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SafeBatPaths

Fumbling in the dark – effectiveness of bat mitigation measures on roads

Final report

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Final report

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Executive summary

The *SafeBatPaths* project aimed to elucidate on the current extent of implementation of bat mitigation on roads in Europe, review the evidence of the effectiveness of the measures and needs for further knowledge, and experimentally to test one type of measure (hop-overs) in a field study. The findings were to be collated in an updated end-user guideline.

This report summarises the main results and recommendations from the *SafeBatPaths* project on themes:

- Implementation of bat mitigation and compensation
- Monitoring standards
- Maintenance standards
- Evidence of effectiveness of mitigation measures and points of attention
- Field test of hop-overs
- Future research needs
- An updated guideline on bat mitigation on roads for relevant road and nature authorities and consultants.

Finally, the actions to disseminate the results and recommendations from the project to relevant stakeholders are listed.

We envisaged that project guidelines, the planned extension to the COST 341 Handbook and potential implementation of the findings and recommendations from the SafeBatPaths projects in EUROBAT documents may stimulate the development of effective bat mitigation interventions in more countries throughout Europe.

1 Introduction

Mitigation of the impact of transport infrastructures on wildlife has become increasingly important in order to develop ecologically sustainable transport infrastructures. Although bats can easily fly across road and railways research have shown that transport infrastructures can have detrimental impacts on bats (Abbott et al. 2015). A variety of interventions to mitigate and compensate for the effects of roads and traffic on bats have been implemented in road development schemes during the past decades. Little is known about the effectiveness of the bat mitigation and as the planning and construction phases of road projects span years, the accumulation of experience within each country can be slow.

The *SafeBatPaths* project aimed to elucidate on the current extent of bat mitigation on roads in Europe, review the evidence of the effectiveness of the measures and experimentally test one type of measure (hop-overs) in a field study. The findings were compiled in an updated guideline on bat mitigation on roads (and railways) for end-users.

This report outlines:

- activities, main findings and recommendations from the *SafeBatPaths* project,
- perspectives for further researches to develop more effective mitigation schemes,
- actions to disseminate the results and recommendations from the project to relevant parties among road and nature authorities, researchers and consultants.

2 Main results and recommendations

2.1 Bat mitigation and compensation

Bat mitigation and compensation measures have been implemented in road infrastructure schemes in 14 of the 29 European countries from which we received information on the issue (Elmeros et al. 2016). Bat mitigation is most widespread in Germany, France, Ireland, the Netherlands and United Kingdom that published guidelines for bats and roads some two decades back. However, comprehensive mitigation schemes have been employed on recent road projects in some other countries as well.

A variety of measures are often implemented in a road scheme to mitigate the different potential impacts by roads on bats. Some measures are purpose-built for bats, but most crossing structures listed as bat crossing structures are large multispecies or multifunctional passages that have been adapted to enhance their suitability for bats. Use of other technical road structures have been observed but does seems to be incidental.

There is an increasing awareness of the need to integrate mitigation measures for bats in new road schemes in most countries; both in countries where bat mitigation has not been applied previously and more intensive mitigation schemes in the countries where the procedures are well established.

Recommendations for bat mitigation on roads

- A precautionary approach is advised as the status of bat populations is very sensitive to increased mortality and landscape changes.
- Mitigation strategies should consider all relevant aspects of road effects (e.g. mortality, road permeability, disturbance, barrier effect, degradation of habitats and loss of roost sites) to neutralise the impact of a road scheme.
- Passages and guiding structures should be in place and operative well before existing habitats are destroyed and before the road opens to traffic to allow the bats to habituate to the measures.
- Establish a national database of mitigating and compensatory interventions to promote better convergence and exchange of experiences between projects, and as management tools for maintenance and monitoring procedures.

2.2 Monitoring

Post-construction monitoring programmes are carried out in most countries, but only the road authorities in Germany, Ireland and the United Kingdom have systematic programmes that provide concise guidance to evaluate the performance of bat mitigation interventions on major road schemes.

Most of post- construction surveys of bat mitigation measures in all countries have been irregular short-term studies. Comprehensive long-term monitoring programmes that also compile information on population development are few. Such studies should be encouraged to evaluate the overall effectiveness of mitigation schemes on landscape and population levels and eventually to enable development of cost-effective bat mitigations.

Survey reports are confidential in some countries. In order to promote better convergence among projects and between countries and expedite development of more cost-effective mitigation schemes, the monitoring results should be easily accessible.

The vast majority of pre-construction and post-construction surveys of bat mitigation measures are descriptive studies of use. More rigorous monitoring methods and publication of the findings in scientific papers should be promoted to ensure future development of cost-effective bat mitigations.

Recommendations for monitoring

- Study design should be rigorous and quantitative for both pre- and post-construction studies to allow comparison.
- Define target species and goals for the monitoring (use vs. effectiveness).
- Select appropriate, accurate methods and include control sites for effectiveness assessments.
- Regular long-term monitoring and assessment schedules, e.g. every 3-5 years, should be integrated in the general road management plan.
- Monitoring should also assess landscape and populations effects
- Monitoring reports should have a clear summary that includes quantitative results, statistical analyses and metrics for the passages.
- Monitoring reports should be publically accessible to increase knowledge exchange between road mitigation schemes, road developers and consultants.

