ software and empirical observation to identify animal-vehicle collisions' hotspots in South Tyrol, Northern Italy

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Animal-vehicle collisions (AVC) with red and roe deer in South Tyrol, Northern Italy, count some 700 cases per year. This amount of animal-vehicle collisions causes several socioeconomic (i.e., insurance expenses, car damages), human health and ecological implications. Due to these numbers and implications, the Administration of the Autonomous Province of Bolzano (South Tyrol) is collecting since 2012, with the help of the Hunters' Association, collision data on the entire provincial road network. The local administrators want to identify and map the locations where AVC occur more frequently than expected, the so-called hotspots, and where the AVC risk is higher than in other areas of the Provincial territory. The final aim of these activities is to better define the further steps for the subsequent implementation of effective mitigation measures and inform the population correctly on the driving behaviour to adopt to reduce the AVC risk. Up to now, experimental mitigation measures on defined road sections have not given the expected results. Nonetheless, the financial resources used. This result proves that a useful and time/money saving identification of AVC hotspots is needed. Eurac Research, the Administration of the Autonomous Province of Bolzano and CDV – Transport Research Centre (Czech Republic), have applied a combined methodology to identify the riskiest AVC hotspots. This approach is based on: (1) Empirical observation of wildlife behaviour in the proximity of the road network done by hunters and wildlife managers; (2) The identification of the most used wildlife passages to overcome the road barriers; (3) A statistical analysis on AVC 2012 - 2014 data using the KDE+ software, which allows the statistical identification of the riskiest hotspots for drivers. The results of this combined analysis allowed an objective selection of significant clusters and a risk ranking of the hotspots according to their significance and collective risks. These results will contribute to the selection of the most needed mitigation measures, according to the local landscape and ecological factors. Further steps foresee new KDE+ analysis on 2015 – 2017 data to be integrated to this first analysis and a detailed assessment in the field. The combination of techniques is a valuable approach to allow the prioritisation of the riskiest hotspots to allocate effectively limited resources to them and reduce the current degree of AVC in the South Tyrolean road network.

How citizen scientists and innovative construction design allow finding and mitigating hotspots in barn owl traffic victims

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Barn owls are the most commonly traffic victim among birds in both the Netherlands and many parts of Europe. Due to their low flight altitude during hunting, and the habit of hunting for insectivores and rodents in road verges, they are vulnerable to traffic mortality. A dataset of over 8,500 ringing recoveries in the provinces of North Holland and South Holland, stemming from citizen scientist that ring juveniles and citizens that report recovered rings, were used to analyse the spacing and timing of victims, their age and origin. The majority of the victims were younger than 1 year and were killed within 30 km of their place of birth. Most victims die in winter months, when these subadults are dispersing. Using tag recovery models, we will test whether the relative large number of subadult victims is due to their higher numbers or whether survival is truly lower for this age group. Using these analyses and another dataset of breeding success, also produced by efforts from citizen scientists, we will parameterise existing population models to test how changes in traffic victims affect population dynamics. The ring recoveries highlighted a number of clear hotspots of victims. Most victims seem to occur when animals are flying towards or sitting on low road signs close to the road. These hotspots will be mitigated using an innovative adaptation in construction, developed by a citizen scientist in cooperation with a bird rehabilitation centre. The principle of this construction is to make unsafe perches on road signs unusable with rollers, and placing higher perch placed further from the roadside ensures verges remain hunting habitats in winter.

Wild vertebrate road kill on selected highways passing through four spatially isolated protected areas of Eastern Ethiopia

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Highways crossing protected areas have an adverse impact upon wildlife, and many studies around the world have investigated the possible factors influencing road kill resulting from these roads. However, few of these studies have been undertaken in developing countries. This study aims to identify the impact of roads on three vertebrate taxonomic groups (reptiles, birds, and mammals), and describe the extent, relative abundance, and conservation status of wildlife-vehicular-mortality on six main highways in Eastern Ethiopia that bisect four protected areas. The data was collected over a five-month period (October to January, and June to July 2016) through conducting systematic road surveys in a car with a driver and three researchers to record the road kill data. A total of 128 road kill causalities were recorded comprising 44 species from 25 families. Birds were the most frequently killed taxonomic group (56.8%), followed by mammals (38.6%), and reptiles (4.5%). Of the 128 road kill casualties, and according to the IUCN Red List of threatened species, 81.8 % were of Least Concern, 6.8% were Vulnerable and 5.7% Near Threatened. Diurnal species constituted the majority of road kill detected (71.3%) with 19.8% being nocturnal, and 2.8 % being crepuscular. Most road kill causalities were encountered on roads adjacent to protected areas rather than roads >60 km from protected areas. This study highlights the potential threat of roads on biodiversity in Eastern Ethiopia. Additionally, it explains the consequent need for further research on additional roads to obtain a better understanding of the potential impacts of roads and factors influencing road kill occurrence.

Animal-vehicle collision and ecological connectivity in the Mont Blanc area: The role of local stakeholders in managing local human-wildlife conflict

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The Working Region "Mont Blanc" of the Alpine Space Project ALPBIONET2030 surrounds the area where Italian, Swiss and French borders meet. This transnational alpine zone is a place of attraction, which participates in intensifying human settlement and traffic, resulting in an accelerated urbanisation. It is also a mountain region with several protected area and a narrow valley, the valley of Arve, with a motorway and a railroad. Simultaneously, the populations of ungulates are increasing and the combination of these factors multiplies contacts between wildlife and human activities, mainly in regards to animal-vehicle collisions (AVC) and their effects on local and pan-alpine ecological connectivity. In Haute-Savoie, the AVC issues remains a hot topic in this area, although local stakeholders and the public sector have been working on mitigation techniques through the years. During the ALPBIONET2030 project, Eurac research, in collaboration with ASTERS (Conservatoire d'Espaces Naturels Haute-Savoie), has involved local stakeholders in developing what should become soon new forms of collaborations to manage the AVC conflict, in order to protect biodiversity and some of the prominent ecological corridors. The main objective was to identify further issues occurring when the participative conflict management process has already been engaged and to identify sources of resistance in the conflict management process. Local stakeholders reported their overview and what the limits to their actions could be, highlighting that the main issues regard the costs of road infrastructures, the lack of support by the politics, the different administrations engaged in the road safety and the increase of urbanization and of ungulates populations. The stakeholders agreed on the fact that more data gaining and sharing would be needed in order to adapt road infrastructures to the growing presence of wildlife. Different organisations need to cooperate to raise awareness among the large public, because each of them can reach a specific targeted group of population. Finally, all of the stakeholders agreed that this kind of issues needs to be faced in a transnational dimension – seen as an opportunity to look for new solutions. They showed an interest in investigating the management of AVC in other areas in order to exchange and improve their action. Further steps foresee several focused meetings that will be organized for local circumscriptions, under the coordination of ASTERS and with the external support of Eurac Research experts. The main objective is to discuss more precisely not only the issues and the measures that should be taken within a specific area, but also the best way to get the visions and the opinions of all the relevant stakeholders and of local populations. The discussion will be then widely opened to various stakeholders with the main aim to collect information that could enable a prioritisation of the different action zones, also with the support of GIS instruments. Additionally, the project will ideally result in concrete outcomes such as improved underpasses and overpasses across the motorway.

Crossing borders between sender and recipient: Better communication and marketing for better wildlife corridors

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Objectives : (1) Inspire other organisations to consider new ways to fund connectivity measures; (2) Support other organisations by providing them with a case study about the awareness-raising effects of political and educational projects. Findings: (1) Wording and imagery: Our experience shows that positive language and imagery may work better than pictures of animal-vehicle collisions (AVCs) and roadkill; (2) Message and target groups: A message tailored to a clearly defined target group works best. It is worth the effort to create different communication projects for different recipients. Pro Natura (Friends of the Earth Switzerland) is a Swiss environmental NGO. It was founded in 1909 and currently has 144.000 supporting members. In January 2017 Pro Natura started the three-year campaign ''Make way for wildlife!'' which includes communication and fundraising measures alongside political, practical and educational projects. Some examples of Pro Natura's campaigning approach that may inspire other organisations and campaigns: (1) Examples Communication: a) Key visual: The key visual for the campaign "Make way for wildlife!" was chosen carefully to convey a positive message and has become a popular sticker; b) Animal of the Year: Since 1998 Pro Natura has appointed the Animal of the Year in Switzerland. In 2017 the red deer was selected as the ambassador for connected wildlife corridors. In 2018 the ermine represents the need for ecologically valuable small structures and connectivity measures; c) Exhibitions: Pro Natura had two different exhibits in nature conservation centres in 2017: one on landscape fragmentation and wildlife corridors, the other on red deer, the Animal of the Year; d) Website and Facebook "Red deer in motion": A communication project based on scientific data of radio-collared red deer. Movement patterns explain the habits of the animals in a fractured Swiss landscape; e) Photo competition: Pro Natura initiates the photo competition "Native wildlife in motion" in spring 2018; f) Leaflet "Attention - wildlife crossing!": background information for road users. (2) Examples Marketing: Pro Natura organised two fundraising and awareness events for the campaign "Make way for wildlife!" in 2017. The proceeds from the poster campaign were very satisfactory compared to similar events for other campaigns in previous years; a) Poster campaign "Passing impossible?! Wildlife needs over- and underpasses", May 2017: Poster campaign plus radio spot and a letter to Pro Natura members and additional recipients. Call to action: donations to support connectivity measures; b) "Chocolate coin" campaign, September 2017: Schoolchildren sold dedicated chocolate to passers-by and residents to raise awareness for the Pro Natura campaign. Pro Natura provided teaching aid for school classes, various information material and the golden chocolate coin with the coinage of native fauna on the front and an overpass with animal tracks on the back. The revenue provides the financial basis for connectivity measures within habitats and landscapes. In the campaign "Make way for wildlife!" the aim of most projects is to purchase anti-tank obstacles and increase their value as wildlife corridors. Take-home message: In non-governmental organisations, practical projects are more likely to be successful if there is a master plan that includes the project itself as well as matching fundraising and communication activities.

Monitoring together! Government and NGO monitoring arboreal crossings and underpasses on Costa Rican roads

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Costa Rica is a biodiverse country with 20% of the territory dedicated to the protection of wild places. Its income is based on tourism, which is mainly focused on its wildlife. Development needs to be in balance with the conservation of its natural resources. Most of its electricity is generated by renewable sources. Road are getting greener as well. Since 2015, the Ministry of Transportation (MOT) started to implement a Guide for Wildlife-friendly roads. This guide recommended environmental measures for roads based on wildlife field data related to the project. Underpasses, arboreal crossings and road signs are now part of new roads in Costa Rica. Monitoring implemented measures for wildlife on roads is crucial to provide recommendations to secure the biological connectivity and reduce mortality. The MOT lacks of experience on wildlife monitoring on roads, while Panthera has worked since 2008 in Costa Rica on wildlife monitoring. Both started designing a monitoring protocol for arboreal crossings and underpasses to be implemented as mandatory for new road projects. This protocol would be tested in three road projects. We present the results of the first time testing this protocol. Route 4 is a new road, 27 km long. We set up 22 camera traps on six arboreal crossings (from a total of twelve), six underpasses (drainage with runway), six drainages (with different dimensions) and four on forest fragments at 50m from the road. Cameras stayed on the field for four months: from July to December 2017. The road was open to public circulation in August. The arboreal crossings were in operation in 2015. The main results focused on mammals (excluding bats): seven species used arboreal crossings, two species used the runways, four species used the drainages and eleven species were found in the forest. From the twelve terrestrial species that have been found, six species are crossing safely under the road. We have no evidence of the other seven species crossing under the road, but we have evidence that two of them are still crossing over the road and were killed (incidental data). Our first conclusion is that there is a lack of information of the species that were crossing the road and the number of arboreal species present at the forest. We recommend repeating this monitoring on the underpasses and drainages another six months after the road was opened, including monitoring of the road. This helps with determining whether or not the other seven species need time to get used to the infrastructure. For the next test we recommend including the monitoring of arboreal species and monitoring of the road. The arboreal crossings were two years old, so many arboreal species are used to them. However, we still need to know if there are arboreal species that are not using the crossings. Through this joint monitoring, the Costa Rican government started to learn how to evaluate the use of infrastructure by wildlife and how to implement adjustments. Additionally, they learned to test the methodology for the monitoring protocol that will be implemented when building new roads in the country.

TRANSGREEN Project: An example of cross-border cooperation in the Carpathian Mountains

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The TRANSGREEN Project was initiated as implementation mechanism of the Protocol on Sustainable Transport of the Carpathian Convention and is co-funded by ERDF. The Carpathians are one of Europe's largest mountain ranges, a unique natural treasure of great beauty and ecological value with a large number of rare and endangered species. As the Carpathians are less fragmented than other European mountain landscapes, they are still home to thriving populations of large carnivores. However, during the last decades, rapid development of transport including construction of highways and high-speed railways has been picking up across the region, and this development is expected to continue in the upcoming years. This is likely to lead to landscape fragmentation with high impact on sensitive mountain ecosystems. The aim of the project is to identify major conflicts between transport and wildlife and to provide recommendations for developing a safer and environmentally-friendly transport system in the Carpathians. The project partnership consists of 10 partners representing public authorities, scientific institutions, NGOs and private business from 5 out of 7 Carpathian countries. The collaboration is supported by 9 associated partners mainly from the ministerial level from altogether 6 countries. Expected deliverables of the project are (1) Handbook on the harmonization of wildlife and traffic including a chapter on monitoring the effectiveness of implemented measures, (2) Catalogues of measures containing concrete solutions for the improvement of infrastructure realized in 4 pilot areas across the Carpathians, and (3) practical tools, among them ready-to-use methodologies for stakeholder participation processes and a training module on Environmental Impact Assessment with a focus on ecological corridors. Specific measures regarding the planning, building, management and monitoring of large infrastructure are focusing on four pilot areas: Tîrgu Mureș – Iași, Arad – Deva (Romania), Miskolc – Košice – Uzhgorod (Hungary, Slovakia, Ukraine), and Beskydy (Czech Republic - Slovakia). The Beskydy pilot area is located in the western Carpathians on the borders of the Czech and Slovak Republics. The Beskydy mountains on the Czech side are protected (Natura 2000 site) for wolf, lynx and bear. However, the habitat fragmentation caused by transport infrastructure and settlements is progressing very quickly in this region. As the large carnivore population in Beskydy represents an almost isolated island, the local populations will be highly threatened by extinction in the upcoming years. The field activities in this pilot area are focused on intensive monitoring of large carnivores, the identification of the permeability of existing transport infrastructure in the pilot area, and the monitoring of fauna mortality on selected roads and railways. Activities in the pilot area have been launched in 2017 and will be completed in 2019. First results show that the fragmentation of the environment is caused not only by transport infrastructure, but also by linear settlements in mountain valleys. Field results from the pilot area will be embedded in the final outputs of the project, notably for the catalogue of measures for this specific pilot area and the handbook on the harmonization of wildlife and traffic in the Carpathians.

Interdisciplinary language barriers that impact on the implementation of the All Ireland Pollinator Plan

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Cross-border projects can make a significant contribution to the protection of both natural resources and habitats in vulnerable areas. This subject is not purely about the geographical connection but also about the connections between national and regional academics, and between decision-makers and practitioners. Connections which make a real impact on the conservation and protection of natural resources and habitats. Both Ulster Wildlife and the "Don't Mow Let it Grow" project in Northern Ireland advise a 2-cut cutting regime a year; also, they are advising not to seed unless required, and when seeding to use local and native species. Current government advice on how to promote practical management that enhances biodiversity along roads in the United Kingdom, advises "appropriate" planting. However, the seed mixes for Northern Ireland contain seeds that are present/introduced but are not native to Northern Ireland. The environmental NGOs and the government are at odds with each other in this matter, this is due to a lack of understanding, potentially created through disciplinary "language barriers". In 2015 the All-Ireland Pollinator Plan was developed to address pollinator decay and protect pollinator services. Sixty-eight organisations from across Ireland agreed upon the eighty-one actions laid out, from; local council, transport departments, and NGOs. Action A.28 of the plan is where this work fits; the adoption of an All-Ireland scheme to create pollinator highways along road networks. The development and implementation of guidelines for pollinator-friendly roadside management, need to bring together ecologists, engineers, and the public. This is to develop a better and more cohesive understanding of the processes involved from implementation to management. This project aims to target both the cross-disciplinary issues of pollinators and the built environment, and remove the "language barriers".

A cross-sectoral and interdisciplinary approach to improving management of trees as Green Infrastructure

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Trees are an essential part of Europe's Green Infrastructure in both urban and rural landscapes. In anthropogenic environments, they help to maintain biodiversity and ecological equilibrium as habitats and ecological corridors. For example, roadside trees (tree avenues) in Central Europe have been reported to be a key habitat and conduit for the hermit beetle (*Osmoderma eremita* group), and the longhorn beetle (*Cerambyx cerdo*). They also play a crucial role in the daily commuting of bats and form a roosting, breeding, and hibernation site as well. Other taxa using avenues and other trees in human-made environments include birds, lichens, fungi, and mammals (e.g., dormice). The EU or national regulations protect many of the mentioned organisms. However, trees are among the least appreciated elements of the Green Infrastructure, often taken for granted by both society and tree managers. The management of trees is often ineffective, with their depletion as a result. Roadside and urban trees have been disappearing in recent decades at many sites, due to hasty road modernisation and mismanagement. For example, from 2011 to 2014, 800,000 trees were taken from sixteen significant cities in Poland. Since 1945, more than 50,000 km of avenues were lost in western Germany. Replanting is rare. Trees are often subject to the improper care, which reduces their life expectancy and impacts public safety, generating criticism of trees in media. It is a challenge to harmonise trees with other types of infrastructure, such as roads, railways, and canals. Using synergies between the green, grey, and blue infrastructures will maximise the benefits the trees offer. The Roads for Nature programme, initiated in Poland in 2009, focused on working with people and institutions that manage trees (road services, public spaces managers, property managers) or grant tree removal permits (local authorities, nature conservation, and historical preservation authorities) to improve their tree management skills. This was accomplished through training, publications, and tree resources surveys and planning. A tree assessment method for non-specialists was created and introduced. A campaign directed to the society at large was conducted to increase public acceptance of trees. A network of grassroots activists was supported with training and publications. Together with a partner in Germany, BUND Mecklenburg-Vorpommern, an international network of organisations preserving avenues and implementing trans-border initiatives was supported. In the years 2012 to 2015, EU LIFE+ supported the programme. The goal of the new LIFE+ project Trees for Europe's Green Infrastructure is improving the role of trees as green infrastructure in rural and urban landscapes through better management practices. Working within interdisciplinary groups of experts (scientists, practitioners) and stakeholders (road authorities, city tree officers), we are creating and implementing guidelines for better tree management. Support will be provided to citizens and NGOs who care for trees and are their advocates in Poland and Germany. The implemented projects demonstrated how crossing boundaries among sectors, disciplines, and countries leads to better management of trees as green infrastructure. Therefore, society's benefits– including biodiversity conservation, climate change mitigation, and life quality are maximised.

Turning scientific knowledge into official technical recommendations

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Terrestrial transportation infrastructure networks are expanding worldwide, especially in developing countries. Environmental Impact Assessments (EIAs) are one of the essential tools to reduce the environmental consequences of those infrastructures by formally implementing the mitigation hierarchy along planning, construction, and operation phases. However, EIAs have been criticised for their low effectiveness to guide the avoidance, minimisation, restoration or compensation of environmental impacts. As a solution, strengthening and enforcing regulations are recognised as ways of increasing EIA quality and effectiveness. We describe a series of actions we have taken in Brazil in the past four years to engage different stakeholders in the improvement of sampling protocols and guidelines related to the environmental assessment of road and railroad impacts on wildlife. We followed six steps in our actions: (1) preparation of issues to be discussed, (2) workshops involving academia, environmental managers, transportation managers, and environmental consultants, (3) definition of questions to be answered and sampling protocols to answer them, (4) identification of research gaps, (5) documentation of results and recommendations, and (6) dissemination of results to academia, institutions, and the general public. During the last four years, we have developed a workshop series at a national level to discuss sampling protocols for assessing wildlife mortality and mitigation effectiveness on railroads, a workshop series at the state level to discuss sampling protocols for assessing wildlife mortality on roads, and scoping workshops to discuss terms of reference (ToR) for environmental licensing of roads. We based our discussions and recommendations on three fundamental questions: 'Why?' (Clearly stating goals for the study), 'What?' (Deciding what data should be collected), and 'How?' (Defining appropriate study design). In all those initiatives we tried to support recommendations with previous scientific evidence and knowledge made available by our research or by literature. When information was not available, research gaps were identified and incorporated into our research agenda. At a state level, the workshop results were turned into official recommendations for the monitoring of road mortality. At a national level, the results are supporting the current revision of national regulations for road and railroads wildlife monitoring. The development of guidelines based on collaboration and consensus of different sectors ensured the fast adoption of recommendations by the state and national environmental agencies. We encourage the adoption of actions for cooperation among sectors in building environmental licensing protocols as a best practice to reduce the impacts of human infrastructures on wildlife and increase the effectiveness of environmental policies.

Common ground: When road authorities and community groups actually work together

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Perhaps the most predictable conflict associated with the planning of new road projects is that of cross-group mistrust. The road authorities assume the community and environmental groups simply oppose everything; the green groups assume the road people don't care. These stereotypical perceptions can be minimised by genuine engagement at the earliest stages of concept development. An example from Australia exemplifies the significant benefits of a willingness to listen and endure informed compromise from both sides. The Logan Enhancement Project is a major motorway upgrade, currently (2017-2019) underway near Brisbane in southern Queensland. By engaging with local groups and seeking environmental input as part of the design process, this project now includes some of the most ambitious road permeability interventions yet attempted. These works effectively provide landscape movement corridors of over 50 km and complements the well-studied Compton Road fauna array constructed 13 years previously. This presentation will outline the initial barriers to effective relationships and how these were overcome. To enable a meaningful assessment of the eventual outcomes associated with this cross-group dialogue, a comparison of the probable plans with and without the inclusion of the intervention will be provided. Without this consultation, the design would have been dominated by engineering priorities, with biodiversity attributed limited entirely to revegetated verges. The inclusion of a broad-based environmental reference group-initiated consideration of options such as vegetated overpasses, extended bridge viaducts, canopy connections and rehabilitation of waterways outside the road corridor. The eventual design features variations on all of these items, formulated and fine-tuned in direct engagement across normally disconnected groupings, including road engineers, environmental specialists, hydrologists and project managers. Crucially, public relations agents recognised powerful positive community-relevant messages emanating from this level of collaboration; this has led to excellent national and international media coverage. In contrast, similar projects of this scale in the same jurisdiction which operated without an environmental reference group typically resulted in poorly designed crossing structures, constructed in inappropriate locations, at greater expense and resulting in considerable community antipathy. Our project is presented here with the sincere objective of encouraging similar arrangements in future plans.

The behaviour of wild mammals living in the vicinity of railway tracks in the field and forest landscape mosaic

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Compared to knowledge about roads (how they are used and their influence on animals), there is a lack of knaowledge about railway ecology. Furthermore, we know little about animals' reactions to arriving trains and none of the published articles (according to our understanding) present results from research conducted on this issue. The study aimed to determine the behaviour of animals living in the vicinity of railway tracks. The research focused on how animals use the railway tracks and how animals react to the arriving train. We did analysis showing how seasons, time of day and moon phases influence animal behaviour. The research was conducted in years 2008-2012 in central Poland along chosen stretches of two railway lines (E20 and E65). We collected the data using digital cameras. Eleven wild and two domestic species of mammals were observed in the vicinity of the railway tracks. Most numerous were roe deer, moose, wild boars, red foxes, brown hares, domestic dogs, and cats. The majority of mammals were observed in spring (especially roe deer, moose, wild boars, brown hares, and cats). Only carnivores, such as red foxes and dogs were observed more frequently in winter. The majority of animals were seen at dawn (moose, red foxes, brown hares, cats), while we registered roe deer and wild boars more often at dusk, and we observed dogs more frequently during the day. The animals were active more often at dark than during bright nights. We registered most observations of animals at night during the first quarter of the moon. The moon phases influenced the probability of the presence of three species: roe deer, red foxes, and brown hares. When no train was approaching, we observed three types of reactions: foraging, walking along the tracks and crossing the tracks. We registered most animals while walking along the tracks. Only roe deer were observed more often during foraging, whereas moose were seen more often crossing the tracks. When the train was arriving, we observed three types of behaviour: escaping, getting alarmed and showing no reaction. The study discovered that the majority of the animals escaped when the train was approaching. Among factors tested, only the moon phases influenced animal reactions to the train. During brighter night, the animals were more alarmed when a train was approaching. The results of the study may help develop new methods preventing animal-train collisions.

The dispersal route of wolf Naya from Germany through The Netherlands into Belgium: Insight from GPS-GSM telemetry on activity patterns and barrier crossings

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Female wolf Naya was caught as a cub in October 2016 in the territory of her family pack near Lubteener Heide, Mecklenburg-Vorpommern, Germany. Researchers from the Technical University Dresden fitted her with a GPS-GSM collar to study her activity pattern, habitat use and interaction with prey species. In October 2017, Naya left the natal pack starting her dispersal trip to find herself a territory. The 18th of December, she entered The Netherlands and the 3rd of January 2018 she entered Flanders, Belgium. There she settled down on a military exercise area near Leopoldsburg. Physiologically, Naya will become sexually mature in February 2018, ovulating for the first time. If a male wolf finds her in time, they might be able to form a pack this year. During her trip through The Netherlands, ecologists from Wageningen Environmental Research have studied her day resting places on instruction from TU Dresden. She visited many National Parks in The Netherlands. Altogether, this provided us with information on habitat preferences, activity pattern, the route taken, and obstacles that have been conquered. Naya crossed many highways, rivers, and channels. In this Lightning talk this dispersal route will be presented, focussing on barrier crossing.

Innovative approaches to open the Afsluitdijk for fish

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The Afsluitdijk is a typically Dutch icon; it is one of the most massive water defence and water management structures in the Netherlands. The dam connects the Northern provinces with the Randstad by road. It was constructed in 1932 and brought safety against flooding and a vast reservoir of fresh water. However, the dam also closed off the former Zuiderzee; the large estuary of the rivers IJssel and Rhine. Today, the Afsluitdijk represents a barrier between the tidal Wadden Sea and the freshwater Lake IJsselmeer. (1) Fish-friendly sluice management and fishway Den Oever (Sophie Lauwaars, Ministry of Infrastructure and Water Management): The construction of the Afsluitdijk resulted in an ecological disaster for migratory fish that need both salt and fresh water to complete their life cycle. The Afsluitdijk is a considerable barrier. Nowadays, there are two complexes of discharge sluices and ship locks at Den Oever and Kornwerderzand, where Lake IJsselmeer and the Wadden Sea are connected. Both complexes in the Afsluitdijk are operated in a fish-friendly way. The discharge sluices facilitate fish migration within the constraint of Lake IJsselmeer, which needs to remain a freshwater reserve. The ship locks are opened during the night specifically to let fish in. Saltwater, which flows towards Lake IJsselmeer returns with a discharge system, specially constructed for this purpose. Near the province of North-Holland, a fish passage for smaller fish species has been built through which many glass eels pass in April and May. The monitoring results of these different technics for fish migration are promising and confirm the presence of millions of fish motivated to migrate upstream. (2) The Fish Migration River Kornwerderzand (Roef Mulder, Province Fryslân - De Nieuwe Afsluitdijk): The Fish Migration River project has been devised to secure fish migration past the Afsluitdijk for all species at any time. It will create an estuary with natural tidal influences and brackish habitats. The challenge is to design an open fishway that connects the tidal sea on the outside with a fixed level lake that needs to remain fresh. The fishway requires facilitating the whole range of migrating fish, from tidal migrants such as the tiny flounder larvae to the strong and agile salmonids. The initial idea was launched in 2011 by a combination of non-governmental organisations. A feasibility study proved that it is technically possible to make the proposed system work within the necessary constraints of water management. Experts were consulted to provide further advice and detail to inform design and engineering considerations. The project has now been incorporated in the overall renovation program of the Afsluitdijk. Procedures for destination plans and permits have been completed, and the works will be contracted this year. The future management of the Fish Migration River will be optimised together with the operation of the sluices and locks. The project demonstrates that it is possible to restore river connectivity at such locations without compromising water quality and safety.

Reevediep a new connection between the River IJssel and the bordering lakes

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A new and innovative way of dealing with high water levels is invented and implemented in the Dutch Room for the River programme. Instead of insisting on the heightening of dykes, measures are taken which provide the water in the branches of the river Rhine with more space. One of the projects is being constructed in the Kampen-Zwolle region. Due to climate change, the risk of flooding is increasing in this region. More space is created for the river IJssel (a branch of the river Rhine) in the Room of the River project IJsseldelta with the following measures: the deepening of the summer bed of the river and the construction of a bypass (flood channel / Reevediep). The result is a substantial decrease of 41 cm of high water levels on the river IJssel near Zwolle in extreme conditions. The Ministry of Infrastructure and Water Management and the province of Overijssel commissioned this project. Reevediep has a northern and a southern dyke. An inlet is being built at the IJssel side to discharge the water safely to the IJsselmeer. This inlet is a concrete bridge. IJssel water is expected to be released into the Reevediep once every five years. At the inlet, a fish passage will be created as well. Before the construction of the bypass started, bridges were built on the highway N50 and the new railway (Hanzelijn). That is why the bypass will be able to pass underneath. Between the dykes, a fairway with a length of seven kilometres is completed. A unique part of the project is the construction of a reed marsh (42.7 hectares in the years 2014-2016) north of the tunnel of the Hanze railway, at the Overijssel side of the Drontermeer. Some hectares are a compensation area in case of losing 4.1 hectares (this is a worst-case scenario) of protected reed banks when the flood channel is being dug to the Drontermeer. The new reed marsh is the habitat of protected birds such as the bittern and the great reed warbler and is added to the existing Natura 2000 area 'Veluwerandmeren'. Part of this area is co-financed by the European LIFE programme. The first breeding of a bittern already happened in 2017 shortly after the reed marsh was realised, which is unique. In the more isolated parts of Reevediep, a new habitat for protective fish species such as the weather fish is being developed as well. The endangered Eurasian water shrew, the biggest shrew in Europe, also gets more living space in the Reevediep. Furthermore, the extra water surfaces of the Reevediep combined with the vegetated banks create an additional foraging area for the pond bat. In total, the IJsseldelta project includes than 350 hectares of new nature. At the same time, the quality of existing areas of nature in five floodplains along the River IJssel is improved. Such a significant amount of new nature and improvement of existing nature is unique for an infrastructural project.

Tracking glass eels

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The European Eel is a migratory fish species with a complex life cycle. The recruitment to fresh water has declined over 95%, hence the Red List status of Critically Endangered. The species is of interest for the European Water Framework Directive and the European Eel Regulation. One of the most essential pressures is fragmentation of habitats due to migration barriers, such as pumping-stations and sluices. Recent years, large-scale citizen science projects have been initiated by collaborations of NGO's and governments to monitor numbers of recruiting juveniles (glass eels) at migration barriers. Nowadays over 40 locations are monitored by more than 150 volunteers along the Dutch coast. The gathered data gives insight into regional recruitment trends and timing, and offer substantiation to prioritisation of measures to overcome these barriers. At a regional scale, we see the recruitment is still in decline. When migration measures are taken, evaluation is important but proved to be difficult. The efficiency for glass eel migration can be evaluated by the use of VIE-tags (Visible Implant Elastomer) in a mark-recapture set-up. In 2017 this technique was first used in the Netherlands in Scheveningen, where the constructed fish passage (from 2009) was evaluated. Here, by recapture of tagged specimens, the glass eel population was calculated to be in the range of 10,000-30,000 at given moments, whereas the overnight migration through the passage was in the range of 30-661. In the research period, only 9 of 1,355 VIE-tagged glass eels managed to pass the barrier. The results show a very low efficiency of the fish passage, indicating additional measures have to be taken by the water manager to facilitate the migration.

WiConNET: A large-scale multimodal wildlife-vehicle-collision mitigation project

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Vehicle wildlife collisions (WVC) are a significant challenge in today's road and train transport networks. The overall number of road accidents in Europe is steadily decreasing. However, the number of vehicle-wildlife collisions are still increasing. In rail transportation, the situation is similar. Some European railway operators face yearly compensation payments due to WVC related service interruptions and delayed trains, often consuming an essential part of the budget. Austria is a leader when it comes to development and is an early adopter of WVC avoidance systems. This has now led to a broad base of installed roadside devices (10,000 active devices and 100,000 passive devices). The Austrian institutions have gained about 20 years of insight in the applicability and limitations of passive and active WVCA systems. Passive optical reflectors have shown a reduction of vehicle-wildlife collisions in everyday traffic environments from 25% to 35%. However, their efficiency decreases with vehicle speeds above 60 km/h. Therefore, passive reflectors alone are not useful in railway networks. Active electronic devices show an improved efficiency from 50% to 90% at vehicle speeds up to 100 km/h. In railway networks and high-speed roads, current systems are still not applicable. The main limitations are the missing functionality during daytime and higher speed operation capability for road and rail traffic. The primary goal of the WiConNET Project is to improve the efficiency of today's WVCA systems. This improving can be done by implementing a wireless communication and networking capability, and by extending the applicability of WVCA systems towards railways and highways. The system should also be cost-efficient to enable a large-scale deployment. The WiConNET Project is border crossing in several ways. First, the WVC topic itself is border crossing, as several Pan-European wildlife migration routes affect Austria. Second, the project is border crossing due to the fact that all WVC-relevant Austrian stakeholders (Ministry of Transport bmvit, the nine Austrian states, the Austrian Research Council FFG, the Austrian highway operator ASFINAG, and the Austrian railway operator OBB-Infra) teamed up to define and fund a 3-year multimodal WVC research, development, and deployment project. Third, the project includes a test and certification laboratory for WVC equipment and will contribute to the national standardisation. Fourth, the project is border crossing because it will include 16 large test-sites (five railway sites, five national road sites, and six highway sites) to evaluate the WVC equipment and the improvement of the real-life environment. Contacted partners are iPTE Traffic Solutions, a leading WVCA system provider, AIT (Austrian Institute of Technology), the largest University-independent Austrian research institute, and WWN-Forstner, an acknowledged expert for wildlife and biosphere projects.

WiConNET-Test sites: Validation Test sites across Austria for of wildlife-vehicle-collision mitigation systems

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The road operators are in a dilemma when selecting a proper Wildlife-Vehicle Collision Avoidance (WVC-A) system, as there are many passive and active systems available on the market. Each of these manufacturers claims their system is perfect. However, there are good ones and bad ones. So, it is hard for the operator to decide which system to choose. Many operators have now to define and to set up their test site. However, the general value of the figures is limited, because the sites are rarely comparable. In 2017, the WiConNET was started to improve the current available WVC-A systems and to extend their applicability to higher speed roads and railways. One of the essential factors is the efficiency (the actual accident reduction percentage). It is challenging to derive the efficiency as a comparable figure. Sure, the physical properties of a WVC-A system can be measured in a laboratory. The efficiency, however, the practical value, needs to be validated in real life test sites. The WiConNET project has now included 16 large test sites across Austria. Five railway test sites, five national road test sites and six test sites for highway operators to protect the un-fenced highway entries and exits. The test site selection process was based on the following criteria: (1) WVC hotspot, i.e., a high number of accidents, statistics available for the last three years; (2) The local wildlife species (a representative distribution across all sites); (3) The wildlife-related environment (water, food, vegetation); (4) The support of the local hunters and infrastructure service; (5) Average driving speed and road or railway layout; (6) Wildlife local and long-distance wandering routes. The test sites are set up and divided into three groups: (1) National road sites with speed up to 100 km/h. The evaluation focus is on layout issues (mix of active/passive devices, spacing), alert optimisation and daytime operation; (2) Railway sites with speeds ranging from 80 up to 250 km/h. The focus is on the remote trigger and trigger forwarding via wireless networking; (3) Highway entry and exit protection. The focus is on wildlife detection and directed deterring to prevent wildlife migration into the (unfenced) highway entries and exits. In total, about 1,000 active and 400 passive WVC-A devices will be deployed. In addition, several dozens remote trigger and Internet gateways will complement the systems. Physical observations, monitoring with IR-illuminated wildlife cameras, thermo cam and, as an option, with a unique wildlife-tracking collar, perform wildlife monitoring.

