Natural England Commissioned Report NECR132

Literature review and analysis of the effectiveness of mitigation measures to address environmental impacts of linear transport infrastructure on protected species and habitats

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Natural England is responsible for ensuring that England's unique natural environment, including its flora and fauna, land and seascapes, geology and soils are protected and improved. As the Government's statutory nature conservation adviser it is a statutory consultee in planning.

Natural England commissioned this research to establish a strong evidence base for the advice it gives regarding environmental mitigation for linear transport schemes. The work focuses on mitigation used to ameliorate on-site impacts. The specific objectives were to:

- Undertake a literature review to identify and summarise relevant studies and evidence (from UK, Europe and beyond) that explore the effectiveness of mitigation measures developed to address the impacts of road and rail schemes on the natural environment.
- Provide a report evaluating the evidence, identifying key findings, common themes and conclusions that provide evidence to underpin Natural England's advice on appropriate mitigation for transport schemes, and to identify evidence gaps where further research could be beneficial.

The results will be used to provide evidence to support, and to improve, the responses of Natural England's Land Use team to development management consultations related to planning applications, Environmental Impact Assessments, Habitats Regulations Assessments and Appropriate Assessments.

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Keywords - mitigation, linear transport, road, rail, transport, environmental impact assessment, transport appraisal, protected species, protected habitats

Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

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Literature Review and Analysis of the Effectiveness of Mitigation Measures to Address Environmental Impacts of Linear Transport Infrastructure on Protected Species and Habitats

Contents

Addendum – This report has been revised to clarify that its review of case studies involving translocation of ancient woodland soils and coppiced stools does not imply that these methods mitigate the loss of ancient woodland. Ancient woodland is an irreplaceable resource, the loss of which cannot be mitigated or compensated. Please see 'Standing Advice for Ancient Woodland and Veteran Trees' (2014) on Natural England's website for Natural England's formal position on ancient woodland. Further discussion of ancient woodland soils translocation can be found at 'Translocation and Ancient Woodland' by Luci Ryan, (2013).

Tables

1 Key Messages

1.1 Natural England is charged with the responsibility of ensuring that England's unique natural environment, including its flora and fauna, land and seascapes, geology and soils are protected and improved. As the Government's statutory nature conservation adviser it is a statutory consultee in planning, if a development needs an Environmental Impact Assessment (EIA).

1.2 This piece of research aims to contribute to the evidence base for the advice Natural England gives regarding environment mitigation for linear transport schemes, implemented as a result of ecological impacts. The research focuses on mitigation used to ameliorate on-site impacts rather than compensation.

The objectives of this study were:

- To undertake a literature review to identify and summarise relevant studies and evidence (from UK, Europe and beyond) that explore the effectiveness of mitigation measures developed to address the impacts of road and rail schemes on the natural environment.
- To provide a report evaluating the evidence, identifying key findings, common themes and conclusions that provide evidence to underpin Natural England's advice on appropriate mitigation for transport schemes, and to identify evidence gaps where further research could be beneficial.

The study was undertaken following a three stage process:

- Stage 1: Inception
- Stage 2: Literature Review and Data gathering
- Stage 3: Reporting

The study made the following findings:

Habitats: transport case studies were identified where the following mitigation methods for habitat loss were deemed to have achieved specific ecological objectives:

- Woodland creation - accelerated presence of ground flora species and ground dwelling invertebrates using translocated soils from an area of ancient woodland and translocated coppice hazel stools, along with tree planting.
- Hedgerow translocation.
- Lowland heath translocation.
- Turf translocation of herb rich grassland, plus use of seed mixes.
- Translocation of species rich grassland.
- Creation of new wildlife ponds and translocation of wetland turfs.
- Creation of coastal lagoon habitat.
- Fen swamp translocation.

Transport case studies were also identified where the following mitigation methods for habitat loss were deemed to have been unsuccessful; this was largely a result of poor implementation or poor maintenance:

- Translocation of base rich mire and stream diversion.
- Habitat creation of chalk grassland on new cutting.
- Translocation of species rich turf (calcareous clay pasture).

Species: case studies were identified where the following mitigation methods for impacts on species were deemed to have been successful:

- Badger use of culverts to mitigate habitat fragmentation
- Small bird use of overpasses to mitigate habitat fragmentation
- Deer crossings and fencing to mitigate habitat fragmentation and road mortality
- Creation of wetland habitat to mitigate loss of habitat for Natura site wetland birds.
- Reconnection of fragmented woodlands and habitat enhancement for dormice to mitigate habitat loss.
- Habitat creation works timed to avoid ground works when dormice were hibernating, and to avoid vegetation cutting when dormice were active, to mitigate for disturbance.
- Hibernacular creation and translocation of reptiles to mitigate for the loss of reptile habitat,
- Fencing of water vole habitat to avoid damage, displacement by strimming used in work area and trapping and translocation to mitigate habitat loss.
- Translocation of soil from ancient woodland sites to enhance invertebrate fauna at the donor site.
- Creation of new pond complex to mitigate for habitat loss for dragonflies.
- Scrub planting of blackthorn and wildflower seedings to provide habitat for brown harestreak and white letterstreak butterfly as mitigation for loss of SSSI area rich in invertebrates.
- Downland creation using turf translocation, seeding and planting to mitigate for loss of chalkhill blue butterfly habitat.
- Translocation of gingerbread sedge.

The review concluded that that:

- The volume of data received through consultation was low, with only a limited number of specific monitoring reports from road projects received.
- From the literature search only a small number of relevant articles where identified where empirical evidence had been gathered to determine mitigation success on linear transport schemes. Often articles were subjective and based on professional judgements rather than conclusive evidence.
- The majority of evidence was based on data related to the use of wildlife crossings, with several articles on studies of large road schemes where tunnel use had been monitored.
- The majority of evidence related to road schemes, rather than rail.

1.3 The limited volume of data which is available is considered to be a result of a number of issues:

- 1) A lack of monitoring being undertaken;
- 2) A lack of enforcement of monitoring requirements;
- 3) Poor communication of monitoring results; and
- 4) No central location/ no single responsible body for collating monitoring reports.

The study makes the following recommendations to improve the evidence base for ecological mitigation of transport schemes:

- *Setting planning conditions to stipulate monitoring and the use of an Ecological Clerk of Works (ECoW) where appropriate.*
- *Commissioning of studies to address information gaps.*
- *Improving follow up on mitigation and monitoring detailed within Environmental Statements.*
- *Undertaking data collection from local authorities.*
- *Holding mitigation workshops to discuss case studies and mitigation evidence.*
- *Setting guidance with respect to the level of information required for Protected Species licence returns and establishing a database for recording the information obtained in returns.*
- *Establishing a central location where ecological monitoring can be logged.*

2 Introduction

Terms of Reference

2.1 Natural England is charged with the responsibility of ensuring that England's unique natural environment, including its flora and fauna, land and seascapes, geology and soils are protected and improved. As the Government's statutory nature conservation adviser it is a statutory consultee in planning, if a development needs an Environmental Impact Assessment (EIA).

2.2 Natural England's Land Use teams respond to thousands of development management consultations every month and provide advice on planning applications, Environmental Impact Assessments, Habitats Regulations Assessments and Appropriate Assessments. Transport schemes makes up a significant element of their casework. Road schemes constitute approximately 50% of their transport casework; with rail a further 29%.

2.3 This piece of research aims to contribute to the evidence base for the advice Natural England gives regarding environmental mitigation for linear transport schemes, implemented as a result of ecological impacts. The research focuses on mitigation used to ameliorate on-site impacts rather than compensation.

2.4 Defra and Natural England have recently commissioned separate research into bat mitigation for roads and Defra has commissioned research into Great Crested Newt mitigation. These European Protected Species have therefore been excluded from this study to avoid duplication.

2.5 The study focused on the following species and habitats:

- Badger
- Birds
- Deer
- Dormice
- Otter
- Red squirrel
- Reptiles
- Water vole
- Natterjack toad
- Fish
- Butterflies
- Invertebrates
- Vascular plants
- Woodland and scrub including ancient woodland
- Mire
- Heathland
- Grassland and marsh
- Open water
- Coastland
- Swamp, marginal and inundation
- Brownfield

Aims and Objectives

2.6 The aims of this study were as follows:

- To better understand and summarise typical mitigation approaches on road and rail schemes.
- To draw out lessons learnt from projects where mitigation has been implemented, i.e. what has been successful (and why), what has been unsuccessful (and why).
- To assess the validity of the existing literature and data on the basis of its quality and robustness.

- To collate information on the successful mitigation approaches, where monitoring has demonstrated this to be the case.
- Identify where gaps in knowledge exists and further research is required.
- To contribute to the evidence base, allowing Natural England to provide advice on appropriate mitigation measures for transport schemes.

2.7 The objectives of this study were:

- To undertake a literature review to identify and summarise relevant studies and evidence (from UK, Europe and beyond) that explore the effectiveness of mitigation measures developed to address the impacts of road and rail schemes on the natural environment.
- To provide a report evaluating the evidence, identifying key findings, common themes and conclusions that provide evidence to underpin Natural England advice on appropriate mitigation for transport schemes, and to identify evidence gaps where further research could be beneficial.

Project Team

2.8 The team leads from Natural England were Kathleen Covill and Clare Warburton, Senior Advisers on transport within the Natural England Land Use team.

2.9 The team leads from LUC were Associate Ecologist, Sarah Bassett and Principal Ecologist, Steve Jackson-Matthews.

3 Methodology

3.1 The study was undertaken following a three stage process:

- Stage 1: Inception

- This step aimed to confirm the detailed methodology, including impact topics and mitigation approaches to focus on, identify key organisations to contact for data and to discuss approaches for questionnaires.

- Stage 2: Literature Review and Data Gathering

- This step aimed to access a wide range of available publications relating to mitigation for linear transport schemes and gather information from a range of sources. It was acknowledged that a review of published literature sources may not provide a complete picture with respect to the effectiveness of mitigation. Much knowledge is held by ecological and environmental consultants who implement mitigation and by site managers and Natural England staff who have visited sites where mitigation has been installed. As such the literature review was supplemented with discussions with relevant organisations and individuals to help build a more detailed picture.

- Stage 3: Reporting

- This step aimed to provide a clear, concise record of the findings of the literature review and data gathering, and based on the findings of step 2, provide recommendations for further steps to establish a mitigation evidence base.

Stage 1: Inception

3.2 An inception meeting was held at the start of the project between LUC and Natural England to agree the approach to the study. During this meeting the recording format for the literature review was agreed, the proforma created included the following:

- list of impact topics for consideration;
- lists of species and habitats to be included within the study; and
- details on the quality of the data (evidence based or subjective, 3rd party or peer reviewed).

Stage 2 – Literature Review and Data Gathering

Consultations

3.3 The following organisations and institutions were contacted in January 2013 as part of the review and requests made for details of any relevant studies, publications or research currently being undertaken. This list of organisations was developed following contacts provided by Natural England and based on professional experience of organisations likely to have relevant knowledge.

- Specialists within Natural England – including the Wildlife Licensing Unit
- Scottish Natural Heritage
- Countryside Council for Wales
- Highways Agency
- Network Rail
- Centre for Ecology and Hydrology
- University of Oxford (WildCru)
- Oxford Brookes University
- The UK Biodiversity Research Advisory Group
- The Badger Trust

- Transport Scotland
- Environment Agency
- RSPB
- Mammal Society
- Vincent Wildlife Trust
- UK Biodiversity Research Advisory Group (JNCC)
- Butterfly Conservation
- Barn Owl Trust
- Reptile and Amphibian Conservation Trust
- Froglife
- British Botanical Society

Data trawl

3.4 A list of transport-related literature and research was also compiled using sources identified by Natural England and professional knowledge. The sources were largely UK focused; with the exception of academic studies, which included European and International papers and review of the Infra Eco Network Europe (IENE) and International Conference of Ecology and Transport (ICOET) websites. The following sources were used:

- Internet search of academic studies and known research programmes
- Search of digital versions of academic journals and bibliographic databases (using the following websites: http://onlinelibrary.wiley.com/browse/publications, http://scholar.google.co.uk/, http://nora.nerc.ac.uk/, http://www.britishecologicalsociety.org/journals_publications/)
- InPractice articles from the Institute of Ecology and Environmental Management (IEEM) magazine
- Highways Agency Design Manual for Roads and Bridges
- Natural England advice notes and website pages on protected species and habitats
- Environment Agency/ Scottish Environmental Protection Agency publications
- British Wildlife magazine
- SNH/ CCW publications
- IEEM – previous relevant conference presentations
- CIRIA guidance
- Relevant species-specific management handbooks (e.g. water voles)
- IENE website
- ICOET website
- http://www.susdrain.org

3.5 In order to record the data sources reviewed and to ensure a robust data trail a spread-sheet has been developed. The data was also assessed in terms of its quality and its strength, i.e. considering the following:

- is it peer reviewed;
- is it based on a clear evidence trail;
- does the data take account of local factors which do not apply at a national level;
- what level of monitoring of the mitigation has been undertaken and by whom (i.e. is monitoring data presented reliable);
- What evidence is available – survey data gathered by a competent ecologist (based on IEEM criteria), photographic evidence etc.

3.6 A pro-forma is provided in Appendix 1 which was used to record details on the information collected and sets out the data which was collected to inform this study. A summary of the key headings and categories for data selection is provided below in Table 3.1.