2.3 Maintenance

An appropriate maintenance strategy is essential to ensure the long-term ecological functionality of the mitigation measures, e.g. vegetation ma block passages or guide bats to unsafe crossing sites. We received little information on maintenance procedures and costs for bat mitigation measures. Maintenance and associated costs for bat interventions are not separated from other tasks in the planning and potential contracting of road maintenance programmes. Thus, it has been difficult to identify maintenance procedures, costs and risk factors associated with the maintenance procedures.

The Dutch road agency has developed dedicated maintenance guidelines for fauna passages, which have successfully been integrated into the general road management plan. The maintenance handbook outlines ecological goals for different types of passages, timing and frequency of inspection and maintenance task.

Recommendations for maintenance

- Maintenance of bat mitigation interventions should be an integrated part of the general management plan for a road.
- The objectives, target species and maintenance requirements for the mitigation structures should be clearly defined.
- Development of standardised maintenance guidelines and schedules for the measures are advised.

- The maintenance scheme should include both the mitigation structure itself, adjacent bat habitats and landscape elements.

2.4 Review of effectiveness of measures

Many types of interventions have been implemented to mitigate and compensate the adverse effects of roads and traffic on bats during the past decades. Initial studies showed that bats use most of the interventions as intended, but only a few recent studies have examined the bats' behaviour and use of the measures adequately to assess their effectiveness (Berthinussen et al. 2013).

To evaluate the effectiveness of road mitigation for bats, we reviewed studies on mitigation and compensation measures, we extracted information from scientific papers, consultancy notes, industry reports, student reports and conference presentations. The quality of the evidence of effectiveness was assessed from the study design. Studies that only reported the use of a measure by bats were included in the review to present the available information on bats and road mitigation.

Few studies have examined the effectiveness of mitigation measures on roads (Møller et al. 2016). Nor did they compare the number of bats crossings at a site before and after the road was constructed. Preconstruction data for most measures was often missing or of inadequate quality to compare to post-construction data to assess effectiveness.

Only a few large types of crossing structures were assessed as effective providing that they are designed and located optimally (table 1). For most of the measures there is little evidence suggesting that they are effective. These measures should be regarded as experimental interventions and should be studied methodically to determine their effectiveness if implemented. Potentially, in situ field experiments could be performed before the construction of the road to optimize the mitigation location and design details of the structure. A robust, quantitative scientific approach appropriate for statistical analysis is advised for such evaluations of effectiveness.

Bats show large species-specific differences in echolocation, flight behaviour and typical flight height. Hence, it is essential for road developers to have exact information on species occurrence in the project area to make informed decisions and implement the most effective mitigation schemes.

It is a complex task to estimate which traffic-related mortality rates and fragmentation levels the bat populations can sustain, and to define universal criteria for the effectiveness of mitigation structures. The level of the mitigation that is required to protect the status of bat populations likely varies between species, population status, habitat use, human land use and traffic intensity. The application of realistic population and landscape modelling to predict the probable effects of roads and mitigation measures on bat populations is hampered by a general lack of quantitative data on demographic rates, population dynamics and road impact. Consequently, to comply with the conservation concerns for bats, a precautionary approach should be applied when assessing the effects of roads and the effectiveness of bat mitigation measures.

Table 1. Provisional assessment of measures and their potential effectiveness to mitigate road impacts on bats differentiated between low- and high-flying species (see Tab. 2).

1/ A recommendable intervention if located and constructed correctly. Good evidence that bats use the structure or that the method is effective.
2/ A potential effective intervention which shows encouraging results. Further assessment requires better documentation of effectiveness or development of the measure.
3/ An intervention where more research is needed to assess its potential. Studies indicate some use and effectiveness for some species.
4/ An intervention that has proved to be ineffective, has shown very ambiguous results, or cannot be used as a compensation method. Not recommendable.

				Assessment	
Mitigation method		**Use (Y/N)***	**Effective (Y/N)***	**In or near vegetation and surfaces**	**Open-airspace**
<u>Fauna passages</u>					
Wildlife overpasses		Y	Y	1	1
Modified bridges	Green verges	Y	(Y)	1	1
	Panels	Y	?	3	n/a
Bat gantries	Open structures	Limited	N	4	4
	Closed structures	Y	?	3	3
Hop-overs		Y	?/N	3	3*
Viaducts & river bridges		Y	Y	1	2
Tunnels & Culverts		Y	Y/?	2**	4
<u>Other interventions</u>					
Hedgerows & tree lines		Y	?	2	3
Barriers		Y	(Y)	2	3
Artificial lighting	Deterrence of bats	Y	?	3	3
	Adaptation of light spectrum	(Y)	?	3	3
	Restriction of light spill	(Y)	?	2	2
Audible warning		(Y)	?	3	3
Speed reduction		?	?	3	3
<u>Ecological mitigation</u>					
Bat boxes		Y	N	4	4
Bat houses		Y	Y/N	2	2
Relocate tree trunks		(Y)	Y/N	3	3
Artificial holes in trees		?	?	3	3
Tree retention		?	?	2	2
Habitat improvements		Y	?	2	2

'Y/N' denotes that studies have shown ambiguous results. A question mark indicates than no information on the use or effectiveness is available. Brackets indicate that some studies have indicated the measure is used or effective, but too few studies with a flawed design to be conclusive. *On low bridges and roads on embankments over tunnels and culverts. **Effectiveness also size-dependent for low-flying species.

2.5 Field test of hop-overs

A hop-over consists of tall trees and shrubs on the road verges on either side of a road. Hop-overs have been suggested as a quick, low-cost method to facilitate safe bat crossings at severed hedgerows. However, information on bats' use of hop-overs is primarily based on incidental observations and quantitative studies are scarce (SWILD & NACHTaktiv 2007).