Designing a ring road, a landscape or both?

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In redesigning the ring road around Brussels, two regions are involved. The ring road lies in the Flemish region. However, it is mostly used for traffic in and around the region of Brussels. The two regions have their own rules and visions on mobility, traffic, and taxes. Since Brussels is known in Europa for its traffic jams, the Flemish government decided to broaden the ring road. However, the planning has been going on for years now, and no final decision has been made. Several parties emphasise the need for a modal shift: car use, and more possibilities for biking to work, more and better public transport, etc. The case I would like to present is the northern part of the ring road. One of the elements causing traffic jams there, according to earlier research, are the hills on the ring road. Trucks go slower and cause traffic jams. Since the ringroad is already located on a deep level in the landscape and since there are still some tunnels underneath it, it might be possible to lower the ring road and connect the landscape on both sides above the lower ring road. In collaboration with the Flemish Land Agency and the Flemish master builder, we launched a study to conceive and design such a ring road. On the Brussels part there is a Natura 2000 area and on the Flemish side there is a large agricultural area. Connecting those two parts would bring lots of advantages for nature, biodiversity, and people. Lowering the ring road and covering it would bring solutions for noise, air pollution, foraging areas, walking, biking to work, etc. However, the company that is responsible for the ringroad considers only mobility to be an advantage. They presented an ecoduct of 85 meters, while there is a possibility to cover 700 to 800 meters. Arguments they mention are the difficulty of the works, the costs, and the character of a precedent. An interesting discussion on how we cope with impact assessments for greener transport infrastructure. Should we only consider mobility or should we examine the problem in a multifunctional way? Should we choose a solution that benefits everyone, instead of a solution that only contributes to motorised transport?

Improving the ecological quality of secondary waterways using the standard approach 'Sustainable Civil Engineering'

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Similar to most countries, The Netherlands, and with that the Province of Noord-Holland, need to meet the climate targets. We face the challenge of reducing our use of raw materials and CO2 emissions. We signed, among other things, both the Green Deal GWW 2.0 and the Green Deal Infra-nature to tackle this challenge. In these deals, about sixty parties such as governments, municipalities, and large and small contractors commit themselves to implement a standard work approach to improve the sustainability of infrastructural projects in planning, construction, tender, and maintenance. A standard method was developed called the standard approach 'Sustainable Civil Engineering'. The project team that I lead uses this standard approach to improve the ecological quality of secondary waterways in some shore protection projects. This project team is responsible for all shore protection projects in the waterways in the province of Noord-Holland. First, we start with a so-called 'Ambition web', a tool to determine our ambitions on different sustainability themes. Surely, we can save many materials and energy when it comes to shore protection works. Additionally, it can help to improve the ecological quality and minimise hindrance for the region. Second, we use the 'regional scan' tool to identify the project's impact on these different sustainability themes. As it turns out, one of the projects has a significant negative impact on ecology. The current degraded state of shore protection offers a habitat for various rare fish species. Renewing the shore protection affects this habitat. Most likely, this habitat would disappear. Once this became clear, the team formulated specific measures to improve the impact of the projects on the themes with a high ambition level in our ambition web. These measures were all ranked on impact (on planning, budget, and quality of the project) and divided into three categories: 'Quick win', 'Requires further study', and 'Not feasible'. The first two categories were specified in the engineering or contractual phase of the projects. This approach resulted in a wide variety of measures, from simple contractual demands such as gaps in the shore protection and swampy areas behind these gaps (so fauna can live there or climb ashore) to selection criteria for contractors to reduce CO2 emission: (1) 1,600 meters of Ecological Shore protection on seven locations, and twelve more kilometres in the design phase; (2) fauna gaps along 6 km of shore protection where the shore protection is slightly higher than water level; (3) 12 km of very light steel shore protection without anchors as a result of selection criteria on CO2 reduction. Usually, we would demand a hundred years of steel, which would require massive steel profiles. This also led to significant cost reductions. Unfortunately, it did not lead to the amount of CO2 reduction we hoped for; (4) conservation of existing Bullhead habitats by the incorporation of swampy areas in new shore protection; (5) market consultation on sustainability for the next project, to improve the selection criteria on CO2 reduction or to find a more sustainable alternative. We want to discuss the possibilities of modular shore protection, so only the degraded part has to be replaced in the future. In conclusion, the approach of 'Sustainable Civil Engineering' offers a useful and systematic method to improve sustainability in shore protection projects. However, this approach should ideally commence in the study stage of a project so that there will be enough time to prioritise and implement the measures.

System certification for eco-friendly materials constructing a greener transport infrastructure: A way to gain knowledge and enhance quality crossing borders between stakeholders

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There are different, additional ways to create an ideal playground where nature can develop: (1) Carry out construction works in a nature-friendly way; (2) Develop nature-friendly constructions; (3) Work with eco-friendly materials. In the work we did, we focused on the third measure. How can we enhance the quality of these materials, the quality of their application, and the quality of the architect's choice? First, it is necessary to know what kind of eco-friendly materials are used to construct greener transport infrastructure. We concentrated our research on materials not yet product-certified in Flanders. A market analysis combined the results in four groups: (1) Living materials, e.g., woody plants, herbaceous species, grasses; (2) Wood and derivatives, e.g., wooden posts and boards, wickerwork; (3) Eco-technical anti-erosion textiles, both biodegradable (made of natural fibres such as coconut, or made of synthetic polymers, such as polylactic acid (PLA)), and not biodegradable, but suitable for root penetration; (4) Eco-technical composites, a combination of materials from the three other groups, or from one of the groups mentioned above and traditional, non-living material. Second, it is necessary to define the determining factors of the quality of these 'living' materials: (1) They are highly subject to interaction with the environment. Therefore, the result after the application is hard to predict; (2) Measuring the required quality is difficult during production because we are primarily interested in the quality of the result after application; (3) Defining product quality specifications is not enough. Application of specifications, evaluation, and monitoring are vital. As a result of many years of project experience, we have learned that cooperation between the different stakeholders is essential. However, there is no practical evidence yet: architects and engineers, developers, research institutions, contractors, and governments have to interact and understand each other's objectives and challenges. Therefore, we developed an 'eco-technical material care system' (NTMB-zorgsysteem) that tries to enhance and stimulate this. It is a certified care system for producers and suppliers. It is possible to extend this care system to contractors and expand it with consulting. This care system evaluates: (1) the way a producer/supplier organises planning, production, supply, services, evaluation, innovation; (2) the technical aspects of the produced/supplied eco-technical materials; (3) the way knowledge is shared with stakeholders. As a result: (1) more technical information is available to everybody (e.g., technical forms, application guides, good practices on websites); (2) a third party (certification body) carries out external evaluation; (3) adequate quality control on the construction site is possible; (4) innovation is stimulated. This care system is very flexible. Continuous upgrades keep up with the fast-moving market. It invites stakeholders to look further than the material as it is. The final goal is to gain and spread knowledge. To enhance this even more, we support the development of a knowledge institute 'greening the construction sector'. This knowledge institute will become the owner of the care system.

Plastic Bridges: New materials for the integrated design of landscape and infrastructure

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Design standards and regulatory requirements for the construction of wildlife crossing structures are typically adapted from conventional designs for bridges supporting vehicular traffic. Overpass structures for wildlife represent a unique category of infrastructure, and therefore existing regulatory standards not only limit the ability of crossings to fulfill very different requirements for use but also restrict opportunities to realize potential savings in the costs of their construction and maintenance. This presents a significant opportunity to assess whether compliance with existing standards is required or even necessary. Next generation wildlife crossing infrastructure might include lighter, more flexible and adaptive materials, or a system of construction that is modular or even dynamic. Adopting innovations in the design of wildlife crossing infrastructure could result in more sustainable, affordable, and efficient solutions. Solutions with the potential to facilitate the widespread deployment of flexible structures that can expand, contract, or be moved to respond to changing habitats and replaced more easily than traditional infrastructure in the event of damage from adverse weather events. Safe Passages is a federally funded research partnership led by Professor Nina-Marie Lister (Ecological Design Lab, Ryerson University) aimed at the development of an integrated approach for the sustainable planning, design, and implementation of wildlife crossing infrastructure and improved landscape connectivity. This research partnership recognizes that there is an emerging public policy and infrastructural design imperative to find new and creative ways to (re)connect our landscapes in support of the safe passage of humans and animals. The primary method for generating research outcomes within the partnership are CoLaboratories (CoLabs): research-based, collaborative studio workshops in which participants come together to apply, present, and share emerging research in the design of new solutions for human and wildlife mobility across urbanizing landscapes. This approach links stakeholders in a creative, hands-on planning and design forum to build on best practices and leading-edge technologies. CoLabs situate the research problem, animate data, realize planning and design solutions, and link these to implementation strategies within both policy and site contexts. This presentation will highlight outcomes from a Spring 2018 CoLaboratory held in Bozeman, Montana co-hosted at the Western Transportation Institute by Robert Ament (WTI, Montana State University) and Nina-Marie Lister (Ecological Design Lab, Ryerson University). The CoLab generated prototypical designs and tested opportunities to construct wildlife crossing infrastructure using recycled plastics, which have been widely used in pedestrian and bicycling bridge applications. Experts in the disciplines of structural and civil engineering, wildlife ecology, urban planning, and landscape architecture and design worked together towards integrating the landscape and habitat surface with the design of an engineered bridge structure. Participants investigated the suitability of plastic bridges for applications in crossing infrastructure as well as the current opportunities and barriers, both procedural and design based, to their uptake and widespread adoption by transportation agencies working to mitigate the incidence of wildlife-vehicle collisions. Plastic bridges may afford novel and cost-effective strategies to build ecologically integrated crossing structures for wildlife.

Crossing the ecofence of the Sonian Forest: joint management and maintenance of infrastructure

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The fragmentation of the Sonian Forest by motorways (R0 and E411), secondary roads and the L161 railway line between Brussels and Luxembourg is a major challenge for the ecology of the forest. LIFE + OZON aims to reconnect the ecological hotspots and habitats of protected animal species. Between 2013 and 2018, the project aims to bring about various infrastructures in the Sonian Forest, such as an ecoduct over the Brussels ringway near Groenendaal, ecotunnels under motorways and secondary roads and approximately 25 kilometres of ecofence along railways and motorways. The various infrastructure works are created through profound cooperation between different government agencies from three different regions (Flanders, Brussels and Wallonia). In this presentation, we give an overview of realised works and zoom into the joint management after realisation. The challenge is to strengthen the future operation of the passages in a partnership with various partners through targeted management measures. Common objectives, thorough inventory, division of tasks, long-term planning and sustainable integration in day-to-day operations are central. We discuss the development process, the elaborated approach in the Sonian Forest and the lessons we learned. Life + OZON is a collaboration between the Agency for Nature and Forest, the Agency for Roads and Traffic, the Environment Department of the Flemish government and Brussels Environment. The municipalities of Hoeilaart, Overijse and Tervuren co-finance the project. The 'Département de la Nature et des Forêts' (Wallonia), the United Nations Environment Program and the municipality of Sint-Genesius Rode support the project symbolically. The project runs with the support of the European structural fund Life+.

Creating a simple solution for a complicated situation: Maintenance of a diverse eco-infrastructure network (Niel, Belgium)

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To provide access to a company and resolve following traffic obstructions a new road was built. The road cuts through a biologically valuable nature-complex, alerting the Flemish Government to impose eco-measures in the building permit. These measures are intended to avoid the fragmentation and compensation of valuable biotopes (reed, eutrophic lakes, willow scrub, and alluvial alder forest) that disappeared during the construction. Leading the process is POM (Provincial Development Agency). However, a mix of public and private partners and owners are involved. DMN has been asked to advise on the design and construction of these eco-measures in addition to the preparation of a management plan. A fauna passage (representative species = otter) is being created over a distance of 1.5 km. The passage connects the Rupel (River) with natural complexes in the hinterland and includes an exit step (River), shrubbery and groves, wadis, grass-lands, pools, water basins, two large and four small fauna tunnels, a bat cellar, and amphibian wall. Ideally, the whole structure should be maintained and managed as one. However, the fragmented ownerships complicate the situation. Despite holding no property interests, the Province is committed to achieving the task. The purpose of our presentation is to illustrate this commitment and the method by which it will be realised. Our goals are as follows: (1) Continuous and correct management of the entire eco-infrastructure; (2) To manage, implement and monitor the maintenance consistently throughout the project; (3) To reduce costs and workload; (4) To create a proper financial cost allocation. Our approach is as follows: (1) DMN defines all the necessary management and maintenance work and describes this in explicit, easy-to-use leaflets; (2) DMN searches for a suitable and neutral coordinator to guide and implement the uniform approach. They are looking for a partner to organise all administrative tasks and maintenance work and to monitor the executed work. Through a cooperation agreement, cost allocation is set in advance. The coordinator assigns all necessary tasks (from the approved management leaflets) and draws up all specifications to execute the work annually. All parties must approve this. The coordinator organises all work and monitors the execution of the work. Each owner receives his or her share of the invoice. All parties decide together how many hours of labour are needed that year, which is then purchased within a blanket order. Advantages of this method are the administrative simplification, financial benefit, continuity in management, and proper management. The DMN team members collaborate with Regionaal Landschap Rivierenland (RLRL). They work on local identity (landscapes, nature conservation, education, and recreation) through real achievements in the field. They are specialised in collaborating with private and public partners, outsourcing tasks, and evaluating work. Additionally, they are engaged in a pilot project to translate all possible management measures to a digital environment (DIPLA) making the succession of management more accessible and more consistent. Once this is well developed and all parties are familiar with the system, it should be more accessible for anyone - e.g., a (chosen) representative of all stakeholders - to take over the role of the RL without undermining the continuity of manage-ment in the long term.

Evaluation of vegetation management in verges of Dutch highways

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Rijkswaterstaat is a Dutch government agency, responsible for the management of the main highways network. Management of the roadside verges is part of the road management and aims at maintaining (1) good technical condition of the road, (2) traffic safety and (3) high biological quality of the vegetation. To evaluate the outcome of the applied management measures in the roadside vegetation, 1600 permanent plots (PQs) were randomly established in 2000-2003. These PQs are mainly located in grassland (3x3 m), and also in forests (10x10 m) and ditches (25x1 m). Each year 400 PQs were sampled using the Braun-Blanquet method. One complete round thus takes four years. In 2016 four repeated rounds of relevés were completed, after which several vegetation characteristics were evaluated. Results: Altogether about 50% of the native Dutch plant species were found in roadside vegetation, with a vast majority of common species. Roadside forests are species-poor and of low botanical value, due to the young age, small size and disturbed soil. Species richness and perennial ruderal species slightly increased over time. The forests are not managed. The vegetation in ditches shows an increase of ruderal species, due to accumulation of cut plant material, but the botanical value didn't decrease. Species richness in grassland PQs shows a slight decrease since 2008. In grassland plots a decrease was observed in relatively rare species, indicators of nutrient-poor dry grassland, ruderal pioneer species, small herbs and the proportion of "flowering herbs". An increase was observed for non-pioneer ruderal species like some dense perennial grass species. The botanical value varied much between plots, but botanically rich plots usually didn't keep their value. Judging from the vegetation, soil impoverishment didn't take place. Additional observations indicate that in many cases the vegetation management was not performed properly: incompletely mown, cuttings incompletely removed, etc. This most probably is the main cause of the increased numbers of some ruderal species and the decrease of the botanical value and lower numbers of flowering herbs. The current vegetation management didn't result in maintaining or increasing the vegetation quality in the roadside verges, as was aimed at.

Implementation of dynamic wildlife warning systems and the use for specifically selected (small) animals

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In general, wildlife vehicle-collision(WVC) mitigation measures are taken to reduce accidents for traffic. The measures explained in this presentation show that these can also be taken to reduce roadkill for especially selected species and small animals with the main purpose of protecting them while crossing the road. When designing and building such type of systems you need to consider several steps. Following the next steps will benefit optimal functionality with low operational costs: (1) Species to consider: Which species are interesting to be detected? Different species require a specific detection method, and this is the starting point in designing the system. For example, wild boar and red deer are behaving totally different, and therefore detection methods should also be adapted to that behaviour. We will explain the otter project that is expected to be installed in 2018. (2) Location: In order to determine the right location for the system to be installed it is necessary to discuss the options with stakeholders like ecologists, road authorities, wildlife managers and other involved stakeholders. (3) Terrain and vegetation: At the preferred location, local circumstances can have a negative impact on the functionality. It is important to select the best suitable location for the type of detection that is needed. (4) Type of detection: When species, terrain and location are known, the most suitable type of detection must be determined. Through our experiences with systems we installed, several options are available. (5) Maintenance costs: While designing the system you need to consider keeping maintenance costs as low as possible. We will explain the issues to consider regarding this topic. (6) Power supply: It is not always possible to connect the system to the power grid. There are other methods of power supply that can be implemented. (7) Monitoring functionalities: End users prefer to stay informed about intensities of wildlife crossings and if the warning system is functioning well. For example detection methods to gain more data about passing wildlife like direction and height of crossing animals. What are the possibilities regarding small mammals? Can current designs be changed to secure a detection of the targeted species, based on specific species characteristics without the risk of unwanted activation of the signs by other animals like rabbits? We present the first results of the otter project. Together with experts on this particular species, we want to show that designing and adapting technology for detection of specific animals is possible. At all nine locations equipped with the latest generation of the Prowild dynamic wildlife warning system, results show a reduction of 90 to 100 percent of accidents. The experience we gain from the otter project will show it is possible to implement similar systems that are adapted to specifically selected species.

Infranature – Infrastructural collaboration and solutions yield more biodiversity

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Biodiversity is increasingly considered as an integrated part of one's everyday environment, though the decline of biodiversity raises awareness. Bees and butterflies are primary insect-indicators for our environment and also very popular by the public, particularly the butterflies. The 8% Natura 2000 coverage in the Netherlands is surrounded with even more spatial infrastructures. Infranature aims multiple targets that sustain biodiversity in infrastructural developments, including railways, national roads, water-, gas- and electricity supplies and many more. To reach this, framing, development of business models, social management, policy and regulation should be explored to connect biodiversity in a natural way. This initiative, taken by the Dutch Butterfly Conservation is running now for two years and is supported by twenty-two national companies and governments who have committed to aim more biodiversity in their core business. Establishing of this unique green deal was not that obvious and easy as biodiversity is beyond the core-business in infrastructural developments. However, the first results reveal some out of the box solutions and unexpected collaborations. This concept is successful for species that have the opportunity to colonise and establish. Most effort is spent on natural capital, circular economy, nature-based solutions and raising awareness and commitment. But most rewarding is the slow change of culture and the transition of a bio(diversity) based infrastructure. Interest in this approach continues to grow and more initiatives and examples are granted in the Netherlands.

Creating landscape connectivity along present transport infrastructure: It takes more than just constructing a wildlife-crossing

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For the preservation of the national biodiversity, mitigating the negative effects of road networks, such as a barrier effect and an increased collision risk, is of high priority. The German program „Bundesprogramm Wiedervernetzung" (BW) aims at reconnecting habitat and wildlife corridors that are currently fragmented by the national highway network. The effectiveness of measures to increase the permeability of highways (e.g. wildlife crossings) depends on the function for target species at two scales. It is evident that the mitigation measure itself has to be suitable and long-lasting. But, the effectiveness can be severely limited by further barriers as well. Consequently, the specific investment at one critical point may be ineffective if corridors are not functional due to unsuitable habitat or other severe barriers in the surroundings. To ensure that conservation investments are made only in promising projects, accurate analyses at the landscape scale covering different land use classes such as forestry or agriculture are necessary. Subsequently, different stakeholders should be informed, and their participation in the future planning process should be ensured at an early stage. We realised such a project in southwestern Germany by evaluating mitigation measures concerning two ecological corridors regarding their future ecological functionality and effectiveness. In a first step, evidence of rare and relevant animal species was collected to get an overview about the biodiversity in the region. Then we chose a set of key species relating to five different habitat types. On the corridors, all habitats, as well as potential barriers like settlements, roads and railway tracks (including all underpasses and bridges), were mapped and evaluated for permeability. We then created a resistance map with this data that was used to develop a management concept with concrete connectivity measures for each corridor and each key species. Landscape analyses yielded a severe fragmentation for both potential corridors due to barriers (roads, railway and settlements) as well as unsuitable habitat. In one of the two corridors, connectivity measures can probably resolve all human-wildlife conflicts. Along the second corridor, however, the barriers for forest mammal species with large spatial requirements as lynx or roe deer cannot be minimised utilising mitigation measures. For these species, the corridor will not be permeable even if all feasible measures are implemented. In this corridor, measures should focus on small species like lizards or bats for which a reconnection may be achieved. All results of this study are communicated to a wide range of stakeholders including the administration of regional planning, municipal administration, and community administrative staff, agriculture and forestry administration and the national railroad company. Our study highlights that focusing on barrier removal at a local scale alone is not sufficient to ensure the long-term functionality of connectivity measures. The landscape scale has to be taken into account as well. Participation of stakeholders and large-scale habitat suitability analyses are necessary to ensure both acceptance as well as the ecological effectiveness of mitigation measures.

Migration study of large mammals at highways in Slovakia

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The Slovak National Motorway Company (Národná diaľničná spoločnosť, a.s. – NDS) has placed an order for a "migration study" since the current status of animal migration on existing operating roads needs to be improved. This can be characterised in two ways. Firstly, a large number of vehicle collisions with animals have been reported in recent years, resulting in accidents with negative impacts. Secondly, the protection of migration passageways for animals in Slovakia is conceptually unfinished. The primary objectives of the study are to identify the current status of large mammals migration and suggest measurements that will improve the connectivity of the landscape and increase safety of transport. The species of animals that we targeted were: bear, wolf, lynx, wildcat, elk, deer, roe deer, wild boar, mouflon and fallow deer. The study was aimed at approximately 700 km of motorways and roads all across Slovakia. The methodology of this study was based on methods and trends in this area of research. In the beginning, it was essential to identify the core regions of occurrence of our targeted species and identify the main migration corridors that connect these areas. Based on literature research, a database of the animal density of state nature conservation, Corine land cover and using GIS analysis of these, have been established in the core areas and main corridors. Next data collection took place in separate sections. Starting with Landep, USES, Corine, the national database of vehicle collisions with animals, thru official numbers and individual questionnaires from the affected hunting areas, and even field survey at three levels or determination of throughput of the road communication at last. For the collecting of the data that we needed, we developed an Android application. That allowed us collecting a standardised dataset with automatic sorting. Using this dataset, we calculated migration potential of structures and objects based on Anděl´s method (2000). By the method of KDE+ critical collisions spots were identified. Complemented by data from field survey we were able to determine the main junctions points of road networks with the significant migration corridors of target species of animals. After identifying the profiles, each local migration profile was evaluated by assessing the local background. Based on this evaluation, landscape structure was GIS analysed using the conducive and limiting elements around the profile. An assessment was made of whether the migration corridor can be implemented across the road, and under what conditions. Each corridor had different variants of placement or design of migration structures. The overall asset of the migration study, in addition to resolving the essential absence of a comprehensive base for the definition of corridors at a national level, was also the proposal of measurements to reduce the overall impact of transport on the superior road infrastructure and mortality of the observed species. Together 108 profiles were identified, of which 30 were marked as critical, with a higher priority for a solution. 40 new migration structures and 22 optimisations of existing objects have been proposed. After finalising the study, the NDS started to implement the proposed measurements.

Inserting ecological connectivity issues and defining ecological corridors in the framework of developing the Strategy for Biodiversity of the Region of Western Macedonia in Greece

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Western Macedonia is the north-western Region in Greece characterized by large mountain areas and rich freshwater natural systems. The combination of these natural factors creates a variety background of forests, rivers, wetlands and agricultural ecosystems with important rich biodiversity which has an increased need of effective management and sustainable environmental policy. The geographical location gives a critical importance as theses ecosystems play an important role for national and Balkan/international scale connecting the natural continuity both in inter-regional/national and trans-border/international level. Following the Greek National Strategy for Biodiversity, the Region of Western Macedonia developed the Regional Strategy for the Biodiversity adopting the Global Nagoya and EU 2020 Biodiversity goals. The Strategy implemented in the framework of 2007-2013 Regional Operation Programme cofounded by Greece and the European Regional Development Fund (ERDF). Towards defining ecological corridors in the framework of developing the Strategy for Biodiversity of the Region of Western Macedonia of a common map implemented including the important biodiversity zones, crucial development areas and infrastructure sectors. Basic green infrastructure areas and natural capital components include: a) 24 Natura 2000 areas with two National Parks, b) 47 Wildlife Refuges, c) 20 Specific Value Landscape Areas, d) The Aliakmon River as the longest river in Greece including large scale artificial lakes and dams and e) A very large number of important wildlife species indicate a high value of biodiversity. Main grey infrastructure categories include: a) Egnatia highway as the main highway in the Region of Western Macedonia as well as in Northern Greece, with the vertical accesses to Albania and FYROM, b) Under design Highways as E65 (Central Greece Highway), c) Existed or under design renewable energy infrastructures as wind farm, hydroelectric dams and photovoltaic stations and d) coal mines as in Western Macedonia is producing about 1/3 of the main electric energy in Greece based on coal. The results of mapping the combination of natural capital and green infrastructure areas with the grey infrastructure developments and focusing on the achievement of the goals of article 10 of Habitat Directive about securing the ecological coherence between the Natura 2000 areas showed the identification of: a) Five (5) main ecological corridors, b) Seven (7) crossing points between Ecological corridors and roads and c) Two (2) high sustainable interest areas with needs of conflict level evaluations in a more strategic and holistic approach and identification of complementary environmental impacts. Inserting ecological connectivity issues incorporating the Biodiversity goals in the Regional Development Policy, our proposals include the adoption of the follow: a) The general principle of the prioritizing of the selections of Avoidance - Mitigation-Compensation in grey infrastructure designing, b) The recognition and management of roadless and low traffic areas, c) The recognition of Ecological Corridors as basic green infrastructure sections and producing special management guidelines and d) The implementation of the ecosystem approach framework in all environmental level of monitoring in all the development sectors.

Designing ecological corridors network for brown bears in Romania

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Europe is characterized by a fragmented natural landscape, interspersed with high human population densities. In Romania, in 2016, highways occupied less than 1,000 km, of which approximately 200 km crossed forested areas. While development of highway infrastructure is vital to country's economic development and prosperity, long-term conservation of the biodiversity can be achieved only by implementing successfully mitigation measures and by harmonizing the sectorial policies for development with conservation strategies. The brown bear requires the use of extensive habitats due to their large home ranges. Based on available data (at national level) and the ecological needs of the species, we generated maps of potential habitats and resistance maps to movements for determining the location of potential corridors. We used 6 environmental variables for identifying the potentially suitable areas and 6 variables for quantifying the brown bear preferences/barriers for/to movement. The model identified around 42,000 km^2 of suitable habitats for the brown bear in the Romanian Carpathians. Potential ranges were also compared with the existing network of protected areas; however, only 41% of the protected areas were found suitable for bears. We identified approximately 7,000 km^2 of suitable ecological corridors outside the suitable habitats, however 61% of the network is located outside the protected areas. Moreover, brown bear conservation will depend on managing ecological corridors, based on supportive science outputs, deeper collaboration and strong policy on connectivity together with plans and strategies that champion large landscape conservation via state, regional and local initiatives.

Integration of an ecosystem service approach in national highway-planning and development in Pakistan: Opportunities and challenges

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Pakistan is the sixth largest country of the world with a population of 200 million people and a surface area of 796,095 km^2. Its road network is about 250,000 km in length and includes motorways, highways, and rural roads. Pakistan has diverse landforms including deserts, mountains, plains, and plateaus traversed by different types of roads. Recently, Pakistan has embarked upon an ambitious, large-scale plan of road construction and improvement. In this regard, two significant plans, Pakistan Vision 2025 and China Pakistan Economic Corridor (CPEC), will contribute substantially to the development and modernisation of Pakistan's road network. For example, Pakistan vision 2025 aims at doubling the road density in Pakistan from 32/100 km to 64/100 km by 2025. Natural ecosystems and roadside vegetation have potential benefits for developing and maintaining sustainable road networks. By the incorporation of ecosystem services for the planning, designing, and building of roads we can achieve the aim of sustainable road infrastructure. Its benefits include cost-effective construction and maintenance of roads, protection from natural hazards, and protecting neighbouring areas from negative impacts of road and transport. These are our objectives: (1) Identification of ecosystem services provided by roadside vegetation; (2) Impacts of ecosystem services on the sustainability of road projects; (3) Evaluation of the current road development and management system in Pakistan regarding ecological and environmental issues; (4) Analysis of opportunities and challenges for integration of an ecosystem service approach in the road transport sector in Pakistan. The information and data from different sources (published, internet, personal communication with concerned departments, and organisations) were collated and analysed. Nowadays, in general, in Pakistan, environmental considerations are given minimum importance in schemes for planning and building roads. This ignorance of ecological concerns results in unsustainable land use changes, unsafe roads, the degradation of surrounding ecosystems, and the loss to neighbouring communities. The primary ecosystem services provided by roadside vegetation to roads and environment were identified as conservation of natural vegetation and other biotas, air pollution mitigation, protection from erosion and floods, carbon sequestration, and protection of natural resources and landscape characteristics. Pakistan is predominantly an arid country with scanty vegetation in more than half of the country. In its irrigated plains, chemical infested agricultural practices have severely damaged its natural flora, and many plant species have become rare or extinct. Pakistan has four world phytogeographic regions: Saharo-Sindian, Indian, Irano-Turanian, and Sino-Japanese. There are chances for building roads that can contribute to sustainable transport infrastructure, conserve natural capital, and improve the safety and livelihood of neighbouring communities. This can be achieved by adopting an ecosystem service approach to planning, building, and maintaining road schemes.

Green infrastructure, ecosystem services and road network in Spain

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According to EU Strategy, the green infrastructure (GI) is "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (ES)". Thus, GI is rooted in policies aimed at conserving biodiversity through the promotion of connectivity between populations. However, it is much more than a conservation instrument as it seeks to promote those ecosystem functions that are ultimately responsible for the services they provide us with. Roads and other linear infrastructures are one of the most prominent elements of the landscape and therefore will have a remarkable interaction with green infrastructure. Firstly, roads can disrupt flows and movements through landscape connecting elements between the core areas of the GI, preventing it from being ecologically coherent if appropriate structural measures against fragmentation are not taken. Secondly, roads induce changes in the supply of ES in the surrounding area at a local level and the spatial structures of the road network condition the land uses that ultimately define the supply of ES. In this research, I examine the relationship between the elements of GI, ES and road networks on the mainland of Spain. GI elements are those that will be included in the future Spanish Strategy (to be published in 2018): protected areas, critical areas for birds and mammals, river and coastal public domains, agricultural areas of high natural value, etc. ES were obtained from the Spanish National Ecosystem Assessment. GI elements have on average lower road densities. However, some essential landscape connectors show high road densities, especially river valleys and their riparian forest associated. The areas with a predominance of provision services show higher densities than those related to the supply of regulation and cultural services.

Identification and development of habitat defragmentation priority projects, within the Green Infrastructure Programme of Catalonia

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Within the framework of the European Union Biodiversity Strategy to 2020 and the Green Infrastructure Communication Enhancing Europe's Natural Capital, the Directorate General of Environmental Policies and Nature has promoted the Green Infrastructure Programme of Catalonia. This is a key-planning instrument of priority actions that aims to strengthen and improve the region's green infrastructure. The programme has two strategic objectives: to enhance biodiversity and ecosystems functions, and to improve the sustainability of human activities concerning green infrastructure. Among the operational objectives related to biodiversity and ecosystems functions, there is one related to restoration of ecological connectors' functions. This communication is focused on the methodology and results regarding the achievement of this specific objective. In other words, it is focused on the identification of critical areas and the definition of specific actions for habitat defragmentation, permeabilisation of terrestrial transport infrastructures, and restoration of ecological connectors' functions in Catalonia. The methodology for the identification of these critical areas is as follows: firstly, we developed a GIS analysis to identify critical areas for ecological connectivity, using available information about ecological connectors, road kills, and potential areas for defragmentation. For that purpose, we updated the database about critical areas for ecological connectivity (Basis of ecological connectivity information, Government of Catalonia, 2012). We have done this in following way: (1) adding new critical areas as a result of overlapping road kills spots (Government of Catalonia, 2012 and 2014) or potential areas for defragmentation (Ministry of Agriculture and Fisheries, Food and Environment, 2013) with principal and secondary ecological connectors (Basis of ecological connectivity information, Government of Catalonia, 2012). (2) Eliminating critical areas where connectivity infrastructures were already constructed (Inventory of connectivity structures in Catalonia's road network, 2014). (3) Grouping critical areas when cases were concentrated. Secondly, we constructed additional critical areas as a result of the expert consultation. Finally, we carried out fieldwork for a more precise diagnostic and a better formulation of the required actions and their viability. We identified 46 critical areas for the restoration of ecological connectors' functions: 40 as a result of the GIS analysis, and six from the expert consultation. Proposals were prioritised considering data such as the relevance of the ecological connector, the severity of the road kills spots, the protection level of the area, and the presence of protected habitats and endangered species. Annually, we will select critical areas from this list for their restoration, according to the available budget. Among priority, other criteria such as land property, responsibility, cost, and action opportunity are taken into account when selecting proposals for their implementation. Thus, seven critical areas have already been selected to begin with their implementation process, and one has already been restored. The definition of concrete restoration actions for each area and its prioritisation was essential for proceeding with its execution in the frame of the Green Infrastructure Programme of Catalonia.

Evidence-based development of a commercial arboreal wildlife bridge to prevent habitat fragmentation and isolation

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The ever-increasing global transport network has the potential to fragment and isolate habitats utilised by arboreal species, including the European Hazel Dormouse *Muscardinus avellanarius.* Evidence-based, effective mitigation is essential to maintain ecological connectivity in human-influenced habitat fragmentation situations. Although a number of 'wildlife bridges' have been installed to allow habitat connectivity for arboreal species, many approved designs have been demonstrated to be both expensive and ineffective, highlighting the requirement for further research to determine affordable and reliable alternatives. This presentation details the development of a new, affordable modular wildlife bridge with proven effectiveness in enabling arboreal species to travel through fragmented habitats in both the United Kingdom and Japan. Historic research conducted in Japan has influenced a UK study by the People's Trust for Endangered Species (PTES) and Animex International that has further confirmed the effectiveness of this unique design of arboreal crossing structure. The study in Japan determined the most suitable materials, structure and design of an arboreal bridge to facilitate habitat connectivity across a roadway for Japanese Dormice *Glirulus japonicas.* This design specification was also proven to effectively reconnect fragmented habitat for a range of other arboreal species including Japanese Dwarf Flying Squirrel *Pteromys momonga,* Japanese Squirrel Sciurus lis, Small Japanese Field Mouse *Apodemus argenteus* and Japanese Martin *Martes melampus.* This success influenced PTES and Animex to conduct a similar study in the UK to assess whether this proven design could be effectively transferred into a European context for the Hazel Dormouse. A bridge adapted from the original Japanese design was installed on the Isle of Wight, connecting two known areas of Dormouse habitat that have been dissected by a railway since the 1860's. Exclusion fencing, with periodic entry points, was installed along both sides of the railway, with motion-activated cameras positioned along the bridge and at each entry point along the fencing. The aim was to determine whether the species would utilise the bridge and, if so, whether a preference was demonstrated for crossing the bridge as opposed to crossing at ground level. The results of the UK study confirmed the use of the arboreal bridge by Hazel Dormouse and Red Squirrel, with Dormice demonstrating a strong preference for crossing the habitat gap via the bridge. Following the proven effectiveness of the design Animex, in partnership with Highways England and in collaboration with municipal councils, Natural England and ecological consultants, has developed a cost-effective, durable structure compliant with Highways England that can be easily installed on a wide range of construction mitigation projects. The installation of the bridge must consider the most appropriate location and be accompanied by a dedicated landscape scheme to ensure its success. Ongoing research is being undertaken to establish how this design can be utilised and adapted to reconnect habitat networks for other species around the globe.