Table 3.1 Key headings for data collection

Source	Mitigation success?	Impact	Habitat	Species	Strength of data	Quality of data	Geographic extent
Website Scientific paper Book Article	Successful Unsuccessful Successful/ Unsuccessful Unknown	Fragmentation Habitat loss Wildlife mortality Wildlife disturbance Air pollution Noise pollution Light pollution Water pollution	Habitats Woodland and scrub Mire Heathland Grassland and marsh Open water Coastland Swamp, marginal and inundation Brownfield	Species Badger Birds Deer Dormice Otter Red squirrel Reptiles Water vole Natterjack toad Butterflies Invertebrates Vascular plant Mammals	Evidence based Subjective	Data quality Peer Review Government Research 3rd party evidence	England Scotland Wales Ireland UK Europe International

The review of literature and data received considered the following:

- The species or habitat discussed and the nature of the impact.
- The type/ method of mitigation is described.
- What evidence is available to determine success – i.e. has monitoring been undertaken, has the monitoring data been published, and is the success based on an author's opinions or empirical evidence.

3.7 No interpretation of success is provided by the authors of this study, success is only based on the data and information within the literature/ information received. It is noted that much of the literature reviewed had an absence of empirical data, and success is often based on the author's opinions.

Questionnaire

3.8 It was acknowledged that a review of literature sources may not provide a complete picture with respect to the effectiveness of mitigation. Much knowledge is held by ecological and environmental consultants who implement mitigation and by site managers and Natural England staff who have visited sites where mitigation has been installed.

3.9 The literature review was therefore supplemented with a questionnaire sent to members of the Institute of Ecology and Environmental Management (IEEM) via a weblink in IEEM's monthly Policy Update..

3.10 A copy of the questionnaire is provided in Appendix 2.

Stage 3 – Reporting

3.11 Following the literature review and data gathering, the documents and information obtained were subject to review. This review looked to identify examples of mitigation practices with evidence of success or failure, based on monitoring.

3.12 The tables within Section 3 of this report were compiled using this information to give a summary of the findings and to identify which mitigation practices are successful in practice. Section 4 of this report, details recommendations for further studies which would supplement and expand on the information gathered for this study.

Limitations of study

3.13 This study has been conducted over a limited timeframe between January and March 2013. As a result the period of time for data requests to be met was short, which has limited the quantity of data received through consultation and also limited the timeframe over which the IEEM

questionnaire was open to responses. It is also acknowledged that the response to the IEEM survey was very low when compared to IEEM's membership. This lack of anecdotal evidence from industry professionals means that the opinions put forward through the survey cannot be taken to represent consensus or accepted practice within the industry.

3.14 It is noted that much of the literature reviewed had an absence of empirical data, and where successful mitigation is identified, this is often based on professional opinion.

3.15 With respect to the literature review, studies published between 2000 and 2012 have been considered, plus any highly relevant studies prior to 2000 identified. We have not included a detailed study of conference proceedings (e.g. International Conference on Ecology and Transportation (ICOET) and Infra Eco Network Europe Meetings (IENE), as the proceedings only provide an overview of studies, and many describe work in progress which has not been peer reviewed. A high level review of conference proceedings has been undertaken, and where considered relevant, authors have been contacted to request further information. Non-English language journals have not been considered.

3.16 There are a number of well-established guidance documents and detailed studies which provide case studies and examples of successful mitigation. This study has not attempted a detailed review or appraisal of these, but has sought to identify where studies or monitoring of transport-related mitigation have been undertaken and published, to increase the bank of available evidence.

3.17 A detailed review of Highways Agency's Post Opening Project Evaluations (POPE) has not been undertaken as part of this study. A large number of reports are available on the Highways Agency website; however these are not easily filtered in terms of identifying those where ecological mitigation has been implemented. Also many of the reports available provide a high level review of the success of mitigation one year after construction. This only provides limited detail and further monitoring would be required to provide robust evidence of success.

4 Findings

4.1 For ease of reference this section has been set out as follows:

- General findings (covering both habitats and species)
- Habitats
- Species

4.2 Within each sub-section on either species or habitat a discussion is provided on the findings of the literature review, consultations and IEEM questionnaire results.

4.3 A summary of all of the articles detailed within this report is provided within the proforma in Appendix 1.

General findings

Consultation Responses

4.4 In general the volume of data received through consultation was low, with only a limited number of specific monitoring reports from road projects received. However, the information received through consultation provided more information on habitats than that found through the literature search.

Data Trawl

4.5 From the literature search only a small number of transport-related articles were identified where empirical evidence had been gathered to determine mitigation success. Often articles were subjective and based on professional judgements rather than conclusive evidence. The majority of evidence based on data related to the use of wildlife crossings, with several articles on studies of large road schemes where tunnel use had been monitored.

4.6 Of the articles identified and reviewed, a strong mammal bias was apparent. Of the 121 articles collected, only 48 of these were found to contain information specifically relating to mitigation where evidence of effectiveness was detailed. Of these 48, 39 related to mammals and only 9 related to habitats. This finding is in keeping with similar reviews, for example a study undertaken in 2010[1] reviewed 244 published studies on road and vehicle impacts, this found that 53% of studies in mammals, with ungulates (predominately deer) the most frequently studied taxonomic group. With respect to mammals the literature available largely related to wildlife crossings with 15 of the papers reviewed relating to this.

4.7 There are also a number of scientific articles, which themselves are literature reviews, for example a paper by Van der Ree et al[2], reviewed 123 studies on the use of wildlife crossings by fauna. This review found that studies clearly demonstrate that most measures designed to increase the permeability of roads for wildlife were successful at the level of the individual animal. However the article did conclude that there was insufficient information and analysis in the majority of studies to evaluate whether the viability of a population is maintained by the mitigation at an acceptable level.

[1] Taylor and Goldingay (2010) Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia. *Wildlife Research* **37, 320-311**.

[2] van der Ree, R., E. A. van der Grift, C. Mata, and F. Suarez. (2007) Overcoming the barrier effect of roads - how effective are mitigation strategies? An international review of the effectiveness of underpasses and overpasses designed to increase the permeability of roads for wildlife. Pages 423-431 in C. L. Irwin, D. Nelson, and K. P. McDermott, editors. International Conference on Ecology and Transportation. Center for Transportation and The Environment, North Carolina State University, Raleigh, North Carolina, Little Rock, Arkansas, USA.

4.8 A number of articles noted issues surrounding mitigation and the absence of monitoring and assessment of mitigation success. An article by Hill and Arnold[3] succinctly discusses this issue and the fact that when monitoring is undertaken it often goes unpublished. This is in keeping with the findings of this literature review which located very few studies derived from monitoring. The Hill and Arnold paper emphasises the importance of understanding if mitigation is delivering a biodiversity benefit, not only due to the amount spent every year on this, but also to ensure that the negative impacts of development are being overcome.

4.9 This review found that this issue is not unique to the UK, with the Swedish COST handbook[4] identifying similar issues surrounding the monitoring of mitigation. The COST handbook highlights an on-going project commissioned by the Swedish Road Administration and the Swedish National Rail Administration, recommending methods for the following-up of environmental impacts of road and railway projects and the compilation of these in a handbook. The handbook will encourage the use of an information system comprising information on EIA follow-up programmes and follow-up results so as to make this information available for future EIA work and development. The COST report also details the problem with evaluating efficiency is that it must relate to a defined goal or aim. Unless it is known or decided how frequent a fauna passage, for example, shall be used by wildlife to fulfil the ecological or economical goal, it is not possible to evaluate whether the fauna passage is efficient or not, noting that in Sweden the use of fauna passages has only been documented in a few cases. This reflects the low status of mitigation measures for wildlife compared to other technical measures, but is also due to the failure of ecologists to provide civil engineers with necessary information.

4.10 The majority of articles reviewed related to road schemes, with only a small number of studies relating to rail schemes.

IEEM Questionnaire

4.11 Only a limited numbers of respondents replied to the IEEM survey, with a total of 34 people providing answers. Of this 34, not all replied to all questions, and in general for each sub section, e.g. questions relating to woodland, between 5 and 10 people responded to the questions regarding habitat creation and maintenance but not to the question regarding translocation. This low level of response does not provide sufficient data to draw any level of analysis as only a small number of views are represented. A brief summary of the responses are provided in the sections below, where over 5 responses to a section where received, but no detailed analysis is provided, and the responses have not been included within the section conclusions as they may distort the findings.

Habitats

4.12 A summary of the findings is provided in Table 4.1 below. In general there was limited information identified relating to habitats, the majority of that reviewed related to woodland, with fewer examples for grassland, heathland and mire habitats. All studies which were located related to impacts from habitat loss and fragmentation, with no information found relating to mitigation for air or water pollution impacts. Full details of mitigation examples are provided in Appendix 3.

4.13 No information was found on open water, swamp/ marginal/ inundation habitats or brownfield sites.

4.14 A review of the CIRIA (http://www.ciria.org.uk) and Susdrain (http://www.susdrain.org) websites, found that although there is an abundance of literature regarding sustainable urban drainage systems (SUDS), no information was found with respect of evidence to its success as a technique to mitigate for impacts on habitats (or species). A number of case studies are provided on these websites, but do not provide detail of evidence to demonstrate success. A

[3] Hill and Arnold (2012) Building the evidence base for ecological impact assessment and mitigation. *Journal of Applied Ecolgy* **49** 6-9.
[4] A.Seiler and L.Folkeson (2006) Habitat fragmentation due to transportation infrastructure. COST 341 National state of the art report Sweden.

Department of Trade and Industry (Dti) funded research project looked into the ecological benefits of SUDS, the reporting of this research is presented in a paper titled Maximising the Ecological Benefits of SUDs. This paper provides a useful overview on designing SUDS to achieve ecological benefits, but does not present any evidence behind the recommendations[5].

[5] http://www.susdrain.org/files/resources/other-guidance/ecological_benefits_summary.pdf - Website accessed 25th March 2013.

Table 4.1 Summary of findings relating to habitats

Full details, including references are provided in Appendix 3. The numbers provided in brackets against each habitat, shows the number of articles reviewed. In addition a number of articles related to multiple habitat types were reviewed.

Impact / Habitat	Fragmentation	Habitat Loss	Air Pollution	Water Pollution
Woodland and scrub (5)	**A2/M2 Cobham to Junction 4 Widening Scheme** Demonstrated that tree re-growth was possible using coppice hazel stools translocated from ancient woodland, and the presence of ground flora species and ground dwelling invertebrates was accelerated through the use of translocated ancient woodland soils. However the measure should not be interpreted as a successful means of mitigating the fragmentation of ancient woodland; a resource which cannot be re-created through tree planting or habitat translocation due to its complex structure and wider-ranging biodiversity. **A658 South Knaresborough bypass** – **enhanced** woodland creation through translocated soils, and tree and shrub planting. Note previous comments regarding ancient woodland.	**A2/M2 Cobham to Junction 4 Widening Scheme** Demonstrated that tree re-growth was possible using coppice hazel stools translocated from ancient woodland, and the presence of ground flora species and ground dwelling invertebrates was accelerated through the use of translocated ancient woodland soils. However the measure should not be interpreted as a successful means of mitigating the loss of ancient woodland; a resource which cannot be re-created through tree planting due to its complex structure and wide-ranging biodiversity. **A658 South Knaresborough bypass** – **enhanced** woodland creation through translocated soils, and tree and shrub planting. **Channel Tunnel Rail Link** – **enhanced** woodland creation through soil translocation and tree and scrub planting. **Lightmore Urban Village – Successful** hedgerow translocation.	-	-
Mire (1)	-	**Southfield Farm Marsh** – translocation of base rich mire and stream diversion – **Unsuccessful** – due to poor management of translocation and subsequent management.	-	-
Heathland (2)	-	**A361 North Devon Link Road –** habitat creation with seeding of verges, tree and scrub planting, and using non calcareous fill in road construction to prevent a change in pH – **Inconclusive**, but monitoring showed signs indicating success. **Blackwater Valley Relief Road** – **successfu**l translocation of a small area of lowland heath.	-	-

Impact / Habitat	Fragmentation	Habitat Loss	Air Pollution	Water Pollution
Grassland and marsh (5)	-	**M3 – Twyford Down –** turf translocation of herb rich grassland, plus use of seed mixes. **Successful.** **A41 Berkhamsted and Kings Langley Bypass –** habitat creation of chalk grassland on new cutting **– Unsuccessful –** possibly due to incorrect seed mix being used. **A14 A1/M1 link Road** – translocation of species rich turf (calcareous clay pasture) – **Unsuccessful** – possibly due to a lack of management. **British Library book depository –**Translocation of species rich grassland **– probably successful –** 2 years of monitoring showed most targets had been met.	-	-
Open water (1)	-	**Blackwater Valley Relief Road** – creation of new wildlife ponds to mitigate for the loss of pond habitats. Turf translocated from ponds which were lost led to early establishment of wetland habitats, demonstrating short term **success**. However longer term management issues are leading to encroachment by dominant species such as reedmace.		
Coastland (1)	-	**A2/M2 Cobham to Junction 4 Widening Scheme** – creation of coastal lagoon habitat, 3 lagoons created – 5 years of monitoring showed **success**, but flooding event occurred which caused substantial damage and no monitoring undertaken post this.	-	-
(1)Swamp, marginal and inundation	-	**Wobaston Road** – fen swamp translocation. First two years of monitoring indicate **success.** Vegetation communities recorded matched those pre translocation.	-	-

Species

4.15 The literature review identified several well documented studies, and well-established sources of information with respect to mitigation approaches for mammals. A summary of the findings is provided in Table 4.2 below.