We examined the effectiveness of hop-overs for *Myotis daubenonii* and collected information on two other moderately structure-bound species, *Pipistrellus pygmaeus* and *Barbastella barbastellus* (Christensen et al. 2016). The effectiveness was evaluated by comparing bat flight height and behaviours before and after two parallel screens (4m high, 20 m long). The screens were installed with 8-10 m between them in natural gaps in commuting routes to simulate severance of a commuting route a road with screens.

The proportion of *Myotis daubenonii* bats that crossed the hop-over gaps at more than 4 m of heights increased from 31% before to 76 % after the installation of the screens, but there was a large variation between sites (46-85%) (fig. 1). No change in the bats' flight heights was observed at the control sites. The proportion of *Pipistrellus pygmaeus* that crossed over the gaps at heights above 4 m increased from 39% to 61%, while on change was observed for *Barbastella barbastellus*, 87% before and 89% after.

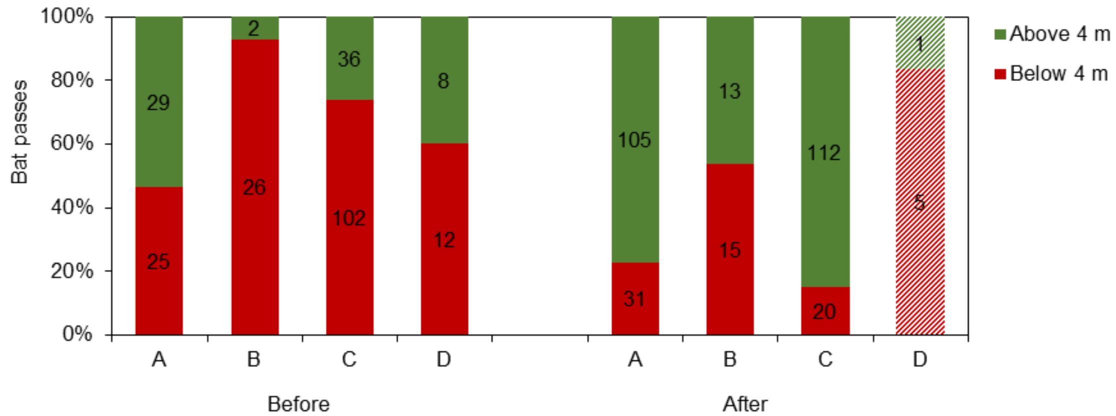

Figure 1 - *Myotis daubenonii* crossing height before and after establishment of the hop-over screens on the four experimental sites. Numbers indicate recorded bat passes. Hatched columns indicate very low sample sizes.

Myotis daubenonii bats habituated quickly to the changed conditions on the flight path. A higher proportion of these bats flew over both screens after two weeks compared to the first night with screens (fig. 2). The proportion of *M. daubenonii* bats that turned around at the screens was very low after two weeks, but the screens presented a barrier for 8% at one site. The flight pattern of 10-33% of *M. daubenonii* bats resulted in crossing of the potential road at hazardous heights.

A high proportion of *Pipistrellus pygmaeus* were observed to bypass the screens (67%) only to cross the gap at low height at the end of the screens. The flight behaviour for the *P. pygmaeus* did not change between the first night and 1-2 weeks after the screens had been installed (site D, fig. 2).

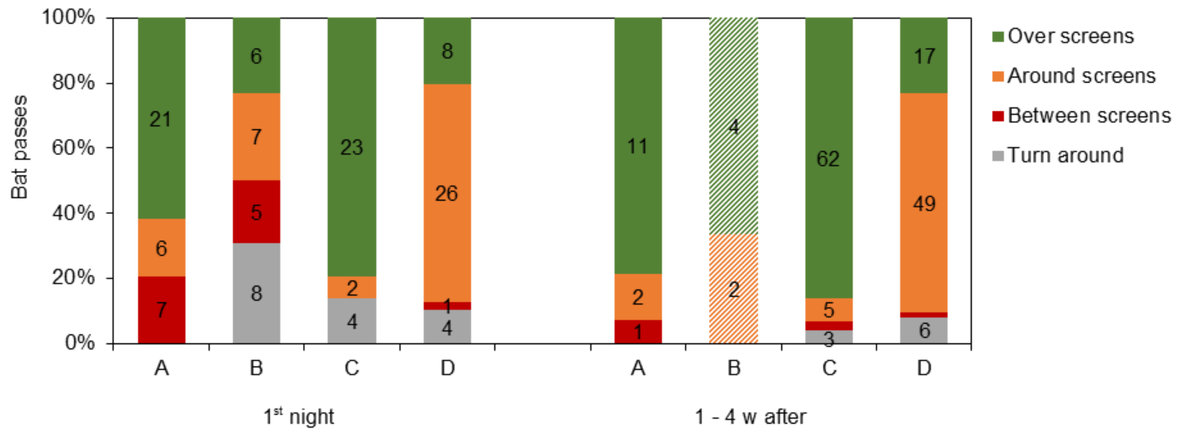

Figure 2 - Behaviour of *Myotis daubenonii* (site A, B and C) and *Pipistrellus pygmaeus* (site D) on the 1st night with screens and 1-4 weeks later based on visual observations. Numbers indicate recorded bat passes or attempts. Hatched columns indicate very low sample sizes.