Next generation of arched wildlife overpass – Yoho National Park, Canada

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Twenty years after the first wildlife overpass on the Trans-Canada Highway in Banff National Park, Canada was constructed as part of highway twinning (four laning), a seventh highway wildlife overpass within Canada's national parks has been constructed. This marks the start of the next generation of highway mitigations as work commences on advancing highway twinning through adjacent Yoho National Park. Building upon the success of environmental mitigations such as right-of-way fencing, and 38 wildlife underpasses and 6 overpasses of varying geometries employed along the 82 kilometers of highway in Banff National Park, this next phase of highway expansion adds to and builds upon this experience. Though adjacent to Banff National Park, Yoho National Park has slightly different ecosystems and geographical differences that must be reflected in constructing wildlife crossings. This presentation starts by highlighting the effect the highway currently has on Yoho National Park's ecology and how the desire to improve highway capacity creates the opportunity and motivation to construct greener transportation infrastructure addressing both wildlife-vehicle collision caused mortality as well as habitat and genetic connectivity. Tight highway geometry in this next phase of twinning requires that wildlife crossings span up to six lanes of highway without a structural mid-support. The result and highlighted in the presentation is the site selection and subsequent design and construction in 2017 of what may be the largest 33 meter, single span, precast concrete arch wildlife overpass in the world. Its design and construction methodology may have wider spread application. The presentation delves into several of these innovative design and construction techniques and challenges associated with the flat elliptical shape of the arch and its span along with the use of a slightly modified design-build tender procurement model. Choice of low maintenance landscaping on the structure appropriate for its location and target use species as well as the use of communication media to explain the construction process to the public and methods employed to reduce motorist delays are highlighted. In addition to this arch structure, four wildlife highway underpass crossings along with a number of other highway environmental mitigation measures that were employed in just eight-kilometers will be presented in this continuation of the largest highway mitigation complex in the world. Finally, the presentation takes the opportunity to take a look ahead to other planned environmental mitigations as Parks Canada embarks on widening a further 40 kilometers of highway through Yoho National Park, Canada as public support continues for constructing extensive and expensive environmental mitigations in association with highway improvements in Canada's national parks.

Adaptation of drainage culvert for a jaguar underpass in a highway, in Guanacaste, Costa Rica

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In the last 10 years, Costa Rica has been improving its road networks to improve the connection within the country, and make it easier for people as well as products to quickly move around the country. For example, the expansion of the Northern Interamerican Highway in the Cañas-Liberia sector from two to four lanes. This route included eight wildlife underpasses and ten arboreal crossings. The wildlife crossings were planned and designed without rigorous scientific research, except interviewing locals and researching points associated with rivers. One month after the highway was in operation a jaguar's (*Panthera onca*) female juvenile (10 months old) was killed by a vehicle in a vital connectivity area connecting several protected areas in the region (Rincon de la Vieja National Park, Miravalles Protected Area, Palo Verde National Park, and Biological Reserve Lomas Barbudal). At the road kill location, a wildlife underpass (1.5 m x 1.5 m) was not included in the mitigation plan. Instead, it coincides with the presence of a drainage culvert (3 m x 3 m). Two months after the incident, we placed camera traps for monitoring wildlife at the site and the presence of other felids in the area. We installed nine camera traps, four on each side of the road at 20-100 m apart, and one at the exit of the drainage culvert. Cameras in the area detected an adult jaguar. Three of the camera stations on the northern side of the road recorded the animal. There was no record of the animal on the south side. Jaguars can be identified by their spots; they are unique in each individual. We used an attractant inside the drainage culvert to guide jaguars to the crossing and prevent additional mortality on the highway. Three months later, a camera on the south side detected a jaguar, and footprints were recorded inside the culvert. Additionally, there were records of puma (*Puma concolor*) and prey species such as deer (Odocoileus virginianus), peccary (*Pecari tajacu*), and paca (*Paca cuniculus*) in the area. This is only the second record of a jaguar using the below-grade passage structure in Latin America. The first was in Mexico by Sega, in 2015, on a route with 28 wildlife underpasses for jaguars. Currently, the Ministry of Transportation is planning to install a fence along the highway to prevent further road kills. This fence will also make sure that the animals use the drainage culvert as an underpass. This research can be used as a reference to promote wildlife underpasses in other sites of jaguar presence in road networks, to avoid the impact on their populations, since it has been recorded as a road-avoiding species. Similarly, it is essential to highlight the efforts of researchers and the government in the adaptation of road infrastructure for wildlife passages.

Can ecoducts contribute to the coherence of large forest habitat?

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Highways in the Netherlands intersect Natura 2000-sites that often contain vast forest and heath habitat. Over the last decades, ecoducts have been realised to reconnect these habitats. An example is the Veluwe, where four highways and several provincial roads intersect an area of 91,000 ahectares of forest and heathland. The infrastructure is the primary cause for fragmentation of Veluwe habitat, causing road kills, decreased connectivity, and limiting nature management. Fencing reduced the number of road kills of large mammals. However, fencing contributes to reduced habitat connectivity. Nine ecoducts have been built at Veluwe to counter fragmentation effects. The improved connectivity aims to contribute to a more sustainable habitat. Three ecoducts have been constructed before 2000. Six ecoducts have been built recently. For those six ecoducts, the fauna is surveyed in the first year after construction using simultaneous methods such as camera traps, sand, and ink pads to register tracks and cover boards. The surveys were carried out at the ecoduct as well as in the adjacent habitat. The number of species observed at the ecoducts within the first year after construction was beyond expectation. Multiple species groups use all of the six ecoducts. Most of the species are known to occur in the surrounding heath and forest habitat. The observation of various species in the first year after construction shows that when animals are present in surrounding habitat, they quickly colonise ecoduct habitat. Among the 'fast colonisers' are reptile species such as sand lizards and slowworms. Ponds constructed at the side of the ecoducts were expected to attract mammal species as well as amphibians. We observed that mammal species such as wild boar, roe deer, red deer, and foxes use the ecoducts frequently, even before dense vegetation has been developed. As expected, natterjacks quickly discovered the ponds. The results are in line with the findings for the three older ecoducts. These results show that the ecoducts facilitate the movements of fauna over highways for a wide range of species. Thus, all nine ecoducts at the Veluwe are contributing to the connectivity of forest and heath habitat. Habitat connectivity can be quantified using indices of Network Theory. We propose the use of Network Theory to calculate the effect of the number and location of ecoducts in habitat networks.

Sleeper Fauna Passage

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Sleepers form a barrier for small crawling animals. A lot of amphibians (frogs, toads, and salamanders) can't jump high enough to jump over the rail. Most likely, they will crawl alongside the rail looking for a place to crawl underneath the track. While searching for a place to cross, they are near the rail for a relatively long time. For these animals, there is a severe risk they will be sucked along by the wake caused by passing trains, which in most cases they will not survive. To lift the railway barrier, small fauna tubes underneath the railway are constructed. Amphibians have high demands on dimensions of the fauna tubes, which are defined by the length of the tube; the longer the tube, the bigger the profile of the tube. Besides demands of amphibians, there are technical demands the design has to meet. Two critical technical demands are the distance between the top of the rail and the top of the fauna tube (1.80 m beneath top rail), and the distance from the maximum water level (0.10 m between the maximum water level and the bottom of the tube). The area that desires amphibian tubes underneath the rail has a high water level in the surrounding area. This usually creates a situation where there is not enough space between the rail (1.80 m beneath top rail) and the water level (0.10 m above maximum water level) to engineer an amphibian tube. Movares has engineered a new way to lift the railway barrier in these regions facing high water levels. This new fauna passage is compliant with railway maintenance and can withstand some influences surrounding the railway (such as passing trains, vibrations, and weather influences). The new amphibian passage, the Sleeper Fauna Passage (SFP), is positioned between the sleepers in and under the ballast bed. Two steel sleepers with an H profile replace two standard sleepers. An example of these steel sleepers can already be found in switches. In between these H profiles, it is possible to slide in a fauna passage, made of light plastic, as if it were a drawer. When maintenance on de the railway occurs, the fauna passage can be removed from the H profile sleepers and slid back afterward. The fauna passage is more than 0,5m in width and the top consists of plastic grates. These grates allow daylight to come into the fauna passage and to prevent suction by passing trains. To lead amphibians to the SFP, good landscaping of the surrounding area is necessary. This includes conduction to the SFP by an amphibian screen. In 2018, a pilot will be launched to test the SFP in the nature reserve Naardermeer.

Comparing the use of railway underpasses by wildlife before and after widening the passages

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Wildlife passages across railways and roads are essential to ensure connectivity of habitats and to reduce animal-vehicle collision. Size and dimension of these passages are still object of discussion. In our study, two railway underpasses have been widened from 5 m up to 12 m and 15 m respectively. We monitored people and wildlife with camera traps in the underpasses during one year before and four years after widening. Before widening, both underpasses were freely accessible to animals and people. After widening, both underpasses were still freely accessible for wildlife but in one of the underpasses the gravel road was removed and the environment naturally restored. This passage officially closed for people. The widening and the access limitation for humans in one of the underpasses have had significant positive effects on the wildlife use of the underpasses.

Upgrading existing drainage culverts to eco-tunnels and bat hibernacula, a multifunctional and cost-effective method?

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The framework of article 6 of the Habitats Directive for projects impacting habitats requires mitigation and compensation. For bat roosts and hibernacula this is easier said than done. Therefore, it is crucial to gain technical knowledge on the creation of successful purpose-built structures. In the Brussels Capital Region (Belgium) five purpose-built bat hibernacula were built in the last decade. Four of those bat hibernacula were constructed under the railroad embankment through the Sonian forest south of Brussels. One structure was purpose-built as bat hibernaculum and proves unsuccessful, while three existing drainage tunnels were successfully upgraded to a bat hibernaculum and small eco-tunnel. The design of the structures and the materials used are briefly discussed. The purpose-built bat hibernacula were intensively monitored to assess their use by bats. Hibernating bats were censored every winter. Three hibernacula succeeded in attracting hibernating bats of two species (*Myotis mystacinus* and *Plecotus auritus*). Some bats already hibernated in the structures before the construction was finished. A preliminary survey with temperature data loggers in 2015 in two hibernacula characterizes the thermal gradients of the structures. Results indicate that the design is successful in creating a gradual variation in mean and minimum temperature in the different segments of the labyrinth. In February 2016, all hibernacula were equipped with data loggers to measure detailed, long-term trends. This is combined with frequent winter censuses that involve precisely positioning the individual hibernating bats. Unattended acoustic recording data from September 2016 suggest that at least two hibernacula attracted swarming bats in autumn. A capture session and an acoustic survey were carried out in autumn 2017 to investigate this further. The structures that double as a small eco-tunnel were intensively monitored with wildlife cameras. The results show that small animals up to the size of a fox frequently use them. They also show quite some disturbance by the public. An overview of identified species is given. Ecologically upgrading existing and relatively unsuccessful underground drainage structures in a vast forest area proved a successful strategy, both as an eco-tunnel and bat hibernaculum. This choice is relatively cost-effective as drainage tunnels in the valleys are a technical necessity. Offering humid (but not completely saturated) conditions and a gradient of thermal conditions in the bat hibernaculum is a real design challenge. Further research on the thermal regime is in progress and will hopefully give more insight why some structures are colonized, and others are not.

The ecology of radical transport infrastructure innovation

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In the last two decades, Dutch spatial planning has developed from the formulation and implementation of comprehensive and strong spatial visions (Randstad, Green Heart) towards network governance in which multiple actors, and especially market parties, play an essential role. There are growing concerns about the implications of this approach for the quality of life of Dutch citizens. Will Dutch cities remain appealing in the long term or will private investors turn to other areas? Especially car transport has a significant impact on the quality of life. Negative effects from today's car transport systems and mobility patterns are vast and affect various societal domains. Mobility is a permanent primary human need. What if we would start looking for alternative transport infrastructures? The objective of this presentation is to demonstrate how transport infrastructure innovation can contribute to defragmentation of green space in urban regions and enhance the quality of life. The presentation is based on a literature study of completed alternatives all over the world and a documented analysis of recent mobility visions in European cities. Various mobility alternatives that have been reported suggest numerous improvements of the quality of life. These improvements are, among other, the enhanced living environment and the enjoyment of transport. Often mentioned are maintaining and improving levels of comfort and accessibility in physical and socioeconomic terms. Transport above the ground (e.g., cable cars) seems to be especially promising, leaving terrains open and available for other land uses. More silent transport solutions enhance the level of appeal of outdoor areas and improve the quality of the living environment of residential areas. Faster connections can link the shrinking and growing regions and enable living in peri-urban environments in combination with working in the city. Rapid connections can also contribute to a better economic balance between regions by connecting urban and rural life, and consumers and producers. Transport of fresh food can be improved by optimising the transport into the city. Alternative transport infrastructure may enable vertical parking instead of horizontal parking. By developing alternative modes of transport (suspended) above the ground, underground or over water, and thereby replacing parts of the sealed road infrastructure in strategic locations, the defragmentation of green space and the development of more encompassing green structure in densely populated urban areas becomes possible. This can help to reduce the risk of flooding, and urban heat stress. However, it can also enhance water retention, drinking water provision, and purification capacity, add recreational grounds, create urban farming opportunities, and private gardens. Green space can become less expensive which may reduce socio-ecological inequality and offers children more opportunities to play outside and develop their mental, social, and physical skills. We will conclude the presentation by demonstrating insights from transition theory concerning path dependency, regime practices, and upscaling of more radical innovations, such as the sky-tran, taxi-drone, hyperloop or hoverbike that are currently being developed by companies. Are public authorities, private companies, and investors willing to take charge of the development of a better quality of life in Dutch urban areas – especially regarding green space – while preserving high levels of mobility?

Adapting the infrastructure to the surrounding landscape

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During the late 1980s and the 1990s, systems for environmental impact assessments (EIA) were developed and introduced into road planning in Sweden. However, the EIA system worked on the individual road project and did not allow to set national goals. Nor did it allow to monitor the outcome on a national level. In 1998, the Swedish Government commissioned the Swedish Road Administration to develop a system for targets and indicators for ecological and cultural heritage values that should be a part of the at that time recently developed system of goals for the transport system. These goals were intended to be the basis for governing the development of the transport system including the infrastructure planning. We were involved in this work, that aimed at identifying the qualities of a road that could be considered as adapted to the surrounding landscape. The idea was to report, on a national level, the proportion of new roads or the proportion of all roads that meet these standards. The development work was later stopped due to declining interest in goal directed management among the authorities, emanating from a high political level. However, the understanding of the central qualities and impacts of transport infrastructures from an ecological point of view continued to increase due to both national and international research programs. Lately, the political interest for the conflict between ecology and transport infrastructures has made a come-back. This is partly due to an insight in the need for a functional green infrastructure. The new interest can be illustrated by the directives for strategic infrastructure planning where the government highlighted the ecological and the landscape issues in a way not seen before. The Swedish Transport Administration has responded to this by basically completing the work started in 1998. A set of standards has been decided for infrastructure that is considered to be adapted to the surrounding landscape. For the issue of ecological adaptation, these standards set tangible target levels for: (1) safe passages for animals; (2) traffic noise pollution in ecologically important habitats; (3) loss of crucial habitats; (4) management and creation of species-rich infrastructure habitats; (5) control of invasive species. While the EIA process is still important to highlight environmental impacts from individual projects, one of its major drawbacks has always been that it lacks well founded reference levels to which the described impacts can be compared, and thereby fail to be relevant on a strategic planning level. The standards provide such a reference, and they are therefore an important complement to EIA. The standards also trigged off opportunities to develop methods for analysing the impact of the existing infrastructure on key ecological functions, which can be transformed into the need for adaption measures. We believe that the use of standards for landscape adaptation is crucial in order to include road and rail ecology issues in strategic planning. However, we acknowledge obvious pitfalls, for example that for the sake of simplicity or lack of knowledge, the standards will not be able to address all relevant aspects and will not include a full understanding of the landscape affected by a project.

Can we plan and build a 'nature-neutral' road?

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National road authorities (NRA) face challenges in developing transport systems that minimise negative environmental effects, and that comply with national and international legislations. Sustainability is the overarching goal included in several internal strategies, national and international regulations and issues, such as the EU Water Framework Directive, the EU Biodiversity Strategy, the Convention on Biological Diversity and the Aichi targets. The Norwegian Ministry of Transport and Communication has given the Norwegian Public Road Administration (NPRA) an initiative to elucidate if it is possible to plan, build, operate and maintain roads that are 'nature-neutral'. However, what does 'nature-neutral' mean? It is a new concept. The following crucial questions arise: which topics should be included in the term? How can we measure if the net effect on nature is neutral? How will a strong focus on specific nature issues (e.g., biodiversity, pollution) affect focus on other environmental issues not included in the term? This paper will present the NPRA's approach to answering the initiative of the concept of a 'nature-neutral' road. The principals of the mitigation hierarchy to avoid, minimise, restore or compensate must be an essential basis for the concept. Fundamental issues that will be discussed are the definition of the term, the use of existing tools in the NPRA to consider environmental issues and how these tools can be improved in the different 'life stages' of roads, need for new tools and scaling issues (i.e., measures in early planning stages are very different from measures in the construction phase). A 'nature-neutral' road could be a road that prioritises nature over other interest conflicts so that the value of nature does not deteriorate even if the road is built. A significant challenge is how to put a value on different ecosystem constituents and then compare them. The project has resulted in a set of criteria and suggestions for the way forward to achieve a 'nature-neutral' road. For example, some of the findings include the need for a more detailed assessment tool in early concept studies, the need to combine impact assessment for terrestrial and aquatic issues in a more comprehensive way, an extended toolbox for appropriate measures and identification of challenges with a future change in the transportation system. There is a need for more knowledge to support NRA's decision-making to implement necessary measures within the frame of the mitigation hierarchy to reach a sustainable future. The building, operation, and maintenance of roads have a high potential to cause harmful environmental effects. The concept of 'nature-neutral' roads is an opportunity to increase the focus on environmental concerns. It may also boost further development of mitigation measures, as well as the possibility to include infrastructure that even may increase biodiversity. Fundamental success factors are also undoubtedly political willingness to prioritise the care for nature.

Ecological infrastructure joins recreational bicycle bridge

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September 7, 2018, the project Fietsbrug en Natuurverbinding Nigtevecht (Bicycle Bridge and Nature Connection Nigtevecht) will officially be put into use. This project produces double defragmentation for both ecosystems and recreation. Since 1998, the provinces of Utrecht and Noord-Holland, and the municipalities Stichtse Vecht and De Ronde Venen have spoken about a bicycle bridge across the Amsterdam-Rhine Canal. Recreational routes for walkers and cyclists are already created on both sides of the canal. Linking these routes would increase their use value significantly. The landscape of the New Dutch Waterline and the Defence Line of Amsterdam with its high military, cultural-historical, scenic, and natural values become more accessible because of the bicycle bridge. Because this defragmentation makes the Amsterdam Metropolitan Area more appealing to people and businesses, the municipality of Amsterdam supports the project financially. As a consequence of major resistance to initial proposals from the local environment, the location of the bicycle bridge could not be determined until 2013, after an intense citizens participation process. Rijkswaterstaat (Agency of the Dutch Ministry of Infrastructure and Water Management) appeared to have plans to restore an ecological connection at that same location. The Amsterdam-Rhine Canal is one of the busiest canals in the world; it is more than a hundred metres wide. With its steel sheet piles and a nearby busy road, it forms an unpassable barrier for different animal species such as Roe deer, Otters, small marten species, and Grass snakes. As such, it cuts off the Natura 2000 areas of Vechtplassen and Naardermeer from the rest of the remaining wetlands in Central Holland and Utrecht. The 'bicycle bridge parties' and Rijkswaterstaat have investigated whether and how both projects could be combined. This has led to a single tender, for a natural connection, bicycle bridge.
The project was awarded in 2015. The work has been put out to tender, awarded and executed for Best Value. Contractor Ballast Nedam, his architect, ecologist and landscape expert have made an integrated design based on wishes, and advice from those involved in the environment of the work.
In his presentation, the speaker wants to take the participants of IENE 2018 along in the sometimes-difficult, organic, and creative process that comes with creating a design for greener infrastructure and how to realise this with the acceptance of locals as well.

Avenues connecting across borders

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This project aims to draw the attention of politicians and the public to the necessity of replanting and new plantings of avenues to save green infrastructure. We have to find as many as possible supporters in local politics, administration, and the public for the preservation of the avenues along the German Avenue Road. The trend of plant decline should be stopped. Nationwide, attention should be drawn to the unique value of the avenues both as natural and cultural heritage and as a tourist highlight. With this presentation, the BUND demonstrates three examples of how we build bridges between authorities, politicians, residents, and avenue activists to find ways to preserve this endangered landscape element, that is, to protect old trees along roads and to plant new ones. (1) Avenues, not borders - Aleje zamiast granic: The cross-border avenue with 50 lime trees connecting two countries, Germany and Poland, was planted in 2014 by BUND and GAJA. The mayor, politicians, and authorities were involved, both on the German and the Polish side. The project cultivates our shared heritage and is an expression of active German-Polish cooperation – avenues such as a bridge between two nations. Politicians and authorities agreed that tree-lined roads in European countries represent shared European cultural and natural heritage. (2) Avenue preservation programme of the German Avenue Road in Mecklenburg-Vorpommern: Ministries, environmental and road authorities, politicians, associations, landscape planners, arborists, activists, and farmers are involved in the development and implementation of an 'Avenue development concept for the German Avenue Road'. With this programme, we will demonstrate how to secure and develop avenues under the requirements of modern mobility. This programme is in process. The plan, so far, is to start planting trees along tree free sections in 2019. (3) Public relations are crucial for building bridges for successful avenue protection: On June 1, 2018, the BUND starts with cyclists a long-distance cycle tour. We will cycle 1,900 km along the German Avenue Road from the island of Rügen to Lake Constance in two weeks. We will meet politicians and government officials and work closely with the media. We will carry the idea of the Avenue Preservation Programme in those ten federal states, through which this tour leads and beyond. We will raise the general public awareness of the disappearance of the avenues and inspire them for new plantings.

Status of road ecology research in Africa: What more do we need to know?

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Roads are a critical element of human economic development and society, and global rates of road construction will likely rise for the foreseeable future. Roads and road users have numerous, diverse, and mostly negative consequences for biodiversity by, among other things, destroying and degrading habitats, fragmenting wildlife populations and their dynamics, direct impacts through collisions, and secondary impacts through increased access to previously unattainable natural resources. The science of road ecology (our understanding of such impacts and how these can be minimised) is fairly well developed in North America, Europe and Australia, but is only in its infancy in regions such as Africa, which is likely to experience rapid infrastructure development in the upcoming decades. In this study, we provide a review of the state of road ecology in Africa, to investigate the scale, scope and geographic extent of current knowledge, and identify gaps and priorities for future research. We used Web of Science to undertake a systematic literature search, generating a database of 210 peer-reviewed papers related to aspects of road ecology across 38 African countries between 1954 and 2016. Most studies were undertaken in the past decade (n = 169), and ~65% originated from just seven countries, with South Africa producing the highest output (n = 66). We categorised studies by geographic location, focal biodiversity components, study purpose, and whether they examined specific interventions aimed at mitigating impacts. We discuss our findings in light of future recommendations for road ecology research.

A vision of sustainable infrastructure by 2050: A project in secondary school with students in the age of fifteen and sixteen in Sweden

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Sustainable development is an area that extends across many topics and central content in the school curriculum. It is important that today's schoolchildren have a broad foundation and knowledge of sustainable development as it is them who are our future. The students are consumers of the infrastructure and will continue to be for a long time. They will need to be prepared to change their way of using (and their way of thinking about it) compared with their parents, to ask for and to create a more sustainable infrastructure. The aim with the project is to use infrastructure as an instrument to provide students with knowledge and understanding of sustainable development, to give the students the opportunity to concretize sustainable development and additionally to create their own vision of how infrastructure can develop in the future. The students work on the project thematically, mainly in the subjects of technology, focusing on planning and building roads and road networks, as well as biology with a focus on ecology and the impact on biodiversity. The project follows the core content of the curriculum in botch subjects and the knowledge requirements. It will be carried out in collaboration with the traffic agency in spring 2018. Students receive lectures by teachers as well as visits by people working on the road network in Sweden, to get a foundation of what the infrastructure looks like today and how planning and road construction works, both theoretically and practically. They also visit the railway- and traffic authorities and conduct discussions themselves about today's infrastructure, what it looks like, what they use it for daily, and what impact it has on the environment. The students get the opportunity to become aware of how to create sustainability in the future while meeting needs (individuals, society, interests, companies etc.) within the environmental absolute conditions and thereby get introductions for their final assignments, how to cooperate with nature while building roads and railways to create a vision of how the infrastructure can look like in 2050, Including for example, how to manage a road area to get artificial, how different passages for animals can be constructed and where to place them and what kind of vegetation may grow on railways. The results of the students' visions are reported at the end of the spring term when they pass grade 9 and the results will be compiled by teachers.

PART 4
ABSTRACTS
POSTER PRESENTATIONS

No net loss of biodiversity: tools for stakeholders?

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Following international agreements on the need to halt biodiversity loss, many countries have implemented an environmental policy to reduce the impact of land development in accordance with the objective of achieving a "No Net Loss (NNL)" of biodiversity. This implies that land developers assess the future impacts of their development projects on biodiversity and apply the mitigation hierarchy which requires that they avoid, reduce and/or offset residual impacts. In France, the 2016 Biodiversity law has reinforced this tool, but, as elsewhere, several problems jeopardise its correct application. One of the main reasons highlighted by researchers and stakeholders alike is the lack of standard methods that are shared and accepted by the different actors to assess ecological equivalence to reach the goal of NNL. There has been growing interest and awareness for the need to develop standardised methods to assess ecological equivalence and compensation measures in diverse research groups and biodiversity governmental agencies and consultants. In a review of the conservation biology literature, we have analysed how the scientific issues address the NNL concept at stake. This reveals that no scientific publications fully address the practical challenge of proposing a method to stakeholders. In this paper, we thus focus on how to combine scientific and practical issues in the development of such methods. Also, we recommend the use of ergonomics (the study of the interaction between humans and other elements of the system) as a framework to explore the hypothesis that a simple reliance on identifying priorities obstructs the development of a functional method to assess compensation options. The use of ergonomics is particularly interesting with two notions to describe a tool that people can use in working situations: usability and social acceptability. The basis of this approach involves a user-centred design in which actors actively participate in each step of the process. In particular, our work aims to define the particularity of usability and social acceptability in the case of ecological equivalence assessment method. In addition to the classical criteria of usability (learnability, efficiency, memorability, errors, satisfaction), we assume that data availability and compliance to the law, institutional certification, scientific bases, social acceptance of the result of the method or mental representation of biodiversity mitigation are essential. We use an experimental device built on a stakeholders network composed of developers, consultants and regulators. We first interview stakeholders to identify both (i) how they perform their part of the job linked to assessment or the definition of the offsets measures and (ii) which tools they use and how they assess these tools. They will test an experimental assessment method of ecological equivalence created by our team in an ergonomic protocol in which the stakeholders use the method in a real-life situation. Our overall goal is twofold: (1) to propose a new mitigation assessment method conjointly elaborated with stakeholders and (2) to identify how to achieve active use of a biodiversity assessment method built on scientific knowledge.

Reduce impacts of the linear infrastructures of terrestrial transport on the amphibian populations (AMPHILTe)

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Linear land transport infrastructure and their influence (ILTe) can impact amphibians in two major and different ways in human-dominated landscapes. The road network is getting denser and acts as a barrier for the amphibians, isolating more and more populations as well as it increases the risk of road mortality with vehicles. We evaluated 25-50 millions of roadkill amphibians per year and breeding period. Undisturbed habitats are getting smaller in size and become less and less accessible. Remnant fragments of suitable habitats may eventually become too isolated to preserve local populations. During the last three decades, many complementary tools of mitigation measures, from temporary drift fences and rescue operations by volunteers to build underpasses, have been created. Which advantages and disadvantages (ecological, cost, relevance, effectiveness) are there between the different mitigation measures? How to estimate the new ecological trajectories of amphibian populations in their environment further to the creation of such infrastructures to preserve viable populations? How does creation of replacement ponds affect the use of these infrastructures? What are the possibilities for innovation and the opportunities offered by the used synthetic materials: are they recyclable or not? What is the social acceptance of these devices, which are sometimes considerably costly? Within the research program 2017 ITTECOP (Land Transport Infrastructures, Ecosystems and Landscapes), Cerema was selected to construct a European project 'AMPHILTe' over several years with different partners. This applied project takes into account the experiences and skills from different and diverse backgrounds, gathers a group of various stakeholders (public and private; NGOs – naturalists and citizens -, research scientists, managers of protected area, infrastructure managers and road/transport planning experts). To achieve these objectives, we will rely on: (1) Identify the precise location of amphibian tunnels and other mitigating road solutions; create a relational and participative database (accessible local and landscape level) with some detailed data about this plurality of devices / external structural factors (landscape, etc.); (2) Define strong methods and strategies to limit the effects of fragmentation and road mortality on amphibian populations (develop scientific studies with a good synergy between theory and practices; decision tree; field surveys and monitoring; hotspot and hot moment mortality, and so on); (3) Develop one or several equipment designed for demonstrational purposes to establish a reproducible pattern in the best cost-profit; (4) Create a network encouraging dialogue, collaboration and information exchange to improve the socioeconomic acceptance of this issue and its consequences; (5) Ensure the information of professionals (e.g. road engineering) and develop adapted communication for different types of public on all the actions of this project.

Challenges in realizing fauna passages

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In light of the Dutch defragmentation program MJPO, roughly 100 small fauna passages are being realised or are already realised underneath Dutch railways. Movares has been involved in engineering a large part of these fauna passages. Generally, small fauna passages are tubes underneath the railway, or ledges and gutters under current bridges. The design is relatively simple. However, when engineering these fauna passages, some challenges may occur. High water levels, property boundaries, permit procedures, and stakeholders may hamper the designing process. In the Netherlands, the engineers and builders of small fauna passages have to balance multiple interests of different stakeholders. Often the stakeholders also need to provide a permit. The primary task of ProRail (the administrator of the rail infrastructure) is 100% availability of the rail infrastructure. Therefore, there are strict guidelines for drilling beneath the rail. The vertical distance between rail and the top of eh tunnel should be 1,80m minimum. This often conflicts with the high water level in the Netherlands. Water levels differ during seasons. Thus, what flooding period of the small fauna passage is acceptable given the species of fauna the passage is designed for? Other solutions are reducing the diameter of the passage, getting special permission from ProRail based on the geotechnical circumstances or engineering individual entrances of the fauna passages. Often, the body of the railway track is also a dyke. The local water board is responsible for the local water management and does not allow drilling holes (such as fauna passages) in 'their' dyke. In some cases, there are solutions. For example, providing a technical provision to close the fauna passage in case of an inundation threat. Other problems occur where the local water board is responsible for the maintenance of the canal alongside the railroad track. The water board demands a 5-meter wide space for maintenance, which often conflicts with the space needed for the construction of the passage or the fence for guiding fauna. The MJPO program also foresees the ecological improvement in current tunnels and divers. A lot of problems occur while engineering such solutions. Sometimes, the tunnel proves to be a cultural or historical monument, which comes with a lot of restrictions. If road traffic also uses the tunnel, the local township has to agree. This proved to be a problem when local officials put road traffic above ecological value.

The historical co-evolution of river infrastructure networks and biodiversity: findings from the French-German Upper-Rhine region and the Austrian-German Danube region

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In our contribution, we will present the first findings from the INTERCONNECT project, which brings together ecologists and social scientists in a joint exploration of river biodiversity restoration. This project first aims to investigate the conjunction of biodiversity changes and the expansion of various river infrastructures and human usages. Secondly, in a double concertation process with ecologists and local stakeholders, the project partners will suggest potential infrastructure adaptations helping to reconcile human activities and biodiversity restoration. We focus on two European border areas: (1) the French-German Upper Rhine region and (2) the Danube and its tributary Inn in the Austrian-German border region. These two fluvial stretches have been strongly shaped by infrastructures such as channelled waterways, hydropower plants, locks, crossing railways and cycling paths along rivers. We conceive these infrastructures as assemblages of linked artefacts, organised in networks and nodes. We assess the evolution of biodiversity as a cumulative effect of infrastructure networks rather than singular infrastructures. During the last two centuries, these infrastructures have boosted the regional economic development, but they have also had a negative impact on the aquatic and terrestrial biodiversity, in particular by interrupting ecological continuity and reducing alluvial forests and aquatic wetlands. In our presentation, we will share significant results of ongoing work on biodiversity changes and infrastructure network expansion, zooming on three small-scale sites in each river area. This analysis is done for three historical periods of the 20th century. To this purpose, we first created a database with existing data for three biological compartments: fish, alluvial forest and macro-invertebrates. Fish have a fully aquatic life cycle that depends on the longitudinal continuity of their hydro-system. Alluvial forests are a transition area between aquatic and terrestrial ecosystems, which makes them a good indicator of lateral continuity. Communities of aquatic macroinvertebrates illustrate the link between aquatic environment and the adjoining ecotones. For each of these three compartments, we calculate biodiversity indicators describing the composition, the structure (diversity indices) and some functional aspects (species traits). We pay particular attention to the disappearance or rarefaction of patrimonial species. In addition, we investigate the spread and importance of exotic/invasive species, most of them being well known as species that benefit from anthropic disturbances. The expansion of infrastructure networks is analysed for each period and site by maps, which display quantified habitat fragmentations and changes of land use. A major challenge for this analysis is to distinguish the effect of infrastructure networks from other pressures such as the changing physicochemical water quality. For that, we adapted the temporal changes-model from the classical DPSIR framework recommended by the European Environment Agency. According to this chain of causal links, 'driving forces' through 'pressures' cause 'states' changes and 'impacts' that affect ecosystems, eventually leading to political 'responses'. The analysis of biodiversity changes will be the basis for a series of interviews and focus groups with infrastructure operators, municipalities and user groups. These will serve to grasp current and historical practices of infrastructure operation and usages, interdependences between these practices, as well as the role biodiversity plays for these practices.

The French railway: Determination of the ecological potential of the SNCF land property for ecologic valuation

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SNCF RESEAU is the infrastructure manager and the owner of railway infrastructures in France (more than 38,000 km of railroads). As such, it ensures the missions of contracting authority of renewal projects, modernization and development of the railway network, and the installations that are necessary for its exploitation and its functioning. Furthermore, SNCF RESEAU is a significant property owner of the territory. This land property is mainly dedicated to railway installations. However, part of it does not have a technical vocation and stay land reserves (nearly 110,000 hectares). Firstly, this projects aims at identifying the biodiversity potential of those land reserves, especially for wet zones. Secondly, we aim to mobilize those reserves to provide mitigation sites directly linked to our railroad activities. At this time, the total surface of our mitigation measures is nearly 6,000 hectares. Based on a detailed map of those land reserves supplied by SNCF RESEAU, the project aims at estimating this ecological potential. Additionally, it has an exploratory nature: (1) By establishing an acceptable and shareable methodology with our stakeholders; (2) Developing forward reproducible methods on the whole national territory and based on a GIS; (3) By proposing orientations to increase the ecological potential of reserve (actions, investments, benefits expected, etc.). Three experiment areas situated in the southwest and southeast of France (covering the scope of three departments) were identified. We applied different methodological approaches to these areas, to compare them and select the one that would be spread all over the national territory. The method always includes the following steps: (1) Sorting of land plots according to their surface, localisation (is it near the railway network or not?) form, united land, degree of mineralisation, type of vegetal land cover, proximity of the ecological preserved zones: 4,955 plots have been analysed concerning 2,560 hectares; (2) Determination of ecological potential of selected land plots, based on bibliographical data, naturalistic inventories, air photography, zonings according to inventories and protections, drafts of ecological planning, an atlas of wet zones, pedological data, etc. At the end of this analysis, land plots are organised by ecological criteria and according to their physical, biological and/or functional characteristics known at this time. If possible, they are also treated on a hierarchical level of interest and capacity to develop their potential; (3) Identification of ecological valuation actions. If the land plots identified as possible interesting ecological potential, orientations and modalities are suggested to maintain the potential identified waiting for specific ecological valuation. Additionally, it reveals or amplifies the recognised potential for mitigation measures. This approach includes analysis regarding the contribution of those plots to the local green corridors.