4.16 15 studies discussed the use of culverts, underpasses, tunnels and overpasses for mammal crossings, and many of these provided evidence of the effectiveness of these measures, in terms of evidence demonstrating their use. Largely, however these studies did not comment on the occurrence of animal-vehicle collisions on roads where wildlife crossings were present.

4.17 Examples of successful crossing structures include the ecoducts in the Netherlands[6]; here two overpasses (cerviducts and ecoducts) were built in 1998 to enable red deer to migrate from one side of the highway to the other. The ecoducts were positioned on an old migration track of red deer, with screening from the visual and acoustic influences of the highway by walls and trees. A year after its opening the ecoducts were found to have been used by deer, boar, badger, hedgehog and fox, details of some species numbers are provided in table 4.1 below. Further monitoring, five years after conduction found an increase in use, likely to be attributable to increasing familiarity of animals with the new construction[7].

Table 4.2 No of species using the Ecoducts in the Netherlands, 1 year post-construction

No. of Species	Terlet (Southern duct)	Woeste Hoeve (Northern duct)
Red deer	294	153
Wild boar	690	292
Roe deer	38	43
Fallow deer	-	51

4.18 A study along the Trans-Canada highway in Bamff[8] looked at the use of 36 drainage culverts, taking into account culvert design and the habitats around the culverts over a four month period, checking each culvert a minimum of 12 times. The study found that culvert attributes influenced species' use but different attributes appeared to affect use by different species. At all scales of resolution (species, species group and community level), traffic volume, noise levels and road width ranked high as significant factors affecting species' use of the culverts. Passage by American martens, snowshoe hares and red squirrels all increased with traffic volume. Weasel passage was positively correlated with culvert height but negatively correlated with culvert openness. Martens preferred culverts with low clearance and high openness ratios. High through-culvert visibility was important for snowshoe hares but not for weasels. The passage by weasels and snowshoe hares was positively correlated with the amount of vegetative cover adjacent to culverts. The study concluded that to maximize connectivity across roads for mammals, future road construction schemes should include frequently spaced culverts of mixed size classes and should have abundant vegetative cover present near culvert entrances.

4.19 A study is currently being undertaken to monitor wildlife crossing structures on Irish roads[9]. This project is being funded by the National Roads Authority (NRA), the body responsible for

[6] H.D.van Bohemen (1995) Mitigation and compensation of habitat fragmentation caused by roads: strategy, objectives and practical measures. Transportation Research Records **1475**.
[7] Van Wieren and Worm (2001) The use of a motorway wildlife overpass by large mammals. Netherlands Journal of Zoology **51(1)** 97-105.
[8] A.Cleveger, B.Chruszcx, K.Gunsun (2001) Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology **38** 1340-1348.
[9] Finnerty et al (2010) Making the Connection: Mammal mitigation measures on national road schemes in Ireland: IENE Conference Short Papers; pg 85-87 In: Richter, V., Puky, M. & Seiler, A. (eds): Improving connections in a

building/maintaining national roads in Ireland. The study is looking at 5 newly constructed motorway schemes (totalling 124 km), primarily investigating the use of 600 mm mammal underpasses, of which there are over 100 across the 5 schemes. The study is also looking into the use of mammal ledges (on culverts) and agricultural underpasses. The study is still underway and as such no literature is available to inform this literature review, but may provide useful information in the future.

4.20 However, the main issue encountered during the study to date concerns installation/ construction of the mammal underpasses on the ground. Drainage is a problem with a number of mammal underpasses permanently flooded or suffering from intermittent flooding. Also, the placement of drainage ditches across the entrance of mammal underpasses can restrict access at times of heavy rainfall. There have also been a small number of cases where the entrances to the underpasses are blocked by the wire mesh from the associated fencing (where the contractor has simply forgotten to cut a hole in the fencing). All of these issues could have been identified and rectified at an earlier stage if post-construction monitoring of the underpasses had taken place. While post-construction monitoring is recommended in the mammal mitigation guidelines, it rarely if ever takes place. Resolving this issue is probably one of the most important "take home" messages of the study (*email comm* Eugene Finnerty, University College Cork). These issues highlight the importance of using an Ecological Clerk of Works to supervise the installation of mitigation and to provide monitoring. The reporting of this study is due to be issued in early or mid 2014.

4.21 No information was obtained/ received on red squirrels, natterjack toads or vascular plants.

Table 4.3 Summary of findings relating to species

Full details, including references are provided in Appendix 4. The numbers provided in brackets against each species, shows the number of articles reviewed relating to these species.

Species / Impact	Fragmentation	Habitat Loss	Wildlife mortality	Wildlife disturbance	Noise/ Light/ Water pollution
Badger (5)[A]	Studies from Spain, Portugal and Netherlands show badgers' use of culverts. Two UK studies into use of mammal tunnels concluded mitigation successful.	-	-	-	-
Birds (6)[A]	Study in Australia – Compton Road Fauna Array found small birds used overpass that had been planted with vegetation. Study in Canada – looked at distance that birds will fly over linear features. The findings of this study recommend that bird movements across linear features can be increased by limiting the gap to cross to less than 45m.	Current mitigation scheme being implemented in Sweden to mitigate for loss of wetland habitat (Natura site for wetland birds). First two years of monitoring have shown the habitat creation to be successful. **Blackwater Valley Relief Road:** Kingfisher nesting sites created, not used – unsuccessful, although likely to be due to suitable alternative habitat in area. New nest boxes also installed, monitoring found a number were lost but of those that remained the majority were in use by house sparrow, blue tits and great tits.	Study in Canada – looked at distance that birds will fly over linear features. Findings of study recommend that bird movements across linear features can be increased by limiting the gap to cross to less than 45m.	-	-
Deer (7)[A]	There are a large number of studies relating to deer crossings and the use of structures. Deer are known to use structures of relatively modest size not specifically built for wildlife crossings.	-	Studies show that high roadside fencing reduces collisions, and success is greatest when fencing channels deer towards safe crossing points.	-	-

Species / Impact	Fragmentation	Habitat Loss	Wildlife mortality	Wildlife disturbance	Noise/ Light/ Water pollution
Dormice (4)	A2/M2 Cobham to Junction 4 Widening scheme – mitigation undertaken to reconnect fragmented woodlands and habitat enhanced for dormice. Successful with confirmed breeding and 50% of nest boxes used.		-	A2/M2 Cobham to Junction 4 Widening scheme – habitat creation works timed to avoid ground works when species hibernating, and vegetation cutting when active. Scheme successful – dormice population breeding.	-
Otter (4)	Various papers discuss the use of tunnels, ledges, ramps and fencing as mitigation, but no studies with empirical evidence found.			-	-
Red squirrel (0)	-	-	-	-	-

Species / Impact	Fragmentation	Habitat Loss	Wildlife mortality	Wildlife disturbance	Noise/ Light/ Water pollution
Reptiles (2)	**-**	**Flood defence works, Horsey –** hibernacular created to mitigate for the loss of adder habitat – **successful.** **South Lowestoft Relief Road –** Three hibernacular created as mitigation for loss of reptile habitat – **successful.** **Blackwater Valley Relief Road:** Translocation of a large number of reptiles. Monitoring studies found healthy populations present at donor sites – **successful** – although evidence not conclusive due to limited study data.	-	-	-
Water vole (3)		**Cabot Park, Avonmouth –** fencing used around water vole habitat to avoid damage. Displacement by strimming used in work area and trapping and translocation. **Successful**, found little change in population levels during monitoring.		-	-

Species / Impact	Fragmentation	Habitat Loss	Wildlife mortality	Wildlife disturbance	Noise/ Light/ Water pollution
Invertebrates (6)		**A2/M2 Cobham to Junction 4 Widening scheme** – By translocating soil from ancient woodland sites, it was found that the area of woodland created had a similar invertebrate fauna to the donor site - **successful**. **A564 Foston Hatton Hilton Bypass** – new pond complex created to mitigate for the loss of one pond. Monitoring found excellent breeding and foraging habitat for dragonflies- **successful.** **M40 –** Loss of area of SSSI rich in invertebrates. Scrub planting of blackthorn and wildflower seeding as mitigation. Monitoring demonstrates **successful** habitat creation, with brown harestreak and white letterstreak present. **M3 – Twyford down –**successful downland creation using turf translocation, seeding and planting. Mitigation **successful** with numbers of chalkhill blue butterflies increasing in the first 3 years. **A30 Bodmin to Indian Queens Road Junction** – case study detailed within Natural England's Butterfly handbook, unknown if measures have been successful. **Blackwater Valley Relief Road:** Ponds created to mitigate for loss of ponds. Monitoring of ponds recorded 22 species of dragonfly.			

Species / Impact	Fragmentation	Habitat Loss	Wildlife mortality	Wildlife disturbance	Noise/ Light/ Water pollution
Vascular plants	-	Blackwater Valley Relief Road: Translocation of gingerbread sedge – **successful.**	-	-	-

5 Recommendations For Further Study

5.1 A key finding of the review is the limited volume of monitoring data which is available. This is considered to be a result of a number of issues:

1) A lack of monitoring being undertaken;

2) A lack of enforcement of monitoring requirements;

3) Poor communication of monitoring results; and

4) No central location/ no single responsible body for collating monitoring reports.

5.2 It is understood that the Natural England Licensing team have already identified a number of these issues.

Addressing issue 1:

5.3 The following suggestions have been identified as potential approaches to address issue 1:

- *Setting planning conditions to stipulate monitoring and the use of an Ecological Clerk of Works (ECoW) where appropriate.* Conditions should also consider stipulating details on the experience of the ECoW to ensure that they are suitability qualified and experienced to conduct the role.

- *Commissioning of studies to address information gaps* – given the limited amount of data collected within this review it is difficult to identify areas on which to focus further studies: evidence-based data was lacking across the majority of species and habitats. However key areas for further research relate to habitats rather than species as some data is currently recorded through the protected species licence application process.

  An example of the type of study which could yield useful information is the current PhD project being undertaken in Ireland to monitor wildlife crossings structures on Irish roads. The study is looking at 5 newly constructed motorway schemes (totalling 124 km), primarily investigating the use of 600 mm mammal underpasses, of which there are over 100 across the 5 schemes.

  Similar PhD studies could be set up following the construction of road/rail schemes where mitigation has been installed, to gather rigorous data and to assess the effectiveness of mitigation techniques. This would likely require collaboration with research institutes, consultants and developers, but could provide a cost effective approach to assessing mitigation.

- *Improving follow up on mitigation and monitoring detailed within Environmental Statements* – greater enforcement of monitoring commitments and reporting of monitoring data should be undertaken to provide a more detailed evidence base.

Addressing issues 2-4:

5.4 Within this review a limited number of monitoring reports were obtained, but it is likely that many more are in existence. The limited time period of this review may have affected the level of response received from those bodies contacted. The following approaches outlined below are suggestions for increasing the bank of evidence for review and for establishing a more pro-active approach to the assessment of mitigation effectiveness. The approaches are listed in order of achievability. It is also noted that these suggestions are not purely applicable to road and rail

projects, but would be equality applicable to other development projects. The data collected could be used to provide updates to standard guidance to ensure that this remains in line with emerging knowledge.

Data collection from local authorities

5.5 This literature review did not extend to data capture from local authorities. Many developments are subject to planning conditions which stipulate a requirement for mitigation and monitoring. Reports detailing compliance with these planning conditions are issued to the planning authorities and may contain a useful bank of information. Given the scale of this task, this clearly will take time to complete, and is it acknowledged that the level of response rate for local authorities is unlikely to be comprehensive.

Mitigation workshop

5.6 A mitigation workshop is recommended with key individuals from relevant organisations in attendance, to share knowledge of road and rail schemes where mitigation has been applied. This workshop should be used to share information and experiences. The outcome of the workshop would be a list of relevant project case studies (where mitigation has been installed and monitoring has been undertaken to provide evidence of success/ failure), and a list of relevant literature known to the different regulators with respect to mitigation. If this proves successful, a workshop could be held annually or every two years to collect up-to-date information.

5.7 Relevant organisations for attendance might include: Highways Agency, Natural England, Environment Agency, RSPB, Network Rail, IEEM, Association of Environmental and Ecological Clerk of Works (AEECOW). Consideration could also be given to the devolved nations.

Setting guidance with respect to the level of information required for Protected Species licence returns

5.8 From the review of licence returns provided by the Natural England Licensing Unit, the level of information provided within these is of limited use for evaluating the success of mitigation. It is recommended that a more structured form is provided to facilitate the collection of data. Licence returns are commonly received prior to all monitoring surveys being completed, so that they cannot confirm the success of mitigation. It is therefore recommended that consideration is given to extending the duration of the licence to include the monitoring period. This would ensure that monitoring is carried out as it becomes an essential part of the licensing process.

5.9 Guidance is provided on the Natural England website with examples and guidance of how to complete EPS and badger licence application forms, but there is no information provided on the level of detail required within a licence return. It is recommended that a guidance document is produced, detailing the level of information expected within a licence return, and that as with a licence application, if sufficient detail is not provided by the licensee then the licence is not considered “closed” until the additional required information is provided.

5.10 The level of information and detail required for a licence to be granted is comprehensive, if the assessment of licence returns is not equally comprehensive, then it reduces the value of the detail in the initial application.