The hop-overs and screens showed some potential for reducing bat-vehicle collision risk and the screens did not appear represent a major barrier for the commuting bats. However, hop-overs cannot be generally recommended, as their effectiveness is too low at some site. At one site more than 50% of individual bats still crossed the hop-over gaps at hazardous heights, and some individuals appeared to switch to alternative commuting routes.

Bat species have significantly different flight behaviours. The results only represent the study species and probably species with similar flight patterns. Bat species with different flight patterns may respond differently to hop-overs and screens (SWILD & NACHTaktive 2007), and further studies are needed understand different bats species' behaviour at hop-overs. Further research is also recommended concerning the effectiveness of hop-over with different characteristics, e.g. denser tree canopy cover overhanging the road, longer or higher screens, wider gaps, and the effects of light and noise pollution from the road. We recommend further experimental studies and that new hop-overs are monitored systematically to collect empirical evidence on their effectiveness.

2.6 Workshop and future research needs

The *SafeBatPaths* project held a small workshop at Aarhus University, Kalø in February 2016. The aim of the workshop was to discuss the status of current road mitigation measures, our present knowledge on their effectiveness, future research needs and best practice for bat mitigation strategies.

Five external bat researchers on bat conservation and road infrastructures were invited to the workshop to compliment the skills and experiences amongst the project partners. Another 16 experts representing road and nature authorities, consultants, NGOs and researchers from a total of nine countries were represented.

In addition to presentations on preliminary results from the SafeBatPaths project, the invited experts presented results from their studies on bat mitigation.

Figure 3 - The participants on the small and very productive workshop held at Aarhus University.

Future research themes

Based on the presentations and discussions on the workshop four themes were identified for future research to improve the cost-effectiveness of road mitigation for bats:

- Monitoring and research projects should focus on estimating the effectiveness of mitigation measures, rather than quality or quantitative records of their use by bats. There is a need for more consistent methods of measuring, analysing and reporting the studies of the use and effectiveness of mitigation measures to facilitate future meta-analyses. As a minimum the reports should re
- There is a need to determine and understand the variability in functionality and effectiveness for some mitigation measures between sites.
- Lighting of roads and mitigation measures may impact their effectiveness, but much is still unclear.
- To improve and plan mitigation schemes more effectively, there is a need to elucidate the effects of roads and mitigation measures at the population levels.

For further details on the documentation of use and effectiveness, the advantages, constraints and uncertainties in the assessments for each of the different mitigation types is presented and discussed in the report For further details - see Dekker et al. 2016).

2.7 Best practice guidelines

The findings from the literature review of the use and effectiveness of various mitigation measures and the discussions on the workshop has been synthesised in an updated guideline document on bat mitigation on roads (Elmeros et al. 2016).

The guideline addresses the following areas:

- Brief description of relevant aspects of bat biology and species differences which must be considered when developing mitigation strategies in road and railway infrastructure projects.
- Methods for pre- and post-construction surveys, monitoring of effectiveness of mitigation measures and potential road impact on landscape and population scale.
- Best practice mitigation recommendations based on the evidence of bats' use and the effectiveness of bat mitigation measures (see table 1).

A Dutch and a Spanish version of the guidelines have also prepared (Dekker et al. 2016, Garin et al. 2016).

3 Dissemination

3.1 Conferences and Workshops

During the project the *SafeBatPaths* project has promoted the projects and presented the findings on workshops and conferences to road agencies, bat researchers, ecological consultants and NGOs.

End-of-programme event, Cologne, Nov. 2016

The outcome of the *SafeBatPaths* project will be presented at the Road & Wildlife workshop in Cologne in November 2016. The main recommendations from the project and the *Harmony* and *SafeRoad* projects have been collated in the CEDR Road & Wildlife Manual, which will be presented and discussed with members from European road authorities, bat experts and ecological consultants.

National Road Authority meeting, The Netherlands, October 2016

Jasja Dekker presented the project and evaluations on a meeting on road mitigation policy and implementation arranged by the Dutch National Road Authority. The other two CEDR Roads & Wildlife projects *Harmony* and *Saferoad* were also presented at the meeting.

IENE, Lyon, France, September 2016

The project was presented with a talk and a poster on the conference (Annex 1). The talk presented the assessments of the different types of measures and recommendations for best practice bat mitigation strategies. The poster presented the results of the hop-over field study.

Ecology in Practice, The Netherlands, March 2016

Jasja Dekker presented the project and preliminary results on a Dutch conference for ecological consultants.

CEDR Bat road mitigation workshop, Kalø, Denmark, February 2016

The workshop was arranged as part of the *SafeBatPaths* project. The workshop aimed to combine experiences accumulated by bat and road experts in different countries to discuss the status of current road mitigation, future research needs and best practice for bat mitigation strategies.

ICOET, North Carolina, USA, September 2015

Morten Christensen presented the project in a talk on bat mitigation measures in Europe at ICOET conference in 2015.

Bat Conservation Trust, London, United Kingdom, March 2015

Morten Elmeros presented a talk on the project and preliminary results at the Wildlife and Transport Infrastructure Symposium held by BCT.

3.2 Further dissemination plans

The final *SafeBatPaths* project reports will be uploaded on the project website and links will be sent to all the road and bat experts, consultants and NGOs that contributed with information across Europe. Links will also be sent to relevant organisations and networks, e.g. IENE, Batlife organization, etc.

The *SafeBatPaths* findings and the guidelines on bats and roads produced within the project have been condensed to a chapter on bat mitigation on the planned CEDR Handbook on Roads and Wildlife, which is intended to complement the existing European COST 341 Handbook.