Developing sustainable road verge habitats in Ireland

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Sustainable highways aim to limit their impact on the environment through some measures that include ecosystem management. But how sustainable and green is Northern Ireland's road infrastructure? There are approximately 9,000 km of roads throughout Northern Ireland with a large area of associated soft infrastructure that requires management to create sustainable highway environment for pollinators. Current design and management plans for Northern Ireland do not adequately address the design of sustainable pollinator habitats. It is stated that they promote practical management that enhances biodiversity while respecting the landscape character and quality with appropriate planting. For example, the plans advised seed mixes for Northern Ireland include two poppy species that, while present in Northern Ireland, they are not native species. This does not appear to be consistent with the plans' definitions of both: sustainable habitat – the maintenance of natural habitat; or, wildflowers – native species that could occur naturally in the area of the road scheme. This study looks at the natural occurrence of wildflower species in Counties Fermanagh and Derry, to better understand native wildflower species availability to pollinators within the road verges. By enhancing the wildflower availability within road verges, we are developing both sustainable highways and sustainable habitats to better advise and promote sustainable road infrastructure; design, maintenance, and enhancement.

Green bridges versus increased fragmentation

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The Veluwe, of which 88,370 ha is Natura 2000 designated area, is the largest terrestrial nature reserve in Northwest-Europe. Fragmentation by roads and railways is the primary threat. Recreational infrastructure, agriculture and human habitation are additional threats from the inside. The Veluwe-landscape consists largely of forest and heathland. Habitats have become isolated because of roads, railroads and fences. In 1988 the first two green bridges were constructed across the A50 highway. Later more followed. A provincial policy document supported by the 'National Defragmentation Program' gave a boost to defragmentation of the Veluwe. More green bridges were constructed, in combination with smaller eco-passages. The removal of wildlife fences also helped to restore the connectivity. Monitoring of the green bridges proves that a great variety of animals uses these structures. Coordinated defragmentation increased the connectivity on the Veluwe. Until recently, a dense infrastructure network divided the Veluwe in a North and South section. In 2013 two major landowners, the National Forest Service and Het Loo Royal Estate, urged for the construction of more green bridges to restore the coherence between both sections. National and Provincial Government joined in, resulting in four extra green bridges to be constructed in 2017 and 2018. These green bridges do not only connect the Veluwe at large, but are also important structures within a network of ecological corridors that connect unique Natura 2000 habitat types in the Central Veluwe, thus important for the conservation of Natura 2000 habitat types and species. National highways with high traffic density and speed limits of 130 km/hr are fenced for safety reasons and thus a hard barrier unless green bridges are constructed. The density of secondary roads is much higher with speed limits up to 80 km/hr. In case of fencing these roads, fragmentation would be disastrous, but mitigating measures as green bridges would be too expensive. These roads need other solutions to reduce collisions and to restore connectivity. At the Veluwe, these secondary roads are frequently used by residents, commuters and tourists. Choices have to be made to preserve the Veluwe as a unique Natura 2000; a green and sustainable traffic infrastructure will be elementary. Strategies to achieve this are: (1) Barriers of fenced national highways should be mitigated by green bridges; (2) Secondary roads should be looked into individually. Unpopular measures have to be taken, like lower speed limits combined with small eco-passages, night closures, or even complete transformation of roads to bicycle tracks and hiking trails. Large Natura 2000 sites deserve a new vision on balancing traffic infrastructure and our green infrastructure.

Implications of ecological barriers on cross-border transport between India and its neighbours

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The research question this work pursues is: "What are the implications of ecological barriers on cross-border transport between India and its neighbours, and how to sculpt a sustainable transport policy to deal with these". India is the fastest growing major economy in the world and trade has been burgeoning for the past three decades. However, just a minuscule part of this trade takes place between India and its next-door neighbours. This is majorly due to the geography of the subcontinent and the not-so-amicable relations, to say the least; India has with its neighbours. This paper primarily focusses on the former. The Himalayas bind India's western border with Pakistan and the northern border with China, Bhutan and Nepal. The northeastern border with Myanmar is marked by the tropical forests of the Patkai Bum hill range. On the east, the Sunderbans and the numerous tributaries of the Ganges divide India and Bangladesh, and on the south, India and Srilanka are separated by the Indian Ocean. However, with the start of India's "Look East Policy" and China's "Silk Road Initiative", this trade imbalance is bound to change. Improved transportation systems and infrastructure can only realize this. Dealing with the fragile border ecosystems is crucial for this to happen. The study involves a comparative analysis of cross-border transport in similar geographies in Europe. Including the system of waterways present in the Netherlands and the adaptability of the same on the eastern border of India. Field studies will be undertaken on the eastern and western borders to study the terrain, flora, fauna and the population that inhabits these regions, and their impact on land-based transport. This work will provide a set of guidelines to sculpt cross-border transport policy for the Indian subcontinent, while commenting on the politics of ecology in the subcontinent.

Ecological effects of pipelines: A case study of the Bailadila-Visakhapatnam iron ore slurry pipeline

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Pipelines move million tons of bulk commodities over vast geographic distances across the globe every year. In addition to oil and gas, pipelines often provide the most efficient and cost-effective mode of transportation for mineral ores (as a slurry). Pipelines are generally portrayed as the least environmentally destructive mode of transportation for such bulk commodities. This is mainly because pipelines have almost no visible environmental impact, and a much lower carbon footprint – especially when compared to transport by rail or road. However, pipelines have multiple long-term impacts, the most critical being socio-economic disruption, landscape fragmentation, and soil and water pollution. Over the last twenty years, slurry pipelines have become the transportation mode of choice in India to move significant volumes of iron ore and coal from remote, relatively inaccessible mines to industrial zones and coastal processing and shipping facilities. Considerable work has been done on the socio-economic impact of pipelines, mostly in the context of land acquisition and livelihood disruption disputes as the richest iron and coal deposits in India are concentrated in areas that are also the traditional lands of indigenous communities that are at the bottom of India's economic and political hierarchy. However, studies focusing on the environmental impact of pipelines are non-existent in India because most such pipelines run through areas controlled either by government paramilitary forces or by armed insurgent groups. This makes such areas too dangerous for any field research activities. The difficulties outlined above motivated our research. This paper presents a pilot case study of a proposed methodology to conduct preliminary environmental impact studies of existing slurry pipeline segments running through inaccessible areas. The pipeline selected for this pilot case study is the Bailadila–Visakhapatnam iron ore slurry pipeline. The 267 km long slurry pipeline carries iron ore mined from Bailadila, in the state of Chhattisgarh, to a pellet plant in the port city of Visakhapatnam, in the state of Andhra Pradesh, passing through the state of Orissa. The pipeline passes through some of the most weathered terrain, which is made even more inaccessible due to the presence of armed insurgent groups and government paramilitary forces. Most of the alignment passes through a fragile ecosystem of open forests and the watersheds of five major rivers. This pilot study employs the TERMPOL review process to assess the impact of the slurry pipeline. Satellite imagery, processed using ArcGIS, is used to study the changes in the physiography and the subsoil over the last ten years (the pipeline was commissioned in early 2006). Fragmentation analysis through FRAGSTATS shows an increase in landscape fragmentation. Qualitative information extracted from regional wildlife surveys indicates significant impacts on wildlife corridors. A limited field survey will be carried out along some of the relatively accessible segments of the pipeline alignment – with focus on where the pipeline crosses state boundaries – to verify the information obtained so far on the effects of the subject slurry pipeline on wildlife. This includes habitat loss, alteration or fragmentation, impact on seasonal and daily movements of wildlife, and impact on local soils and groundwater.

Safety by nature: development of erosion resistant and species-rich river dyke vegetation through adapted management

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Dykes are constructed as a flood control measure. However, when thoughtfully designed and managed they represent considerable ecological potential as habitat and corridor at the same time. Grasslands on the dense network of dykes in Flanders (Belgium) form a continuous grassland of more than 1,000 hectares and will expand even more in the future by the implementation of the actualised Sigmaplan. Nowadays, this network of dykes shows a wide range of vegetation types, erosion resistance, and above-ground biomass (considered as a proxy of maintenance cost, the lower the above-ground biomass, the lower the maintenance cost). We researched the relationship between vegetation patterns and abiotic conditions. From there, we proposed design and management guidelines to optimise the combined flood control and ecological functions of the dykes under acceptable maintenance costs. These guidelines are then spatially specified in a proposed management plan for the dykes. Based on 219 vegetation plots, five types of grassland vegetation were distinguished and described. In each of these percentages of cover (as a measure of erosion resistance), above-ground biomass (as a measure of maintenance cost), and soil nitrogen and phosphorus contents (as a measure of trophic condition) were measured. Species-rich grassland and species-rich *Arrhenatherum*-grassland combine the best erosion resistance with low maintenance cost and high ecological value. Therefore, they are proposed as target vegetation types for the top- and landsides of the dykes. Guidelines for maintenance management are described for the target grassland vegetation types, as well as guidelines for restoration management towards the development of the target vegetation types from species-poor *Arrhenatherum*-grasslands, deteriorated *Arrhenatherum*-grasslands, and stinging nettle vegetation. The proposed management measures are both general (concerning fertilisation, use of pesticides, breeding birds, entomofauna, and rare plant species) as well as vegetation specific (mowing, grazing). A vegetation map has been created and then conversed into a management proposal. For every mapped unit, management measures follow the implementation of the general guidelines according to the specific situation. A monitoring plan to assess the evolution of the distance to target vegetation is proposed to allow for adaptive management.

Complementary use of statistics and simulations for assessing incident-risk with large wild mammals on a 3,500 km railway

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In the New Aquitaine region (the Southwestern part of France), incidents (collisions and wanderings) with large mammals (roe deer, wild boars, and deer) account for 30% of train incidents with animals. For security reasons, each collision requires the immobilisation of the train for inspection. This immobilisation causes delays for the passengers and repair and compensation costs for SNCF réseau (French railway company). From 2005 to 2016, the number of incidents increased by 235% (from 30 to 101 incidents), resulting in a 700% time-lapse increase (from 30 hours to 200 hours). This trend is likely to continue due to the increased populations of large mammals reported in France (e.g., +300% deer in 20 years). SNCF réseau seeks to design a development program of these lines to limit the number of incidents to manage the 3,500km railway. For this, SNCF réseau commissioned TerrOïko a large-scale mapping of the risk of collision on its network. The study aims to target hotspots with high potential for incidents to reduce the scope of investigations at a smaller scale and to define the nature of the work that has to be done. For this aim, TerrOïko has developed an analysis method including crossing data on the location of the incidents reported by the drivers and demographic and displacement data of large mammals to map and prioritise the hotspots. The statistical method of Generalized Additive Model (GAM) analysed the collision data, and the SimOïko simulator obtained the displacement data. At the end of this research, 85 hotspots were identified and prioritised at four levels of priority. This pre-diagnosis reduces future investigations to a finer scale at 941km or 27% of the total network. In each sector, the finer analysis of the simulated movements will make it possible to define the nature of the actions to be considered to reduce the passage of animals: fences, landscaping, passage to wildlife, etc.

Roadside Grass Collection: benefits and impacts on vegetation management

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French road network is about a million-kilometres-long and covers 5,000 square-kilometres of green verges representing a potential of 2 to 3 million tons of biomass. Today, in France, there is no law requiring to collect grass during roadsides maintenance. Therefore, cut-grass rot on roadsides and nitrogen increases in vegetation and water. Local authorities and public road services, in particular in the West of France, manage roadsides since a few years by mowing and collecting the grass to provide biogas and composting plants. There are no recent studies in France informing the effects and inter-ests on the vegetation of grass collecting on roadside verges such as costs and gains, contamination levels and relocation towards anaerobic digestion. Can this process be set up without any risk? Ad-dressing this question, the search project CARMEN (characterisation of PAH [Polycyclic aromatic hy-drocarbon] and heavy metals on the road verges grass used for anaerobic digestion has been imple-mented by Ineris, Aile, Lasalle Beauvais and Cerema through the Ademe (French agency for environ-ment and energy management) CIDE (impact and knowledge of waste management) call project in 2015. Three study sites, Loudéac (10,000 average annual daily traffic [AADT]), Rennes (40,000 to 100,000 AADT) and Mayenne (5,000 AADT), have been monitored for two years and submitted to various analyses: grass and soil sampling, and anaerobic digestion pilot test. These three sites and their manage-ment have been observed (time, cost, climate, fuel consumption etc.). 40 vege-tation plots have also been surveyed on the Loudéac site to measure the impact of grass collection on flora richness concerning traditional practices (i.e. without grass collection). Concerning pollution, the results of the three campaigns are similar and show PAH and heavy metals values in grass lower than specified limits for compost quality (NF U 44-051). Therefore, the concentration of the expected val-ue during anaerobic digestion process returns the compatible digestate with soil return. However, in a few cases, the high levels of zinc and chrome at a lower scale, need further investigations. Concern-ing vegetation, first signs of change have been observed, but their origin can also be due to the cli-mate, to the impact of management change or both. The cost-benefit study shows some additional direct costs related to biomass transport and to the lower operating speed of the technique. Never-theless, analytic results show less direct pollution (PAH, heavy metals) as well as indirect pollution (nitrogen). A favourable effect on flora biodiversity, a positive energy balance, a good grass quality and a proper biogas potential have been observed. However, the direct and indirect impact on the fauna of this new method has not been assessed in this project. In conclusion, grass collection on roadsides seems to be a better technique for road managers and a solution for the future with the implementing of new machinery. This biomass may be of interest for biogas farmers to replace a part of their crops rotation system. At a local scale, positive energy territories can be developed through projects between different partners (road managers, farmers, local authorities and public services).

Are movements across roads and their timing linked to the traffic load in the Red Deer?

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Traffic load and the timing of traffic peaks are likely to influence the fragmentation impact of roads as well as on the collision risk with wild animals. It is also expected to have an effect on the crossing behavior of a given species by increasing the avoidance of the road. To test this hypothesis, we considered a Red Deer population centered on a forest patch crossed by an unfenced road with high traffic load (over 12,000 vehicles per day). We fitted fifteen individuals with GPS collars to assess their movements. The aim was to evaluate the frequency of road crossings for each and to determine if there was a temporal pattern for these road crossings. Therefore, timing of road crossings was compared to the hourly traffic load measured by a traffic counter. Our results showed that most individuals frequently crossed the considered road stretch despite the traffic. However, they did it when the traffic load was at its lowest. Thus, the local Red Deer population did fit the timing of road crossing to the periods of lower traffic. The question remains: is the traffic in itself influencing this behavior, or is it due to the presence of wildlife warning reflectors, a combination of optic and acoustic deterrents?

Biodiversity and wildfire prevention at Infra Transport Routes

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Can we stop an uncontrolled wildfire? In the Netherlands, wildfires are an underestimated risk. The risk does not only apply to the large concentration of residential and recreational areas but should also be applied to the infrastructure that has been built crossing a nature reserve. Transport movements in highway and railway routes, among other things, increase the chance of the occurrence of a wildfire. The natural compartment borders often include broadleaved belts and thus form a natural stop line where a wildfire is supposed to stop. The aim is not only preventing wildfires but also increasing biodiversity and protecting vulnerable nature.

U.S. Forest Service online Drought and Climate Galleries

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In 2017, the USDA Forest Service developed online Drought and Climate Galleries to support environmental analysis of the risks and impacts from increasing temperature and drought. The Galleries include maps, tools, GIS layers, fact sheets, and other resources for natural resource specialists, managers, planners, GIS practitioners, and the public. The galleries harness Esri's ArcGIS Online technology to deliver a collection of vibrant mapping content based on scientific drought and climate data. This site will be used as both a data repository and communication toolkit, to inform and educate stakeholders, including the public, about the influences of drought and climate change on natural resources and built infrastructure. In addition to climate information, the gallery contains tools for analysing current and projected changes in stream temperature, stream flow, and snowpack. These galleries act as a single repository for climate-related information and include not just maps and data, but also stories, photos, fact sheets, and videos. A key outcome of the galleries is the provision of a singular resource for credible and citable climate-related data for anyone involved in land management and infrastructure planning on National Forest System lands in the United States. The galleries function as a living repository and can be modified or supplemented as new information becomes available. The galleries will help streamline agency planning and monitoring practices by providing a standard set of data to address questions of climate and drought consistently. These data will help users to take such issues into account when making strategic planning decisions, and to better adapt on-the-ground actions to a changing environment. Moreover, by providing this information in a form that is easily accessible by U.S. government agencies, non-profits, and other organisations, these galleries can help enable public-private partnerships and other collaborative efforts. These tools allow agencies and partners to think strategically about climate effects on infrastructure, and to better communicate these issues to the public.

WWW.ECOLOGICAL-NETWORK.EU and WWW.LEBENSRAUMVERNETZUNG.AT

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www.ecological-network.eu / www.lebensraumvernetzung.at is an online information portal provided by the Austrian Federal Ministry of Sustainability and Tourism, which serves to provide existing geodata and further information on ecological networks and green infrastructure. The anthropogenically induced loss and fragmentation of habitats, which are expressed by the high degree of fragmentation of cultural landscapes in Austria, are adversely affecting migration and dispersal possibilities of living beings and cause the loss of ecological fitness, genetic variability, and biodiversity. Flora and fauna, as well as the human being, are negatively affected by the degradation of ecosystem services. Therefore, national and international conventions, laws and regulations demand the preservation and restoration of ecological networks. The website www.ecological-network.eu / www.lebensraumvernetzung.at was launched by the Austrian Federal Ministry of Sustainability and Tourism as a contribution to the national Austrian Biodiversity Strategy 2020+ and as an essential outcome of the project Green Infrastructure Networks in Austria ("Lebensraumvernetzung Österreich"). The objective of the online portal is to make existing ecological network concepts visible and accessible to the public and stakeholders. All parties concerned are thereby able to gain a clear and complete overview of the ideas and projects concerning ecological networks and habitat defragmentation that exist in Austria as well as in the neighboring countries. The website shows all available international, national and regional ecological networks of Austria, Germany, Switzerland, Czech Republic, Slovakia, Hungary, and Italy. The various concepts are presented and described on individual subpages. Ecological networks are shown in a viewing service on interactive maps. Furthermore, spatial data is available for download in a geodata catalog. The website also provides links to more information, project websites and contact partners. A publications section offers numerous links to reports and articles concerning ecological networks and green infrastructure. The portal aims to serve as a central thematic portal for ecological networks in Europe. It intends to interconnect the topic related activities of regions and countries to make their data available for the public and each other and to bring their initiatives closer. Any interested party is encouraged to participate by sharing their projects or activities either via external links or directly on the web portal.

Ecological permeability along and across traffic routes in an intermodal transport environment

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Transport infrastructure such as highways or railway lines are well known to contribute to landscape fragmentation by several factors such as habitat destruction, disturbance or increased mortality rates. The severity of these effects differs across species groups and, under certain conditions, e.g. in intensively used agricultural areas, the green corridors along traffic routes have been shown to attract or even provide a refugium to many species. Thus, these green corridors may be an important component for the practical implementation of European commitments with respect to the conservation of biodiversity. Such efforts will be most successful and cost-effective if the entire intermodal transport infrastructure network is considered. The 'Network of Experts' established in 2016 by the German Federal Ministry of Transport and Digital Infrastructure, stands out through its unique focus on such intermodal research questions from many different fields. Within this network, we designed a landscape-scale biodiversity study aimed at assessing the potential role of green corridors for conserving and promoting biodiversity from an intermodal perspective. In a typical German low mountain landscape, we conducted a standardised survey of biotope types, plant species, and six different animal groups (amphibians, birds, butterflies, ground beetles, reptiles, and spiders). Our multi-factorial study design incorporated: a) different spatial configurations of traffic routes such as intersections and parallel stretches of federal roads, railway lines, and waterways; b) the different role of traffic routes in regions of extensive and intensive agricultural use; c) the distance decay of all the above effects away from the transport infrastructure. Here, we present the results from the statistical analysis of the vegetation data highlighting the role of traffic-adjacent green corridors as prospective sites for maintaining and promoting biodiversity, also beyond common species. Analysis of species turnover rates, along a 125 meter transects perpendicular to the traffic infrastructure, revealed a steep vegetation gradient suggesting a certain degree of autonomy of the green corridors along traffic routes from the surrounding landscape matrix. We found this to be especially true within areas of intensive agricultural use. In contrast, the analysis of biotope types, as well as Non-Metric Multidimensional Scaling of vegetation relevés along and at the intersections of traffic infrastructure, showed the similarity of vegetation composition, especially along roads and railroads. Our results emphasise the importance of intermodal decision-making towards a greener transport infrastructure.

Eco-ducts in Dutch Dunes: Practical tips for construction work!

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Natura 2000-site 'Kennemerland-Zuid' includes 'National Park 'Zuid-Kennemerland' and 'Amsterdamse Waterleidingduinen'. The urban areas of Zandvoort and Bentveld are located between both areas of the Natura 2000-site. Provincial roads, Bloemendaalse Zeeweg (N200) en Zandvoortselaan (N201), and railway Haarlem-Zandvoort intersect the site. This infrastructure is a significant barrier for migration of fauna between the National Park and Amsterdamse Waterleidingduinen. To improve the coherence within the Natura 2000-site, three eco-ducts 'green bridges' have been built. Therefore, a 7000-hectare unique dune will be connected in total. The green bridge Zandpoort at Zandvoortselaan (N201) has been built in 2014. In 2017 the green bridge Zeepoort at Bloemendaalse Zeeweg (N200) opened for fauna. In 2018, the last green bridge over the railway (Duinpoort) will follow. The three green bridges connect the middle dune landscape, essential for 'Grey Dunes', which is a Natura 2000 priority habitat. The migration within the separate areas of the Natura 2000-site of flora and fauna of dry dune grassland is made possible by the green bridges. Additionally, they facilitate the movements of larger mammals, which contribute to vegetation management, and distribution of seed and vertebrates of shrubs, dune forests, and wet dune habitats. When building the green bridges, the constructor has to take care of protected species that are present at the spot. Mitigation measures are carried out, such as translocating animals from the work area to prevent unnecessary killing. The vegetation of the green bridge is selected for target animals as well as a connection with available habitat in the adjacent dunes.

Evaluating the effectiveness of a wildlife overpass in restoring gene flow in a slow worm population

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In the Netherlands, roads have fragmented many slow worm populations (*Anguis fragilis*). Currently, wildlife-crossing structures are being built across the country intending to reduce the barrier effects of roads and to facilitate animal movements and gene flow across the landscape. However, we know little about the degree to which these structures reduce the barrier effects and enhance the exchange of individuals and genes between populations on opposite sides of a road. Our objective is to evaluate the effectiveness of a wildlife overpass in restoring gene flow in a slow worm population in the Gooi region in the Netherlands. The overpass, constructed in 2013, bridges a motorway and two-track railroad and is 50 m wide and 170 m long. It is positioned within a nature preservation area with mixed forests, heathlands, and fens. In 2014-2015 slow worms were caught at the overpass and in the surrounding preserve over a distance of about two kilometres from the overpass. We genotyped 153 individuals at nine microsatellite markers to analyse population structure and determine the origin of migrants found on the overpass or its ramps. We identified three genetic clusters with a distinct spatial pattern. We discovered that the motorway had been a genetic barrier; individuals from the western and eastern road verges belong to different genetic clusters. Individuals that were found on the west ramp and top of the overpass seem to originate from the genetic cluster on the west side of the transport barriers. Genetic diversity and heterozygosity were found to be extremely low in the western cluster, which indicates genetic impoverishment and inbreeding. Our research shows that transport infrastructure may result in a genetic barrier for slow worms. The genetic differences between the populations on opposite sides of the transport barriers will allow for evaluating gene flow after the vegetation on the overpass has been fully developed and slow worms have had sufficient time to reach and accept the structure. Therefore, the genetic sampling will be repeated in 2020. Our study highlights the value of applying genetic techniques in road ecology and emphasizes the importance of studies that go beyond the monitoring of the use of crossing structures by wildlife.

Knotweed: a worldwide problem

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Worldwide knotweed doesn't need much introduction with ecologists; biodiversity is at risk and the functionality of ecoducts/wildlife crossings will be reduced if not treated. However, in some countries landowners and infra administrators are not familiar with knotweed and the danger it causes to infra. They are not aware that the roots of this weed can cause major damage to stone and even concrete structures, not to mention the difficulties to terminate knotweed. Most of all, knotweed doesn't hold at borders of land or even countries, what makes it in an ironic way very appropriate to the theme of this conference: Crossing Borders. And that is the biggest challenge of all; because the level of policies and regulations about knotweed vary dramatically between countries. For example, the policies and regulations in the United Kingdom are very tight, but the European Union and Netherlands have none at all. On this poster we provide some examples of problems knotweed could cause to biodiversity and infra. Also, we would like to set up a mailing list to the exchange of experiences, advice and questions.

Road and ecological network interaction: An analysis of ungulate road accident in the Province of Turin (Italy)

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The ecological network is an "interconnected system of habitats to safeguard biodiversity", and it is essential in environmental planning and to preserve landscape quality and biodiversity. The expansion of the road network and the rise in vehicular traffic can cause interruptions of the ecological network, undermining its function. Consequently, in the last years, a significant increase in collisions with wildlife species has been registered, representing one of the most significant causes of biodiversity decline due to human activity. Considering the above, we evaluated the consequences of the road network expansion on the ecological connectivity in Province of Turin (Piedmont, Italy), using the distribution of road accidents with wild ungulates as an index to identify critical areas. To this purpose, the spatial relationships among three geographic features (shapefiles) were investigated using: I) the ecological network; II) the road network; III) the geo-located car accidents with wild ungulates. One hundred thirty-two accident points and the same number of randomly generated points were considered, to verify the hypothesis of connections between the occurrence of car accidents and the area of interaction between ecological and road networks. To this purpose we calculated the linear distance of all points (real and random) to I) the ecological network and II) the area of interaction between ecological and road network. The results show that the median distance of the accident points from the ecological network, as well as the distance from the road-network intersections, is significantly lower than the one of the random points: respectively 276 vs 629 meters, and 344 vs 724 meters. Therefore, the road accidents can be considered an effective indicator of the critical areas of interaction between roads on the ecological network. The roads act as a barrier to the movement of animals and determine landscape fragmentation, dividing animal populations into smaller groups, and the genetic exchange is compromised. The overall effect is to make local extinctions more likely because the exchange of individuals among subpopulations is reduced or blocked. Considering all the above in the points of the accident, we could intervene to: I) improve road safety and II) restore their natural role to ecological networks. For road safety, in Italy, in 2017 a system consisting of acoustic and visual warning devices was tested inside the Life "Strade"; which on the one hand alerts the driver of presumable danger and on the other dissuades the animal from crossing the way. While for the restoration of ecological networks some Italian regions are sensitive to this problem. First of all Friuli Venezia Giulia, which has built four green bridges up to 800 meters long, four tunnels and 50 underpasses. Then there is the Regional Park of Ticino in Lombardia with a bridge of over 500 meters that serves as a crossing over a highway. And finally, in the Province of Turin (Piedmont) special tunnels called "rospodotti" have been created to limit the number of common toads invested during their movements.

Coordinated planning of connectivity for wildlife at a bundled motorway–railway corridor in Sweden

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Sweden is currently planning the construction of the country's first system of a high-speed railway (HSR; >300 km/h) connecting the cities of Stockholm, Gothenburg, and Malmö. The *East link* line is the first section of this HSR to be built. This 150 km section will be 'bundled' with (i.e., parallel and in proximity to) the existing motorway E4 for the more substantial part. The East link line will be effectively fenced for wildlife, which creates a significant barrier for wildlife movements. While parts of the line will go into the tunnel or onto the bridge, other sections may be impermeable barriers for wildlife and need mitigation measures such as wildlife passages. The location of wildlife passages must be planned with consideration to wildlife movement in the surrounding landscape. The fenced motorway and the opportunities for wildlife to pass the motorway on existing bridges for local roads or streams primarily structure these movements. Conversely, the new railway line may, in turn, increase the overall barrier effect and re-structure wildlife movements, thereby pointing out demands for wildlife passages also along the current motorway. The East link case illustrates the importance of coordinating the management of wildlife movements across bundled traffic arteries very well. We will describe this case, our planning approach, and the output in the form of barrier assessment, wildlife movement simulation, and proposed wildlife passages along both infrastructures. We will acknowledge some practical and institutional limitations to the coordinated planning of bundled infrastructures, for example, differences in timing, in planning processes and planning traditions, and difficulties in getting various financial recourses to invest in the same goal. The planning process is still ongoing, and the East link line will be constructed in 2022-2032. Therefore, the impact of coordinated planning on effective mitigation and future wildlife connectivity has yet to be discovered.

Evaluation of wildlife mortality and the effectiveness of animal underpasses in the Northern inter-American road, section Cañas-Liberia, Costa Rica

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Research has shown the various effects of roads and vehicular traffic on both the ecosystems and the fauna that inhabits them. Most of these effects include the loss and fragmentation of habitats adjacent to roads, changes in the behavior of local fauna, sonic and chemical contamination, as well as the increase in mortality rates of wild animals due to collisions. What is the impact of a two-lane road that will become four lanes on the fauna? And in addition, was the wildlife underpass included in it effective? From June of 2013 to January of 2014, counting and locating the carcasses on the Inter-American Highway, Cañas-Liberia, assessed mortality due to car collision of wildlife. Samples were taken from 5:00 a.m. to 8:00 p.m. and from 9:00 p.m. to 10:00 p.m. (30 km/h) three times a week. As another source, we included the social perception. For that we used a semi-structured open interview with the residents of the communities adjacent to the road. We did these interviews two years later, in 2015 and 2016. We made a second study to know the effectiveness of the underpasses and curves in the highway. For this, we evaluated the eight underpasses constructed exclusively for fauna as well as selecting eight culverts. We made a characterization of each structure considering various measurement elements, as well as the temperature and noise measured in dBA. Each passage of subterranean fauna and culvert was monitored by means of indirect observation, considering traces of wild animals. Tracks (Tks), feces (Fcs) and burrows or nests (Nst). A trap camera (Bushnell) was placed in each underpass of wildlife and four cameras in those culverts with higher height, this for a period of fifteen days. In addition, the roadkill near the selected structures were recorded through the detection of dead animals on the road within a perimeter of 100 m of each structure; the monitoring was carried out during three consecutive days per week between 05:00 h and 08:00 h and 18:00 h and 22:00 h. A total of 671 trampled animals distributed in 55 species were counted. Amphibians were the group with the highest number of abuses by individuals (55% of the total), followed by reptiles (20%), mammals (15%) and birds (10%). Most people (98%) mentioned having ever seen a run over animal. However, 88% of the reported animals corresponded to domestic animals, among which cats and dogs stand out. With respect to wild species, 22 overrun species were mentioned by the settlers, among which the snakes were the most reported. The locals perceive that the road has a high impact, but to themselves and not towards wildlife. The hotspots allowed to determine the sites with the highest accumulation of roadkill, these must be considered when implementing mitigation measures. The square-shaped culverts, with a size greater than 1.5 m, were more successful in registering traces. The eight subterranean fauna passages have a registry of traces mainly of small and medium-sized animals, which indicates that their use is being effective for generalist and smaller animals. On the other hand, these types of structures do not allow the passage of large mammals such as the jaguar (*Panthera onca*). The results indicate that there is a significant impact. And although mitigation measures were included, if these are not specific and placed in the appropriate sites (hot spots), they are not effective. The structures that exceed the measure of 1.5 m were the most used. Nevertheless, these are not underpasses for fauna but culverts. That is why it is extremely important to consider previous research when building a new road. When we know where and who are, we know what measures have to be taken.

Bats overpasses, an insufficient solution to funnel bats crossing the road

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Roads have many negative effects on wildlife, including the prominent role as habitat fragmentation. Habitat fragmentation particularly affects bats during their daily movements between roosts and their foraging areas. According to the protection status of bats in Europe, developers have to implement specific mitigation hierarchically structured in order to achieve a null net impact. However, very few specific mitigation measures have been carried out specifically for bats. Bats overpasses are among these proposed improvements intended to reduce the fragmentation impact of road but rarely tested. While the efficiency of the setup of overpasses allowing bats to safely cross the road is critical for justifying such a mitigation measure to be implemented. We herein assess their ability to funnel bats to cross the road near the overpass. We studied three bat overpasses in France although with different designs. We developed an innovative method to characterize bat crossings using Acoustic Flight Path Reconstruction (AFRR). Our sampling design involved six pairs of stereo acoustics recorders in different habitat context, disposed on both sides of the road and working simultaneously across the night. We obtained 57,941 bat passes and 284 bat crossings of six species across the three study sites. Our results suggest that crossings are globally more numerous at the overpass than at the other habitat context, when overpass are well localized according to bats commuting routes identified during the Environmental Impact Assessment (EIA). However, the proportion of bat crossings in the commuting route remain of the same magnitude than crossings at the overpass, suggesting that overpasses do not fulfil the function of funnelling bats crossings, even from within a few hundreds of meters from the overpass. During road construction process, avoidance of impact on biodiversity is the first step of the mitigation hierarchy. However, when it remains residual impacts after construction, mitigation measures have to be implemented. Our results suggest that road construction can, in some case, modify the existing commuting route. It is also necessary to monitor between road construction and the installation of mitigation measure to ensure their placement at the correct position.

No effects of wildlife warning reflectors

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Every year, 260,000 wild animals are killed in road accidents in Germany. Wildlife warning reflectors are the most commonly used prevention measures against road kill. The question of whether installing wildlife warning reflectors influence the behaviour of wild animals in the proximity of streets or when crossing roads was studied in a five-year research project of the Forest Research Institute Baden-Württemberg (FVA). The project focused on the question if the light stimulus of the blue semicircle reflectors minimizes behaviour of roe deer that leads to accidents. To analyse the behaviour of roe deer at five different street sections, thermal heat cameras were used. It turned out that the proximity of the roe deer to the street is decisive for how strongly the animal reacted to approaching vehicles. Animals next to the road reacted most commonly through security or fleeing behaviour. The further they were from the street the less common was this kind of reaction. The blue semicircle reflectors did not change the behaviour of the animals in a way such that fleeing and security behaviour was increased when there were approaching vehicles. The reflectors had no effect on the behaviour of the animals. The reactions of roe deer to blue semicircle reflectors were also tested in an enclosure under controlled conditions on 33 animals. Both male and female animals showed the same unaltered behaviour as the roe deer studied at the road sections. Thus, the results of the field experiment were confirmed. In addition, the behaviour of 46 roe deer was observed over several years with the aid of GPS telemetry transmitters. The investigation centered on whether spatial or temporal changes in road crossing behaviour occurred after installing blue semicircle reflectors. Thirty-two deer eventually crossed roads and they made 13,689 crossings, which were analysed. The frequency of road crossings was determined by the recorded movement activity of the individual animal: active animals crossed the road more often than inactive animals. Additionally, the activity of the animals was subject to diurnal as well as seasonal fluctuations. At twilight and at night, as well as in spring and autumn, animals were more active. Also, in this investigation, the blue semicircle reflectors did not influence the behaviour of the roe deer. There was no change in frequency of road crossings in the different observed areas or where there were shifts of attempts of crossings from twilight and night to daytime hours. Also, the number of approaching vehicles had no effect on crossing behaviour.