Establishing a database for recording the information obtained for licence returns

5.11 If the licence return form is restructured, it should be done so in a manner that allows the information to be transferred into a database. If a database is created to store the information collected through the licence returns, this can then be used by the Licensing Unit and other case officers within Natural England when responding to consultations.

Establishing a central location where ecological monitoring must be logged

5.12 Currently significant resources are spent by developers in producing mitigation plans and time is spent by the regulating authorities in reviewing and commenting on these. Time and effort could be saved if there was clear data collected in a central location to show where mitigation is successful and what is required to ensure its success. This would enable realistic advice to be provided to developers and ensure that mitigation techniques develop and become more effective over time.

5.13 Due to the number of different parties who receive monitoring reports, e.g. developers, local authorities, statutory regulators, data from monitoring of mitigation is not held in a central location and the information detailed within these reports is not being effectively used. It is suggested that consideration is given to creating a central depository at Natural England (or other appropriate body) for all ecological monitoring reports to be issued to. Any regulators or planning authorities would need to stipulate in conditions that all any monitoring reports supplied to them must also be issued to the central depository.

5.14 This action would clearly require funding, and likely require the creation of a job role. The role would involve the creation and maintenance of a database of information collected from the reports obtained. In order for this to be effective the findings of monitoring would need to be circulated at regular intervals (for example an annual review report). Information obtained from the review should be circulated to a wide audience to ensure any lessons learnt are taken into account in the development of mitigation strategies. The data collected could be used to provide updates to standard guidance documents (e.g. the DMRB) to ensure that standard mitigation approaches are effective.

5.15 In order for this to be as effective as possible, the role should be held by someone with database and data analysis experience. Ideally (but recognising this is beyond Natural England's scope) a standardised approach should be formulated for monitoring reports, to allow for data manipulation, analysis and management. This could be achieved through working with the IEEM and AEECOW, to set out monitoring reporting guidelines for ecologists.

5.16 The possibility of tying this in with other ecological recording bodies should be considered, for example the NBN gateway or the Biological Records Centre.

5.17 This suggestion also has implications for data management and confidentiality and these issues would require careful consideration from the outset.

Further data collection

5.18 The review identified a number of projects, for which useful monitoring data is likely to be available, but none was forthcoming through the avenues investigated in this study. The UK COST[10] report identified a number of projects where mitigation measures were being installed, but the monitoring had yet to be undertaken. A number of projects were also identified where summaries of the mitigation measures and monitoring were obtained for this study, but original data reports were not obtained.

5.19 It is recommended that further contact is made with the Highways Agency and the Department for Transport to request any ecological reports relating to the mitigation installed and any monitoring undertaken for the following schemes:

- Channel Tunnel Rail Link
- M40: Junction 8-9 Wendlebury to Waterstock, Oxfordshire
- M3 Bar End to Compton (Twyford Down)
- M40 Buckinghamshire
- M25 - Epping Forest green bridges
- A34 Wilmslow and Handforth Bypass
- A 30 Bodmin to Queens Road
- Temple Wood, Kent (railway overpass)
- Great Wood, Kent (railway overpass)

In addition to this a detailed search of project information on the Highways Agency website could be undertaken, in consultation with the agency to identify projects of likely interest in terms of ecological mitigation (for example POPE five year after reports). Contact should also be made with Network Rail and National Roads Authority of Ireland in 2014 to request data from Network Rail's Great Western Electrification Programme, which is installing mitigation for dormice and from

[10] Highways Agency (2000) COST 341 Habitat Fragmentation due to transport Infrastructures - UK National State of the Art Report.

the study into the Effectiveness of Ecological Mitigation Measures on National Road Schemes in Ireland.

Given the limited data sources available from mitigation from linear transport schemes, it would also be beneficial to draw on data drawn from mitigation for other types of development, given that many of the lessons learnt will be transferable. However, this was beyond the remit of this study.

6 Conclusions

6.1 In conclusion, this study found there to be limited evidence available regarding the success of mitigation techniques on road and rail schemes. The majority of information available related to mammals and their use of wildlife crossings, and habitat creation/translocation for woodland, grassland and invertebrates.

6.2 Consultation responses to the study were low, which may have been a result of the limited timescales of the project. This highlights the requirement for greater cross agency working to pool knowledge.

6.3 The response to the IEEM questionnaire was low, and although it is considered that ecologists are well placed to comment on the effectiveness of mitigation techniques, there is a need for greater communication between parties to ensure that this knowledge is captured.

6.4 The limited volume of data which was available is considered to be a result of a number of issues:

1) A lack of monitoring being undertaken;
2) A lack of enforcement of monitoring requirements;
3) Poor communication of monitoring results; and
4) No central location/ no single responsible body for collating monitoring reports.

6.5 Given the time and expense spent on assessing the impacts of road and rail schemes and in developing mitigation, this study would suggest that resources should be channelled into the assessment of mitigation to ensure that there is greater confidence in the predictions of mitigation success. This study recommends a number of steps that could be taken to improve the evidence base relating to mitigation success in England.

- *Setting planning conditions to stipulate monitoring and the use of an Ecological Clerk of Works (ECoW) where appropriate.*
- *Commissioning of studies to address information gaps.*
- *Improving follow up on mitigation and monitoring detailed with Environmental Statements.*
- *Undertaking data collection from local authorities.*
- *Holding mitigation workshops.*
- *Setting guidance with respect to the level of information required for Protected Species licence returns.*
- *Establishing a database for recording the information obtained for licence returns.*
- *Establishing a central location where ecological monitoring must be logged.*

6.6 This study concludes that there is a limited evidence base from which Natural England can draw its recommendations for mitigation for road and rail projects.

6.7 Following a review of this report's conclusions the Natural England Licensing team have confirmed that they have already recognised some of the issues identified, and a number of measures are being implemented to address these.

6.8 The following actions are currently being undertaken by Natural England:

- A new IT system is being built for Licensing Team (to be launched in late 2013). This will allow a greater level of detail to be captured, reported, and disseminated.
- New licences being issued for surveying licences have been revised to clearly state what information is required in reports and that data must be submitted to Local Record Centres. In some cases existing online national databases for reporting (until Natural England's own online reporting tool has been developed) are being utilised, for example, dormouse data is to be loaded on the PTES dormouse database and crayfish data on the CEH database.
- Additional resource to be made available to allow more scrutiny of licence outcomes (i.e. monitoring success).

2	1	Doc Ref
Scientific paper	Scientific paper	Source
Overcoming the barrier effect of roads - how effective are mitigation strategies? An international review of the effectiveness of underpasses and overpasses designed to increase the permeability of roads for wildlife. Pages 423-431 in C. L. Irwin, D. Nelson, and K. P. McDermott, editors. International Conference on Ecology and Transportation. Centre for Transportation and The Environment, North Carolina State University, Raleigh, North Carolina, Little Rock, Arkansas, USA.	Wildlife Research 37, 320-311: Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia.	Document reference (Title/ Web address)
van der Ree, R., E. A. van der Grift, C. Mata, and F. Suarez	Taylor and Goldingay	Author
2007	2010	Date
Study of effectiveness of wildlife crossing structures from reviewing studies.	Literature review of studies on publications on wildlife and roads.	Summary of document objectives
This review found that studies clearly demonstrate that most measures designed to increase the permeability of roads for wildlife were successful at the level of the individual animal. However the article did conclude that there was insufficient information and analysis in the majority of studies to evaluate whether the viability of a population is at an acceptable level.	Study undertaken in 2010 reviewed 244 published studies on road and vehicle impacts, this found that 53% of studies in mammals, with ungulates (predominately deer) the most frequently studied taxonomic group. No detail provided on mitigation specifics.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Yes	n/a	Mitigation success?
Fragmentation	n/a	Impact
n/a	n/a	Habitat
Mammals	n/a	Species
Evidence based	Evidence based	Strength of data
Peer Review	Peer Review	Quality of data
International	International	Geographic extent

4	3	Doc Ref
Scientific paper	Scientific paper	Source
Habitat fragmentation due to transportation infrastructure. COST 341 National state of the art report Sweden.	Journal of Applied Ecology; Building the evidence base for ecological impact assessment and mitigation.	Document reference (Title/ Web address)
A.Seiler and L.Folkeson	D.Hill and R.Arnold	Author
2006	2012	Date
Detailed overview of roads and ecology in the Sweden.	Overall assessment of the evidence available for impact assessment mitigation.	Summary of document objectives
Discusses different types of mitigation, but also the issues with limited monitoring data.	Good summary of the issues surrounding the limited evidence available with respect to mitigation success.	Key themes and issues relevant to the study
No	No	Specific project examples within article
Unknown	n/a	Mitigation success?
Wide ranging reporting covering the majority of impacts	n/a	Impact
All	n/a	Habitat
All	n/a	Species
Evidence based	Subjective	Strength of data
Government Research	3rd party evidence	Quality of data
Europe	UK	Geographic extent

6	5	Doc Ref
Scientific paper	Scientific paper	Source
Mitigation and compensation of habitat fragmentation caused by roads: strategy, objectives and practical measures.	http://www.susdrain.org/files/resources/other-guidance/ecological_benefits_summary.pdf	Document reference (Title/ Web address)
Van Bohemen	DtI	Author
1995	undated	Date
Summary of general objectives of the Dutch transport Structure Plan.	Summary of research into the ecological benefits of SUDS.	Summary of document objectives
Provides details on ecoducts across the A50 and number of mammal passages demonstrating its success.	Provides overview of measures for techniques for maximising benefits of SUDS for ecology, but no details of examples to demonstrate success given.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Yes	Unknown	Mitigation success?
Fragmentation	Water pollution	Impact
n/a	Open water	Habitat
Mammals	n/a	Species
Evidence based	Subjective	Strength of data
3rd party evidence	Government Research	Quality of data
Europe	England	Geographic extent

8	7	Doc Ref
Scientific paper	Scientific paper	Source
Drainage culverts as habitat linkages and factors affecting passage by mammals.	The use of a motorway wildlife overpass by large mammals.	Document reference (Title/ Web address)
Clevenger et al	Van Wieren and Worm	Author
2001	2001	Date
Study looking at culvert usage along the Trans-Canadian Transport Corridor.	Assessment of use of the wildlife crossing over the A50 Motorway on the Netherlands.	Summary of document objectives
Different culvert attributes affect what species will use them. Martens - preference for culverts with low clearance and high openness ratios, weasels preference for high clearance and low openness ration and low through visibility. Recommends culverts placed every 150-300m, with a mix of culvert sizes. 1-1.5m for medium mammals, and 0.5-1m for small mammals, with vegetation cover to the edges.	Discusses the use of the ecoduct, monitoring of the structure 5 years on. Shown to be used by deer, badger and smaller mammals.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Yes	Yes	Mitigation success?
Fragmentation and wildlife mortality	Fragmentation and wildlife mortality	Impact
n/a		Habitat
Mammals	Mammals	Species
Evidence based	Evidence based	Strength of data
Peer Review	Peer Review	Quality of data
International	Europe	Geographic extent

10	9	Doc Ref
Scientific paper	Article	Source
COST 341_ Habitat fragmentation due to transport infrastructure.	Making the Connection: Mammal mitigation measures on national road schemes in Ireland: IENE Conference Short Papers; pg 85-87 In: Richter, V., Puky, M. & Seiler, A. (eds): Improving connections in a changing environment. Collection of short papers from the 2010 IENE Conference. Varangy Akciócsoport Egyesület - MTA Ökológiai és Botanikai Kutatóintézete - SCOPE Ltd., Budapest - Vácrátót. 5-8.	Document reference (Title/ Web address)
Iuell *et al.*	Finnerty et al.	Author
2003	2010	Date
Detailed overview of roads and ecology in the UK.	Details of study in Ireland looking at success of mitigation on road schemes.	Summary of document objectives
Examples of different mitigation types for different species and habitats although does not provide details with respect to monitoring on these schemes. Mitigation detailed largely follows DRMB.	Details current study into mitigation measures on road scheme - findings of study not yet known.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Successful	Unknown	Mitigation success?
Wide ranging reporting covering the majority of impacts	Wide ranging reporting covering the majority of impacts	Impact
All	Multiple	Habitat
All	Multiple	Species
Evidence based	Evidence based	Strength of data
Government Research	Peer Review	Quality of data
UK	Europe	Geographic extent

12	11	Doc Ref
Scientific paper	Article	Source
Mitigation of the effects of road construction on sites of high ecological interest.	A2/M2 Cobham to Junction 4 Widening Strategy, 10 year Ecological Monitoring Strategy 2000-2009 Final Monitoring Report.	Document reference (Title/ Web address)
Chinn, Hughes and Lewis	HyderCresswell	Author
1999	2013	Date
Review of 14 English road schemes, assesses the success of the mitigation on each of these schemes. Study undertaken for the Highways Agency.	Details of 10 year monitoring of mitigation for woodland creation and dormice translocation.	Summary of document objectives
14 case studies provided of major road schemes, details mitigation and surveys undertaken to assess their success. Looks at a wide range of ecological interests. The surveys found varying degrees of mitigation success. Included assessment of well known schemes on M3 and M40. Of the 14 schemes assessed only 3 were considered completely successful. The two main reasons for schemes not being successful was inadequate management of the implementation of mitigation and inadequate post-construction monitoring.	Details mitigation measures for woodland creation, and translocation and habitat enhancements for dormice. Also lagoon creation for lagoon worm. Monitoring over 10 years demonstrated that tree re-growth was possible using coppiced hazel stools translocated from ancient woodland, and the presence of ground flora species and ground dwelling invertebrates was accelerated through the use of translocated ancient woodland soils.Also that habitat enhancement for dormice was successful.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Successful/Unsuccessful	Yes	Mitigation success?
Multiple	Habitat loss	Impact
Multiple	Woodland and open water	Habitat
Multiple	Dormice and invertebrates	Species
Evidence based	Evidence based	Strength of data
Government Research	3rd party evidence	Quality of data
England	England	Geographic extent