We envisaged that project guidelines and the planned extension to the COST 341 Handbook may encourage to the development of national bats and road guidelines, as well as effectively will stimulate the employment of effective bat mitigation methods, standardised monitoring and maintenance procedures for fauna passages in more countries.

Furthermore, we aim to present the results and recommendation for bat mitigation on roads on the upcoming European Bat Researchers Symposium in August 2017. We also aim to publish a scientific paper on bats' behaviour at hop-overs based on the results from the field experiment performed in Work Package 3.

The *SafeBatPaths* consortium partners are liaising with EUROBATS' working group on 'Impact of Roads and other Traffic Infrastructures on Bats' to share our findings and support the resolutions and guidelines that EUROBATS are preparing on the subject. EUROBATS is an agreement under the Bonn Convention that aims is to provide coordination and direction for the conservation, protection and research of European bat populations across their range (Europe, Northern Africa and the Middle East) through legislation, education, conservation measures and international co-operation.

4 Acknowledgements

The research presented in this report was produced as part of the CEDR Transnational Road Research Programme: Roads & Wildlife. The funding provided for the research by the national road administrations of Austria, Denmark, Germany, Ireland, Norway, Sweden, The Netherlands and United Kingdom. We are grateful to the many bat and road experts who contributed with information on bat mitigation measure throughout Europe and participated in the project workshop. EUROBATS kindly circulated our request for information in their network. Finally, we thank the CEDR PEB members for comments on the draft project reports.

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Annex A:

Project presentations on the IENE conference in Lyon 2016.

Morten Christensen, Esben T. Fjederholt, Julie D. Møller, Hans J. Baagøe & Morten Elmeros

Over or under the road?

Effectiveness of bat road crossing mitigation measures

Roads may have detrimental effects on bat populations. At road severances of bat commuting routes, e.g. hedgerows, forest edges and river crossings, mitigation structures are sometimes constructed to reduce the mortality risk. Bat species have different flight characteristics. Consequently, the effectiveness of mitigation structures may differ between species. Clutter-adapted and moderately structure-bound species are most at risk when crossing roads, as these species tend to decrease their flight height when crossing open gaps.

To explore the effectiveness of two types of road mitigation measures for bats we studied 1/ two existing underpasses for rivers and 2/ four experiential hop-overs plus a control site. The two studies focused on two moderately structure-bound species, *Myotis daubentonii* and *Pipistrellus pygmaeus*, but other species were recorded as well. These two species are common in most of Europe, and due to their flight behaviour experiences a high collision risk when crossing roads. More than 2500 bat passes were analysed at seven sites.

Study 1 – Effectiveness of Underpasses

Methods

- 2 sites (Sakskøbing and Maribo) at river crossings under a old motorway built on a low embankment.
- 10 survey nights (27 June to 28 September 2013).
- 5 synchronised microphones per site placed through the culverts to record flight path.
- Bat passes over the road above the underpasses were recorded as control.
- Additional visual observation.

Tab. 1. Dimensions of the two culverts.

	Sakskøbing	Maribo
Width	7.2 m	5.6 m
Height	1.4 m	2.4 m
Length	24 m	30 m
Index (W*H)/L	0.42	0.45

Results

- *M. daubentonii* commuting and foraging on the rivers made extensive use of the culverts to cross under the motorway, but a relatively large percentage turned back at the low culvert.
- All other bat species crossed over the motorway, if they crossed the motorway. For most of these species the motorway was a barrier and they abandoned their attempt to cross the motorway.
- Roads on embankments are particularly dangerous to other bat less clutter-adapted species, if bats maintain their flight height on leaving the treelines and hedgerows.

Tab. 2. Percentage of bats that crossed over or safely under the motorway through the culverts, or abandoning the attempt to cross the road transect.

	Barbastalla barbastellus	*Eptesicus serotinus*	*Nyctalus noctula*	*Pipistrellus nathusii*	*Pipistrellus pygmaeus*	*Myotis daubentonii*	All species
Sakskøbing	(N= 19)	(N= 29)	(N= 99)	(N= 37)	(N= 537)	(N= 474)	
Over the road	47.4 %	20.7 %	44.4 %	27.0 %	39.5 %	3.2 %	38.7 %
Via underpass	0 %	0 %	0 %	0 %	0.2 %	71.7 %	0.1 %
Turned back	52.6 %	79.3 %	55.6 %	73.0 %	60.3 %	25.1 %	61.1 %
Maribo	(N= 4)	(N= 8)	(N= 127)	(N= 47)	(N= 316)	(N= 815)	
Over the road	0 %	37.5 %	59.1 %	48.9 %	35.8 %	0.5 %	42.5 %
Via underpass	0 %	0 %	0 %	0 %	7.9 %	96.9 %	5.4 %
Turned back	100 %	62.5 %	40.9 %	51.1 %	56.3 %	2.6 %	52.2 %

Conclusion – Underpass

- Underpasses were only effective for *M. daubentonii*.
- The height of the underpass is important for the effectiveness, even for *M. daubentonii* at rivers.
- The motorway was a barrier for a large percentage for most other bats.

Study 2 – Effectiveness of Hop-over sections

Methods

- 4 experimental sites and 1 control site at natural gaps in commuting routes.
- 5-7 survey nights per site (10 June to 3 September 2015). 2 nights before, 1st night with and 2-4 nights at weekly intervals after the screens were installed.
- 5 surveys at the control site (8 July to 17 September).
- 2-4 synchronised microphones at different heights at the hop-over to assess flight height.
- Visual observation and 4K night-vision video.