A push for growth, a pull on the environment: Brazil's highway plans and their environmental impact

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Throughout the twentieth century Brazil's national transportation policy promoted a highway centric model; however, throughout the 1970s to 1990s economic and political circumstances prevented many highways from being built or expanded. As Brazil entered the twenty-first century with significant economic growth potential, it became clear that the country's highway-dominated, yet capacity-sparse, transportation network was a barrier to Brazil's economic future. During the past two presidential administrations, the national Growth Acceleration Plan (*PAC*) placed transportation infrastructure as a critical element of national development. However, the resulting current plans for Brazil's federal National Road System (*SNV*) are essentially the same as plans dating from the 1970s, which did not account for ecological wealth and areas of conservation concern throughout the mega diverse country. The Brazilian road network is still at an early development stage given that, when accounting for roads administered at federal, state, and municipal levels, only 13.5% of the country's major roadways are paved and only 0.81% are four-lane highways. Thus, Brazil stands at a crossroads. In order to grow, the existing federal SNV plays a key role and needs to be improved; however, the current plans are set to make the same ecological mistakes that European and North American countries made in the mid-twentieth century. To highlight the magnitude of the problem, 4,313.47 km of Brazil's paved four-lane highways run through priority conservation areas and 1,448.16 km run through protected areas, equalling 37.43% of four-lane SNV infrastructure. For two-lane highways, 30,525.82 km run through priority conservation areas and 5,162.2 km run through protected areas, accounting for 39.45% of two-lane SNV infrastructure. For unpaved highways, 6,903.38 km run through priority conservation areas and 2,595.46 km run through protected areas, comprising 55.10% of unpaved SNV infrastructure. Finally, for planned highways, 7,639 km would run through priority conservation areas and 3,838.95 km would run through protected areas if plans are built in their current form, representing 59.25% of planned SNV infrastructure. In order to overcome this problem, we propose a discussion about Brazil's highway future, acknowledging that expansion is necessary for the country to grow, but questioning the SNV's environmental outlook. We developed a highway analysis model and territorial suitability matrix using geospatial data of legally protected areas, official priority conservation areas, land cover classification, and demographic data to identify both highways and geographic areas posing environmental concern. We found approximately 44% of Brazil's SNV crosses areas of environmental concern. Existing highways traversing areas of environmental concern should be a priority for mitigation, and planned highways splitting areas of environmental concern potentially should not be constructed or should be re-planned through an alternate route. Our suitability matrix also highlights the existing and planned SNV highways that appear to pose no significant ecological impacts at a large scale and thus may be justifiably expanded, if projects pass further environmental licensing at a smaller scale. Finally, our results demonstrate that revising current transportation policy in the light of potential environmental impacts is crucial to Brazil's development of ecologically sustainable infrastructure.

How long should we survey road kills before taking action?

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Wildlife road kill is one of the impacts that directly affect animal populations persistence close to highways. Road kill spatial analysis is crucial. It can tell us where animal populations may be at risk and inform us about where to apply mitigation measures. However, since surveys demand people and money, one question frequently asked by Brazilian environmental managers is if a short-term study gives us enough information to apply mitigation measures or if it is essential to accumulate data for a more extended period. We used a database from Rodovia do Sol highway (ES-060), in South-eastern Brazil, to compare road kill spatial patterns over time. We divided the dataset into two groups of species (cursorial and flying), as their different locomotion types might require different types of mitigation measures. The highway inspectors collected road kill data daily for thirteen years (2004-2016). We separated the road kill data in thirteen datasets of cumulative years (1st year, 1st and 2nd year, and so on until the complete dataset of thirteen years). We used the K Ripley's test (initial radius of 500 m, radius increase of 500 m, 100 simulations of random distribution and 95% confidence interval) to determine if road kills were aggregated along the highway. We used the 2D HotSpot Identification analysis (radius of 500 m, 100 road divisions in segments of 665 m each, 1000 simulations of random distribution and 95% confidence interval) to locate these aggregations. Both analyses were available in Siriema software. The hotspots we considered were segments with a road kill intensity value higher than the upper confidence limit. We quantified the number of hotspots identified in each dataset and verified (1) the percentage of hotspots in the initial survey years that were also detected in the cumulative datasets, and (2) the percentage of new hotspots that emerged after data were accumulated from more years of the survey. When we compared the hotspots among the different datasets, we observed that more than 71% of the hotspots of cursorial animals identified in the first year of data appeared when we analysed the complete dataset (2004-2016), whereas for flying vertebrates this value was over 85%. Additionally, after three years of data collection, only about 33% of the identified hotspots were new, the proportion that remains constant up to the complete cumulative dataset (thirteen years of surveys) for flying animals, but value decreases to approximately 15% for cursorial animals. These results indicate that resources applied in the implementation of mitigation measures based on hotspots identified in the first year of data collection would be well applied, since the vast majority of these hotspots continue appearing after several years accumulating data, at least within similar landscape contexts and survey procedures. Furthermore, the long-term road survey carried out for several years allowed the identification of a few new hotspots, indicating that long-term studies are also essential to mitigate new areas of road kill aggregation, especially for flying animals.

Multiple-criteria analysis for the definition of viability corridors for railroad expansion

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The Brazilian railroad network encompasses more than thirty thousand km, where approximately 500 million tons of cargo is transported annually. Since the 1990s, the federal government started to privatise the construction, maintenance, and operation of railroads. VLI Logistica, a corporation that operates in Brazil, is responsible for more than ten thousand km of the existing railroads. The railroads operated by VLI are located in regions of Atlantic Forest, Cerrado, Caatinga, and Amazon biomes, areas with high biodiversity and conservation value. These railroads were built between 1904 and 1996, an era with geometric designs that are now old, and different construction and logistic limitations from an operational perspective. However, from an environmental standpoint, most of these railroads were projected and built in a time without environmental concerns. Nowadays, the environmental perspective is a reality for the transportation sector in Brazil. Not attending environmental criteria limits a project or the operation of a railroad. Considering the extension and the temporal and geographical diversity of its railroad network, VLI has know-how that is not limited to the overcoming of adverse situations in the railroad operation and maintenance. Their actions also focus on predicting situations of environmental impact to anticipate solutions that minimise damages and costs. VLI actions agree with the need for modernisation in the transportation planning process. The current environmental policies, that direct transportation planning, are broader and more complex compared to the ones from the past. In the recent scenario, the maturity of remote sensing and geoprocessing systems allows the development of modern and integrated solutions for better planning of the transportation system, such as the use of multiple-criteria analysis for the definition of viability corridors for railroad construction. We present the example of a partnership between the Federal University of Minas Gerais and the company VLI Logistica to improve the planning of the railroad expansion. Because of this partnership, it was possible to study the environmental viability of a planned railroad. The study was developed in a Geographic Information System fed by official public databases. We developed an approach based on geographic intelligence focused on the anticipated identification of environmental impacts to be avoided and minimised. With a multiple-criteria analysis, different spatial layers were overlaid and integrated into this process and were modelled with decision rules based on the interpretation of legal regulations, on knowledge of environmental constraints, and socioeconomic, logistic, and market attractors. This type of analysis integrates a broad set of variables to support decision-making. This innovative approach agrees with the new view that is being promoted by VALEC – the national agency responsible for railroad construction in Brazil – and TCU – the national agency responsible for supervising government spending. The resulting viability corridors were satisfactory because they optimise the decision-making process at the planning stage. Furthermore, the modelling results channel efforts for road planners and engineers towards the project design.

Integrating Multiple Methods for Tracking Shoreline Change Resulting from Sea Level Rise

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Shoreline habitats and infrastructure are being negatively affected by sea level rise (SLR) and extreme events. As global temperatures continue to rise, these impacts will become more severe. The ability and way in which governments and individuals adapt to SLR could have profound consequences for adjacent ecosystems, transportation systems, and urban settings. The costs associated with implementing adaptations will also increase over time. Natural systems often weaken impacts of SLR and storms, providing a free, often un-recognised and under-appreciated protective service for shoreline infrastructures. In San Francisco Bay, CA, SLR has exceeded 20 cm over the past 100 years. In US coastal areas, it is likely to rise by at least another 30-45 cm by mid-century. However, there is no current information available to shoreline agencies on fine temporal and spatial scale changes in shoreline ecosystems and infrastructure in response to SLR. This rapid rate of SLR means that it is essential to include planning for infrastructural modifications in current transportation plans. Accurate and timely information about the actual extent of SLR impacts to shorelines will be critical during transportation adaptation. To provide this critically needed knowledge, we describe an approach composed of four interacting methods to monitor shoreline and infrastructure changes in response to SLR across a wide range of time and space scales: (1) Time-lapse cameras for two years along coastal areas in two US states to track low and high tide inundation. We have found that the method was sensitive to vertical changes in sea level of <1 cm, roughly equivalent to 1-2 years of SLR under the current global trajectory. The method described is possible for a near-term (1 to 10 years) and a long-term application and can be used for measuring fine-resolution shoreline changes (e.g., the degree of inundation, plant cover, and geomorphology) in response to SLR and storm events. (2) RTK-GPS (real-time kinetic geo-positioning systems) is being used in transects across tidal marshes adjacent to and independent of infrastructure to measure inter-annual changes in elevation. This method has very high vertical resolution (1 cm), but because of effort requirements is typically only carried out on an annual timeframe. (3) Drone-based terrain-mapping to repeatedly monitor sample areas. This method has high vertical and horizontal resolution and is practical for monthly and post-event monitoring in order to track medium (<1 year) and long-term geo-morphological and vegetation cover changes. (4) Visible and infrared satellite imagery and airborne hyperspectral imagery to provide historical shoreline data and automatically and manually identify areas and degree of shoreline change. This method has low spatial resolution in comparison to drone-based mapping, but is freely available and can be carried out over very large areas. The outputs from these techniques are being used to validate commonly-used models of SLR threats to coastal systems and inform transportation, conservation and regulatory decision-makers. These approaches provide a critical missing piece in the assessment and decision-making process of SLR adaptation in shoreline areas.

Parkway A2: An integrated approach to nature and landscape

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Restructuring of existing transport infrastructure, such as highways and canals, may offer possibilities for resolving bottlenecks in ecological networks and improving landscape quality. The case of the project A2 Het Vonderen – Kerensheide in the Province Limburg in the Netherlands, is an example of an integrated approach to road design, nature, and landscape. Ecological principles, engineering and landscape architecture, are combined in designing mitigation works. Added value is created when different disciplines and stakeholders work together. The road and its surrounding landscape are conceived as a parkway. The parkway is a spatial concept that is visible on both sides of the highway. The parkway combines different functions, such as water retention, recreation, noise reduction, biodiversity and cultural heritage. The purpose of the parkway A2 is to create a park-like experience that reflects the diverse topography of the landscape. At the same time, the parkway conceals the highway from the surrounding area, with continuous plantation on both sides of the highway. The road verges and parkway can become a biotope or refugium for diverse wildlife species. Two crossings with the highway and one with a canal that is part of the Dutch Federal Defragmentation Programme are located on the trajectory. The corridor "Geleenbeek" is a bypass of the small river Geleenbeek and crosses the highway A2 and the Juliana Canal. The east-west connection "Den Uil" connects the river Maas with valuable nature reserves in the east of Limburg, for target species as roe deer, polecat, ermine, badger, weasel, tree marten, and wildcat. The parkway functions as an ecological corridor for the fauna-passages and is in turn part of the larger regional environmental network. The design of the parkway shows different forms and densities, depending on the surrounding landscape. These forms range from dense woodlands to a transparent form with solitary trees and species-rich grasslands in the open landscape. The parkway fits into the gentle slopes of the terrain and integrates existing structures, such as (remnants) of historical planting and tree lanes. In this way, the parkway A2 and the fauna passages counteract habitat defragmentation and contribute to the establishment and maintaining populations. While the parkway includes necessary compensation measures for woodlands and nature, one of the lessons learned is that nature compensation finally needs to fit into legal and policy frameworks. A coherent package of measures for the loss and defragmentation of nature is developed. The process of planning and design is an example of cooperation between different disciplines and stakeholders.

Evaluation of mitigation measures for a high-speed railway line with a strong amphibian challenge

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On many subjects, knowledge in Railway Ecology is weak or missing. The effectiveness of amphibians' wildlife crossings is poorly studied despite the fact that amphibians are strongly impacted by linear transport infrastructure through habitat fragmentation and direct mortality. ERE, the contractor of the High-speed railway line (HSR) "Bretagne - Pays de la Loire (BPL)" in western France and inaugurated in June 2017, wanted to know more about mitigation measure effectiveness for amphibians' community. HSR BPL's environmental observatory has drawn up a research program to assess this question. The landscapes crossed by the line are rather heterogeneous, mixing several types of habitat with woodlands, pasture meadows, cultivated fields and cattle ponds, the main aquatic habitat colonized by the amphibian community along the line. The minimisation and offset measures have been carried out in several locations along the route with the challenge of limiting the barrier effect for biodiversity, and in particular for 12 amphibian species. To mitigate the fragmentation effect, and limit the direct mortality, wildlife crossings (hydraulic structure and dry tunnel) were built under the HSR. Their characteristics (e.g. dimensions shape) were conditioned by construction standards and expected to be compatible with amphibians use. Fine mesh fences have been placed to prevent the intrusion of amphibians on the tracks and guide them to the entrances of crossing structure. Small ponds are dug near the entrance to increase its attractiveness. Finally, the ponds destroyed during the HSR's construction were replaced by new ones. In the frame of the research program, a monitoring plan has been implemented to evaluate these mitigation measures' concrete impact on the railway line's ecological transparency. Several methods are used simultaneously: (1) Four species (the Water frog, the Alpine newt, the Marbled newt and Great Crested newt) were individually marked with PIT-tag in order to evaluate the use of the tunnel (i.e. crossing from one side to the other of the HSR). This capture-marking-recapture (CMR) design will inform on the population functioning in the new network of ponds, and connectivity on both sides of the HSR; (2) The behaviour of amphibians when using the tunnel was studied with homing experiments: marked individuals were released in tunnel equipped with 4 RFID antennas laid on the ground. Several species (Common toad, Fire salamander, and newts) are tested in this experimental design. This combination of methods with multispecies monitoring aims at testing the effectiveness of the implemented mitigation measures, in order to assess the long-term amphibian community viability in fragmented landscape.

Decision support tool for tidal river bank management: Towards a more sustainable riverbank protection

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This study aims at establishing a framework for waterway managers to choose for suitable and sustainable bank protection measures in the Sea Scheldt estuary (Belgium). The main maintenance measure to prevent erosion currently consists of ad hoc strengthening the riverbanks by means of rip rap. This often results in over-protection of the tidal flats and marsh edges. However, this practice is expensive and threatens estuarine habitat functioning. Waterway managers feel the need for a more objective, sustainable and nature-friendly management strategy. In this study, sustainable bank protection means optimal use of ecosystem services, keeping in mind the preconditions for flood control and navigation. The basic principles for this decision support system are: (1) to guarantee bank protection; (2) to safeguard erosion-sensitive marshes, and (3) to provide sufficient space to allow a natural tidal marsh cycle. The chosen method advocates use of fortified bank protection where needed and enhances natural bank protection if possible. Nature-friendly bank protection (NFBP) provides an intermediate solution. This approach is cost effective and favours both the conservation status and the good ecological status of the estuary. Based on objective criteria – based on empirical evidence in the Scheldt system - the type of bank protection is selected in a decision tree, taking advantage of the natural protection against erosion provided by natural tidal habitats. Criteria are the width and slope of tidal flats and shallow water zone together with an index indicating a relative sensitivity to erosion of the tidal marsh edge integrating modelled ship wave exposure and water velocities. For the entire Sea Scheldt, the preferable bank protection at a specific site is mapped at a resolution of 50 m sections. This "bank protection atlas" is compiled through an automation in a geographical information system (ArcGIS). As a result of this tool, if erosion occurs, less tidal marshes should be strengthened by rip rap or alternative more nature friendly protection is possible. At present, the tool is implemented in the waterway management and based on a monitoring protocol the need for servicing the bank zones is determined. This protocol foresees in a desktop study of erosion maps and periodical field inspection.

Ecology in Practice: Improving infrastructure habitats along roads (EPIC ROADS) - A new CEDR project

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Habitats related to Transport Infrastructures (HTI) may reduce negative impacts on biodiversity and improve landscape connectivity, given their proper design and construction. Here the transportation sector can contribute to halt the loss of biodiversity and secure ecosystem services in Europe through, planning, construction and management based on ecological knowledge. A number of local and national initiatives for enhancing biodiversity in HTI, together with several scientific studies and recent reviews on ecological traps provide rich sources of experience and knowledge. However, there is an urgent need for compiling and synthesising such information to develop guidelines for improved construction and maintenance of transport infrastructure. To meet this need for praxis-oriented knowledge syntheses, the project has ambitions to deliver a set of practical guidelines that will outline principles for defining objectives and targets for planning, construction and management of HTI. These guidelines will address processes from the landscape, to the habitat and ecotone and will contain recommendations of how to increase connectivity, prioritise habitats and design ecotones to prevent ecological traps. How to generalise results across Europe, as well as how to identify regional differences are also central aspects. A framework for classification of HTI that can be used for assigning proper packages of management activities to different groups of habitats will also be developed. In addition, we will generate scientific review papers, and a paper based on a modelling study on the impact of roadside characteristics on landscape connectivity for different organism groups. We also attempt a meta-analysis on the influence of HTIs on populations and species diversity. To achieve this, we use systematic reviews of both scientific and grey literature based on literature searches of peer-reviewed literature and collection of experience-based information, e.g. documentation of inventories, monitoring, management activities, citizen-based data etc., at a European level using the CEDR network. Then we synthesise information widely across taxonomic groups including plants, insects and small vertebrates and translate the knowledge into guidelines and recommendations for HTI management.

The defragmentation programme for the provincial road network in the Province of Noord-Brabant (The Netherlands)

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Besides drought and eutrophication, fragmentation is one of the leading causes of the deterioration of the ecological significance of Noord-Brabant, as shown in *State of Brabant* nature reserves in 1996. The base for the defragmentation programme was the annotation on defragmentation (1998) that gave an idea of the fragmentation of nature reserves in Noord-Brabant by the provincial road network. This resulted in a list of 216 infrastructural barriers. The aim is to lift the infrastructural barriers by drawing up a plan for implementation, ensuring that the animals can walk undisturbed from one side of the road to the other, either under or over it. From 2001 until 2007, 216 bottlenecks have been eliminated resulting in approximately 360 different passages for fauna under provincial roads in Noord Brabant. This means that virtually every bottleneck identified by the province of Noord-Brabant in 1998, is now a thing of the past. Analysing these bottlenecks, the province focused on realising passages connecting the current and future nature reserves in Noord-Brabant, the so-called EHS (Main Ecological Structure), GHS (Main Green Structure), and EVZ (ecological connecting zones). Noord-Brabant developed a project book containing the project plan with sub-plans. The realisation of these plans was based on field research on target species, habitat types, figures of traffic accidents with animals, and technical possibilities. The province emphasised voluntariness to stimulate the defragmentation of the nature reserves in Noord-Brabant. For this reason, the province invested in the Mutual Gains Approach, consulting with different stakeholders, to wit agencies for nature and water management, the agricultural sector, estate owners, and private individuals. Several information sessions and so-called kitchen table-conversations eventually led to the achieved result, i.e., agreements with landowners about management and maintenance. In total, about 130 agreements were created. Additionally, in some areas, these tunnels and passages for wildlife have been a stimulating agent for the defragmentation measures at municipalities as well as at water boards. Nature management authorities also participated in the construction of nature-friendly banks, ecological connecting zones, and landscape components such as hedgerows, which bonds both with the new facilities and the extension of existing ecological connecting zones. The arrangement and implementation were project-based, with a project team covering the usual tasks and risks, including managing environment, contracts, technical aspects, and the project itself. Factors determining the success of any project include realistic planning and appraisal, and a sufficient budget. The recommendations were as follows: (1) Consider the entire chain from preparation and realisation up to and including the development of a management plan for the passages; (2) Communication, interaction, and using the knowledge of local stakeholders; (3) The vision of the management of wildlife reserves is pragmatic. The performance of the passages must be secured; (4) Developing a clay tunnel for wildlife suitable for several target species; (5) A monitoring program is necessary to demonstrate that the passages for wildlife meet the requirements of the target species in the area; (6) Target species come and go and depend on the design of the area. In the effect of the passages, wetting and drying out play a crucial role; (7) The defragmentation programme of the Province of Noord Brabant was intended to catch up on the existing road network. It is necessary to recalibrate the passages and to adapt them to the target species and the habitat in the area when reconstructing the roads to assure the optimal performance of passages.

Small links make great chains: how imposed local eco-measures trigger an entire hinterland (Rupelstreek, Belgium)

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A new road has been built to provide access to a company and resolve accompanying traffic obstructions. The road cuts through a biologically valuable nature network, alerting the Flemish Government to impose eco-measures in the building permit. These measures intend to avoid fragmentation and compensate valuable biotopes (reed, eutrophic lakes, willow scrub, and alluvial alder forest) that disappeared during the construction. Leading the process is POM (Provincial Development Agency). However, a mix of public and private partners and owners are involved. DMN has been asked for advice in designing and constructing these eco-measures in addition to the preparation of a management plan. A fauna passage (representative species = otter) is being created over a distance of 1.5 km. The passage connects the Rupel (River) with nature networks in the hinterland and includes an exit step (River), shrubbery and groves, wadis, grasslands, pools, water basins, two large and four small fauna tunnels, a bat cellar, and amphibian wall. Ideally, the entire structure should be maintained and managed as one. However, the fragmented ownerships complicate the situation. Despite holding no property interests, the Province is committed to achieving the task. This topic is already submitted for a full presentation ('Creating a simple solution for a complicated situation: Maintenance of a diverse eco-infrastructure network' (Niel, Belgium)). However, the commitment of the Province goes beyond that. It seeks for opportunities to work on a large-scale network of wildlife passages through all kind of human-made infrastructure elements (transportation infrastructures, business parks, new reclamations) in a broader region called Rupelstreek. This region has a strong local identity due to the presence of clay close to the soil surface and its corresponding long history of the brick industry. It has caused a highly distorted and fragmented landscape filled with quarry-like depths (now often natural areas with a lot of pools). Roads and other infrastructures are located higher. The Province fulfils this task by encouraging and financing studies, finding grants, giving advice, raising awareness, creating policy frameworks, bringing together the right partners, stimulating green business areas. The goal of the poster is to demonstrate all defragmentation initiatives that are going on in the Rupelstreek. With each initiative, the parties (public, private, and other) that are involved and on which representative species or kind of connection they work will be mentioned. Additionally, we will refer to the studies that are ongoing and where there are missing links to accomplish a large-scale network of wildlife passage. The poster will include a large aerial photograph on which the network that has to be realised will be printed. Arrows will indicate frames with pictures and brief explanations of the achievements, studies, other opportunities, and missing links.

Permeability of roads for wildlife in the cross-border area Beskydy - Kysuce

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While motorways represent, due to their technical features, physical barriers to the free movement of wildlife, the barrier effect of 1st and 2nd class roads is the result of the high traffic levels, especially in the night hours. To better understand the barrier effect of these types of roads, an extensive monitoring of traffic flow was carried out at selected locations and its distribution patterns over time were then analysed within the Transgreen project (Interreg Danube programme; no. DTP1-187-3.1-TRANSGREEN). Examined model area extends over cross-border territory of the Czech Republic and Slovakia and in the Beskydy, Kysuce and Malá Fatra Mountains. This area is home to the westernmost Carpathian populations of bear, lynx and wolf. The transportation is one of major threats to the existence of local populations because of their low population density. A total of 38 sites have been identified on important roads on both sides of the border, where an AVC resulting in death of carnivore was recorded or where is known that animals regularly use the migration corridor to cross the road. At each of the locations, all passing vehicles were recorded by the Sierzega Traffic Detection Device SR4 for a period of 168 hours. Subsequently, the traffic intensity patterns over time of day were analysed from collected data on the basis of gaps between individual records. Four categories of permeability have been proposed to represent the predicted behaviour of the animal in relation to the traffic (Class 1 - permeable, Class 2 - repelled, Class 3 - disturbed, Class 4 – collision and probable roadkill). Every second of the total measured time (604,800 seconds overall) was assigned to one of the four categories above, depending on its position in relation to the passage of individual vehicles. The permeable time (Class 1) was defined outside the interval of 5 seconds prior plus 40 seconds after the vehicle passage. In the case of several vehicle passages in the period shorter than 45 seconds, the class respective to the shortest gap was assigned. The share of individual categories in the total time is then the final evaluation of the road in terms of its permeability split by individual hours of the day. The results confirmed that the lowest permeability can be expected on 1st class roads included in the European system. Especially during working days traffic on the roads does not stop even in late night hours and the busiest roads are permeable in less than 25% of the 24-hour period. In the daytime, the intensity is so high that there is no way to expect any permeability. For less busy roads, only those with a calculated AADT around 1,500 vehicles and less were classified as permeable in at least 40% of the daytime. During late night hours, when the traffic intensity was significantly reduced, the share of permeable time has reached at least 60 % on all roads outside the European system.

Dispersal potential of badgers and the importance of badger tunnels

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Badgers living along highway A27 near Hilversum, the Netherlands, were studied to protect them during the reconstruction of the highway. A total of 16 badgers were followed with GPS-collars, which collected detailed information on their ranging behaviour, assembling altogether almost 50,000 fixes. Badgers lived in group territories on both sides of the highway. Sometimes badgers made excursions from their own territory, visiting neighbouring territories or making long exploratory trips. Some of these excursions are presented in the poster. Such long trips illustrate the dispersal capacity of the badger, which is otherwise a conservative, sedentary species. In our densely populated country, badger tunnels (plus the accompanying fences) under highways, lower grade roads and railways allow the badgers to safely reach new habitat or other badger populations, thus securing gene flow. The tunnels and fences in the study area have led to a spectacular population increase, from 4 individuals in 1983 to at least 300 in 2015. The badger tunnels are used by other species as well, such as pine marten, polecat, rabbit and red fox.

Online user-friendly management plans at a wide scale

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During the LIFE Elia-RTE project, natural habitats in high-voltage right-of-ways were restored or created on a wide scale in Belgium and France. A suitable management plan was planned to guarantee that the value of these habitats will be maintained or will increase with time. The management of the sites involves many kinds of stakeholders such as the Transport System Operator (Elia in Belgium, RTE in France), farmers, the forest and nature administration, hunters, municipalities, private owners, etc. We decided that management plans should be accessible to each manager, everywhere (including on-site or during indoor meetings) and should be understandable by non-professionals because of the diversity of contexts. We used open-source tools to build a web-accessible platform containing many useful documents (from technical to communication documents), an interactive web map leading to all needed information, and a timeline describing the timing for management actions. The main advantage of this kind of presentation is that the content may easily evolve as it is automatically produced from a structured database. Moreover, it is based on low-cost tools that are continuously improved by the open-source Internet community. The administrator of the platform can be changed easily on the condition that a new administrator learns the basics of the system (lots of tutorials and books are available online). The feedback earned so far is that the tools allowed a dynamic, comprehensive and illustrated presentation with minimal preparation. Each stakeholder is permitted to use this resource since they have bookmarked the web link.

Measuring bat activity in forest power lines right-of-ways

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Biological monitoring is a process, which is addressing different goals such as the quality of habitats by assessing species populations or measuring the effect of management of habitats. It is achieved by measuring species diversity and richness and detecting rare or patrimonial species during repeated standardised inventories. A method was developed to monitor bats in the context of a LIFE project aiming at increasing the quality of habitats in forest right-of-ways created by overhead power lines in Belgium. We wanted to assess species diversity and the level of activity to evaluate the value of encountered habitats in electric network dependencies. We recorded bats ultra-sound signals during four years on 44 sampling points with a standardised method, and we developed a process of semi-automatic measurement of activity with an open-source environment. Our process evaluates the type of individual activity (hunting, moving, social interaction) in addition to species identification, which allows us to compare results with published data. We detected more than nine bat species, including three species in the Natura 2000 directive of patrimonial value in the European Community. We stress the importance of R-O-W of power line network for feeding and travelling for most of the bat species. The level of activity we found is comparable to the activity measured in high-value grasslands published by Barataud (2013). By differentiating the bat-use of habitats, we can propose new strategies for vegetation management of electricity transport operators to increase the biodiversity in dependencies. We compared species richness, diversity index, and level of hunting activity in the light of ecological parameters and structure of habitats. These comparisons characterise the distribution and the environmental requirements of bats in forests.

Convincing significant industries: A case study on the set up of a cost-benefit analysis and communication tools under the high-voltage network

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It is widely known that the high-voltage network is part of our landscape. Wherever this network crosses wooded areas, trees can quickly become a significant problem for the network safety as they continuously grow. To ensure the security of the network in wooded areas and the subsequent safety of electricity supply, Transmission System Operators (TSOs) who are in charge of the network management should control the security of the infrastructures: pylons, HV lines, and substations. Therefore, no trees or branches should fall on or touch the cables. The challenge for the maintenance team is to guarantee maximum safety while striving to save money. Vegetation management is mostly carries out by regular mulching or manual tilling. However, it has two main consequences: it creates an open space free from vegetation, and it enriches the soil by providing nutrients produced by the mulching. Eventually, these consequences are the best way to promote the regrowth of the species the TSOs are fighting against. The seeds from pioneers tree species coming from neighbouring forests will find a perfect place to germinate and grow quickly, benefiting both from full enlightened and richness of the soil. The idea followed by the LIFE Elia-RTE project (2011-2017) is that we can change our point of view and consider vegetation as an ally rather than an enemy. By a set of alternative actions, it is possible to combine electrical safety with biodiversity. These actions are also involving local stakeholders, which contributes to increasing public acceptance. However, it takes a lot of effort for the TSOs to make the shift regarding vegetation management. Existing procedures have to be modified, teams need to be trained, and the market has to be adapted. Two significant tools were set up to convince large companies such as TSOs: cost-benefit analysis and communication. A cost-benefit analysis showed that these methods were cheaper (1.4 to 3.9 times on thirty years) than the ongoing vegetation management. Other benefits such as better social acceptance, landscape improvement, or better relations with authorities - much harder to determine - are included in the analysis. It is of utmost importance to do what we say and to say what we do. Communication tools have been designed to reach TSO staff, subcontractors, stakeholders, and the general public. Best-practices documents, booklets, training, on-site didactic panels, watching towers, conferences, articles, and other tools contributed to the deployment of the project. Furthermore, the project has launched a networking campaign towards TSOs. The team is in contact with seventeen TSOs and has organised a two-day event in Belgium that gathered forty people from all over Europe. A partnership with these TSOs leads to the exchange of vegetation management best-practices and the creation of pilot sites to test LIFE Elia-RTE methods.

A six-lifestyle grid to interpret cumulatively (diffuse) impacts of high-speed railways (HSR) on wildlife-relationships (organism interactions / population-to-individual links)

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Land transport infrastructure (LTI) projects, such as High-speed railways (HSR), impact biodiversity throughout time (land-buying, building, exploitation, etc.). Strategic-impact studies and scientific literature show effects on biocenosis at a fine scale that can be grouped into five categories (road kill, barrier-effects, habitat-loss, pollution and invasive species). While models have been proposed to show diffusion of direct, indirect, induced and cumulative impacts of LTIs, 'diffuse' impacts all along HSR projects can now be taken into account in a global perspective, especially fragmentation and landscape change. Though, apart from direct barrier-effects, studies tend to show that fragmentation is relatively limited in space, whereas the decreasing of biodiversity (populations of birds, insects, etc.) is spatially massive. How can we disentangle the effects of LTIs, at an enormous landscape scale, from industrialisation and urbanisation? Therefore, we propose to interpret LTI cumulative effects on biodiversity and wildlife among 'diffuse' criteria, such as organism-to-environment interactions (basic needs), organism-to-organism relationships (competition/mutual-aid), and population-to-organism links ('learning' periods in eating, housing and reproducing).The methodology consisted of a literature review about LTI impacts on wildlife and biodiversity. We then built a global analysis grid, based on life-activity potentials on Earth, by inter-crossing atmosphere, hydrosphere and lithosphere with biosphere, which altogether drew six central living interaction potentials, that we completed with five criteria (in column: significant landscapes -river and lake, shore and isle, etc.-, micro-habitats -skin, bark, etc.-, physical factors -light, temperature, etc.-, life-forms of productivity -herbivores, predators, etc.- and naturalist categories -benthic, pelagic, etc.). Our first results from literature review led us to propose a three-item grid (feeding; resting; reproducing) to analyse LTI impacts on wildlife and biodiversity (road kill that causes diffuse impacts firstly on feeding-chains; fragmentation, which diffuse-effects first impact resting activities; and pollutions that impact diffusely at first reproduction). Then, the analysis grid lets us hypothesise potential diffuse impacts on competition/mutual-aid interactions (inter- and intra-specific). Indeed, as LTIs kill animals, populations tend to be replaced by ones of other species with a relatively constant total of biomass. They also fragment landscape (habitat-loss plus barrier-effects), the loss of vegetation leads globally to a decrease of animal populations, but with no certainty of species replacement. Lastly, if the spread of pollutants can lead to species replacement (by causing infertility), it thus affects the total population of the ecosystem (except for some resistant organisms that also wouldn't feed on organisms). Finally, the general scheme allowed us to evaluate qualitatively (with a 'fuzzy-logic' approach) the loss of living potential interactions due to LTIs. It suggests that landscape change profit to species that can quickly adapt due to longer 'learning'-periods (weaning, housing, fertility) especially as for changing the 'intestinal flora'. An expected result is yet also a table of learning-periods, for the seventy-four protected species recorded in the legal 700 meters around the Bretagne – Pays-de-la-Loire (BPL) HSR in western France (built in 2012-2017). The active interest of our grid is to anticipate diffuse impacts of LTIs that may have not yet been identified, due to inevitable lacks in environmental information.

Successful implementation of ecological measures in road construction: From burden to added value

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In 2011 the 'Combinatie Buitenring' consortium started the construction of the 26 km ring road 'Buitenring Parkstad Limburg'. The consecutive six years the contractor was responsible for dealing with over 40 strict protected flora and fauna species within the project boundaries. This included the dos and don'ts concerning ecological and juridical requirements. A solid implementation of mitigation and compensation measures in the project organization was achieved by teaming up with experienced ecologists, putting ecology on the daily agenda, creating awareness among project members and propagating the organisations' environmental efforts. This resulted in less planning risks and failure costs, effective minimization of the impact on protected species and areas, the contribution to a positive image of the organization, the support of environmental stakeholders and local communities and a more than satisfied client. The aspect of ecology developed within the project organization from a top ten risk to an essential part of project management from which the project organization, as well as the local (natural) environment, did benefit. Critical factors for success: proactive 'hands-on' experienced ecological support on all levels in the project organization, taking time to invest, involvement, respecting and recognizing different interests within the organization, clear overall communication skills, sharing ecological knowledge and enthusiasm.

How river lampreys deal with the weirs, locks and fish passes in the fragmented river Scheldt, Belgium

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In the past century, most migratory fish species have disappeared from the cross-border river Scheldt (Belgium) due to human impacts. Since the second half of the nineties, a river lamprey population has been trying to re-establish, which could be the reason for the disappearing migratory fish species. Due to migration barriers, it is unclear if they can reach potential spawning grounds and nursery habitats. River lamprey is an important indicator species for the integrity of the ecosystem and connectivity within the Scheldt catchment area. The estuary of the river Scheldt extends from the mouth at Vlissingen (The Netherlands) to Ghent (Belgium), where the first river obstruction, a sluice-weir complex, impairs the tidal wave in the Upper Scheldt. Weirs equipped with shipping locks actively fragment the non-tidal part of the river Scheldt between the French-Belgian border and Ghent. Lampreys have to negotiate the tidal lock-weir complex in Ghent to reach the non-tidal part of the river. During high discharge and high tides, the tidal weir is wholly lifted creating opportunities for upstream migrating fish to pass the free-flowing tidal weir. During the last decade, two nature-like bypasses were built at upstream weirs. Lampreys were caught during several dyke sampling events at the tidal weir, upstream weirs, and in traps in the fish bypasses alongside the weirs. The migration patterns and behaviour of river lamprey were studied with acoustic telemetry in 2010 and 2011 (nine individuals tagged), and in 2011 and 2012 (32 individuals tagged), always between December and May. The acoustic transmitters were inserted into the body cavity. After recovery, the lampreys were released. Lampreys were tracked by 46 submersed acoustic receivers that were located on strategic positions in the Scheldt, its tributaries, and in the fish bypasses. These receivers captured and logged the acoustic signal of the transmitters. Based on their migration patterns the 41 tagged lamprey could be divided into different groups. We report on the migration of these groups of lamprey, and we illustrate how far upstream they penetrated into the River Scheldt basin. We evaluated searching behaviour and passage success at lock-weir complexes with and without nature-like bypasses. The long delays at weirs suggest that the bypasses do not have optimal attraction efficiencies and thus negatively influence condition, reproduction, and survival (i.e., predation risk) of river lampreys in the river Scheldt. Based on the results of this study, we can conclude that changes in fish pass management are necessary to increase the attraction and passage efficiency. We need better management of the (tidal) weirs and sliding doors at the inlets of the fish bypasses, and adjusted water management of the river Scheldt to assure free and permanent fish migration.