14	13	Doc Ref
Article	Scientific paper	Source
Translocating wildlife habitats: A guide for civil engineers: http://www.atkinsglobal.com/~/media/Files/A/Atkins-Global/Attachments/corporate/about-us/our-publications/technical-journals/Technical-Journal-06.pdf	Vegetation succession on a relocated ancient woodland soil.	Document reference (Title/ Web address)
J. Box and K.Stanhope	Helliwell et al.	Author
2010	1996	Date
Summary of three habitat translocation projects - hedgerow, grassland and fen/ marsh.	Discuss soil translocation of the Channel Tunnel Rail Link.	Summary of document objectives
Details methods used and monitoring of success. All short term monitoring of sites show evidence of success.	Discuss methods for soil translocation as mitigation for the loss of ancient woodland. Monitoring of the site found that of the 99 species recorded at the receptor site, 83 species were recorded at the donor site, and after 6 years monitoring surveys found the site to contain woodland cover recognisable as woodland.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Yes	Partial	Mitigation success?
Habitat loss	Habitat loss	Impact
hedgerow, grassland and fen	Woodland	Habitat
n/a	n/a	Species
Subjective	Evidence based	Strength of data
3rd party evidence	Peer Review	Quality of data
England	England	Geographic extent

16	15	Doc Ref
Article	Scientific paper	Source
The Blackwater Valley Road - Shaping the Landscape.	Water quality monitoring during the construction of the M3 motorway in Ireland.	Document reference (Title/ Web address)
Blackwater Valley Countryside Partnership	P.Purcell, M.Bruen, J.O'Sullivan, L.Cocchiglia & M.Kelly-Quinn	Author
2004	2012	Date
Reporting detailing the mitigation measures for a 17km dual carriageway and monitoring of those measures.	Summary of effectiveness of mitigation measures used during the construction of a new motorway over a river designated as a Nature 2000 site.	Summary of document objectives
Scheme mitigation included pond construction and translocation of habitats and reptiles. Mitigation measures for reptiles, heathland, pond creation and translocation of gingerbread sedge were all successful.	This study found that the mitigation measures applied were successful in minimising water quality impacts. Mitigation included wide span bridges, holding ponds and interceptors, bottomless culverts, avoiding in channel working during spawning periods, translocation of species (crayfish, lamprey) before channel diversions, using buffer strips between water courses and construction areas to reduce impacts from sedimentation.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Successful	Successful	Mitigation success?
Fragmentation, wildlife mortality, pollution, habitat loss	Water pollution	Impact
Heathland, open water	Open water	Habitat
Reptiles, vascular plants	n/a	Species
Evidence based	Evidence based	Strength of data
3rd party evidence	3rd party evidence	Quality of data
England	UK	Geographic extent

18	17	Doc Ref
Scientific paper	Scientific paper	Source
Effectiveness of wildlife crossing structures and adapted culverts in a highway in Northwest Spain.	Conservation Evidence. Use of badger tunnels by mammals on Highways Agency schemes in England.	Document reference (Title/ Web address)
Mata *et al.*	Bonnie Eldridge & Jules Wynn	Author
2003	2011	Date
A study in Spain assessed 82 passages beneath a road, looking at circular culverts, adapted culverts, wide underpasses, wildlife. underpasses, overpasses and wildlife overpasses.	Study examining the effectiveness of badger tunnels and considers design factors.	Summary of document objectives
All structure types were used by vertebrates, both those specifically designed for wildlife and those that are not. Most species showed some selectivity among passageway types. Badgers were found to exclusively use underpasses rather than overpasses. Adapted culverts ranked highest, followed by wildlife underpasses, circular culverts were occasionally used. (The study did not provide specific details about the design of culverts or underpasses).	Study shows badgers will use tunnels- 89% of those monitored used. Things to consider include (i) pipe diameter, 600mm concrete, (ii) landscape planting at tunnel entrance/exit, (iii) positioning of tunnel and fencing to guide animals to crossing points, (iv) ensure tunnel drainage adequate.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Successful	Successful	Mitigation success?
Fragmentation, wildlife mortality	Fragmentation	Impact
n/a	n/a	Habitat
Mammals	Badger	Species
Evidence based	Evidence based	Strength of data
Peer Review	Peer Review	Quality of data
Europe	England	Geographic extent

20	19	Doc Ref
Scientific paper	Scientific paper	Source
English Nature Research Reports (No 178) - The significance of secondary effects from roads and road transport on nature conservation.	Response of carnivores to existing highway culverts and underpasses: implication for road planning and mitigation.	Document reference (Title/ Web address)
Natural England - D. Markham	Grilo, Bissonette and Santo-Reis	Author
1996	2008	Date
Wide ranging report discussing impacts, mitigation measures and success of mitigation.	Review of use of existing passages in Portugal. 57 passages monitored over a 252km stretch of road.	Summary of document objectives
Pages 69-71 provide details of examples of mitigation success based on published literature. Covers a range of impacts and mitigation measures. Recommends that further studies are required, along with pre, during and post construction monitoring to develop an evidence base.	Study found that the use of passages varied with structural landscape, road related features and human disturbance. Larger passages with vegetation close to the entrance and favourable habitat in the surrounding area with low human disturbance where the key attributes to regular use.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Successful/Unsuccessful	n/a	Mitigation success?
Fragmentation	Fragmentation and wildlife mortality	Impact
Various	n/a	Habitat
Various	Mammals	Species
Evidence based	Evidence based	Strength of data
Government Research	Peer Review	Quality of data
International	Europe	Geographic extent

22	21	Doc Ref
Scientific paper	Scientific paper	Source
Factors affecting the permeability of transportation and riparian corridors to the movements of songbirds in an urban landscape.	Vegetation structure on overpasses is critical in overcoming the road barrier effect for small birds: In Improving Connections in a Changing Environment: A Collection of Short Papers from the 2010 IENE International Conference on Ecology and Transportation.	Document reference (Title/ Web address)
Tremblay and St. Clair	Darryl Jones	Author
2009	2010	Date
Assessment of the willingness of song birds to cross roads, railways, watercourses and transportation bridges over watercourses.	Paper discusses that green bridges can be of benefit to birds.	Summary of document objectives
Study concluded that bird movements will be increased by limiting the gap to cross to less than 45m, especially where it bisects important habitat patches. This can be done by planting trees either side, recommending tall trees rather than shrubby ones. Birds showed a preference for flying over bridges rather than under bridges. Recommends bridges flanked with trees to enhance safe movement across. Mitigation recommendations based on survey findings, but no evidence detailed to indicate if successful.	Small gaps between trees (created by roads) can present an impassable barrier to small woodland birds. A study of a green bridge in Australia found that a green bridge was used by birds (of various sizes), especially once shrubs and tree begin to mature.	Key themes and issues relevant to the study
No	Yes	Specific project examples within article
n/a	Successful	Mitigation success?
Fragmentation and wildlife mortality	Fragmentation, wildlife mortality	Impact
n/a	n/a	Habitat
Birds	Birds	Species
Subjective	Evidence based	Strength of data
Peer Review	3rd party evidence	Quality of data
International	International	Geographic extent

24	23	Doc Ref
Scientific paper	Scientific paper	Source
Barn Owls and Major Roads: Results and Recommendations from a 15-year research project.	Wetland creation and restoration near the Bothnia line railroad – a pioneer project in ecological compensation for northern migrant birds: In Improving Connections in a Changing Environment: A Collection of Short Papers from the 2010 IENE International Conference on Ecology and Transportation.	Document reference (Title/ Web address)
Ramsden	N.Lindberg and A.Enetjern.	Author
undated	2010	Date
15 year study into the effects on roads on barn owls carried out by Barn Owl Trust.	Paper discussed mitigation measures for a new rail scheme which affects a Natura site for wintering birds in Sweden.	Summary of document objectives
Provides recommendations for mitigation measures, but no evidence supporting these measures in terms of success rates. Evidence based assessment on impacts, but details on mitigation appear subjective.	The compensation measures include pumping of freshwater onto arable fields to create temporary spring floods, restoration of moist estuarine meadows, creation of shallow freshwater wetlands and growing of crops favoured by the birds. In total, the compensation areas cover an area of 500ha. During springs of 2009-2010, the areas were already in use by thousands of wetland birds.	Key themes and issues relevant to the study
No	Yes	Specific project examples within article
	Successful	Mitigation success?
Fragmentation and wildlife mortality	Habitat loss	Impact
n/a	Grassland and marsh	Habitat
Birds	Birds	Species
Subjective	Subjective	Strength of data
3rd party evidence	3rd party evidence	Quality of data
England	Europe	Geographic extent

26	25	Doc Ref
Scientific paper	Article	Source
Pilot study to assess the potential of selected existing structures on the A30 and A38 trunk roads to provide safer crossing places for deer.	IENE Conference proceedings and abstracts.	Document reference (Title/ Web address)
Langbein	Various	Author
2010	2012	Date
Study looking at existing structures on two roads and how these are used by deer.	Range of abstracts from conference proceedings.	Summary of document objectives
The report provides a lengthy summary of studies and evidence regarding deer use of structures and as such is not repeated in detail here. Page 8 of this report provides a useful table of dimensions of structures which have been used by deer (for which there is an evidence base) and recommendations arising from past reviews for design of overpasses or underpasses suitable for wildlife.	Wide ranging, but only brief summaries given, so not detailed or assessed here.	Key themes and issues relevant to the study
Yes		Specific project examples within article
Yes		Mitigation success?
Fragmentation and wildlife mortality		Impact
n/a		Habitat
Deer		Species
Evidence based		Strength of data
3rd party evidence		Quality of data
England		Geographic extent

28	27	Doc Ref
Scientific paper	Scientific paper	Source
Use of highway undercrossings by wildlife in Southern California.	The Use of Highway Underpasses by Large Mammals in Virginia and Factors Influencing their Effectiveness.	Document reference (Title / Web address)
Ng et al.	B.Donaldson	Author
2004	2005	Date
15 crossing points monitored 4 times a month of year in California.	Investigate the effectiveness of Virginia's large mammal passes and determine what makes a mammal pass effective.	Summary of document objectives
Study finds that habitat on either side of crossings is an important factor in predicting their use and side of crossings is important with respect to deer.	1 year study with remote cameras on underpasses in Virginia, assesses camera images and mammal usage and considers the types of structures used.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Yes	Yes	Mitigation success?
Fragmentation and wildlife mortality	Fragmentation	Impact
n/a	n/a	Habitat
Mammals	Mammal	Species
Evidence based	Evidence based	Strength of data
Peer Review	3rd party evidence	Quality of data
International	International	Geographic extent

30	29	Doc Ref
Scientific paper	Scientific paper	Source
Deer and road traffic accidents: A review of mitigation measures: costs and cost-effectiveness.	How effective are wildlife fences in preventing collisions with wild ungulates: In Improving Connections in a Changing Environment: A Collection of Short Papers from the 2010 IENE International Conference on Ecology and Transportation.	Document reference (Title/ Web address)
R.J.Putman, J.Langbein and B.W.Staines	M.Niemi, A.Martin,A.Tanskanen, P.Numm	Author
2004	2010	Date
Review of mitigation approaches to avoid impacts on deer and makes recommendations of mitigation approaches.	Paper discussed research the effectiveness of large mammal fencing, i.e. does it reduce collisions?	Summary of document objectives
Highway fencing most appropriate on high speed roads and motorways, combined with dedicated crossing places. On minor roads if fencing not feasible - reduction in speeds in high risk areas recommended, plus deer crossing signage. On existing roads - fencing leading to well sign posted crossing areas, away from accident blackspots - preference of dynamic signs which switch on when deer approaching. Use of cattle grids either side of crossing points, to prevent animals wandering into road. On high volume existing roads - provide long lengths of fencing to existing crossing points, provide one way deer gates or leaps to allow any animals on the carriage way to escape. Use of "green bridges" - converting existing bridges to green bridges. For new roads with low traffic volumes predicted measures should be as per existing roads. For new roads with high volumes of traffic - barrier fencing with adequate provision of underpasses or green bridges. Information within the report is based in literature review, does not provide detailed specifics or examples.	Collisions in the study area were shown to have declined, although collisions elsewhere increased, i.e. the animals were displaced by the fencing and were hit by vehicle elsewhere. Key point = fencing need to filter animals towards well designed and safe crossing points.	Key themes and issues relevant to the study
No	Yes	Specific project examples within article
Unknown	Successful	Mitigation success?
Fragmentation, wildlife mortality	Wildlife mortality	Impact
n/a	n/a	Habitat
Deer	Deer	Species
Evidence based	Evidence based	Strength of data
Government Research	Peer Review	Quality of data
Scotland	Europe	Geographic extent