Results

- The percentage of *M. daubentonii* that crossed the hop-over site at heights above 4 m increased from 31 % to 76 % (X^2=109, P<0.001), but variation between sites was high (Fig. 1). No change in flight heights was observed at the control sites.
- At site D, the proportion of *P. pygmeaus* that crossed the hop-over gaps at heights above 4 m increased from 39 % to 61 % (X^2=7.1, P<0.01) after installation of the screens, while no change was observed for *B. barbastellus* (before 87 %, after 89 %).
- *M. daubentonii* habituated quickly to the screens, and the screens did not present a barrier.
- 67 % of *P. pygmeaus* flew around the screens to cross the imaginary road at heights, where they would be at high risk for vehicle collisions.

Fig. 1. *M. daubentonii* crossing height before and after establishment of the hop-over screens based on recordings from synchronised microphones. Numbers indicate recorded bat passes.

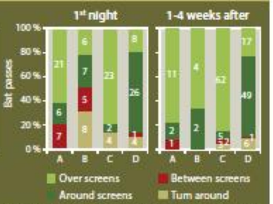

Fig. 2. Behaviour of *M. daubentonii* (site A, B and C) and *P. pygmeaus* (site D) on the 1st night with screens and 1-4 weeks later based on visual observations and night vision video. Numbers indicate recorded bat passes or attempts.

Conclusion – Hop-over

- Hop-overs with screens showed a potential for reducing bat-vehicle collision risk, and did not appear to represent a major barrier.
- However, hop-overs cannot be generally recommended, as their effectiveness is too low at some site.
- Hop-overs may not reduce collision risk notably for *P. pygmeaus* but just move the collision site to the end of the screens or dense vegetation.

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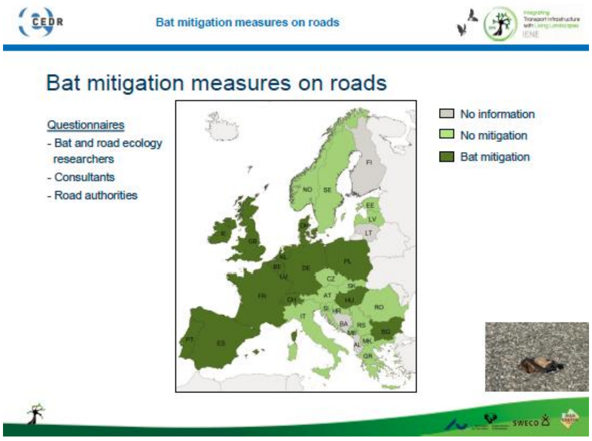
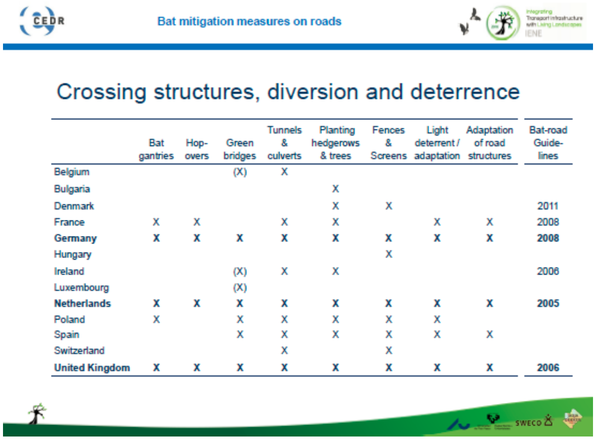
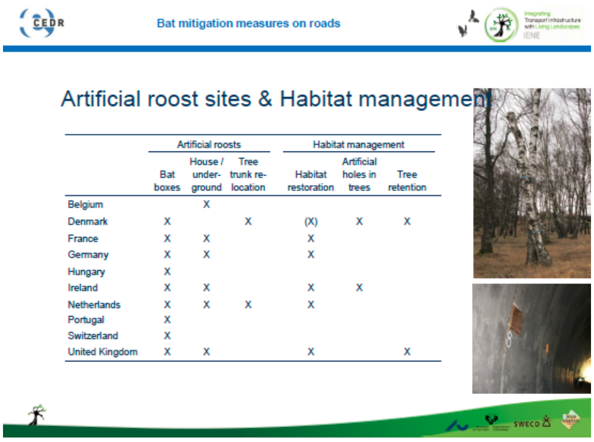
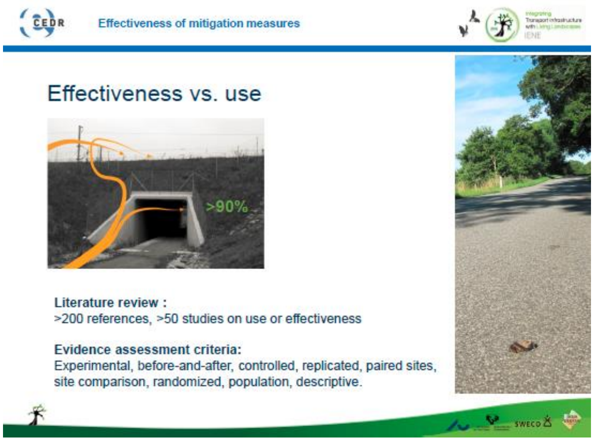