Evaluation of green infrastructure along canals as aquatic habitat for fish populations

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Although the chemical water quality improved substantially during the last decades, many waterways in Flanders (Belgium) still show a poor ecological quality. Since habitat loss and fragmentation are widely accepted as the key factors affecting the ecological status of waterways, additional efforts are needed to achieve the objectives of the Water Framework Directive. Such efforts include the use of ecological bank protection techniques, considering economic preconditions such as navigation. Canal banks are particularly relevant for restoration since their reinforced banks form a significant migration barrier between the water environment and the riparian habitats. Efficient allocation of these efforts thus requires a sound evaluation of the different restoration projects and therefore contributes to sustainable water management in Flanders. This study evaluates the suitability of green infrastructure, more specifically shallow water zones, as an aquatic habitat for fish communities in three different canals. Furthermore, it evaluates different riparian habitat types (concrete, gabions, ripraps, eroded banks, grasslands, marsh vegetation, reedbeds). The results indicate that nature-friendly banks provide the best habitat for juvenile and adult fish. An appropriate construction and management of the shallow water zones, maximizing heterogeneity in depth, bank structure, and vegetation cover, is a crucial factor for their efficiency. Meanwhile, shallow water zones are an anchorage for the more sensitive species. A relatively high number of species was observed in the canals (between 12 and 23). At least half of this number developed a healthy and sustainable population. The results confirm the importance of nature-friendly banks for the development of populations since the majority of species and the totality of the sensitive species are exclusively observed near shallow water zones. These riparian structures seem to have a high efficiency thanks to high habitat heterogeneity. Shallow water zones also enhance the potential of the reaches further downstream and act as an anchorage for populations of marine (seabass, thin-lip mullet), catadromous (eel) and amphidromous species (flounder).

Modelling wildlife road kill hotspots in Flanders using citizen science data and surrounding landscape characteristics

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Roads are vital for the economy and growth, but have adverse effects such as habitat degradation and loss of biodiversity through wildlife road kills and landscape fragmentation. In Flanders (northern Belgium), mitigation measures are proposed at a regional and a more local scale, based on current knowledge and a dynamic tool with spatially modelled priority locations for defragmentation. However, there is still an incomplete understanding of the factors responsible for high road mortality. We used a large dataset of wildlife road kill observations (approximately 52,000 records) to model wildlife road kill hotspots in Flanders. We had the following hypothesis: in addition to the road type on which different kinds of animals (large and average mammals, bats, birds) were killed, the surrounding landscape has a crucial effect on road kill hotspots in Flanders as well. We drew circles of different radiuses around the road kill locations to determine at what scale the landscape had the most significant effect so we could include the landscape effect. We will present the preliminary results of the model, including some challenges and open questions. By the end of 2019, we will use the final results of the model to update current guidelines and tools for road kill mitigation in Flanders. The application of the model can also be used in other regions around the world.

Evaluating the Egnatia Highway as case study of environmental policy on transport development towards securing ecological connectivity for wildlife in Greece

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Aiming on preserving the earth's living environment for future generations the "grey" - "green" infrastructure harmonized coexistence is of tremendous importance. The Egnatia Motorway development with its Vertical Axis in Greece, is such a case. This case shows that a significant factor that needs to be taken into account on transportation projects' planning is the dynamics of the wildlife species' populations as the increase of the brown bear population and distribution in Greece. In the critical bear habitat of the Egnatia Motorway Grevena – Panagia section (section 4.1) almost 50% of the length has been covered by mitigation measures. A 34 km-long section of the motorway is finally 40% covered by 13 tunnels (500-2,400 m length range) and 10% by 10 viaducts (150-600 m length range). In another section of the Motorway (Vertical Axis 45 of Siastista-Kastoria-Krystallopigi which connects Egnatia Motorway with the Albanian borders) the presence of brown bear was insignificant during its design. In both motorway segments, despite the existence of mitigation measures, the initial typical fence was inappropriate to avoid significant numbers of road accidents with brown bears, so in a later phase a series of additional measures have been taken, such as special motorway fencing and fauna crossing alerting signage for the drivers. Towards overcoming the initial difficulties on planning changes on an overall three-level approach has been implemented: a) The re-designing of the alignment with a significant increase of special mitigation measures especially in the initial phase of motorway planning, b) The implementation of a special wildlife monitoring program, and c) The implementation of several operational protection measures. Egnatia Odos SA in cooperation with IENE evaluates and presents the Egnatia Motorway case and the lessons which can be extracted from its planning, construction and operation in Greece in the last twenty years towards shaping a roadmap on translating scientific results and technical decisions into recommendations and their implying to policy and applied biodiversity conservation on ecological connectivity issues. Our evaluation as main objective based on the comparison of the all stages from the planning until operation in combination with the general principles of IENE for environmentally sustainable linear transportation infrastructure. The overall framework of conclusions can include the following: (1) The "coalition" between technocrats and environmentalists in a win-win situation and non-stop procedure. (2) The implementation of the ecosystem approach in all development plans following the demands of the local habitats' landscape and adopting the principle of "any case is a unique case". (3) The recognition of Ecological Corridors as basic "green" infrastructure sections in combination with the dynamic of the wildlife populations and especially with their potential recovery. This factor designates the importance of the ecological cohesion of Natura 2000 network. (4) Prioritizing the selection of Avoidance-Mitigation-Compensation in "grey" infrastructure design. (5) "Isolated" measures cannot be evaluated as solution to achieve the ecological connectivity between two sides of a road. A system of measures is needed to be established and functioned in a long-term procedure.

Long-term studies of the impact of WVA on rare mammal species, advised in education and planning

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With just a few thousand wildlife-vehicle accidents (WVA) registered per year by the Lithuanian Police Traffic Supervision Service, their impact on mammal diversity would seem negligible. As a result, there is a limited official appetite for State bodies to allocate funds for animal safety structures, nor is there much public attention to the problem other than to human casualties resulting from WVA. We intend to present how the results of 11 years of observations of unregistered WVA on the roads of Lithuania differ from the official data. Moreover, we want to present the results of 4-year-long constant monitoring of a 65 km stretch of the main road. Our results indicate that official WVA data underestimate the true impact and mostly relate to cases concerning human safety and vehicle damage compensation (15 mammal species, primarily ungulates). Our long-term observations (31 species) and the four-year monitoring (16 species) indicate a more significant impact on mammal diversity and a significant impact on rare species. Long-term observations and monitoring both emphasize the WVA impact on populations of common species, such as raccoon dog, red fox, and marten species, exceeding or adding to the impact of hunting and on Eastern European hedgehog. For all these species, WVA has a regulatory effect on population size in certain years. In particular, the monitoring effort shows a particular impact on the European hare, badger, European polecat, pine marten, stone marten, Canadian mink, and Eurasian otter. There are six Red Data or rare species involved in WVA in Lithuania. We have already proposed changes in the moose-hunting quota as the only viable immediate possibility to reduce risks to human safety. We propose: (1) to change the approach of evaluation of WVA, putting emphasis on diversity and population impact, (2) to involve citizen science activity, the only possibility to collect data without significant financing of monitoring activity, and (3) to use monitoring and long-term observation data in planning of road safety infrastructure. The European bison and Eurasian otter could be used as flagship species.

Kill the killer

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The roadside spread of invasive species is a menace to biodiversity. Garden lupin (*Lupinus polyphyllus*) is one of these invaders, posing a threat to many less competitive native endangered species. The Swedish (and many other countries) transport administration(s) needs easy methods to root out garden lupin, making this a critical study. Lime may be a useful weapon in the armoury. Garden lupin, native to the western parts of the North American continent, has been introduced in Europe and other parts of the world since the 19th century, primarily because of its decorative beauty. Today, garden lupin is widely spread throughout the European continent, and because of its aggressive spread, the species is considered to be invasive. It tends to grow in dense stands suffocating most other species, causing a drastic decline in biodiversity. We must act now before the problem escalates further. The longer we wait, the more expensive it will become. In Sweden, garden lupin is mostly occurring along roadsides, lanes and in meadows. Roadsides are a suitable habitat to many species, but they also work to spread garden lupin to new areas, both on a local and a landscape level. Since many less competitive endangered species thrive in the same habitats, the importance of putting this spread to a halt cannot be stressed enough. Unfortunately, we currently lack knowledge of effective and cost-efficient methods to do so. Garden lupin tends to be calcifuge, cyanobacteria that live in metabolism. But the plants' root system seems to prefer a more acid environment. This provides the foundation of this study. We want to add to the knowledge of how garden lupin reacts to high basic conditions in the ground along roadsides. This will give us an insight into new methods to manage garden lupin and reduce its spread. It seems that garden lupin prefers an environment where the acid level is beneath seven on the pH-scale. Therefore, we have exposed different plots in a colony of garden lupin to various basic levels, raised above seven on the pH-scale by using lime. By doing so, we expect to see physical results within the plots. We hope to establish a level where regrowth of garden lupin is efficiently reduced, to find the regrowth barrier and reduce the distribution of garden lupin. We are in an early phase of a multiple-year case study. Results of our experiment will be updated during the upcoming summer and autumn. Other significant considerations for choosing lime in this study are, for example, the availability and cost of lime, possibilities to handle and spread lime along roadsides, and the environmentally friendly character of the matter. In addition to the result of the ecological effects of treatment, results of the best practice analyses such as cost and availability of lime, best technique for handle and spread of lime of different origin and texture, logistics, etc. will be presented.

Artificial nighttime lighting influences the use of wildlife crossing structures by insectivorous bats in Southeast Australia

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Barrier-to-movement impacts of roads on nocturnal species, such as bats, may be amplified by the presence of artificial nighttime lighting. Wildlife crossing underpasses are often used to reduce road impacts. However, the new design of installing lights in underpasses for human co-use may reduce underpass use by bats. In this study, we designed a before-during-after-control-impact experiment, in which we introduced light to these structures to evaluate if the presence of light alters bat activity. We monitored the level of bat activity under and above underpass bridges and culverts along a major freeway in Victoria, Australia. When lights were introduced, bat activity was lower under the structures but higher above the structures. This suggests that bats actively avoided the lit passageway, even if that meant potentially accessing 'unsafe' habitat such as a roadway. Light can have a significant impact on the behaviour and movement of insectivorous bats. Where possible, lighting should be avoided around critical bat habitat and in crossing structures actively used by bats.

What are we not seeing? Impacts of a short and narrow road on wildlife

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Short and narrow roads are generally overlooked when evaluating road impacts on wildlife, but they may cause significant damage. We aimed to assess the impact of a short two-lane road (CPM road) on wildlife, by monitoring vertebrate road mortality and comparing our results to an extended four-lane road (SP-348). We collected roadkill data along CPM road from 2010-2016 and identified hotspots with significant roadkill aggregation. We identified hotspots conducting a 2-D Ripley K statistic, which identifies a non-random spatial distribution of roadkilled animals, and then a cluster analysis (2-D Hotspots analysis). We estimated roadkill variation along the SP-348 (roadkill data from 2010-2014) by dividing the road into sections of 1, 5 and 10 km, and compared roadkill numbers and variation between sections, and roads. We recorded a high roadkill rate along CPM road. Mammals were the most frequently recorded group, and most species were considered habitat generalists (~67%); no threatened species were recorded. Three roadkill hotspots were identified, located at stream crossings where the road cuts across riparian forests, which are the remaining structural connectivity in the landscape. The average roadkill numbers in SP-348 was similar between different sections, but the variation number per kilometre declined with more extended sections. Spatial scale alone explained the high roadkill rate in CPM road when compared to SP-348. Nonetheless, when considering 1 km sections, SP-348 also presented high roadkill rates in some sections. Therefore, our results showed that even short and narrow roads can have considerable roadkill, which can cause substantial damage to wildlife, stressing the need to look at these types of roads carefully.

Scaling the importance of Roadless Areas to improve overall connectivity in Natura 2000 network

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Contemporary human demands have resulted in a mass and rapid expansion of road networks worldwide, whereas future projections indicate further, even more extensive, development of road systems. Spread of invasive species, changes in micro-environmental conditions and biochemical and topographic characteristics adjacent to roads, and increased mortality rates for many species are listed among main road impacts. At landscape level, one of the significant ecological impacts of roads is the loss of biodiversity. The decrease of landscape connectivity forms one of the most determinant road impacts, resulting in disruption of landscape processes and reduction of species abundance along with accompanying effects. Recognizing the need for preserving landscape connectivity, recent European environmental policy initiatives promote the protection of less disturbed natural areas. Roadless Areas (RAs) – natural areas of low anthropogenic disturbance at least 1km away from roads- provide many ecological benefits by safeguarding or even increasing connectivity, the ecological and social value of pristine sites, and providing multiple ecosystem services while contributing to climate regulation. Consequently, RAs could act as stepping stones to existing protected areas systems such as the Natura 2000 (N2K) network, consequently reinforcing their effectiveness and preventing further biodiversity loss. However, considering the anticipated difficulties entailed (additional funding, land use allocation etc.), a methodological framework for evaluating the individual contribution of RAs to connectivity is necessary to ascribe RAs a stronger conservation status in policy, planning and practice. Here we propose a method which makes use of existing graph-based software and habitat availability metrics, to evaluate the synergistic potential of individual RAs for improving overall N2K connectivity. Study areas in Greece, Estonia and France were selected to encompass, to a sufficient degree, the multiplicity of landscape configurations and characteristics of N2K networks in different EU member states and their last remaining RAs. Specific adopted criteria were the relative coverage of N2K and RAs in each country, mean size and number of RAs. First, we analysed the connectivity of N2K networks for three groups of species (having poor, medium and good dispersal ability) and identified the sites with the most significant contribution to overall N2K connectivity. Next, we identified those RAs that could provide synergistic effects for the coherence of the N2K networks under study. RAs were treated as new potential habitat sites and were therefore ranked based on the evaluated improvement of overall landscape connectivity in the examined networks. Through this approach, we demonstrate which RAs have the potential to act as connecting elements (new potential habitat sites, links or stepping stones) among protected areas, improving the connectivity of N2K. The proposed method could be used as a tool to support decision-making in landscape planning and biodiversity conservation, through the identification of critical RAs and quantification of their contribution to overall connectivity at various geographical contexts and under different conservation goals. Their preservation and successful management could counteract road impacts in a cost-effective and long-term way, while their integration in N2K could significantly improve the network's effectiveness and contribute to European environmental policy.

The French railway: Between ecological transparency and security of railway circulations

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Every year, the collisions with wildlife cause more than 200,000 minutes lost and affect around 8,000 trains. The wild boars and roe deer are causing essential damages on trains and cause extreme inconvenience for the travellers. Rabbits and badgers cause problems with instability of the platform by digging their dens. Therefore, they do not contribute to good relationships with the residents, farmers in particular. The collisions evolve according to: (1) species and their biological cycle (rutting season, births period, the dispersal); (2) seasons (spring/autumn); (3) moment of the day (dawn/nightfall); (4) hunting period; (5) type of crossed landscape. Every year, in autumn, we observe a peak of collisions. This can be explained as follows: (1) the coincidence between periods of animal activity and peaks of human movement, which is between 7 am and 9 am and between 5 pm and 7 pm; (2) the cereal harvests, which prevent animals from meeting their needs (refuge and food) in cultures; (3) the pressure of hunting around railways, from the onset of hunting season, which urges animals to go to find shelter somewhere else, instead of in their usually quiet housing environment. The problem is getting more prominent because of the ever-expanding population and the increase of externals pressure. So even if SNCF RESEAU took charge of this project for several years, on high-speed railways first and foremost, we still have to find new solutions for this problem. On classic lines and high-speed lines, the stakes are different. This is why it is necessary for us to identify adapted solutions considering several parameters such as the crossed landscapes, the configuration of the railway, the type of vegetation, and the type of protection equipment (fences). That is why we are working on the following projects: (1) security of the railway's premises (installation of new specific fences, strengthening or renewal of existing fences, temporary small repairs, adaptation of railings over ditches); (2) adapted management of the vegetation (reduction of appetent species, improvement of the visibility with a return to an herbaceous level, adapted management); (3) communication with the external stakeholders (state services about regulatory aspects, partnership convention with the national federation of hunters and residents); (4) detection devices (infrared cameras, drones); (5) exit devices for animals (springboard for deer, boar flap, escape sas); (6) methods to reduce intrusions (anti-intrusion cover, light reflectors, sound system to scare the animals, arrangements of bridges and structures supporting railway, and existing hydraulic structures to make them functional for the passage of animals); (7) the improvement of internal circuits of information (alerts by train drivers, maintenance technicians, monitoring of incidents, the creation of an application for traceability of the interventions of fauna regulators); (8) the regulation of the species which can engender an impact on the railway's security (with the implementation of fauna regulators, commonly used by lieutenants of wolf societies and hunter federations).

Graffiti Art Ecoduct Groenendaal

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Recently the realisation of Ecoduct Groendaal has been finished. This bridge is built across the ring road of Brussels (R0), the capital of Belgium. The Sonian Forest is very popular not only for the inhabitants of Brussels but for every Belgian citizen. The R0 highway is a very busy international road with many traffic jams every day. Building the ecoduct got much attention, not only of nature minded people but also of graffiti painters. Right from the start of the building process graffiti tags appeared on every blank concrete spot. Since the cost of removing graffiti is a very expensive measure and since this is also damaging the concrete we decided to turn the problem into a positive complement to the project.
We commissioned a Belgian muralist, named DZIA, who is nature oriented and offered him both sides of the middle pillar as canvas (each 300 m^2) to perform an artwork in the theme. The resulting graffiti shows different target species of the ecoduct: capreolus capreolus, meles meles, martes martes, lacerta vivipara, carabus auronitens putzeysi, myotis species and many others. Judging the positive reactions afterwards (by citizens, media and policymakers) we think to have added a little extra in making Ecoduct Groenendaal a landmark. We will show the old graffiti (before) and the new graffiti art (after). In addition, two time-lapse movies of the artist at work will be shown. Next to this, together with the artist, we also designed six different postcards to spread our message. These postcards are for free. Life + OZON is a collaboration between the Flemish Agency for Nature and Forest, the Flemish Agency for Roads and Traffic, the Environment Department of the Flemish government and Brussels Environment. The municipalities of Hoeilaart, Overijse and Tervuren co-finance the project. The 'Département de la Nature et des Forêts' (Wallonia), the United Nations Environment Program and the municipality of Sint-Genesius Rode support the project symbolically. The project runs with the support of the European structural fund Life+.

Migration permeability assessment of selected linear transport infrastructure in the Eastern part of the Czech Republic

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Habitat loss, avoidance, and fauna mortality due to construction and operation of linear transport infrastructure (roads and railways) are one of the primary factors causing landscape fragmentation. Landscape fragmentation has a negative impact on animal species. One of the requirements needed is the building of mitigation structures (underpasses, overpasses, culverts) on roads and railways. Therefore, the crucial question is necessarily related to the real permeability and the proper functioning of such structures. Many factors, e.g., the type of structure and its dimensions (openness index), terrain type either on or underneath the structure, location, and type of surroundings, play an inevitable role in the final usability and actual permeability for various animal species. Wildlife passages identification and assessment of their actual permeability for wildlife have been done in the scope of project DTP1-187-3.1 TRANSGREEN, funded by Interreg Danube Transnational Programme. The pilot study area primarily encompassed the Protected Landscape Area Beskydy and its great surroundings. It was delimitated especially concerning 1) main transport corridors, which connect the Czech Republic with Slovakia and Poland (e.g., TEN-T network), and 2) the presence of the most crucial mitigation structures in the area. The pilot area encompassed almost 5,000 km^2 including the main parts of two regions – Moravian-Silesian and Zlín, and marginally the third region, Olomouc. Inventory of mitigation structures, wider than five metres and outside the urban areas, was done on main railway corridors in the area. These include the following track sections: Přerov – Ostrava, Český Těšín – Jablunkov, Hranice na Moravě – Vsetín – Horní Lideč, and Přerov – Staré Město. Moreover, the inventory of mitigation objects took place on all motorways and first-class roads in the pilot study area. These are (part of) D1, D48, D55, I/11, (part of) I/35, I/47, I/48, I/49, (part of) I/55, I/56, (part of) I/57, (part of) I/58. Furthermore, culverts and underpasses on second-class roads were checked in the Protected Landscape Area Beskydy. All mitigation objects were inspected in the field and photo documented. Technical parameters, object type, and disturbance factors, e.g., the presence of barriers in the vicinity, terrain type on or under the object were recorded as well. We also noticed the presence of mitigation measures and their current status. We described and recorded each object into the GIS database. Based on these field checks, we have proposed the unified form with the description of current status of the object (actual migration permeability for different species classes), and the recommendation how to improve migration permeability through the object at the selected site. Knowledge and assessment of the status of existing mitigation structures on the linear infrastructure are a prerequisite to carry out further steps to improve the migration permeability for wildlife in the area.

Ecoduct Sandsjöbacka: Challenges and solutions when constructing an ecoduct over an existing highway

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Ecoduct Sandsjöbacka will be completed in the summer of 2018 and stretches over an existing highway with an average traffic volume of 65,000 vehicles per day. The ecoduct is located at the south of Göteborg at the Swedish west coast. The ecoduct will connect to a large Natura 2000 area and nature reserve directly west of the highway and will be adapted to suit a wide range of species, from larger ungulates such as moose, fallow deer, and roe deer to smaller animals such as dormice, sand lizards, and smooth snakes. We identified and compared three possible ecoduct sites during the pre-study. The selected location had the best precondition of constructability, high ecological values in the vicinity, and the surrounding landscape provided good ecological connections. In addition to the ecoduct, the project also includes improvements of the wildlife fence at three interchanges to reduce the risk of animals entering the highway, five animal escape ramps, and one cattle guard. Therefore, the goal is to generate increased connectivity and reduce wildlife accidents at the highway. Several jurisdictions due to the presence of the Natura 2000 site and rich biological diversity at the construction site challenged the project during the planning phase and set the framework for the construction conformation. We created a 3D digital terrain model to optimize all aspects of the constructability. The design and construction methods were primarily governed by the ecological function of the target species identified, traffic solution during construction time and the Natura2000 area west of the highway. The intrusion in Natura 2000 area was limited to 300 m^2 by creating an arched design on the bridge and by pushing down the side areas. The ecoduct is constructed as a cast concrete bridge that spans 64 m across the highway and is 32 m wide. A 2.2 m high screen of standing wood panel is mounted on the bridge beams and protects the animals from highway disturbances. The dry and nutritionally poor heather moorland and dry meadows found throughout Sandsjöbacka Natura 2000 protection area serve as the primary target vegetation types on the ecoduct and the side areas. The present soil was stored at the site and made friable before it was used as a top layer on parts on the ecoduct. Additionally, we made a lot of effort to find external soil and plants that would match the local conditions. Patches of open sand areas with layers up to 50-60 cm are habitats for insects and stone heaps, and tree stumps will serve as hunting grounds for the rich reptile community. The planning process and construction of ecoduct Sandsjöbacka have contributed to highlight the importance of connectivity and put green structure planning on the agenda both in the region and at a national level. Subsequent monitoring of several species groups and a variety of scientific studies will answer the in-depth questions about the ecological values of the project, and the ecoduct's ability to defragment the landscape.

Effects of a retrofitted protection screen on wildlife use of an underpass in southern Sweden

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Some of the existing wildlife crossings may not be as effective for mitigating the road-caused fragmentation of wildlife populations as planned initially. This was suspected to happen for the underpass (w: 10 m, h: 4.4 m, l: 15.3 m) designed primarily for red deer and fallow deer near the village of Vomb in the south of Sweden. In an attempt to enhance the use of the passage by deer, the Transport Administration plans to install a noise and light-reducing screen along the road, above the entrances of the underpass. The effect of the retrofitted protection screen on animal movements and behaviour will be evaluated using camera monitoring. We present baseline data from the period before the installation. We used five motion-triggered cameras, placed at strategic locations in and around the underpass, to detect animal movements. From July 2016 to November 2016 and from April 2017 to November 2017, we recorded an average of 1.75 visits (an animal or a group of animals were closer than 20 m from the underpass) by roe deer, 0.76 by red deer, 0.72 by fallow deer and 1.23 by wild boar per operational day. When a group of individuals made these visits, we focused on the leading animal and its behaviour. Roe deer utilised the underpass quite frequently, with 67.3% of visits resulting in passage use. Red deer and fallow deer were more reluctant, as only 56.0% and 31.4% respectively of the recorded visits resulted in one or more individuals of the visiting group crossing the underpass. Almost no deer turned back after having entered the underpass (0.1 deer per operational day, which means 0.045 roe deer, 0.038 red deer, and 0.02 fallow deer). However, many showed signs of stress or agitation before entering (i.e., ~38% all deer), with red deer (stressed in 65% of approaches) being the most cautious and hesitant to use the passage. Additionally, males seemed generally more stressed while passing through the underpass than females. If noise and light of passing cars effectively discourage animals from moving through the underpass, we expect to see a decrease in the number of stressed animals when they are approaching the underpass. If the screen will also encourage more animals to cross through the passage has yet to be determined. The crossing will be modified in the summer of 2018.

Nature inventories of bats, insects, lichens, mosses and mushrooms in tree avenues along public roads in western Sweden in 2004-2017

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Between 2004 and 2017, extensive inventories of bats, insects, lichens, mosses and fungi were carried out in 19 areas across different types of public managed state roads in western Sweden (counties of Halland, Västergötland, Bohuslän and Värmland). The various tree avenues were surveyed on behalf of the Swedish Transport Administration (former Swedish Road Administration), with the aim of mapping the natural values of tree avenues with a particular focus on the presence of protected (by law), red listed (according to national lists) or other rare species on roadside trees. The result of the inventories would then be used as a basis for caring measures e.g. pruning and restorations, in old tree avenues that were often planted in the 19th century. The earliest inventories focused mostly on rare or threatened species (protected, red listed, indicator species and the like), while the latter were more complete species surveys, at least in the case of beetles and lichens. In total, about 2,000 trees were studied, meaning all kinds of deciduous trees in the tree avenues, roughly the same amount per hectare in a normal harvesting forest (1,795 trees / ha) in the province of Götaland, southern Sweden. The natural values and diversity of species, however, differ significantly from the normal forest. In total, no less than 691 species were recorded, of which 62 are red listed. A large number of so-called "Signal species" (according to Swedish Forest Agency) and rare species were also noted, as were 11 species of bats, the latter being particularly strongly protected in European and Swedish legislation e.g. the Habitats Directive. Beetles was the most prolific group of 366 species, followed by 191 species of lichens. The variation between the various tree avenues is large, and none of the species were noted in all avenues. The difference compared to a piece of common forest is thus very large, and the result sets the 19 avenues in parity with the country's most valuable natural areas in terms of the numbers and densities of red listed species. The surveyed tree avenues, though, constitute a small and somewhat "subjective" sample, but the assessment is that tree avenues with older deciduous trees of oak, elm, ash, maple, and linden are one of the most valuable habitats in the country for the fauna, flora and fungi (lichens and mushrooms). The knowledge that the tree avenue environments are so rich in biodiversity is essential for the traffic authorities in the management of these tree habitats. All management must be able to perform correct assessments of nature conservation, tree safety and various road management measures.

Surveys of ants (Formicidae) and carabid beetles (Carabidae) along public roads in Southwestern Sweden in 2014

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Occurrence of carabid beetles (Coleoptera, Carabidae) and ants (Hymenoptera, Formicidae) were studied at road sides using pitfall traps in four regions, Halland, Västergötland, Skaraborg and Bohuslän in Southwestern Sweden. Localities in each region, in total nine localities, were chosen based on database information at Trafikverket, Sweden, on ground condition, vegetation, etc. These localities were considered as "species rich" in respect to occurrence of an interesting plant life. We found 426 individuals and 40 species of carabids, ca 11% of the Swedish fauna. On average there were circa four individuals and 0.4 species per trap. Diversity, Shannon index, was 2.33 while Shannon evenness was 0.632, indicating poor carabid community. A few species dominated while majority, circa 70%, occurred in three or less individuals. Highest species richness, 27 species, was found in Västergötland, followed by Skaraborg 19, Halland 16 and Bohuslän 10. Average number of species per trap and diversity (Shannon index) was similar in regions. Evenness was low in Västergötland and high in Bohuslän. *Pterostichus lepidus* was the commonest species constituting 43% of individuals and dominated in all regions. Number of individuals and species significantly were negatively correlated with Shannon evenness while mean number of species per trap was significantly positively correlated with mean number of individuals per trap. This may suggest that in localities with high abundance there are more species but many low abundant species and few dominating species (as explained by low evenness). This imply caution because species richness and diversity may not show similar pattern. Number of individuals showed a significant decrease from south to north but may be an effect of sampling effort. We found 5,642 individuals and 37 species of ants, circa 46% of the Swedish ant fauna. On average circa 56 individuals and circa 0.4 species per trap were found. Both diversity and evenness were a little bit higher, 2.59 and 0.717 respectively, compared to carabids. Highest species richness, 26 species, was found in Västergötland, followed by Bohuslän 23, Skaraborg 21 and Halland 18. Bohuslän had highest number of individuals and species per trap while other regions did not differ much. Bohuslän had low diversity compared to other regions. Number of species and mean number of species per trap decreased significantly from west to east but still region could not explain variation in any ant variable. This imply that further analysis at lower taxonomic level might be needed. Dominating species are *Formica exsecta, Formica fusca* and *Myrmica sabuleti.* Overall our conclusion is that road sides containing open ground, especially sandy exposed ground, and ground with sparse vegetation may have high species richness of both carabids and ants, and these may increase species richness in road sides already having a high species richness of plants.

Development of a deterrent sound for the prevention of deer-train collisions

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To evaluate an efficiency of a newly developed deterrent sound which consist a deer alarm call and a dog vocalization for the prevention of deer-train collisions. A deterrent sound, which consists of a deer alarm call (3 times) and a dog vocalization (20 seconds), was developed. To evaluate its efficiency, the deterrent sound was played from a commercial train, where a stereo system was installed for this purpose. The sound pressure was 90 dB at the 1 m distance from the speaker settled in the front end of the train. The deterrent sound was played throughout the sections, in which there were many deer-train collisions happened so far (in total 55 km long). For the evaluation, an investigator was on the train and counted deer appearance around the railway from the cab of the train. The result of the observation was 88 times deer appearance in 1,100 km during the track where the deterrent sound was played. The observation of the track where no sound was played, it resulted in 90 times in 660 km. From these results, a deer observation frequency was calculated in both cases and it was 7.5 (times/100 km train operation) and 13.6, respectively. It was shown that the deterrent sound played from the train resulted in the reduction of deer observation frequency by 45%. It was confirmed that the reduction was statistically significant by $\chi 2$ analysis ($p=0.05$). Playing the deterrent sound resulted in the 45% reduction of deer observation frequency. This shows the effectiveness of the deterrent sound developed in the study and playing the sound from the train will be an effective countermeasure for the collisions.

Why do the deer jump out suddenly?

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To prevent wildlife-vehicle collisions, other than establishing facilities for accident prevention, various efforts to increase drivers' awareness of the accident risk have been made. For example, by providing risk information through brochures, websites, and installing warning signs. To make those efforts more effective, more specific accidents situations need to be identified. The authors discussed wildlife-vehicle collision situations based on driver visibility. We carried out a questionnaire about the traffic accident with the deer. 78% of people who collide with a deer answered that a deer jumped out in front of their car. It was the same tendency even if we researched the accident data of the police. Why did the deer seem to jump out suddenly? We believed 'the driver's useful field of view' to be related. When we drive a car, we always confirm whether it is safe in front of us. When an animal approaches a vehicle, the driver is still looking in front of him rather than at the side of the car. In that case, the driver does not notice that there is an animal. As a result, the driver feels as if the animal comes out of nowhere. It would be useful to inform drivers about the existence of animals in a particular area to prevent any accident from happening, for example by using animal detection systems.

Egnatia Motorway: Fish protection measures in a major landslide stabilization project

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The Northern Greek Egnatia Motorway section "Arachthos River – Peristeri" lies within Ioannina Prefecture and follows the course of the Metsovitikos river, a tributary to Arachthos river. Because of geotechnical instabilities present on either side, a number of alternatives were examined for the motorway alignment through the area, both along the North and the South bank of the river. Measures applied as part of the final solution include the construction and backfilling of a 150 m-length twin culvert over the Metsovitikos river to provide adequate improvement of stability. In addition, further measures were taken to address environmental issues caused by the construction of a structure covering this continuously flowing river with a recorded presence of migrating fish. The structure design incorporates a hydraulic configuration that ensures the free traffic of migrating fish, as well as a natural lighting system to provide light of similar quality to the fish travelling through the obscured river section. For natural lighting conditions inside the closed structure, which was environmental term of the project, solar tubes were proposed to avoid the energy consuming electrical lighting. Solar tubes transfer solar light indoors using reflection. The lighting study during various meteorological conditions led to the installation of a system of solar tubes at the ceiling of the structure, achieving adequate light. Further consideration of the success of the proposed measures is needed, monitoring the presence of travelling fish (especially the indigenous trout) in the Metsovitikos river. The engineering solutions provided for the ecological design of the project, which shows a unique case in Greece, in our point of view need a feedback from other cases in a European or broader level.

Guidebook for the identification of eco-ethological criteria to be considered for ecological continuity restoration close to transport infrastructures

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Fragmentation due to transport infrastructure has particularly impacted fauna in France and more generally in Europe, leading to an important loss of connectivity due to railways, roads network and waterways. Through an intense literature review (more than 70 documents were used including scientific papers, books and ministerial reports), CEREMA Nord Picardie has drawn up a guidebook to identify the eco-ethological criteria affecting ecological continuity in the presence of transport infrastructure. Various eco-ethological criteria have been pointed out and used to develop this manual designed for infrastructure managers. The purpose of this guidebook is to help them identify the important criteria to be taken into account to optimize ecological continuity close to transport infrastructure thanks to wildlife crossing structures: (1) Structure features: Evaluate which wildlife crossing structure elements are important to take into consideration; (2) Noise/Traffic: Analyse the noise and anthropic disturbance around the wildlife crossing structure; (3) Light: Take stock of the light pollution surrounding the wildlife crossing structure; (4) Taste/smell as an attractor: Analyse gustatory and olfactory elements on and around the wildlife crossing structure; (5) Vegetation: Structure and type of vegetation on the wildlife crossing structure and surrounding areas; (6) Location: Analyse the insertion of the wildlife crossing structure within the landscape; (7) Specific natural heritage issues: If there are very important species (rare or endangered) in the area, the type of development to be carried out has to be achieved according to the needs of these species; (8) Inter or intra-specific competition: Analyse the interactions between species (invasive species, predators, overpopulation...). The guide is designed as a questionnaire to characterise ecological continuity break for each eco-ethological criteria, thanks to a succession of simple questions about several elements on and around wildlife crossing structures. At the end of the questionnaire, the user can identify the main elements likely to lead to a break in ecological continuity, and, using the practical sheets following the questionnaire, get more information on how to dodge or at least reduce this continuity break for each situation. These findings aim to systematically identify a list of eco-ethological criteria affecting ecological continuity and wildlife crossing, to help the infrastructure manager to define technical issues to improve the ecological functionality on a case-by-case basis.