32	31	Doc Ref
Article	Scientific paper	Source
British Wildlife - Wildlife bridges for small mammals.	Effectiveness of wildlife warning reflectors in reducing deer-vehicle collisions: a behavioural study.	Document reference (Title/ Web address)
Pat Morris and Shusaku Minato	Ujvari, Bassgoe, Madsen	Author
Feb 2012	1998	Date
Discuss success of green bridges and arboreal pathways.	Study of habituation of deer to repeatedly occurring light reflections.	Summary of document objectives
Examples of successful green bridge and arboreal pathway projects, e.g. Lamberhurst Bridge and Japanese studies.	Study found that habituation of deer and technical limitation of the reflectors, such as limited angle and low light intensity of the refection, mean that reflectors are not reliable as a method to reduce the number of deer vehicle accidents on a long term basis.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Successful	No	Mitigation success?
Fragmentation	Wildlife mortality	Impact
n/a	n/a	Habitat
Dormice	Deer	Species
Evidence based	Evidence based	Strength of data
3rd party evidence	Peer Review	Quality of data
International	Europe	Geographic extent

34	33	Doc Ref
Article	Book	Source
Post Opening Project Evaluation A30 Bodmin to Indian Queen Improvement 1 year after study.	The butterfly handbook - General advice note on mitigating the impacts of roads on butterfly populations.	Document reference (Title/ Web address)
Highways Agency	English Nature	Author
2010	2005	Date
Details of assessment of scheme 1 year after construction.	Review of effect of road schemes on butterfly populations and presents details of mitigation measures and case studies.	Summary of document objectives
Details the mitigation measures for butterflies and summary of findings after 1 year, which have found that the site has not been monitored.	Examples case studies of successful habitat translocation - M40 Oxfordshire, compensation area created that now supports 25 butterfly species. Wildflower seed mix used within motorway fence line. Motorway designed so that a link was created to allow invertebrates to move along roadside verges between two SSSIs. Blackthorn planted for the black hairstreak butterfly. Twyford Down, habitat restoration successful for butterflies, chalk hill blues increased in the first 3 years following the opening of the M3. Details approaches followed on both schemes, limited information provided on monitoring.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Unknown	Successful	Mitigation success?
Habitat loss	Habitat loss	Impact
Grassland	Grassland and marsh	Habitat
Butterflies	Butterflies	Species
Subjective	Evidence based	Strength of data
Government Research	Government Research	Quality of data
England	England	Geographic extent

36	35	Doc Ref
Scientific paper	Scientific paper	Source
Conservation Evidence. Adder Vipera berus hibernacula construction as part of a mitigation scheme, Norfolk, England.	Otter Road Casualties.	Document reference (Title/ Web address)
Christian Whiting & Helen J. Booth	P.Channin	Author
2012	2006	Date
Case Study : Outlining the success of creating an adder bank.	Issues of otters and road construction.	Summary of document objectives
Flood alleviation project required the capture and release of adders (outside the core works area). A number of adder banks were created outside the works area (structure described in doc) - the banks supported the adder population during development. Breeding occurred on the banks and some females chose the created habitat as a natal den. Post-construction some adders chose to remain in the banks.	Acknowledges that while otters are killed on roads, there is no evidence to suggest that numbers killed on roads in the SW England is sufficiently high to have an adverse effect on the otter population recovery. Provides recommendations for mitigation measures. On existing structures create passages using ramps or ledges about the flood water level, and fencing to prevent access to the road. Does not provide details of evidence behind recommendations, based on professional judgement of author.	Key themes and issues relevant to the study
Yes	No	Specific project examples within article
Successful	Unknown	Mitigation success?
Habitat loss	Fragmentation	Impact
n/a	n/a	Habitat
Water vole	Otter	Species
Subjective	Subjective	Strength of data
Peer Review	Peer Review	Quality of data
	England	Geographic extent

38	37	Doc Ref
Book	Scientific paper	Source
Water vole Conservation Handbook, 2nd Edition.	Conservation Evidence. Creating hibernacula for common lizard, *Lacerta vivpara*, The Ham, Lowestoft, Suffolk England.	Document reference (Title/ Web address)
R.Strachan and T.Moorhouse	Showler, Aldus and Parmenter	Author
2006	2005	Date
Details on water vole ecology, and development and mitigation.	Details creation of hibernacula to mitigate for the loss of hibernacula on a road scheme.	Summary of document objectives
Details of mitigation techniques provided and case studies.	Three hibernacula were created to mitigation for the loss of one hibernacula used by common lizards as part of a road scheme. Paper details methodology for building hibernacula. Considered successful and adult and juvenile lizards observed using hibernacula - but no detailed monitoring undertaken.	Key themes and issues relevant to the study
Yes	Yes	Specific project examples within article
Yes	Successful	Mitigation success?
Habitat loss, fragmentation, mortality	Wildlife mortality	Impact
n/a	n/a	Habitat
Water vole	Reptiles	Species
Evidence based	Subjective	Strength of data
Government Research	Peer Review	Quality of data
UK	England	Geographic extent

39	**Doc Ref**
Article	**Source**
British Wildlife - Water voles and development.	**Document reference (Title/ Web address)**
A.Bennet, D.Watson and D.Hill	**Author**
2001	**Date**
Case Study: outlines a mitigation strategy used for a development which includes new roads.	**Summary of document objectives**
Steps taken included, feature retention (where possible), sympathetic culvert design, strimming to displace, exclusion fencing (indicated in an earlier paper as being limited in success), trapping, habitat creation. Post construction surveys find population size similar to that recorded pre development.	**Key themes and issues relevant to the study**
Yes	**Specific project examples within article**
Successful	**Mitigation success?**
Habitat loss	**Impact**
n/a	**Habitat**
Water vole	**Species**
Subjective	**Strength of data**
3rd party evidence	**Quality of data**
England	**Geographic extent**

Appendix 2 Questionnaire to IEEM Members

Section A: About yourself:

1) Please select your occupation:
   - Consultant
   - Academic
   - SNCO
   - Charity
   - Other _ please specify
2) How long have you been in practice?
   - 1-2 years
   - 2-5 years
   - 5-10 years
   - 10+ years
3) Select those areas in which you have experience:
   - Ecological survey
   - Ecological assessment
   - Road and rail projects
   - Mitigation design
   - Implementing mitigation
   - Post construction monitoring
   - Assessing mitigation success

Section B: Habitats

Skip to Section C if no mitigation experience with respect to habitats

Please provide additional information within the comments box where relevant.

Woodland – if no experience skip

1) In your experience is habitat re-creation of woodland a successful mitigation technique?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?
   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

2) In your experience is habitat translocation of woodland a successful mitigation technique?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?
   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

3) In your experience is enhancement of existing retained woodland areas (e.g. supplementary planting, invasive species management) a successful mitigation technique?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?
   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

4) In your experience is the use of exclusion zones around woodland a successful method of protecting habitat?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?

   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

5) Have you undertaken any novel (i.e. not standard best practice) approaches to mitigate against impacts on woodland, if so please provide details?

6) Was this mitigation a success, and if yes was this success based on monitoring?
   - No
   - Yes – subjective –no monitoring
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs+
   - Yes – Other_ please specify

Bog/ Mire – if no experience skip

7) In your experience is habitat re-creation of bog/mire a successful mitigation technique against habitat loss/ fragmentation and severance?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?

   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

8) In your experience is habitat translocation of bog/mire a successful mitigation technique against habitat loss/ fragmentation and severance?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?

   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

9) In your experience is enhancement of retained areas of bog/mire habitat (e.g. through grazing management or hydrological management) a successful mitigation technique?
   - Yes
   - No

   Comments:

   Is this assessment of success based on monitoring and if so to what degree?

   - No
   - Yes – 1 yr
   - Yes – 2 yrs
   - Yes – 5 yrs
   - Yes – Other_ please specify

10) In your experience is the use of exclusion zones around bogs/mires a successful method of protecting habitat?
    - Yes
    - No

    Comments:

    Is this assessment of success based on monitoring and if so to what degree

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

11) Have you undertaken any novel (i.e. not standard best practice) approaches to mitigate against impacts on mire, if so please provide details?

12) Was this mitigation a success, and if yes was this success based on monitoring?
    - No
    - Yes – subjective –no monitoring
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs+
    - Yes – Other_ please specify

Heathland– if no experience skip

13) In your experience is habitat re-creation of heathland a successful mitigation technique?
    - Yes
    - No

    Comments:

    Is this assessment of success based on monitoring and if so to what degree?

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

14) In your experience is habitat translocation of heathland a successful mitigation technique?
    - Yes
    - No

    Comments:

Is this assessment of success based on monitoring and if so to what degree?

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

15) In your experience is enhancement of retained areas of heathland habitat (e.g. through scrub management, grazing regimes or burning) a successful mitigation technique?
    - Yes
    - No

    Comments:

    Is this assessment of success based on monitoring and if so to what degree?

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

16) In your experience is the use of exclusion zones around heathland a successful method of protecting habitat?
    - Yes
    - No

    Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

17) Have you undertaken any novel (i.e. not standard best practice) approaches to mitigate against impacts on heathland, if so please provide details?

18) Was this mitigation a success, and if yes was this success based on monitoring?
    - No
    - Yes – subjective –no monitoring
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs+
    - Yes – Other_ please specify

Grassland– if no experience skip

19) In your experience is habitat re-creation of grassland a successful mitigation technique against habitat loss/ fragmentation and severance?
    - Yes
    - No

    Comments:

    Is this assessment of success based on monitoring and if so to what degree?

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

20) In your experience is habitat translocation of grassland a successful mitigation technique against habitat loss/ fragmentation and severance?
    - Yes
    - No

    Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

21) In your experience is enhancement of retained areas of grassland habitat (e.g. through altered mowing/ grazing regimes, additional planting) a successful mitigation technique?
    - Yes
    - No

    Comments:

    Is this assessment of success based on monitoring and if so to what degree?

    - No
    - Yes – 1 yr
    - Yes – 2 yrs
    - Yes – 5 yrs
    - Yes – Other_ please specify

22) In your experience is the use of exclusion zones around grassland a successful method of protecting habitat?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

23) Have you undertaken any novel (i.e. not standard best practice) approaches to mitigate against impacts on heathland, if so please provide details:

24) Was this mitigation a success, and if yes was this success based on monitoring?
- No
- Yes – subjective –no monitoring
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs+
- Yes – Other_ please specify

Aquatic environments– if no experience skip

25) In your experience is the use of SUDs ponds or other SUDs measures successful mitigation techniques against water pollution?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

26) In your experience is the use of standard pollution and sediment control measures (e.g. PPGs 5 and 6) successful mitigation techniques against water pollution?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

27) In your experience is the use of exclusion zones around aquatic environments a successful method of protecting habitat?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

28) Have you undertaken any novel (i.e. not standard best practice) approaches to mitigate against impacts on aquatic environments, if so please provide details:

29) Was this mitigation a success, and if yes was this success based on monitoring?
- No
- Yes – subjective –no monitoring
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs+
- Yes – Other_ please specify

All habitats - if no experience skip

30) In your experience is the use of a bespoke habitat management plan a useful tool to ensure the effectiveness of mitigation?
- Yes
- No

If yes, please provide details

31) If yes, is this opinion based on monitoring?
- No
- Yes – subjective –no monitoring
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs+
- Yes – Other_ please specify

32) Have you had experience of implementing mitigation for air quality impacts?
- Yes
- No

If yes, please provide details

33) Was this mitigation a success, and if yes was this success based on monitoring?
- No
- Yes – subjective –no monitoring
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs+
- Yes – Other_ please specify

Section C: Species

Skip to Section D if no mitigation experience with respect to species

Please provide additional information within the comments box where relevant.

Badgers – if no experience skip

34) In your experience is fencing (as per DRMB standard) a successful mitigation technique against collision risk from road and rail projects?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

35) In your experience are underpasses and culverts (as per DRMB standard) a successful mitigation technique against collision risk and severance from road and rail projects?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 y
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

36) In your experience, following temporary sett closures will badgers return to use a sett?
- Yes
- No

Comments:

Is this assessment of use based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

37) In your experience, is permanent sett closures and the provision of artificial setts a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

38) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

39) In your experience is the use of exclusion zones around badger setts a successful mitigation method?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

40) In your experience is avoiding night working to prevent disturbance to badgers a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

41) In your experience is the sensitive management of light a successful technique to prevent disturbance to otters?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Dormice – if no experience skip

42) In your experience is trapping and translocation of dormice a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

43) In your experience are green bridges a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

44) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

45) In your experience is the use of exclusion zones around dormice habitat a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Water vole – if no experience skip

46) In your experience is trapping and translocation of water voles a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

47) In your experience is displacement through habitat manipulation (e.g. strimming) a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

48) In your experience is fencing around areas where water voles have been excluded successful in maintaining an area free of water voles?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

49) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

50) In your experience is the use of exclusion zones around water vole burrows a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Reptiles – if no experience skip

51) In your experience is trapping and translocation of reptiles a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

52) In your experience is hand searching vegetation for reptiles and relocating to suitable adjacent habitat a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

53) In your experience is trapping through tinning and translocation of reptiles a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

54) In your experience is fencing around areas where reptiles have been excluded successful in maintaining an area free of reptiles?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

55) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

56) In your experience is the use of exclusion zones around suitable reptile habitat a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Natterjack Toad – if no experience skip

57) In your experience is trapping and translocation of natterjack toads a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

58) In your experience is hand searching vegetation for natterjack toads and relocating to suitable adjacent habitat a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

59) In your experience is fencing around areas where natterjack toads have been excluded successful in maintaining an area free of toads?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

60) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

61) In your experience is the use of exclusion zones around suitable natterjack toad habitat a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Otter – if no experience skip

62) In your experience is fencing (as per DRMB standard) a successful mitigation technique against collision risk from road and rail projects?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

63) In your experience are underpasses and culverts (as per DRMB standard) a successful mitigation technique against collision risk and severance from road and rail projects?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

64) In your experience is avoiding night working to prevent disturbance to otters a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

65) In your experience are artificial holts a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

66) In your experience is the sensitive management of light a successful technique to prevent disturbance to otters?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

67) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique against fragmentation and severance?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

68) In your experience is the use of exclusion zones a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Red squirrel – if no experience skip

69) In your experience are green bridges a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

70) In your experience are rope bridges a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

71) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree:

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

72) In your experience is the use of exclusion zones around red squirrel habitat a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Deer – if no experience skip

73) In your experience is fencing (as per DRMB standard) a successful mitigation technique against collision risk from road and rail projects?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Birds – if no experience skip

74) In your experience is the use of exclusion zones a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

75) In your experience is habitat manipulation to prevent nesting a successful mitigation technique (e.g. strimming of grass to deter ground nesting birds, removal of scrub/ trees)?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

76) In your experience is the use of planting to encourage flight cover roads and railways (“hop overs”) a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

77) In your experience is the use of embankments/ fencing/ cuttings a successful mitigation technique to avoid disturbance to surrounding habitats used by birds?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

78) In your experience is the use of bird boxes or creation of other roosting/ nesting habitats a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

79) In your experience is the use of bird scarers a successful mitigation measure?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

80) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique?
- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Butterflies and other invertebrates – if no experience skip

81) In your experience is the use of exclusion zone a successful mitigation measure to protect invertebrate habitat?

- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

82) In your experience is habitat creation for butterflies/ invertebrates a successful mitigation measure?

- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

83) In your experience is maintaining/ creating habitat connectivity a successful mitigation technique?

- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

Species – General

84) In your experience is the presence of an onsite ecologist (e.g. Ecological Clerk of Work) required to ensure mitigation is correctly implemented?

- Yes
- No

Comments:

Is this assessment of success based on monitoring and if so to what degree?

- No
- Yes – 1 yr
- Yes – 2 yrs
- Yes – 5 yrs
- Yes – Other_ please specify

If you would be happy for you project example to be used as a case study, please indicate and provide contact details. Examples of both successful and unsuccessful mitigation are welcomed. Case studies should either relate to road and rail projects or be applicable.

Appendix 3 Habitat Information

Table A3.1 Woodland

Literature Search:

Case Studies: A2/M2 Cobham to Junction 4 Widening scheme[11]

Mitigation was designed in response to the loss of ancient woodland and monitoring was undertaken over a 10 year period to measure the impact of the mitigation. At a site known as Cossington Fields, new woodland habitat was created in part through the translocation of ancient woodland topsoil and hazel coppiced stools. The aim of the soil translocation was to speed up the development of habitat by translocation of ground flora species and ground dwelling invertebrates. A total of 10,000 tonnes of topsoil was translocated to a receptor site. Subsoil samples were taken from the receptor site and the physical and chemical characteristics were compared with the donor sites to ensure compatibility. Works were planned to avoid loss of function of subsoil, i.e. to prevent over compaction. In additional to the soil translocation, 60,000 nursery grown native trees and shrubs of local provenance were planted at 1m spacings. Hazel coppiced stools from the donor woods were also moved; this helped with the early development of shady conditions and formed a wildlife corridor connecting isolated fragments of woodlands.

When compared with a woodland creation site where the topsoil translocation was not undertaken, the 10 year monitoring programme concludedthat Cossington Fields has developed a range of woodland species, including ancient woodland indicator species, whereas the site where the topsoil had not been translocated had not developed these species. As part of the project another area of woodland was created adjacent to an SSSI with ancient woodland, the site is known as Great Crabbles. The woodland plant species within the SSSI where not found to have colonised the created woodland area within the monitoring period. It has therefore been demonstrated that the translocation of soil can be beneficial in accelerating the rate at which certain ancient woodland indicator species are established.

However, this assessment has only been made over a 10 year period and further monitoring has been recommended at the site to ascertain the benefits, and successes, over a longer term. While this measure demonstrates a means of accelerating the rate at which certain ancient woodland indicator species establish, thus creating habitat which is potentially more diverse than at those sites which did not receive ancient woodland topsoils and coppiced stools, it must not be interpreted as successful mitigation for the loss of ancient woodland as an entity in its own right. Ancient woodlands are complex and highly diverse systems which support delicate and fragile niches and symbioses, developed over centuries. There is no evidence to suggest that ancient woodland translocation or re-creation is an effective or successful mitigation measure.

Case Study: A658 South Knaresborough bypass[12]

This bypass constructed in 1991/92 bisected a SSSI, with a landtake on 0.9ha. The SSSI, Birkham Wood is designated for ancient woodland on acidic glacial drift. An area of woodland planting was undertaken to the west of the SSSI and a band of planting was undertaken along the northern edge of the new road. The woodland creation was undertaken by removing nutrient rich topsoil and trees and shrubs were planted from seed and/or vegetative material taken from Birkham Wood. Deadwood within the construction corridor was carried into the new woodland to aid the introduction if invertebrates and fungi. Within the new woodland planted, the verges of the road were seeded. New hedgerow planting was designed to link existing hedgerows severed by the road alignment. Within the SSSI, topsoil was collected from the area of landtake and stored during the construction period, and then replaced along the new road verges to encourage natural regeneration. To prevent contamination of the woodland soil by surface water run-off from the carriageway, the surface water was to be fed via tapered gulleys sealed into longitudinal carrier drains.

[11] HyderCresswell (2013) A2/M2 Cobham to Junction 4 Widening Strategy, 10 year Ecological Monitoring Strategy 2000-2009 Final Monitoring Report.
[12] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.

The site was surveyed in 1997, five years after scheme completion. The surveys found no significant differences between percentage cover between the new edge ground flora and the woodland interior, thus no edge effects or effects from run off were identified. Tree planting mitigation was assessed as a success with survival rate of 90% and the hedgerow had established. The areas of road verge where woodland soils had been spread had developed as damp pasture land with a number of woodland ride species and this technique was considered to be a partial success. The seeding of the road verges through the area of woodland planting was not considered successful as few species persisted; reasons for this failure were not given within the report.

Case Study: Channel Tunnel Rail Link[13]

As part of the Channel Tunnel Rail Link an area of woodland was to be lost to create the rail link terminal in Folkestone. This woodland was created to mitigate for the loss of part of Biggins wood, a site of ancient woodland. The woodland creation was undertaken by stripping 300mm of top soil from a receptor site, and 200mm of top soil from the donor site was transferred using a dumper truck. A total of 10,000m^2 of topsoil were transferred. No attempts were made to move trees or shrubs; the site was then planted with nursery grown trees and shrubs. The ground conditions were considered, with "dry" areas of the donor site moved to freely draining slopes in the receptor site, and "wet" areas of the donor site moved to moist areas in the receptor site. Monitoring of the site found that of the 99 species recorded at the receptor site, 83 species were recorded at the donor site, and after 6 years monitoring surveys found the site to contain woodland cover recognisable as woodland. The paper regarding the work identified that the translocation as a partial success and concluded that future woodland creation schemes should consider moving existing trees and shrubs or obtaining plants of local origin and using herbicides on a limited proportion of the site.

Case Study: Lightmore Urban Village, Telford[14]

A section of hedgerow was translocated as was within the footprint of a proposed housing development; the approach used would also be applicable on road and rail schemes. The hedgerow was assessed to be of considerable age and species richness, with a diversity of woody species, including hazel, ash, holly, common hawthorn, blackthorn and field maple. The paper details the following methodology for translocation:

"Approximately 100m of hedgerow was cut to a height of 300 – 500mm at the start of 2007 to prevent birds nesting. Ash and field maple trees up to 225mm in diameter were reduced to about one metre in height. The translocation was undertaken in late September 2007 at the start of the earthworks programme. A trench was dug at the receptor area immediately prior to the hedge translocation to prevent the receptor trench drying out. The base of the receptor trench was scarified and slow-release fertilizer (20:4:10 N:P:K with mycorrhizal additive) and water-retaining gel was spread along the trench. The hedgerow was dug out in sections (approx 1.5m width x 1m length) across the line of the hedge to a depth of at least 1m using a tracked 360o excavator with the largest ditching bucket available. During the excavation, a chainsaw was used to free roots and branches where necessary to prevent them being torn. Sections of hedge with thick horizontal stems were moved without severing the stems and were transported immediately to the receptor trench before the next section of hedge was excavated. These hedge sections were placed in the receptor trench in the order in which they were removed and soil used to backfill any voids and gaps. Subsequent watering during the autumn was undertaken in dry conditions."

Monitoring in 2008 and 2009, found abundant new growth. There was evidence of holly die back in 2008, but in 2009 there was healthy regrowth. In 2009 the old hawthorns were showing severe die back, but younger hawthorns showed healthy growth.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contain any details relating to mitigation or its effectiveness.

[13] Helliwell et al (1996 b) *Forestry* 69 **1** 57-74.
[14] Box and Stanhope (2010) Translocating wildlife habitats: a guide for civil engineers Proceedings of the ICE - Civil Engineering, Volume 163, Issue 3, pages 123 –130.

IEEM Questionnaire:

The questions relating to woodland were answered by a total of 11 respondents.

To the questions 'is habitat creation of woodland a successful mitigation technique' and 'is woodland enhancement a successful mitigation technique', 9 out of 11 responded yes. With respect to habitat creation 65% based their response on monitoring and with respect to enhancement 50% based their response on monitoring. 100% of respondents agreed that exclusion zones (i.e. setting up a no-go area around an ecologically sensitive location) were a successful mitigation technique, 50% based their response on monitoring.

No other questions were answered by respondents.

Conclusions:

The case studies listed above have demonstrated that translocation of ancient woodland soil can be beneficial in accelerating the rate at which ancient woodland indicator species can be achieved. Soil translocation appears to have beena successful means of accelerating the rate at which certain ancient woodland indicator species established on the A2/M2 Cobham to Junction 4 widening scheme and and was deemed partially successful on the A658 bypass and the Channel Tunnel Rail Link in the reports reviewed. IEEM survey respondents did not answer the question relating totranslocation so there is no industry opinion to elucidate the findings of these case studiesIt is evident that the level of disturbance to soils during translocation is a critical issue. It is also evident that longer term monitoring is required (25 years plus) to determine whether initial ecological gains from soil translocation are maintained in the longer term. It is important to note that while soil translocation and the translocation of coppiced hazel stools appear to be successful in establishing ancient woodland indicator species and tree re-growth, they do not claim to successfully mitigate the loss of ancient woodland habitats and require the loss of ancient woodland in order to proceed. As noted above, ancient woodlands are complex and diverse systems which can only be achieved through centuries of growth and development. There is no evidence to suggest that the loss of ancient woodland can be successfully mitigated.

Hedgerow translocation was deemed to be successful in the study reviewed, however only one transport-related study was found to demonstrate this.

Table A3.2 Mire

Literature Search:

Case Study: Southfield Farm Marsh[15]

Between 1988 and 1990 the A14 dual carriageway was constructed across the centre of Southfield Farm Marsh SSSI. The SSSI was designated for its tall grassland washland, the site supports base-rich mire on silty peats. An area of low lying land adjacent to the SSSI was purchased and soil from the line of the new road was translocated. The course of a stream was diverted to feed this new area of habitat. The owner of the SSSI reported that the translocation of the soil was undertaken using a large earth removal machine and the receptor site was not prepared. The site was surveyed in 1996, four years after the scheme was completed to assess the success of the mitigation. The mitigation was found to be unsuccessful (both the translocation and the drainage measures), the translocated area did not resemble the remaining fragments of habitats; this was considered to be due to the poor management of the translocation and the lack of subsequent management.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not provide any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

The questions relating to mire were answered by a total of 7 respondents.

To the question is habitat creation of mire a successful mitigation technique, 5 answered yes, and 2 no, with 70% of responses based on monitoring.

To the question is mire enhancement a successful mitigation technique, 5 out of 5 responded yes, with 80% of responses based on monitoring.

100% of respondents answered that translocation was not a successful technique, with 40% of responses based on monitoring.

83% of respondents agreed that exclusion zones were a successful mitigation technique, 66% based their response on monitoring.

Conclusions:

Only one example of mire habitat translocation was identified, this was found to be unsuccessful due the poor management of the translocation. Whilst the IEEM survey only yielded a low number of responses, all of those which did respond answered that mire translocation was not a successful mitigation technique.

[15] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.

Table A3.3 Open Water

Literature Search:

Case Study: M3 Ireland[16]

The M3 motorway in Ireland was constructed between the years 2007 and 2010. The motorway crosses the River Boyne, which is a designated salmonid water under the EU Freshwater directive.

The following mitigation measures were undertaken to prevent impacts to the River Boyne SAC:

- The use of a 50m single span bridge across the river Boyne, negating the need for piers within the river, thus avoiding in-river construction;
- The incorporation of holding ponds and interceptors to attenuate the impact of runoff, during- and post- construction;
- The use of bottomless culverts to preserve the natural river characteristics to facilitate fish passage under all but extreme flow conditions;
- Appropriate design of river and stream diversions to reflect natural conditions;
- Avoidance of in-stream works in watercourses frequented by salmon or trout during their spawning season, typically the beginning of October to the end of February;
- The capture and translocation of salmonids, crayfish and lamprey before rediverting these rivers through the newly constructed culverts under licence from the relevant fishing authority.