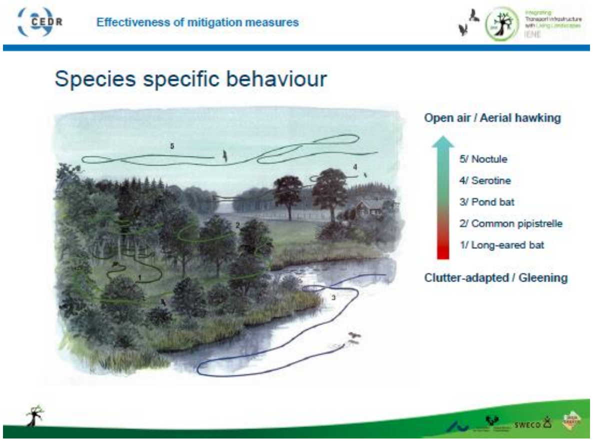


	Bat gantries	Hop-overs	Green bridges	Tunnels & culverts	Planting hedgerows & trees	Fences & Screens	Light deterrent / adaptation	Adaptation of road structures	Bat-road Guide-lines
Belgium			(X)	X					
Bulgaria					X				
Denmark					X	X			2011
France	X	X		X	X		X	X	2008
Germany	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**2008**
Hungary						X			
Ireland			(X)	X	X				2006
Luxembourg			(X)						
Netherlands	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**2005**
Poland	X		X	X	X	X	X		
Spain			X	X	X	X	X	X	
Switzerland				X		X			
United Kingdom	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**2006**



	Artificial roosts			Habitat management		
	Bat boxes	House / under-ground	Tree trunk re-location	Habitat restoration	Artificial holes in trees	Tree retention
Belgium		X				
Denmark	X		X	(X)	X	X
France	X	X		X		
Germany	X	X		X		
Hungary	X					
Ireland	X	X		X	X	
Netherlands	X	X	X	X		
Portugal	X					
Switzerland	X					
United Kingdom	X	X		X		X

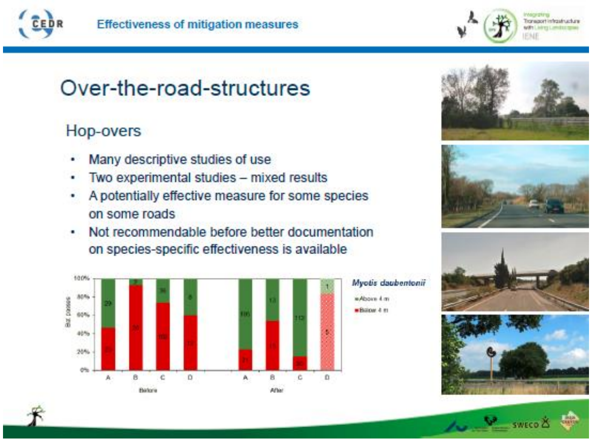


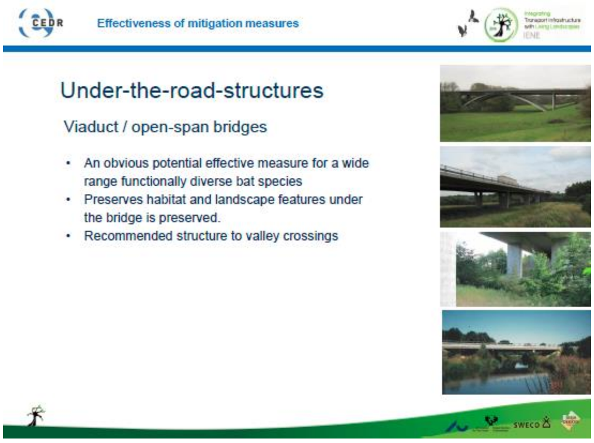

Effectiveness of mitigation measures
Species specific behaviour
Open air / Aerial hawking
5/ Noctule
4/ Serotine
3/ Pond bat
2/ Common pipistrelle
1/ Long-eared bat
Clutter-adapted / Gleening

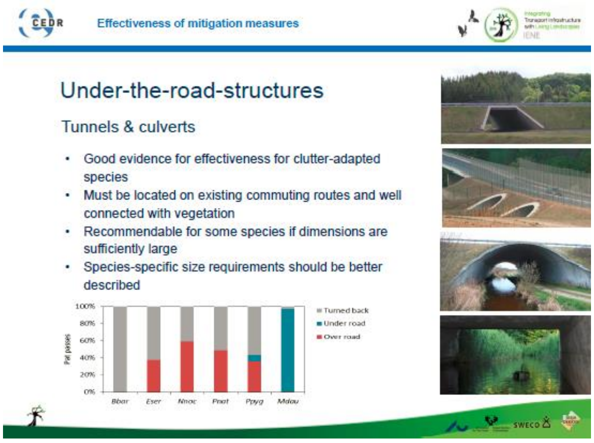

Effectiveness of mitigation measures
Over-the-road-structures
Green bridges
• Effectiveness documented
• Use by a range of functionally diverse group of species well documented
• Recommended if constructed optimally, vegetated and with high connectivity to adjacent bat habitats