Designing nature with infrastructure: the Antwerp Left Bank infrastructure works

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The Antwerp Left Bank infrastructure works are part of a larger master plan for improving mobility in the wider Antwerp area. The project involves the reconstruction of the existing highway and local road infrastructure on the left bank, which will be linked in the future with a new Scheldt tunnel. The Antwerp Left Bank is a unique and fragile area. In the 20th century, a new part of the city was built on the inner convex bank of the Scheldt, following several successive post-war urban development waves. The result is a strange kind of city, with imposing, modernist high-rise buildings and broad avenues, alongside more intimate garden areas. Beautiful nature reserves are also located in the area, reserves that are today intersected by one of the busiest motorway intersections in the country. The design of the city attempts to temper the harmful effects of the road infrastructure on the inhabitants and nature as much as possible. Here we were able to fit the purely infrastructure-technical project into a pre-eminently urban and nature project, which connects the various existing interests as far as possible. We approached the project as a whole through three networks, which we placed within the Left Bank landscape: a road network, a network with footpads, local and bike roads and the ecological network. The ecological network is currently under great strain from the large-scale motorway infrastructure, which forms an uncrossable barrier for fauna and flora. The design of the Left Bank Infrastructure Works links green areas, which are currently fragmented, into one large nature area that is connected through ecoducts, ecotunnels, and ecologically designed streams, in combination with cycle and footpaths. The project provides a number of local connections for ecological links, cycle paths or local roads. The design of the infrastructure and engineering structures is tightly interwoven with the landscape. Embankments are planted in relation to the adjacent landscape. Lines of trees accompany the service road and the cycle paths, according to the scale of the landscape or road and concerning possible ecological use. Nature is thereby made more accessible for animals and humans. An ecological corridor in combination with a (physical separated) cycle path forms a flyover for the wildlife crossing over the motorway. The redesign of highway intersections let to a more compact form and opens up a very large space, which will be used as a recreational forest area that will be connected to existing green and nature areas. In this zone, the two existing connections across the tracks are transformed into green bridges, in combination with recreational use. In a next phase of the project, a tunnel will be built under the river Scheldt, and this development will lead to a further connection of the existing green areas and the creation of different new habitats.

Stimulating biodiversity and circular economy in rail verges

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ProRail is responsible for the construction and maintenance of more than 7,000 km of railway in The Netherlands. This also means that there is more than 7,000 km of verges alongside the railways throughout the country. ProRail asked Sweco to conduct a study to enhance the biodiversity of the verges by improving the maintenance and including opportunities created by the circular economy in this study. The Dutch railway network extends to all corners of the country and is rather dense. That is why rail verges are a prominent feature in the Dutch landscape. The verges compose a network that contains and connects nature. Yet, the current way of maintenance is merely 'technical'. To enhance biodiversity and fulfil the ecological potential of the railway shoulders, biomass should be removed after mowing. By doing so, the soil will become less nutrient-rich. This will create different ecological zones and stimulate biodiversity. However, this requires a broader view of verge maintenance than the current 'technical' scope. ProRail hires contractors to maintain the railways and its verges. The contracts are mostly technically specified. Reliability and safety are the primary concerns of the asset manager. Sustainability and ecology are not on top of mind, and present agreements contain minor ecological criteria. ProRail's ambition is to enhance the ecological quality of the verges and maintain these in a greener and more sustainable manner. ProRail also wants to stimulate the circular economy, to reduce its carbon footprint and its use of scarce resources. Sweco and ProRail have conducted a study about the question how the management of the verges can be improved to enhance the biodiversity of the shoulders. Additionally, Sweco investigated how this new approach could contribute to the circular economy, to create a win-win situation. Sweco concluded that it is possible to improve the biodiversity when the mowed biomass is removed from the verges. This contradicts the current situation, where the contractor leaves the mowed grass behind. To stimulate this, the contracts for maintenance should be adapted to include the moment, way and removal of mowing. The contract for maintenance should be altered and should include the moment of mowing as well as how to do it and what to do with the removed grass. Furthermore, Sweco proposes a radical new design of the rail verges to divide the technical and ecological zones. This will also enhance the biodiversity and will make the maintenance more straightforward and cost-efficient. The removed biomass can be used in the circular economy. For instance, using it to generate bioenergy (such as biogas). It can also be used for making bio-based materials. ProRail can stimulate the circular economy by using bio-based products and buying biogas. The latter is already happening. ProRail and NS are increasingly using biogas instead of natural gas. In 2020 all procured gas will be of renewable origin.

Citizen science approach revealing impacts of the extensive road system on wild fauna in Cyprus

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Important data providers for transportation ecology and conservation biology in the last decades are without a doubt modern citizen science-based observation systems. Citizens, volunteers, public officers, and researchers can report dozens of road kill observations through the use of their smartphones and user-friendly online databases. These observations are then analysed and statistically processed to unveil interactions and impact difficulties; if possible, these are extracted via traditional field-based studies. Although in Cyprus, a global biodiversity hotspot, a fast increase in road length and extent has been observed in the last 30 years, this has not been followed by studies looking at the impacts of roads on biodiversity. The extent of roads on the island including all existing road categories as well as forest roads, but not forest tracks, cover a total length of 13,267 km. The average road density in Cyprus is 2.3 km/km^2, but road density within Natura 2000 sites often exceeds that. Through the newly deployed Cyprus Roadkill Observation System (CyROS), the collaborative efforts of volunteers and the contribution of sporadic records provided by the Department of Public Works, a first effort for understanding the effects of the road network on wildlife road kill in Cyprus is being made. So far, the project has engaged four government departments and a hundred voluntary scientists. Preliminary results demonstrate that reptiles (including endemic and rare species included in the EU Habitats Directive) are the animal group most affected by roads, followed by hedgehogs. The number of observations recorded so far is not related to the frequency of road use or road type. Future steps are discussed, including increasing recording effort and visibility of the system, assessing road kill in protected areas and developing strategies and plans for road mitigation measures. As an ultimate goal, the project intends to focus on examining transportation ecology in an island context, considering limited space and rapid encroachment of urban development.

Identifying blackspots of wildlife collisions on the Swedish railroad

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The number of wildlife train collisions (WTC) on the Swedish railroads is increasing at a rate that does not match the development of the wildlife populations in comparison with the expansion of the railroad traffic. Therefore, it is essential to identify and predict areas, blackspots, where WTC are frequent and aggregated. These are spots where mitigating efforts, such as fencing, may be most effective. WTC reports do not refer to specific locations of accidents on the roads. Instead, they are calculated as frequencies per railroad segment. The 10,492 km long railroad network contains 1,289 segments, with an average length of 10.5 km (with a maximum of 62 km). We studied 39,157 WTC with roe deer and moose registered from 2001 to 2016. Median frequencies in WTC with moose and roe deer were respectively 0,047 and 0,066 WTC/km*year. Peak frequencies were about tenfold higher, exceeding 0,52 WTC/km*year for moose and 1,26 for roe deer. Variation between years on frequency levels and in peak frequencies was substantial, while the overall trend was significantly upward. We defined blackspots by combining a measure of stability in WTC frequencies with the relative volume of WTC for each given year. We tested four different variations of blackspots (WTC above the 60th or 70th percentile per year for at least 60% or 80% of the years). These represented a minimum of 46 segments in moose and 67 in roe deer or 5% (539 km) and 6% (671) of the railroad network, containing 20% of all WTC with moose and 28% of all WTC with roe deer. We then applied logistic regression analyses comparing blackspots with “cold spots”; segments that had at least one but not more than 5% of the annual WTC frequencies occurring during the same period. For this, we used a suite of factors (land cover, topography, infrastructure density, traffic volume) as predictor variables, describing environmental conditions within a 500 m buffer along the depicted railroad segments. Logistic model strength was best for blackspots with the highest requirements on stability over time. This suggests that segments with recurring high WTC frequencies can be primarily foreseen using a rather simple set of environmental criteria and thus targeted with mitigation plans.

Assessing realism of metapopulation modelling tools deployed in French EIA

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The CIRFE project aimed to determine whether various metapopulation models could mimic the original species metapopulation dynamics (demography, dispersal, and genetics) to assess what their contribution could be in the Environmental Impact Assessment (EIA). Indeed, facing the global reinforcement of environmental regulation within EU to achieve the biodiversity "No Net Loss" goal, the EIA has to estimate actual impacts of projects on species metapopulation functioning at larger and larger spatial scales and with more and more accurate and realistic evaluations of this functioning. In this respect, modelling tools may contribute to the improvement of the current EIA practices by providing large-scale metrics of metapopulation functioning. However, as emphasised by previous works, modelling tools often suffer from a lack of *in situ* testing and validation. In the CIRFE project, we compared outputs from five models commonly used in the French EIA: Euclidean-distance-based method, movement-cost-based method, graph-theory-based model (Graphab), circuit-theory-based model (CircuitScape), and an agent-based model (MetaConnect – SimOïko), and compared these outputs to actual field results obtained on three species (*Alytes obstetricans, Maniola jurtina* and *Abax parallelepipedus*). These species were living in a landscape with a railway, a motorway, a gas pipeline, power lines, a prominent national road, and a dense secondary road network. Comparisons between field data and model outputs are carried out on population genetic structure, connectivity metrics (flow of individuals moving from a sub-population to another), preferential pathways of animals, and population dynamics (population size). In the CIRFE project, we demonstrated that agent-based models could mimic the genetic structure of field studied species population. We also demonstrated that outputs produced by the studied models are not all equally realistic. Additionally, their relative performances are often firmly dependent on their input data quality (resolution of the land cover map).

The assessment of the ecological quality of roadside verges as a building block for optimising functions along Dutch highways

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Rijkswaterstaat is the Dutch government agency responsible for the management of the primary highway network, including the roadside verges. These roadside verges encompass approximately 20,000 hectares and can be regarded as a green network within the Netherlands. The current management practice of the grassland verges includes mowing once a year. Rijkswaterstaat has national goals and ambitions for the circular economy, sustainable energy, utilising natural capital, and improving biodiversity. This raises the question of how one should decide between the different functions, and whether combinations of functions are possible, or how Rijkswaterstaat can optimise one function. For example, the roadside verges are regarded as suitable locations for placing solar panels. Roadside verges are also interesting to harvest the green biomass. A third function that is of interest to Rijkswaterstaat is improving biodiversity. Maybe these three functions can co-occur. However, it is more likely that one function will be optimised. A decision support tool will be developed to make such an assessment. Furthermore, we need to establish what kind of information is necessary to feed into this decision support tool, so that we can make well-supported decisions between functions regarding the benefits of the ecosystem services and the ecological qualities of the verges. Additionally, we need to be able to assure that the most viable hotspots for biodiversity along the highway network are preserved. These questions are examined in a pilot project in the eastern part of the Netherlands. The location of this pilot project is the highway A37 between Hoogeveen (Drenthe) and the German border. In this pilot project, we developed an ecological quality assessment for roadside verges including three abiotic parameters (width of the verge, abiotic variation, hinterland), two biotic parameters (floristic quality, faunistic quality), and one parameter on management. This will be a building block for the decision support tool. For each transect (or polygone in GIS), these six parameters are scored on a scale from zero to two, with higher values representing higher quality. The scores are then combined in a final ecological quality score ranging from one to five, with one being of limited value and five being extremely valuable. Using available GIS information combined with a field visit can score the parameters. In our presentation, we will give background information on the choice of parameters and how these are ranked. This will be illustrated by results from our pilot, the highway A37, where the placement of solar panels is currently debated. The applicability of the ecological quality assessment and its usefulness for a decision support tool will be critically discussed.

Van Gogh National Park defragmented

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Eight area alliances* in Brabant are the initiators of a significant new National Park as the green heart of Brabantstad: the Van Gogh National Park. Vincent van Gogh is a source of inspiration in an area where nature, landscape, culture, heritage, and economy merge. In the footsteps of Vincent van Gogh, the alliances will - with the support of many other parties - work with nature close to home, to create exceptional quality for Brabant and touristic recreational opportunities in an international context. A significant challenge is the strengthening of the cohesion between top nature reserves (i.e., De Loonse en Drunense Duinen, Kampina, Oisterwijkse Bossen en Vennen, Vlijmens Ven, Bossche Broek, Dommeldal, Beerzedal, Helvoirts Broek, Nuenens Broek, Moergestels Broek, Maas floodplains) in the prospective National Park. All these areas have a 'National Nature Network' status. The five first mentioned also have the European status of 'Natura 2000 area'. It is our ambition to reinforce these nature reserves and to connect them in a better way. This also means that some highways (especially the A2, A58, A59, N65, N261, and the railway between 's-Hertogenbosch and Eindhoven) passing through this area have to be defragmented because they form a significant barrier for the cohesion of the nature reserves. We desire to create robust nature passages on these massive infrastructures on eight specifically indicated locations. The work will be done along the guidelines of the recently introduced 'Nieuwe Brabantse Standaard'. This standard includes agreements on the quality of the ecopassages for animals. While planning the measures needed for defragmenting the area, this standard will be used to make the crossing for animals as easy as possible. Eventually, they should be able to move freely through the entire area. The most prominent species are a leading factor in this project. For dry passages, this will be the deer (and for the railway and the passage of the Beerze in the A58, this will be the red deer). For wet passages, the species determining the crossing capability are the beaver and the otter. While developing the nature passage possibilities, we will look for challenges in the areas of water (climate buffers), recreation (walking and cycling passages), and landscape (i.e., the recovery of stream valleys such as the Beerze). The desired nature passages are in different stages of development. Some are already being built; some still have to be integrated into the plans for space and infrastructure.

* National Landscape Het Groene Woud, Nationaal Park De Loonse en Drunense Duinen, Area Development Oostelijke Langstraat, Region Agri Food Capitol, Region Hart van Brabant, Van Gogh Brabant, Brabants Landschap, Natuurmonumenten, supported by the province of Noord-Brabant.

The Ringerike Railway line and E16 Main Road Joint Project

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Plans for a direct rail connection between the Oslo region and Ringerike have existed for over a century. In 2016, the government asked the Norwegian National Rail Authority and Norwegian Public Roads Administration to start planning the Ringerike Railway line and the E16 main road as a joint project. The railway from Sandvika to Hønefoss will be nearly 40km long with a new station at Sundvollen. The E16 from Skaret to Hønefoss will contain a brand-new 30km four-lane motorway. The overall project is estimated to cost around NOK 26 billion. The joint project is located in one of Norway's most precious natural areas. It includes the unique wetlands and floodplains along the river Storelva. Both national and international designations protect these areas. The river Storelva and associated floodplains are unique to southern Norway, with large intact oxbow lakes in various stages of succession, intact meanders, and an untouched delta area. The joint project will pass through the Synneren Nature Reserve, which was designated in 1985 to preserve a very rich wetland area with particular importance for wetland birds. In 1996, the wetlands gained the RAMSAR status. The joint project will also pass through a large forest area, which is essential for lowland woodland wildlife and will result in habitat reduction and fragmentation. Through a series of mitigation measures, the joint project has aimed to reduce the impacts on the natural environment. Mitigation measures have been incorporated into the technical plans and include noise barriers, waterway collections, fauna passages, and flood channels to reduce hydrological changes. The developer aspires to achieve a 'no net loss' of natural values. Accordingly, an ecological compensation plan has been implemented to compensate for the loss of natural areas.

Lessons learned about animal-vehicle collisions from dash cam videos uploaded to YouTube

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In general, most studies about animal-vehicle collision (AVC) have been based on traffic reports drafted by the road safety authorities. Traffic reports tell us when and where the AVC occurred and the species involved. However, reports do not provide valuable information about both animal and driver behaviors. If we could record the AVC, we would be able to better understand the factors involved, as well as to design and to improve mitigation measures. In this sense, dash cams installed inside vehicles, which are mandatory in some countries, could be particularly useful. Some of these recordings are uploaded to sites such as YouTube and are accessible to the public, so it is possible to gather a vital sample size. In this study, we have compiled 507 videos through YouTube searches from 21 countries with dash cams showing AVC or animal crosses of 17 large-sized species. We categorized the animal behavior according to speed and crossing path, as well as the driver behavior. In 24% of cases, the dash cam reported vehicle speed at the time of the collision. The results show that a remarkable number of AVC is caused by the sudden onslaught of an animal or group of animals running at high-speed perpendicular to the road. The reaction time of the driver is short, to the extent that it is really the animal that laterally hits the vehicle in a significant percentage of cases. The probability of an AVC is lower if the animal is quiet on or the road surroundings since the driver has more time to react and avoid a collision. I recognize that getting YouTube videos has a remarkable bias but, always keeping that in mind, the recordings do not stop having value. According to the results of the study, this animal behavior decreases the effectiveness of measures such as animal detection systems, since the time that elapses between the detection of the animal and its arrival to the road is minimal.

The relationship between roads, human diversity, and biodiversity

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Charles Darwin, in his *On the Origin of the Species*, suggested that the environmental factors related to biological speciation are also involved in cultural and language differentiation in humans. Thus, at a global scale, it is possible to find a spatial correlation between human linguistic diversity and biodiversity. Furthermore, much research effort has focused on the impact and relations between roads and biodiversity. Many species tend to disappear in areas with high road density. Roadless areas, for example, are valuable zones that should be protected to conserve world biodiversity. Nevertheless, the impact of roads on human diversity and cultural features as languages has been scarcely considered by science. If Darwin was right and both diversities share common origins, it might be expected that roads also would shape human diversity spatial distribution. Since roads promote cultural homogenization, those areas with high road density may have a lower level of linguistic diversity. In this study, the spatial relationship between roads, human linguistic diversity, and biodiversity was analyzed at world level. Global species distributions for mammals, reptiles, and amphibians were obtained from the International Union for Conservation of Nature (IUCN). BirdLife International dataset was used for bird species. Language maps were obtained from the Ethnologic catalog. Although with essential differences between areas, both biodiversity and human linguistic diversity correlate negatively with road density. Logically there are large biomes where this correlation is not true, mainly in the desert areas. In addition, those areas where a higher number of languages and species have disappeared currently have a high level of road density.

An overview of wildlife-train collisions in the Czech Republic

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Railway transport is more environmental friendly than cars due to its lower energy consumption and high transport capacity per unit. Despite this fact, railway infrastructure also causes landscape fragmentation thus affecting natural migration of wildlife. The Czech railway network ranks among the densest in the world with 121 m of track length per km^2. Agricultural land, including meadows and arable land, forms the largest area (36%) within 50 meters along the railway tracks. Forests are then situated along 27% of railway network length. The aim of this study is to provide an overview of wildlife train collisions (WTC), which are, in contract to crashes with animals on roads, insufficiently studied in the Czech Republic. For this purpose we collected and analysed relevant data from various sources. The primary data source were databases of the Czech National Railway Administrator (SZDC) and the web application srazenazver.cz, developed and administered by CDV. Between 2008 and 2017, a total of 1,600 WTC records were collected. The evidence contains relatively small amount of crashes in comparison to road transportation, however. This is, to all the probability, the result of the different transportation modes, related traffic intensities and extreme difference in weight of road and railway vehicles. A collision with animal thus will cause an accident rather on a road then on a railway track. On the basis of the collected data we used KDE+ method to identify locations where collisions are clustering. The results will be presented in a map and within a web-map application www.srazenazver.cz. More than half of all WTC were crashes with roe deer (32%) or with wild boar (27%). The number of collisions with roe deer was relatively stable throughout a year. However, slight deviations could be identified. Fewer collisions were recorded between March and August and more between September and February. A different trend was found for collisions with wild boar. These events occurred more often in the second half of a year (from August to December). The other most common WTC were with dogs (11%) or cattle (5%). 9% of WTC were caused by unidentified animal (this number differs largely from WVC on roads, 50%). The rest of the collisions (16%) are with other animal species (e.g. sheep, horses, foxes, etc.). Higher amount of damage was only recorded in collisions with large mammals (e.g. ungulates). Whereas collisions with animals on roads usually occur with individuals, trains quite often collide with herds of wild, but also domestic ungulates. For example, cases of train collisions with a herd of 14 goats or 50 sheep have also been documented. The results provide an insight into the WTC and can be used for further research in this area or as a basis for application of protective measures (mitigation of the number of collisions and their consequences).

Impact assessment of a wildlife corridor on a human populated area in Thailand

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This study focuses on bridging the forests along National Highway 317 (NH317) in Chantaburi Province, Thailand, a site in the Eastern forests complex that was ranked high priority for its elephant habitat and potential connectivity to Cambodian forests. The study takes into account the ecosystem conditions, comments from local residents, topography, and land use, in consideration for the appropriate wildlife corridor location and design. Field survey was conducted to collect evidence of the presence of elephants, i.e. dung and footprints, along with the flora and fauna survey. Elephant encounters and conflicts records, together with interviews with the locals and heads of wildlife sanctuaries, were combined with topography and land use information to map the elephants travelling routes. Ultimately, the suggested corridor will serve connectivity of elephants as the principal species. With the proposed preliminary design of the wildlife crossing structures and guide fences, we conducted an environmental impact assessment and proposed mitigation measures. The proposed site is located in the Eastern region, a strategic place for the country's economic development. The site has NH317 aligning in the North-South direction, with the Khao Soi Dao Wildlife Sanctuary lying approximately 3 kilometres away north-westward and the Khlong Kruewai Chalearm Phrakiat Wildlife Sanctuary nearby the NH317 with Patch 1 sitting 500 meters to the left and Patch 3 located about 3 kilometres to the right. NH317 serves the lower North-eastern – Eastern regions connectivity. The primary challenge of the site is the intricate existing land use of fruit orchards, rubber tree plantation, and houses along the path that elephants from nearby wildlife sanctuaries visited for fruits. A combination of viaduct and tunnel have been proposed for animal underpass and overpass, respectively, along with elephant fences that encompasses the proposed wildlife corridor area. Impacts to the locals residing and harvesting in the proposed corridor will be in socio-economic aspect, due to increased risks of encounters and losses due to elephants. Mitigation will call for an innovative mechanism for the provision of compensation to the actual settlers who are not lawful landowners in either case of human-elephant coexistence or resettling people out of the area. A warning system and trainings for safe coexistence are among the measures proposed to ensure that existing residents can safely coexist, should they opt to stay while animals can pass the area unobstructed and thrive sustainably. The novel approach for human-elephant coexistence would be unprecedented in Thailand and further detailed survey and study will be required for implementation. The findings from this study form the basis for decision makers who administer these conservation areas in the future development of wildlife corridor. The government's policy to handle disputes with settlers in conservation areas will be critical to the materialisation of the proposed wildlife corridor.

Mapping green infrastructure based on ecosystem services and national ecological network: a case study in Taiwan

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Developing the national ecological network (NEN) is important for biodiversity and landscape conservation, water management, and also for the improvement of the climate change adaptation in the highly urbanised areas. The mapping data, collected and supported by Geographical Information System (GIS) for NEN, can identify, promote and preserve a strategically planned green infrastructure (GI) for ecosystem services, as well as provide a priority for spatial planning and decision-making process in national conservation, agriculture policy, urban development or river basin management. In this study, a mapping methodology will be proposed to identify and map the GI-elements based on ecosystem services and ecological, economic and social benefits both for human lives and nature conservation in the planning context in Taiwan. The IG-elements are integrated with mapping of the natural capacity to deliver ecosystem services and the identification of core habitats and wildlife corridors. The mapping process includes four steps: 1) typology mapping: habitat classification, 2) function mapping: assessment of ecosystem services, 3) needs mapping: opportunities assessment for service and benefits of the ecosystem, 4) needs met and not met: value and action plan. The mapping results will present the habitat functions and contribute to the national ecological network for Taiwan. This study aims at applying the GI-elements at the landscape scale to identify and classify the habitats, and then evaluate the impacts of ecosystem services in the planning context for decision-making and implementation of strategies. The GI-analysis results will contribute to policy strategies on developing national ecological network and action plans for natural conservation and resource management.

Meta-population models in Environmental Impact Assessments

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The CIRFE project aimed to determine whether various meta-population models were able to mimic the actual species meta-population dynamics (demography, dispersal, and genetics) to assess how they could contribute to Environmental Impact Assessments (EIA). Its economical work package, the subject of the presentation, had two goals: to characterise current fauna and flora studies on infrastructure projects in France (cost, quality, survey pressure, etc.), and to describe the entire cost of using these models (data, time, computer, etc.). To define current fauna and flora studies, 26 EIA, of various size projects (rail, road projects, etc.), have been studied. The selected EIA had been produced after 2008 so that they are almost all under current French regulation. For all of them, twenty variables have been completed such as the stage of the project, its length, the width of the surveying areas, the number of survey days, a score assigned by adding up the number of species in each class of the red list, etc. To describe the entire cost of using the meta-population models (the ones studied were: Fragstats, Euclidean distance-based method, movement-cost method, Graphab, CircuitScape, SimOïko), several costs were determined: procurement of habitat surveys according to the different needs of the models and the species, model configuration costs (time of labour and qualification of operators), need for computers, etc. We discovered that early stage EIA's are made with more or less the same survey pressure as the late stage ones. We also found that there is no strict relationship between numbers of survey days and 'official' survey areas. For long infrastructure projects, it seems that optimisations (to focus on surveys with the best circumstances) are done to keep costs low. We also demonstrated that models are not often used to assess the ecological network. Concerning the entire cost of the use of the models, we found that the configuration cost of the most accurate model is four times higher than for the less accurate one. However, habitat survey procurement is by far the main cost compared to other expenses. Models are sensitive to input data, but the cost of the habitat survey needed for the most accurate model is comparable to the price of current habitat surveys in EIA. Therefore, the last ones could be used for modelling at no additional cost. Additionally, the recent average cost of fauna and flora surveys is far higher than the estimated cost of modelling. To conclude, population genetics and modelling could be used in combination with traditional practices to improve the EIA, especially for projects including substantial survey areas. Furthermore, as fauna surveys are not needed for these models, part of these surveys may be avoided if the models give a better comprehension of the functioning meta-populations and the prediction of a future situation.

ITTECOP: the French public-private research programme on infrastructure and environment

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Policy makers, researchers and practitioners alike seek substantive scientific responses to professional questions, as well as methods to transfer research from lab to land. Since 2008, with more than 50 research financed, ITTECOP (Infrastructures de Transports Terrestres, écosystèmes et paysages) seeks to attain this goal. ITTECOP is a multi-disciplinary research programme dedicated to infrastructure effects on landscapes and biodiversity. This programme is led by the French Ministry of Ecological and Solidarity Transition (MTES), in coordination with the Environment and Energy Management Agency (ADEME). Since 2013, with more than 2 million euro invested, ITTECOP has enlarged its funding and its audience by a public-private partnership including the Research Foundation on Biodiversity and all national infrastructure operators: rail, road, river and energy and, in a close future, port and airport. A grant agreement is based on trust between the partners and describes the mutual relationships and responsibilities, in particular the total independence of the scientific council and the funded researchers. In France, today ITTECOP is the meeting point for a community of practice consisting of researchers, professionals and members of NGOs who directly contribute to the emergence of novel thoughts which cab form a basis for public decision-makers when evaluating infrastructure impacts. This broad and integrated approach include spatial and temporal dimensions, regional governance issues and, to a large extent, ecological factors: noise pollution, compensation strategy, invasive species, genetic analysis, infrastructure management, improvement of green infrastructure networks. In the past ten years, ITTECOP has evolved to adapt to new goals and financial constraints while maintaining its main goal: to provide independent, fully public research actions validated by the scientific council to ensure a wider audience of results. ITTECOP aims to organize the French research framework that focuses on infrastructure assessments as a whole. It includes scientific support to practical operations, project labels, supports for young searchers and local or international cooperation such as with the IENE network or KHEOPS in Canada. Finally, special attention is paid to the scientific facilitation of the program, that seeks to optimize research projects to ensure that knowledge is passed on directly to public policy actors, researchers and practitioners. Publications, newsletters, annual conferences and a regularly updated web documentary, including the most recent report and numerous interviews with researchers, try to improve the network and to share experiences in a national approach and internationally.

The effects of habitat fragmentation and isolation on Japanese raccoon dog (*Nyctereutes procyonoides viverrinus*) roadkill in Japan

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The objective of this study was to examine how habitat fragmentation and isolation in urban and suburban areas influence the occurrence of Japanese raccoon dog (*Nyctereutes procyonoides viverrinus*) roadkill. Our aim was to determine potential migration directions in greenspaces and contribute to road planning to increase the viability of raccoon dog populations. We constructed a model to predict the probability of raccoon dog roadkill occurrence in an urban area, and then analyzed the effects of various roadkill risk factors. We used raccoon dog roadkill data collected by the Kawasaki Juvenile Science Museum, and performed a logistic regression to determine the probability of future roadkill occurrences. A dummy variable coded as either 1 (observed roadkill location) or 0 (random point) was used as the dependent variable, and the independent variables were habitat factors within a 200-m buffer and a 500-m buffer around each point. The results of the logistic regression analysis indicated that a combination of woodlands, distance to nearest urban core area, parks and greenspaces, roads, distance to nearest farmland, and residential areas within a 500-m buffer influenced roadkill occurrence. The most important variable explaining roadkill occurrence was the proportion of woodland around roads. These results suggest that the fragmentation and isolation of forests and grasslands, which are progressing due to the increase in road area concurrent with rising urbanization, increases raccoon dog roadkill occurrence. Roadkill occurrence was highest in areas with a high isolation level because roads and urban areas had substantially fragmented the forests. The installation of road-crossing infrastructure is an important raccoon dog conservation measure because land use is limited in urban areas where fragmentation and isolation are high, making the creation of dedicated habitat environments for raccoon dogs difficult. Road-crossing infrastructure should thus be installed in locations where urban core areas, extensive road networks, large forested areas, and greenspaces coexist, and where roads have high traffic volume. It is also important to compensate for the fragmentation of raccoon dog habitats by providing greenspaces such as farmland and grasslands, such that large tracts of habitat remain available even in suburban areas, forming an ecological network.

Effective culvert design to facilitate amphibians across roads in Changbai Mountain Area, China

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The road traffic is regarded as the main factor causing the decline of amphibian populations in Changbai Mountain area in China. The proper location of amphibian tunnel is one of the efficient measures to mitigate the negative impacts of road traffic on amphibians worldwide. However, little is known about how to design palatable culverts to promote amphibians crossing the roads safely. We selected two amphibian species (Chinese Brown Frog *Rana chensinensis* and Asiatic Toad *Bufo gargarizans*), which suffered most severe road mortality along the roads in Changbai Mountain area. Presently, as test species, we placed experimental arrays of culverts of varying sizes (diameter 1.5 m, 1 m and 0.5 m for circular culverts; side length 1.5 m, 1 m and 0.5 m for box culverts), types (circular culverts and box culverts) and substrate type (soil, concrete and metal) to examine the preference of both species during migration season in May and September of 2016 and 2017. This study was attributed to evaluate the preferences of two amphibian species in connection with the size, type and substrate of the culverts, to investigate the effectiveness of heights barriers towards Chinese Brown Frog, and to find a suitable angle of roadside ditch that could help in escape of amphibian when they fall into it. The results reveal that both Chinese Brown Frog and Asiatic Toad preferred the box culverts as compared to circular culverts, while Chinese Brown Frog preferred culverts with middle and large size and soil culverts. Secondly the 45°or less gradient of roadside ditch walls was the optimum angle for amphibian species escape and guide fences of 0.4 m in height were effective barrier to Chinese Brown Frog. We conclude that box culverts with side length ≥1 m line with soil and accompanied by ≥0.4 m high guide fencing and ≤45°gradient of roadside ditch walls would best facilitate road crossing for both the species and likely other amphibian species in Changbai Mountain area, China.

Developing the National Ecological Network in Taiwan

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Taiwan is a small subtropical island with frequent earthquakes and seasonal typhoons that shape the landscape and its rich wildlife. However, as the second most densely populated nation in the world with strong economic position, the conflicts between human activities and the conservation of biodiversity have become a serious issue in recent decades. The Forestry Bureau, as the central agent responsible for conservation, has acknowledged that conserving protected areas and national parks alone cannot protect natural habitats and wildlife in the long term. It is necessary to connect farmlands, forests, rivers and the coasts which involves multiple sectors and stakeholders. Also, developing a national ecological network is a good strategy. Over the past year varies discussions and consultations were made and funding was secured, and the multi-year project is ready to launch this March. The proposed project aims to complete a national framework in the first year with three steps: (1) identifying habitat types and ecological functions; (2) using landscape ecology theory to measure habitat amount, integrity and connectivity; (3) highlighting the bottlenecks where habitats are fragmented by human development such as roads and other infrastructures and ranking. We will also conduct three case studies on a local scale, using standardised habitat survey and mapping methods to ensure proper consideration of restoration planning. With the success of the first year, other bottlenecks will be targeted, and a network of corridors connecting core areas will hopefully benefit the ecological integrity of the island.

PART 5
ABSTRACTS
WORKSHOPS

Global wildlife-vehicle conflict reporting systems

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Supporting the evolution of ecologically sustainable transportation requires collecting and analysing data about road and traffic impacts on natural and human systems. Some of the most visible impacts are the carcasses or injured animals resulting from wildlife-vehicle conflict (WVC). For many wildlife populations, WVC may pose an existential threat through direct mortality of individuals and genetic separation of sub-populations. Vehicles and operators are also at risk from both collision and avoidance of collision with animals of almost any size (but primarily large mammals). Mitigating these impacts requires knowledge of both when (hot-moments) and where (hotspots) WVC is more common than adjacent areas and times. This, in turn, requires rigorous and extensive data collection, management, and analysis by trusted institutions. One approach mostly taken on a national basis is to involve volunteers in collecting data on road-killed animals on a broad geographic range. These data can be combined with data from agencies, or their contractors, collecting carcass observations along roadways, as well as other types of wildlife-related observations to obtain a complete picture of wildlife occupancy, movement, or mortality.

This workshop aims to give an overview of existing monitoring approaches worldwide and to find a way of implementing these approaches in a global observatory system. This workshop builds upon a similar workshop organised by Fraser Shilling for IENE 2014, entitled "Systematically reporting live and dead wildlife on and near roads". The group listed above surveyed current smartphone and web-based systems for collecting and managing WVC data to establish common and innovative approaches that are being taken. We have also identified areas of expansion that could be accomplished by taking advantage of current and emerging data collection and technologies. So far, we have concluded that innovative types of data collection can be employed with both volunteers and agencies and that these innovations are critical for solving safety and conservation challenges on transportation-ways. Finally, when extensively, systematically collected, these data may also become essential for investigating other ecological phenomena on national, continental, or global scales.

During the workshop, we will carry out four main activities:

1. Structured introductions among participants: name, affiliation, current related research and interests, key questions and goals for the workshops, and interest in global collaboration.
2. Short presentations by five members of the organising group (5-6 minutes each) detailing fundamental activities and issues worldwide.
3. Round-table discussion of key questions and issues raised by the participant group and the lead group. These will include WVC data collection (getting more observers, technologies), data management and sharing (e.g., through web-systems), data analysis (current spatial and temporal-spatial methods in GIS and geostatistics), visualizations and public-education, affecting policy and management of transportation systems.
4. Collaborative opportunities that all participants can engage in to grow the field and increase rate and extent of data collection. This could include a follow-up paper, funding proposals, and globally communicating web-systems.

We will focus on surface transportation systems (roads and rail) and vertebrate animals. However, we will entertain other transport modes and animal groups that people bring forward. We will pay special attention to driver-assistance and autonomous vehicle systems that are under development and being tested.

The organising group is currently working on a manuscript that provides an overview of the state of the field, which we will provide to participants. We will also take copious notes that we will give back to participants following the workshop, along with the slide presentations.

De-fragmentising waterways

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In general, the focus in studies on the relationship between infrastructure and nature is on (rail)roads. However, the effect of waterways on nature should not be underestimated. Especially, canals and canalised rivers can have detrimental effects on wildlife. Their steep shores form barriers for animals that want to cross the water. They might get into the water but might not get out anymore. Additionally, canalised rivers lack naturally vegetated shores where aquatic animals can live and breed. Canalised rivers also require resting sites for migrating fish.

The EU Water Directive (Directive 2000/60/EC) sets out rules to halt the deterioration in the status of European Union water bodies and achieve 'good status' for Europe's rivers, lakes, and groundwater by 2027. This includes, among others, restoring the ecosystems in and around these bodies of waters. The Dutch Province of Noord-Holland came with the idea to combine the obligations of the EU Water Directive with mitigation measures to de-fragmentise the canals in the province. Because contractors with Design & Construct contracts carry out most projects, they needed guidelines with functional specifications.

In this workshop, we give a presentation of the guidelines, and we want to discuss the applicability of these guidelines in other countries. Of course, any suggestions for improvements to the guidelines are welcome as well. The objective is to come to guidelines to de-fragmentise canals and canalised rivers and at the same time contribute to the implementation of the EU Water Directive. For a successful workshop we need participants with different backgrounds and from different countries: (1) Scientists: for input of the requirements of (aquatic) fauna and of the requirements for stable canal shores; (2) Waterway managers: for input about tenders and contracts; (3) Waterway engineers: for input about the practical aspects of canal engineering.