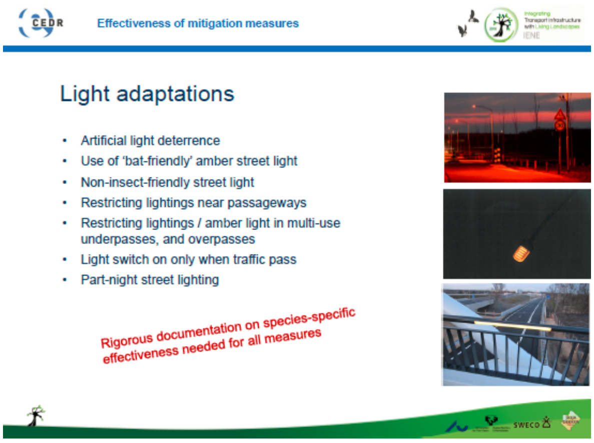

Effectiveness of mitigation measures
Over-the-road-structures
Adapted bridges
Green verges
• Little documentation of effectiveness, but promising
• Vegetation on bridge must be well-connected to existing commuting routes.
• Road unlit
• Recommended measure as supplement to passage dedicated to wildlife.
Panels on sides, etc.
• Successful experiments for horseshoe bats
• General effectiveness is not documented.
• Awaiting further development and testing before further assessment

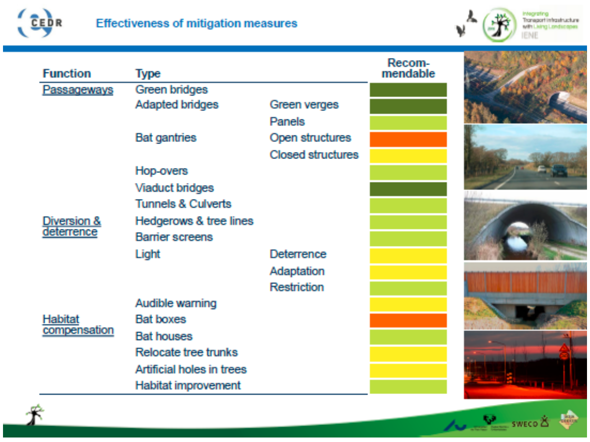

Effectiveness of mitigation measures
Over-the-road-structures
Bat gantries
Open structures
• Wire gantries documented ineffective
• Observations suggest low effectiveness of other open-structured gantries
• Wires with acoustic reflectors ?
Closed structures
• Effectiveness not been adequately documented
• Further testing needed

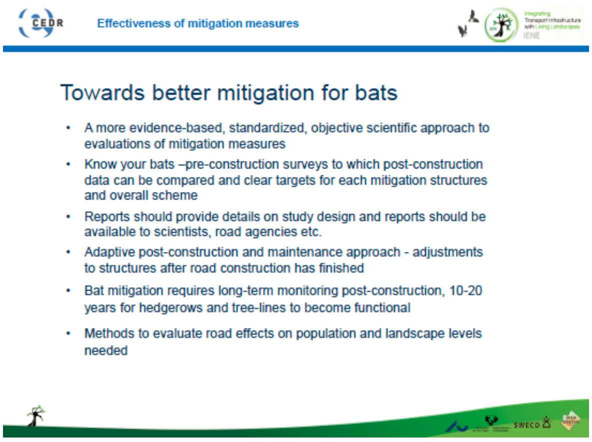

Effectiveness of mitigation measures
Over-the-road-structures
Hop-overs
• Many descriptive studies of use
• Two experimental studies – mixed results
• A potentially effective measure for some species on some roads
• Not recommendable before better documentation on species-specific effectiveness is available
Myotis daubentonii


Effectiveness of mitigation measures
Under-the-road-structures
Viaduct / open-span bridges
• An obvious potential effective measure for a wide range functionally diverse bat species
• Preserves habitat and landscape features under the bridge is preserved.
• Recommended structure to valley crossings


Effectiveness of mitigation measures
Under-the-road-structures
Tunnels & culverts
• Good evidence for effectiveness for clutter-adapted species
• Must be located on existing commuting routes and well connected with vegetation
• Recommendable for some species if dimensions are sufficiently large
• Species-specific size requirements should be better described
100%
80%
60%
40%
20%
0%
Bat passes
Turned back
Under road
Over road
Bbar
Eser
Nnoc
Pnat
Ppyg
Mdau


Effectiveness of mitigation measures
Light adaptations
• Artificial light deterrence
• Use of 'bat-friendly' amber street light
• Non-insect-friendly street light
• Restricting lightings near passageways
• Restricting lightings / amber light in multi-use underpasses, and overpasses
• Light switch on only when traffic pass
• Part-night street lighting
Rigorous documentation on species-specific effectiveness needed for all measures


Effectiveness of mitigation measures
Function
Type
Recom-mendable
Passageways
Green bridges
Adapted bridges
Green verges
Panels
Bat gantries
Open structures
Closed structures
Hop-overs
Viaduct bridges
Tunnels & Culverts
Diversion & deterrence
Hedgerows & tree lines
Barrier screens
Light
Deterrence
Adaptation
Restriction
Audible warning
Habitat compensation
Bat boxes
Bat houses
Relocate tree trunks
Artificial holes in trees
Habitat improvement


Effectiveness of mitigation measures
Towards better mitigation for bats
• A more evidence-based, standardized, objective scientific approach to evaluations of mitigation measures
• Know your bats –pre-construction surveys to which post-construction data can be compared and clear targets for each mitigation structures and overall scheme
• Reports should provide details on study design and reports should be available to scientists, road agencies etc.
• Adaptive post-construction and maintenance approach - adjustments to structures after road construction has finished
• Bat mitigation requires long-term monitoring post-construction, 10-20 years for hedgerows and tree-lines to become functional
• Methods to evaluate road effects on population and landscape levels needed


CEDR Transnational Road Research Programme
Roads and Wildlife
Merci pour votre attention
Thanks to all contributors and photographers