The structure of the workshop will be as follows:

1. Introduction
   - Short introduction round.
   - Short introduction to the goal(s) of the workshop and the discussion methods used.
   - Presentation of the guidelines 'Nature-friendly shores for Design & Construct contracts'. The presentation describes the method of systems engineering, how to combine the obligations of the EU Water Directive with nature-friendly shores and measures for animals to leave the water and how these obligations and requirements are translated to functional specifications for D&C contracts.

2. Listing issues to tackle
   - Short plenary discussion to discover the main problems that the participants expect. When trying to combine ecological and transport functions in canals, one might expect conflicting interests. For example, the shores must be strong enough to withstand the bow waves of the boats, but at the same time be sloping to facilitate animals to get out of the water.

Sloping shores can be reinforced with stones, but this is contradictory to the requirements of the EU Water Directive. With D&C contracts it is always challenging to find the balance between describing guidelines and the freedom of the contractor to design and carry out the work his way. How to handle invasive alien species that follow canals? The problems will be grouped on a whiteboard by the different levels of a shore (underwater, the watermark, and the land).

3. Listing solutions
   - The participants will brainstorm in small groups about possible solutions for (a selection of) the main issues listed in the previous session. Each group treats at least two issues.
   - Plenary session where each group presents the possible solutions (put together on a whiteboard).
   - The participants can react to the ideas for solutions of the others. We will give particular attention to differences between countries (in types of waterways or water management) and the borders between the three levels of a shore.

The workshop will finish with a short discussion about possible follow up actions. These can be, for instance, an article in a water management journal, an additional chapter to the COST 341 handbook, a publication (with downloadable document) on the IENE website, etc. A summary of the outcomes of the workshop will be published on the IENE (conference) website. If the participants decide to elaborate more on the outcomes and prepare a (short) publication, this will also be published on the IENE (conference) website. The Province of Noord-Holland will use the outcomes of the workshop to improve their guidelines and the implementation of these guidelines. Preferably, the workshop will also initiate guidelines for nature-friendly canals in other countries.

Civil engineering meets ecological engineering in the designing process

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Good communication between road builders, ecologists, landscapists, and maintainers is essential for creating a good design that will satisfy the needs of all parties involved. Mostly nature measures are implemented at the end of the designing process because the project engineer was not aware of the importance. Sometimes, it is applied only as an obligation in building permits or other permits. Maintenance is frequently neglected in the design as well. Along the way, we learned that ecologists, landscapists, and road builders often work in different ways. They speak another language and have different goals. Therefore, it is essential to bring these three parties together at an early stage of every project. This can happen at every step of the process. Not only for designing new roads but also when roads are rebuilt or adjusted:

- Communication is necessary from the moment a project commences. This way, we can examine the affected natural areas or aspects, the existing opportunities in the current situation, essential elements to avoid fragmentation. As a result, we can make a well-incorporated road with much potential for local flora and fauna, taking into account the management afterward and making proper agreements for maintenance, management, and monitoring;
- As the design is getting more concrete it is essential to implement an optimal realisation of the selected measures;
- During the building process specific components can be adjusted on site;
- Afterward, agreements must organise maintenance, management, and monitoring.

The primary objective of the workshop is bringing together road builders, landscapists and ecologists to discuss their approach and viewpoints. This way, they can try to understand each other and compromise. They will share good and bad experiences. During the designing process of building a new road or rebuilding an existing road, it is a challenge to match civil objectives with ecological or landscape objectives and to reflect on maintenance. While rebuilding an existing road, it is even more difficult than having to start from scratch when building an entirely new road. However, the process of rebuilding an existing road gives the opportunity to restore existing fragmentation.
During the workshop we want to submit one or more potential projects. We will let civil and ecological practitioners work together in small groups to redesign a road that is more integrated in its natural surroundings, with attention to fauna passages and verge design.

The workshop will be structured as following:

- The group will be split into smaller groups with a maximum of five people, while keeping in mind the importance of a good mix of different backgrounds.
- The workshop will start with a short presentation clarifying the objective and approach of the workshop and situating the project. This will be the N19g project that will be visited during an excursion in Flanders. Different project documents of the project will be presented together with additional technical and environmental information:
  o Technical plan of the road;
  o Why will it be (re)build;

  - o Vision on the road after (re)building: width, bicycle lanes;
  - o Vision on landscape integration (available width, light, trees);
  - o Existing transmission lines, sewage system;
  - o Landscape elements: topography, water table, crossing watercourses;
  - o Surrounding nature: type, preservation status, ecological information on fauna and flora;
  - o Budget;
  - o Maintenance requirements.
- The groups prepare proposals and note their remarks for a better nature integrated road. The goal is to challenge the different parties to develop their different viewpoints and practical solutions. The starting point is a largely printed plan and different markers to put down their ideas.
- Each group will give a short presentation of their proposal. After each presentation, there will be a discussion.
- Conclusions.

The results of the different proposals can be shown afterward in the public rooms of the conference, linking to the conference app. This way, we hope to facilitate a discussion with the other participants and to demonstrate the plan of the actual realisation of this project. Furthermore, the outcomes of the workshop will be collected and spread after the conference, such as: (1) Good and bad experiences; (2) Points of friction between the civil objectives with ecological or landscape objectives; (3) Viewpoints of maintenance (who is responsible, what will it cost, etc.); (4) Suggestions for missing information or better ways to work together.

How to address barrier effects of railways? Impact factors and guild specific impact assessment due to different types of railways

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Different morphological or ecological groups of species are expected to show a guild specific reaction to barriers caused by railways. The respective active factors, such as substrate types, verge vegetation, railway width, type of cable runways or curbstones, fences, noise, or habitat contrast and many more (including their combinations) are supposed to cause a wide variety of guild-specific effects. However, most effects seem to be unclear and difficult to assess. While road effects on species are extensively stud-ied, railways effects are poorly investigated. Even the most critical barrier factors of railways are not clearly defined, which is especially true for the small fauna and traits of new railway techniques. Nevertheless, for impact assessment, mitigation and com-pensation it is necessary to have at least a common understanding (or conventions) for the impact severity of each relevant factor of railway design features and operating characteristics. Therefore, the workshop shall stimulate and enable a robust compila-tion of expert knowledge and opinions to achieve a significant improvement for prac-tical impact assessment, mitigation, and compensation. Ecologists on the one hand and engineers and planners on the other can place their knowledge on impact factors, species responses, risk probabilities and risk assessment.

In the workshop we will discuss a previously via internet forum developed tabulation about relevant barrier features, respective guild specific species responses and impact risks. Furthermore, we will work on the compilation of: (1) a list of the relevant im-pact factors (current and expected future features of railways), and (2) a list of differ-ent types of acceptors (defined ecological response guilds of sensitive species and best fitting indicator or flagship species for different eco-regions). This will allow us to to make up: (1) a balanced cross table with a guild specific rating of risks caused by the particular impact factors by expert hypotheses on the guild-specific severity of each factor; (2) the compilation of references - if existing - for each rating in the crosstable (mainly by using the pre- and post-conference platform for related ecological knowledge), and (3) the prioritisation of most important research to evaluate hy-potheses that seem to be most potent for environmental planning and operation of railways.

In addition to the provisionally via a pre-conference internet forum prepared infor-mation, the workshop discussion will be further facilitated by illustrations from case examples. Each topic will be dealt with by the same procedure:

1. A presentation of working hypotheses (= results of the pre-conference internet forum) (2-3 min);
2. A concise discussion and annotation and complementation of the hypoth-eses (8-10 min);
3. A debate about consequences for railway ecology and risk mitigation along railways and stimulation of further discussion groups or participation in the post-conference internet forum (5 min).

All findings – especially the expected verified risk assessment for relevant guilds – and post-comments will be summarized after the workshop. These findings

will be pub-lished via the previously established internet forum that will be hosted by the German Agency for Nature Conservation (BfN) or Kiel University or – if possible – by IENE and cared for by the universities of Kiel and Kassel until autumn 2020. Both institutions will further provide a literature review and a related practical analysis of at least the German railway features with respect to the German habitat networks and a case study about the activity of ground-dwelling insects and small vertebrates on railways which is supported by the German Agency for Nature Conservation and granted by the Federal Ministry for the Environment.

Going off-road: New partnership arrangements for biodiversity-friendly management practices for green verges

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Managers of land transport infrastructure (LTI) are increasingly aware of the importance of Green Verges, such as roadsides, banks, and power line corridors, for biodiversity (species and habitat conservation, connection to green and blue corridors). They are willing to embark on new management arrangements for these spaces. Currently, the implementation of more biodiversity-friendly practices for Green Verges is being considered primarily through the development of managerial knowledge and by adopting knowledge from external expertise (raising awareness of the staff, staff training, learning from practical handbooks). Appreciating the importance of such efforts, this approach has temporal, economic and social implications that are neither necessarily within reach of all managers, nor are they the best answer to all situations encountered in the field. This workshop aims to discuss options from across Europe that go beyond the development of internal competencies by land transport infrastructure managers for biodiversity enhancement, to take into consideration the ecological and organisational opportunities provided by the particular landscape context on which the transport infrastructure is superimposed.

Specific new collaborative governance modes are at stake when taking such local potential into due consideration. Indeed, all over Europe, numerous and diverse competent local actors have developed expertise in the management of natural or semi-natural environments, supporting national or local authorities or Non-Governmental Organisations, and can carry out or organise the action on the field. For land transport infrastructure managers, taking advantage of the skills and knowledge of these local stakeholders in nature and landscape management could be an efficient and pragmatic way to achieve their wish of implementing biodiversity-friendly practices in the management of Green Verges, both concerning nature protection and enhancing ecological connectivity. Such collaborative action and social learning do exist from place to place, but generally, it remains occasional, poorly known and rarely enduring. As a result, the possibility for replication in another context (i.e. a combination of natural environment and a specific type of land transport infrastructure) remains hard to realise, thus probably underrated.

In this workshop participants are invited to report their experiences, contributing to a first overview of state of the art and its inherent diversity across countries and land transport infrastructures. From their knowledge and experience, a rapid assessment of success and failure factors of partnership-based management will be carried out. Lastly, the relevance and opportunity for international cooperation intended to improve the feasibility of this contextual ecological management of Green Verges will be considered. The target participants of the workshop are professionals, researchers and representatives of non-profit organisations involved in the management of Green Verges or natural environments, with a background varying from ecology, nature management, and law, to landscape architecture and the humanities (governance, socio-economy).

The workshop structure is as follows. After a short introduction of the organisers, we will invite a round of 3-minute 'elevator pitches' from each participant (repre-

senting as many countries as possible) to report on the experience of collaborative Green Verge management; noting fundamental characteristics. After maximum 20 minutes, this will yield the first overview of state of the art and the diversity of experiences, as reported by the participants. The second step of the workshop (25 minutes) is focussed on bringing structure in the collected observations. For different kinds of land transport infrastructure (roads, railways, power lines, waterways - the size of the list will be adapted to the experience gathered by the participants), the various possible modes of partnership-based management of GVs are considered: ecological conservation (species); agro-ecology (grazing, mowing, specific crop), ecological corridor (connection); green activities (hiking, biking, riding), water activities (canoeing, sailing, fishing). The general discussion aims to clarify which modes have the highest potential in which cases, regarding ecological relevance and main difficulties encountered. The organisers will facilitate this step, filling with all the participants a summarising table *Land transport infrastructures versus management modes*, with, in each box, the identification of success and failure factors of partnerships (considering ecological, juridical, and socio-economic points of view). Based on the questions and opportunities raised as a result of the previous general overview, the last step (15 minutes) will be dedicated to conclude on the motivations and justifications for an international multidisciplinary cooperation intended to treat the issues bound to the most promising and relevant partnership arrangements (*Land transport infrastructure; management mode*). Stakeholder incentives and legal regulations can vary a lot from one country to the other. Hence positive teachings from abroad may drive improvements for each one and the general situation for biodiversity along land transport infrastructures.

The outcomes of the workshop will be: (1) An overview of success and failure factors of partnership arrangements from ecological, juridical, and socio-economic points of view, for the management of green verges of a set of land transport infrastructures. Considering various modes of management (e.g., ecological conservation, agro-ecology). (2) Identification of the opportunity for an international multidisciplinary cooperation to consider studying and developing the most promising and relevant partnership arrangements (*Land transport infrastructure; management mode*). The findings of the workshop could be used as a basis for a publication in an international journal.

Worldwide Knotweed: A blueprint for preventing or terminating knotweed

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Worldwide knotweed doesn't need much introduction with ecologists; biodiversity is at risk, and the functionality of ecoducts and wildlife crossing structures will be reduced if it is not treated. However, in some countries, landowners and infra administrators are not familiar with knotweed and the danger it causes to infra. They are not aware that the roots of this weed can cause significant damage to stone and even concrete structures, not to mention the difficulties to terminate knotweed. Most of all, knotweed doesn't hold at borders of land or even countries, what makes it in an ironic way very appropriate to the theme of this conference: Crossing Borders. And that is the biggest challenge of all because the level of policies and regulations about knotweed vary dramatically between countries. For example, the policies and regulations in the United Kingdom are very tight. However, the European Union and the Netherlands have none at all.

In this workshop, we would like to draw a blueprint of a set of policies and regulations based on the experiences of the attendees with knotweed. This blueprint will be helpful for every landowner, infra administrator and many others who have to start preventing or terminating knotweed. It could help with providing information for budget, cooperation with other stakeholders, etc. Additionally, we would like to set up a mailing list of the attendees enabling the exchange of experiences, advice, and questions.

The workshop attendees preferably have some experience with knotweed, because we will spend only a little time on the introduction of knotweed, we will spend most of the time on debate. But a few people who would like to be introduced with the plant are welcome as well. We aim for about 20 attendees (4 groups of 5 people). The program of the workshop will be:

- For starters, we introduce the subject and ourselves briefly. Plenary, we'll ask the attendees, how much knowledge they have of knotweed, by raising hands.
- With raising the hands we split the group into four groups of five people with four stickers with different colours. The groups should be a mix of people with no knowledge, a little knowledge and a lot of knowledge.
- We will have group debates. We'll provide the attendees with sheets for their data and open space for notes. The sheets will contain four questions that we want to get the answer to during the debates. The questions will be:
  1. When and how did you first found out about knotweed? What problem(s) did the knotweed cause?
  2. How did you try to solve the problem? Were you successful?
  3. Which regulations were working for you? Were there regulations in the way of solving the problem? Were there regulations missing?
  4. Do you have recommendations of any kind?
- Each group will briefly discuss the results of one question.

Finally we will summarize what has been discussed. We will ask the attendees to tick a box on the sheet if they would like to keep being updated. We will take in the sheets, and after the workshop, we will compose a set of rules and recommendations useful for the attendees and send them by email. In the email, we will also ask if the attendees would like to join an international expert panel.

Helping communities connect with their local wildlife / Involving citizens to monitor and create support for wildlife crossings

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Wildlife crossings help to protect the lives of thousands of animals every year. In order to know how the crossings function and which, when and how many animals use these crossings, it is essential to monitor wildlife crossings. But processing monitoring data is a lot of work. Additionally, it is a challenge to translate or communicate (positive) results to citizens, to create general support for wildlife crossings. To meet these challenges we involved citizens in monitoring wildlife crossings, by creating an online platform called Wildspotter.nl.

In the Netherlands, Arcadis developed an innovative concept for monitoring wildlife crossings. Capturing videos from over 100 crossings and sharing them online with the public through an online monitoring platform: www.wildspotter.nl. Built as an interactive platform with gamification – an increasingly crucial digital engagement tool – people can watch monitoring videos and identify the animals they see, helping with categorizing and logging the variety of species. Dozens of users identify every video, so the video is analysed based on 'crowdsourcing'. Users can motivate and discuss their answers with other users and share videos on social media. This improves the data quality, makes it possible to learn from each other and increases the level of involvement. So far the site has had over 17,000 visitors, from which 2,250 visitors participated in the video analysis. Generating a lot of media attention, it has helped to dispel criticisms that wildlife crossings do not work and, more importantly, create more support for constructing and monitoring wildlife crossings. The interactive platform also showed how the public could support the execution of projects by contributing to data analysis, such as identifying animals, saving organisations time, resources and money. So far, over 1,500 videos have been analysed. To compare the reliability of the data produced by Wildspotter.nl, we compared the identifications from the public with those made by an ecological expert. As it turned out, the general public identified a number of 98% from the 973 videos from 2016 correctly. This analysis shows the strength of the concept and that involving citizens in data analysis can be highly effective.

In this workshop, we want to share our (and your) experience on involving citizens in ecological monitoring, using digital platforms to facilitate participation and communication and on how to create support. We will mainly focus on involving large groups of people using digital tools. We will discuss the dos and don'ts, look for (other) ways to involve citizens, and we will explore how citizen participation can become part of your projects and initiatives. We want to share our positive experience with involving citizens in monitoring activities; both for the benefit of performing better and more efficient research, as for the need to create more support. We believe that involving citizens can benefit the development and monitoring of wildlife crossings, but also to (re) connect citizens to nature in their 'backyard'. We will use the online platform wildspotter.nl as a showcase:

- To show the potential success and benefits involving citizens can have on developing and monitoring wildlife crossings;
- Sharing experiences on involving citizens with digital platforms. We are also

keen to hear about the experiences of the workshop participants involving citizens in general;
- Explore other ways and benefits in involving citizens or more specific groups of volunteers, preferably with example projects or initiatives from the workshop participants;
- Discuss the data quality, risks, and benefits, when involving citizens;
- Also, we would appreciate any feedback on Wildspotter.nl or on engaging citizens in general;
- People involved in developing or monitoring ecological corridors and that are willing to explore the benefits of involving citizens in the process. Researchers, project developers, and policymakers.

A summary of the outcomes of the workshop will be made and send to the interested participants. We will use the feedback to improve Wildspotter.nl and other platforms. We hope to inspire and motivate participants to start involving citizens more actively and to gather specific information to make the first steps.

Evaluation of international policy on environmentally sustainable transportation infrastructure in an era of rapid global expansion

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The global demand for the construction of roads in the 21st century is enormous while the rate of biodiversity loss is well above historical averages. Much of the new transportation infrastructure will be developed within and around areas currently managed for biodiversity and ecosystem service values, thereby undermining past, current and future conservation investments. Roads and other 'grey' linear infrastructure, such as railways, waterways, and pipelines, are essential for sustainable development. However, often these roads have deleterious impacts on species, communities, and ecosystems, including human and wildlife injury and mortality, deforestation, barrier effects, carbon emissions, wildlife poaching, and land clearing. Impacts can extend for kilometres from the transport infrastructure itself and continue to develop for years, thereby affecting ecosystems and their services across the landscape. On the other hand, maintaining healthy ecosystems, particularly in the warming climate scenario, can both protect 'grey' infrastructure by reducing potential damage from hazards such as landslides, flooding, and erosion - and provide 'green' infrastructure that can protect communities from harm.

In collaboration and consultation with colleagues in Europe, Africa, Latin America, Asia and the Pacific, IENE, WWF, and ANET have been working together to build a coalition of partners interested in developing a globally relevant best-practice guidance to ensure that the linear infrastructure we build today is as ecologically sensitive as possible. The coalition evolved from experience gained in a project to advise on how to address the ecological challenges of a road project through the biologically rich trans-border area of Myanmar and Thailand. This collaboration has been gaining partners and momentum since it was first presented at the ICOET 2015 International Conference in Raleigh, North Carolina, USA.

The framework of the "International Guidelines for Environmentally Friendly Linear Infrastructure" (IGELI) project focuses on developing countries as more environmentally vulnerable countries and increased demands for development, which includes two parts. The first is to prepare a review of the existing international policies on ecological connectivity, transportation, and development covered by four International Conventions: a) the Bonn Convention on Migratory Species (1979); b) the Convention on Biological Diversity (CBD) (1992) 2011-2020 Aichi targets; c) the UN Sustainable Development Goals (SDG) (2015) and d) the UN Framework Convention on Climate Change Paris Agreement (2015). In the second part, an international discussion on guidance has been underway through special sessions and workshops at international meetings, including the IENE 2016 International Conference (Lyon, France), the IUCN World Conservation Congress (Hawaii, USA, September 2016), the ICOET 2017 International Conference (Salt Lake City, USA), the International Forum on Sustainable Infrastructure (Hanoi, Vietnam May 2017), and the International Workshop on Sustainable Harmonization of Green with Grey Infrastructure in South Eastern Europe (Faget, Romania, October 2017). During these events, special presentations and discussions took place on linear infrastructure guidance, defining the needs, concepts, tools, and strategies for an international policy that could be included in guiding the development of environmentally sustainable linear infrastructure projects globally. Participants at

these events covered a wide range of topics, including specialists in ecology, engineering, policy making, international finance and economics and representing environment and transport sectors, government ministries, banks, universities, international institutions, and NGOs from all over the world.

The workshop at IENE 2018 will aim to develop recommendations for the parties to the Convention on Biological Diversity this year as they consider the priority theme of mainstreaming biodiversity in the infrastructure sector at the CBD Conference of the Parties in November of 2018. The workshop will include three sections:

a) Short presentation of the results of the policy review of the four international conventions and the conclusions to date of the on-going international discussion on linear infrastructure guidance;
b) Discussion of these results and conclusions and formulation of recommendations in small groups of 8 to 10 participants;
c) Presentation of the group recommendations defining the overall final feedback.

The results of the workshop will be included in the final report and the deliverables of the IGELI Project. At the same time, the framework of the recommendations for the CBD will be further developed by the organisers in cooperation with other international organisations, such as IUCN (Connectivity Conservation Specialist Group/Transport Working Group), to as input in CBD Conferences of Parties Egypt in November 2018 and China in 2020.

Data for conservation: Towards the exchange of road kill and wildlife observations in Europe

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Roads form barriers for traveling and commuting animals. If animals try crossing a road, they might end up as road casualties. Many measures are invented to diminish these conflicts between human and animal commuting routes. To be effective, these measures have to be constructed in the right places. We need data, e.g., about hotspots of road casualties among animals to find the right places. Data about road casualties can also help to evaluate the effectiveness of measures taken: do they solve the problem or do they create new hotspots?

Currently, citizens are involved in recording sightings of animals in several European countries, in some cases with a particular focus on road kills. In Belgium, the Netherlands, Austria, and the UK citizen scientists record road kills on a continuous basis. Other countries, such as Sweden and the Czech Republic, base road kill monitoring systems on car crash data and make efforts to combine this with citizen science data from national nature observation platforms. However, many European countries don't monitor road kills, despite the many advantages of research and mitigation of road effects on wildlife and increasing driver safety. Existing monitoring systems differ. Some record incidental sightings of road kill, some record sightings along regularly travelled transects, and other countries do both. Earlier, data collected by drivers in the UK and the Netherlands lead to the identification of hot spots. The data could also be used to evaluate the effect of roads on the viability of local species populations.

To learn more about the effects of roads on animal species, by identifying hotspots as well as by evaluating mitigation efficacy, we want to upgrade the citizen science projects on road casualties to a European wide level. Ideally, we plan to have a wildlife registration system in every European country in a couple of years. The systems can differ per country but the data collected should enable research on a European level. For example, to analyse differences between road kill hotspots, mitigation solutions, or scientific questions connected with the EU Green Infrastructure Strategy. In essence, the systems should collect more than just road kill data because the effects of roads on species populations extend further into the landscape than the road itself.

In this workshop, we will discuss the practical aspects of implementing registration systems in countries without such a system. It will also explain the exchangeability of the data from these systems to answer European wide road ecological questions. The aim is to come to road kill and wildlife observation systems in all European countries that deliver data for road ecology research on a European level. For a successful workshop we need participants with different backgrounds and different nationalities: (1) Scientists: for criteria to get useful data for scientific studies; (2) Volunteer managers: to suggest ideas for recruiting and motivating volunteers; (3) Tool builders: to discuss tools that facilitate the collection and sharing of data; (4) Road managers: for road management criteria; (5) Road authorities: for funding criteria.

The workshop will be structured as following:

1. Introduction
   - Short introduction round.
   - Short introduction to the goal(s) of the workshop and the used discussion methods.
   - Presentation of 'Dieren onder de wielen' (road kill monitoring in Belgium). The presentation describes the registration system, fundamental success factors, the people involved and the scientific questions that can be answered with the data.

2. Listing issues to tackle
   - Short discussion in small groups to find the main problems that the participants expect in (1) the establishment of national wildlife registration systems used by citizen scientists and (2) the exchange of data at a European level. The discussion will focus on practical aspects of setting up a national system. For example, whether to create a new registration platform (website and app) or to adopt an existing one, establishing a user community (citizen scientists), keeping citizen scientists engaged, guaranteeing the reliability of data, warrant the exchangeability of data, collecting enough data for statistical analysis, the cooperation of national road authorities, multiyear funds to keep the systems operational.
   - In a plenary session, we create two lists of primary issues to tackle based on the feedback of the groups: one for national systems, one for research with data from different observation systems.

3. Listing solutions
   - The participants will brainstorm in small groups about possible solutions for (a selection of) the main issues listed in the previous session. Each group treats one issue.
   - Plenary session where each group presents the possible solutions.

The participants will be asked to take part in a project group. The project group will use the outcomes of the workshop to set up a strategy for the establishment of national observation systems and the use of the data for European wide scientific questions. The first two actions of the project group will be to find organisations that want to participate in the implementation of the strategy and to find funds to make this possible.

The results of the workshop, for example, the onset of a strategy plan, will be published on the IENE (conference) website and on the websites of the organisations that take part in the follow-up and implementation of the strategy. It will also be published on social media, including the LinkedIn and Facebook pages of IENE. Follow up activities might be organised under the umbrella of IENE, such as supported workshops and meetings, which will be announced on the IENE website and in emails sent to the members.

The goal at the end of the workshop is to create a team of people that will elaborate and carry out the strategy to come to a road kill and wildlife observation registration system in every European country that delivers data for research on (green) infrastructure and its effect on wildlife (populations) in Europe. Most likely the two first steps after the workshop will be:

1. Finding organisations that want to collaborate in as many European countries as possible;
2. Finding funds.

KDE+ workshop: New approaches to WVC hotspot identifications

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The first KDE+ workshop was held in Lyon during the IENE conference in 2016. The idea behind this second KDE+ workshop is to allow the attendees to receive information on new developments with this software and test it on actual data. This event is planned as a practical exercise for researchers equipped with their laptops. A concise overview of the theoretical background will be provided, but we encourage the attendees to study the very basics of the KDE+ method in advance (www.kdeplus.cz). We want to present the recent developments of the method to existing and new KDE+ users. This workshop is opened for everyone interested in both theoretical and practical approaches of WVC hotspots identification using KDE+.

Although there are no limitations to the number of participants, we encourage the participants who would like to work actively with the software to register at gis@cdv.cz. Do not hesitate to bring along data. We strongly encourage the attendees to have their data ready for the analyses. Only road network data and WVC data are necessary. Inform yourself in advance if your data are suitable for the analyses. The workshop organisers are ready to check the data quality in advance. It is no problem if you do not have data. The organisers will provide you with sample test data. Do not forget to bring your computer.

The KDE+ method has been implemented into two forms: a standalone JAVA app that will run on both Windows or Apple platforms and an ArcGIS Toolbox. In the latter case, you have to have ArcGIS 10.1 – 10.5 installed. The JAVA app requires input data being in CSV files or shape files. The ArcGIS Toolbox process only shapefiles. The workshop is intended for users who can work with a GIS or with spatial data in general. However, other users, for example, practitioners, field workers, and decision makers are also welcome to attend the workshop.

The workshop is planned to take one hour only, but feel free to ask the workshop organisers during the conference. We recommend the prospective workshop attendees to send us their data before the workshop so we can check its quality. Time needed for hotspots computation varies according to the number of roads and WVC data. It is not necessary to have analysed the entire country during the workshop, only a few selected roads or a small region would be enough to obtain an idea of how the software works and how to interpret the results.

Avenues and other trees in rural landscapes: How to maximise their ecological and social benefits as Green Infrastructure

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In the past, roads and other transportation infrastructure have been perceived only as a barrier for many organisms. However, their role as green infrastructure for biological diversity is increasingly appreciated. Trees are an essential part of many traditional European landscapes, both urban and rural. In these anthropogenic environments, they help to maintain biodiversity and ecological equilibrium as habitats and ecological corridors. Insects, birds, lichens, fungi, and mammals (e.g., dormice) use avenues and other trees in open environments. EU and national regulations protect many of the mentioned organisms. However, trees are also among the least appreciated elements of the green infrastructure, often taken for granted by both society and tree managers. The management of trees is often ineffective in European countries. As a consequence, the resource becomes impoverished. Roadside trees have been disappearing in recent decades from European countries, due to hasty road modernisation and mismanagement. Replanting is rare. The growing trees are often subject to improper care practices, which reduces their life expectancy and impacts public safety, generating criticism of trees in media. How to reconcile the presence of trees with other types of infrastructure, such as roads, railways and canals are particularly challenging. Using synergies between the green, grey and blue infrastructures will maximise the trees' benefits. At the 2016 IENE conference in Lyon, there was a separate session on tree avenues as ecological corridors. The final declaration called to "Recognise the importance of trees in HTI for the ecosystem services they provide in cultural landscapes as well as their role as habitat for small fauna".

The goals of this workshop are: (1) To explore how trees in rural landscapes, particularly roadside trees, contribute to ecological connectivity - being a backbone of biodiversity in rural landscapes and providing numerous benefits to society, including climate change mitigation and providing life quality; (2) To explore threats to trees and discuss how they can be preserved (good practices); (3) To formulate recommendations for management of trees as green infrastructure to maximise the benefits to nature and society. Emphasis will be put on roadside trees (avenues). However, other settings will also be considered, such as trees along waterways, urban trees, trees in agricultural fields. Target groups for the workshop are: (1) Biologists researching ecosystems of road verges; (2) Conservationists working to protect traditional landscapes; (3) Infrastructure managers and designers.

The workshop will be structured as follows:

- Introduction and discussion to define the role of trees in Green Infrastructure;
- Reviewing threats to trees;
- Exchanging best practices;
- Formulating recommendations - for management and policy.

The outcomes of the workshop will contribute to the final declaration of the conference. The complete outcomes will be used in the framework of the LIFE project "Trees for Europe's Green Infrastructure" in working groups elaborating specific recommendations. They also will be disseminated through seminars in Brussels (planned for the year 2019), Germany, and Poland. The products of the project will be presented at next IENE conference in 2020.

Crossing borders between ecological planning and engineering technology to achieve faster approval procedures and better species and habitat protection

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Measures of landscape planning - especially in the field of species and habitat protection – need to be directly effective (without a scientific doubt) under European law. The commonly used measures of landscape planners dealing with the planting of vegetation are often not adequate (plantings are susceptible to interferences, only have long-term and limited spatial effects). Therefore, measures for species and habitat protection have to become more technical-oriented; especially to avoid time lags. Sometimes, a kind of particular vegetation technology is necessary. The realisation of an infrastructure project is often dependent upon the most creative and useful application of particular technical solutions for the protection of species or habitats. Nevertheless, many projects suffer from the lack of adequate technical solutions. Sometimes projects fail, or projects are delayed because no (technical) solution was found. The workshop gives better understanding and stimulates a better cooperation between landscapers and engineers and aims to identify and discuss best practice examples of timely solutions.

The content and the strategy for the workshop are presented using five examples.

1. Mobile protective walls as a measure of damage limitation and preventive measures (for a lot of impacts in Natura 2000 Areas) like crossing aids for birds and bats, barriers to prevent animals from entering the construction area;
2. Technical protection of lizards (e.g., *Lacerta muralis, Lacerta agilis*) against predators as a part of the relocation of populations (continuous ecological functionality measures, CEF measures);
3. Installing of technical markers on wires of existing power lines as „favourable conservation status", FCS measures to compensate bird strikes (directly effective mitigation measure for collision risk at a bridge for the same population of birds);
4. Transplanting of large trees to protect populations of xylobiont beetles (e.g., *Osmoderma eremita*);
5. Construction of Benjes hedges to reach directly useful structures (relinking, breeding or hunting habitats for birds).

A lot of relevant species and habitat protection measures can be realised in certain cases by directly effective and most innovative technical solutions. The relevance of the best technical solution to solve ecological problems is presented in case studies from the poster session of the FGSV (see below). The aim is to motivate participants to create posters for the best practice collection of the FGSV. The discussion will be structured as follows:

1. The participants are expected to comment on the solutions presented.
2. Discussion:
   - How can we achieve directly effective measures regarding damage limitation or mitigation?
   - How can we use all possibilities of technical potential to get the best result, which means to speed up projects and reach legal security?
   - How do we need to optimise the application of engineering technology in the field of species and habitat protection?

During the discussion, the participants should briefly present other cases of best practice examples of their own country or experience. Additional information on the best practice collection can be found on the website of the Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV, Cologne (http://www.fgsv.de/gremien/strassenentwurf/landschaftsgestaltung/296-landschaftspflegerische-kompensationsmassnahmen.html).

The organiser of the workshops will create posters of the workshop results and upload them to the FGSV platform. Posters and other input papers of the participants will be uploaded as well. So far, the collection contains about 140 posters. The poster sessions are already internationally organised (in German and English). Beside various German examples the following countries are involved: Austria, Switzerland, Luxemburg, Poland. The website is operated professionally and will be updated on a regular basis. Therefore, long-term documentation of the findings is ensured. The poster sessions have been used in a research project of the „Bundesanstalt für Straßenwesen, (BASt)". Based on the research project, some guidelines of German infrastructure planning (concerning risk management and mitigation in particular) have been developed or updated. The results of the IENE workshop will be part of updates or intended guidelines of the FGSV and will be published in national („Straße und Autobahn", „Straßenverkehrstechnik") and international journals.

Challenges for assessing mitigation effectiveness: Does an ideal study design exist?

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In order to mitigate road impacts, a variety of mitigation measures have been implemented on roads worldwide. The costs vary widely according to the type of measure, but expenses associated with mitigation implementation and maintenance can be an important part of a road budget. Although impressive efforts are invested in mitigation, proportional investments do not follow these in assessing mitigation effectiveness. Recent literature has pointed out that little is known about what types of measures are most effective and if mitigation measures are actually mitigating road effects at all. A common problem in these mitigation studies is that study designs employed are usually inadequate to assess the effectiveness of mitigation measures.

This workshop aims to discuss how monitoring studies can be improved to better assess mitigation effectiveness and generate knowledge that can be applied to other roads. The workshop targets an audience of researchers and practitioners, including both road managers and environmental consultants. The workshop will be 60 minutes in length and structured in three different moments: a short presentation, discussion in small groups, and a general discussion with all participants. The organisers will present a few study designs that ideally would be applied to assess mitigation effectiveness. This will be a brief introduction about the challenges of assessing mitigation effectiveness, where ideal study designs required to answer important questions about effectiveness will be presented to participants as topics for discussion. Then, the audience will be divided in small groups where they will be asked to list positive and negative aspects, as well as feasible and impractical aspects of each study design. Finally, a discussion involving all participants will be facilitated in the third moment of the workshop with the goal of first sharing the discussions taken within each group and latter synthesizing the ideas.

The facilitator will lead the discussion using participatory tools, first by gathering the ideas from participants of each group and then using stacking rounds to encourage the involvement of all participants. Seating arrangements will be made to allow maximum interaction between attendees. Tracking will be used to follow important elements of the topics being discussed and to synthesize the main topics. Expected outcomes of this workshop are the identification of any gaps in understanding, in expectations, and in feasibility about mitigation studies. We seek to identify barriers to the implementation of satisfactory study designs from the perspective of road planners and managers. The main findings of the workshop will be a synthesis about positive and negative, and feasible and impractical aspects of each study design for monitoring mitigation effectiveness based on researchers and practitioner experience, with recommendations about study designs for the assessment of mitigation effectiveness. These findings will be communicated in an opinion paper to be written after the workshop where we will discuss how studies can be improved to counteract negative and unfeasible aspects while guaranteeing good designs, as well as presenting the opportunities and challenges for their implementation. By integrating researchers, road planners, and managers in an interactive way, this workshop can help to decrease the gap between the questions about mitigation effectiveness that need to be answered and the efforts necessary for answering them.

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