The success of the mitigation measures was reviewed by: comparing preconstruction, during-construction and post-construction water quality data, (b) comparing measured water quality with relevant standards, (c) comparing water quality data upstream and downstream of river crossings, (d) the establishment of a pilot-scale real-time water quality monitoring station at the downstream end of the works before discharge into the river Boyne. The study concluded that the measures taken have been successful in minimising the water quality impacts associated with the road scheme.

The UK COST[17] report provides limited detail on the A1(M) Walshford-Dishforth scheme, where within two years of the motorway opening to traffic waterside planting had established, however no details are provided on the specifics of the mitigation or monitoring.

Case Study: Blackwater Valley Relief scheme[18]

In total, approximately 10.5ha of lake was infilled but the creation of new waterbodies resulted in a total gain of 5.8ha. The number of waterbodies within the study area increased from 31 prior to the road to a present day total of 72. This increase is a result of the construction of balancing ponds to deal with polluted road runoff, wildlife ponds created as mitigation measures and gravel extraction for road building materials.

To compensate for loss of lakes and ponds a number of wildlife ponds were created along the route of the road. In total about 25 waterbodies were built or restored from gravel pits for wildlife conservation purposes.

A major area where wildlife ponds were created was at Lakeside Park, here to provide a range of features of benefit to wild flora and fauna the ponds were constructed in a variety of sizes and designs. Trees were also felled around existing shaded ponds. The ponds were built in advance, which allowed them to be used as receptor sites for marshland habitat to be lost. One pond was built to resemble a pond which supported a significant amount of regionally rare water violet and prior to the destruction of the water violet pond much of this plant was translocated to this new pond.

Wetland plants from a marsh considered to be exceptional quality were also translocated with the

[16] Purcell et al (2012) Water quality monitoring during the construction of the M3 motorway in Ireland, Water and Environment Journal 26 175-183.
[17] Highways Agency (2000) COST 341 Habitat Fragmentation due to transport Infrastructures - UK National State of the Art Report.
[18] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape.

aim that species would survive transplanting if moved in large enough turfs, and that invertebrates moved with the vegetation might establish colonies on the new site.

Annual monitoring of the ponds this concluded that although some natural colonisation would be expected, especially from dormant seeds in the disturbed silt, it was felt that this translocation of plants aided the establishment of these ponds. Priming new ponds by using turfs from established ponds to be lost to development was found to be a useful technique for creating diverse emergent vegetation quickly (that is, in two or three seasons) though not, it must be stressed, for recreating an identical habitat. Plants moved to a new site respond to subtle environmental factors, leading to changes in the balances between species, and the final vegetation community is likely to be different in a number of ways.
Monitoring found that more competitive and tall species increased while lower growing, less competitive or annual species declined with a number of years. This example demonstrated the relative ease with which a good quality wetland habitat can be created, but also highlighted the considerable difficulties in maintaining it. The less competitive species which are most easily lost include many of the scarcer ones and therefore habitat management is required in order to maintain the level of biodiversity.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contact any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

The questions relating to open water were answered by a total of 5 respondents.

100% of respondents answered that SUDS ponds were a successful technique, with 50% of responses based on monitoring. 80% of respondents agreed that exclusion zones were a successful mitigation technique, 50% based their response on monitoring.

Conclusions:

Limited information was obtained on mitigation measures to protect aquatic habitats, with the data collected not detailed enough to draw any firm conclusions. Only a small number of IIEM members responded, but all respondents agreed that SUDS ponds were a successful mitigation technique.

Table A3.4 Heathland

Literature Search:

Case Study: A361 North Devon Link Road[19]

Hares Down, Knowstone, Rackenford Moor SSSI is designated for its lowland heathland. A new road was constructed over the moors between 1988 and 1990. Mitigation for the scheme included seeding of verges, tree and shrub planting, and creating an underpass beneath the road to enable cattle to graze. Non calcareous fill was also used in the road construction to prevent a change of the pH of surface waters. The site was surveyed in 1995, which found that the original seed mix dominated on the verges, and in localised areas similarities were developing between the verges and the SSSI. The report concluded that it was too early to judge if the mitigation was a success.

Case Study: Blackwater Valley Relief scheme[20]

As part of the Blackwater Valley Relief scheme, a 17.6 Km new dual carriageway, several very small areas of heathland were present in the vicinity of the proposed road. This habitat was translocated. The donor site consisted of an area of approximately 50m x 15m, dominated by mature plants of heather with cross-leaved heath and round-leaved sundew also present. The receptor site was 60m x 20m, and was situated approximately 50m west of the donor site. It was very sparsely vegetated with moss, grass, birch scrub and young pine trees and contained large areas of bare sand. Prior to translocation, the site was levelled by digger and most of the existing vegetation removed to leave an open expanse of bare sand. A shallow depression was constructed, approximately 8m across and 1m deep, the soil from this being used to construct a low embankment immediately to the north of the depression.

Before turfs were dug, most of the heather in the donor site was cut to a height of 30cm, in order to make the turfs more manageable, as well as reduce the nutrient and water demands of the plants in the next growing season. The heather cuttings (which contained abundant seed) were raked up and spread over part of the receptor site. Small turfs containing sundews were dug manually and placed in the depression on the receptor site.

Monitoring using fixed quadrats was, from 1992 to 1995 and in 2003.

Initially the percentage cover of heather fell in both the cut and uncut sections and the 2003 survey indicated that in the long term establishment was very similar between the cut and uncut heather. Heather had also established in the treatment areas of heather brash and leaf litter as well as the control area of bare ground. Surveys in 2003 did not illustrate a significant difference between the percentage cover in the areas where leaf litter, heather brash were spread and the areas of bare ground.

Monitoring recorded in excess of 50 round-leaved sundew in the specially created depression. Cross-leaved heath was recorded in the cut turf section with a maximum total of 48% cover (sum of % cover in 10 fixed quadrats) in July 1992 followed by a decline in subsequent surveys, no explanation was provided for the decline. Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not provide any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

Limited information was obtained on mitigation measures to protect heathland habitats, the data collected it not detailed enough to draw any firm conclusions.

[19] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.
[20] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape.

Table A3.5 Grassland and Marsh

Literature Search:

As part of the M3 Bar End to Compton project, downland habitats were created on new road verges and on adjacent arable land. Restoration methods aimed to create new herb rich habitat (this restoration was undertaken to create butterfly habitat, see details within invertebrate section below). Restoration techniques included turf translocation, using traditional hand methods and large scale macro turfing (moving turfs 2.4m x 1.2m ad up to 30cm thick). 260kg of seeds were needed to cover the 6.5ha, this used a commercial seed mix, and in addition 100,000 plug plants of important butterfly food plants were used. The COST[21] report details that preliminary monitoring suggest that both turf translocation and development of turf from seed seem to be progressing well, but details of the monitoring studies are not given.

Case Study: A41 Berkhamsted and Kings Langley Bypass[22]

This scheme constructed between 1991 and 1993, cut through an area of SSSI resulting in the loss of chalk grassland. An area adjacent to the SSSI was purchased for creation of chalk grassland and mitigation also including creating chalk grassland sward on the new cutting. The site was surveyed three years following the completion of scheme to assess the success of the mitigation. The mitigation was not judged to be successful as the sward that had developed did not resemble that within the unaffected chalk grassland. The reason for the lack of success was not clear, but the study suggested this may have been a result of the use of an incorrect seed mix.

Case Study: Brampton Meadows[23]

The A14 A1/M1 link road was constructed through Brampton Meadow SSSI, which is designated as a species rich meadow (calcareous clay pasture). The scheme was completed in 1991. Mitigation included the translocation of species-rich turf. To create the ridge and furrow topography, the mitigation design was to remove all roots greater than 5mm from the receptor site, and the surface to be remodelled so that the ridge and furrows aligned with those on the remainder of the SSSI, the surface compacted and scarified prior to laying turves. The site was subject to monitoring following completion and found the translocated turf supported species-poor rank grassland, it was considered that a lack of management had led to deterioration of the SSSI as a whole, not just the translocated habitat.

Case Study: British Library book depository[24]

Grassland translocation was undertaken of species rich grassland, containing orchids (pyramidal orchid, common spotted orchid and bee orchid) which were within the footprint of an extension to the British Library book depository. Monitoring undertaken 2 years after the translocation found that many of the targets had been met; the species rich grassland was flowering well and contained pyramidal orchids, common spotted orchids and cow slips.

Box and Stanhope detail the following methodology for the translocation:

"The species-rich grasslands covered an area approximately 130m in length by 10m wide on a steep northeast facing slope. There were two distinct grassland communities – short open grassland covering around 900m$_2$ that was typical of calcareous soils and taller grassland covering around 400m$_2$ that was more characteristic of neutral soils. The receptor sites were the north-east face of the main landscape bund (the same aspect as the donor site) and the southeast face of the adjoining bund (as an additional site). The landscape bunds were designed with a surface layer of at least 1m of limestone over the materials used to construct the bund in order to mimic ground conditions at the donor site. The bunds were graded to give slopes of 1v:2h and were not covered with topsoil or treated in any other way. The translocation involved carefully excavating turves that were 1m by 0.5m and 300mm deep using a tracked 360$_o$ excavator with a modified

[21] Highways Agency (2000) COST 341 Habitat Fragmentation due to transport Infrastructures - UK National State of the Art Report.
[22] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.
[23] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.
[24] Box and Stanhope (2010) Translocating wildlife habitats: a guide for civil engineers Proceedings of the ICE - Civil Engineering, Volume 163, Issue 3, pages 123 –130.

bale-cutting bucket (turf box cutter). The turves were either placed directly by the excavator onto the toe of the southeast face of the bund that was very close to the donor site (Figure 7) or placed on a flat-bed trailer for transport to the other bund where they were placed at the base of the north-east face by a telehandler fitted with a wide bucket. Each turf was carefully placed to ensure a tight fit with the adjacent turves and was pressed down by the bucket to expel air from between the turves and the underlying substrate. Turf offcuts and soils from the donor site were used to fill any gaps between turves and along the four external sides of the translocated turves. Voids between or under the turves were not permitted because the air spaces would cause drying out of the fragile grassland root system. Rain during the latter part of the translocation operation caused some problems with vehicle movements on site but meant that watering of the turves immediately after translocation was not required. The translocation works took about three weeks to complete."

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contact any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

The questions relating to grassland were answered by a total of 8 respondents.

To the question is habitat creation of grassland a successful mitigation technique, 100% answered yes, with 71% of responses based on monitoring.

To the question is grassland enhancement a successful mitigation technique, 100% responded yes, with 65% of responses based on monitoring.

83% of respondents answered that translocation was a successful technique, with 80% of responses based on monitoring.

85% of respondents agreed that exclusion zones were a successful mitigation technique, 50% based their response on monitoring.

Conclusions:

The review found two schemes where grassland translocation has successfully been achieved and two further schemes which were assessed as unsuccessful. The lack of success was identified as being a result of a lack of management, demonstrating the importance of this in any translocation scheme. The majority of IEEM members that responded agreed that both grassland enhancement and translocation are successful mitigation techniques.

Table A3.6 Coastland

Literature Search:

Case Studies: A2/M2 Cobham to Junction 4 Widening scheme[25]

Creation of coastal lagoons.

As mitigation for the loss of an area of coastal lagoon habitat, which supported the tentacle lagoon worm, replacement lagoons were created. Three basins were created and to replicate the conditions of the original lagoons, surface mud, sediment and marginal vegetation from the original lagoon was translocated and a connection to the tidal creek was maintained. Additional planting of suitable lagoonal plants was also undertaken. For the first 5 years of monitoring it was found that an appropriate salinity regime had established and the tentacle lagoon worm had been found in two of the new lagoons. However a flooding event in 2005 caused substantial damage and no future monitoring was undertaken.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contact any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

There were no questions within the questionnaire relating to coastland.

Conclusions:

Limited information was obtained on mitigation measures to protect heathland habitats, the data collected it not detailed enough to draw any firm conclusions.

[25] HyderCresswell (2013) A2/M2 Cobham to Junction 4 Widening Strategy, 10 year Ecological Monitoring Strategy 2000-2009 Final Monitoring Report.

Table A3.7 Fen/ Swamp Case Studies

Literature Search:

Case Studies: Wobaston Road, Wolverhamton[26]

As part of a development translocation of fen/swamp vegetation was undertaken using a tracked 360^{O} excavator with a digger bucket to take approximately 500m^{2} as turves from the wetter areas of the fen/ swamp vegetation as these had the greatest ecological value. The turves were placed at four locations within the receptor site to 'seed' it with aquatic planting. The receptor area was a large expanse of low lying land which had been previously shaped and compacted as a surface water attenuation area. This area receives surface water drainage from the development site as the final stage in a sustainable drainage system involving a series of newly created swales and ponds along a watercourse that runs through the site and discharges into the adjacent brook. Monitoring of the fen/ swamp vegetation in 2008 and 2009 showed very successful regrowth of aquatic plants. Much aquatic vegetation appears to have developed of its own accord from the existing seedbank and plant roots in this area. However, the translocated turfs clearly stand out as areas of more established vegetation and provide structural diversity within the new wetland habitat. Monitoring confirmed vegetation was originally classified as reed sweet grass swamp before translocation and the vegetation can still be classified as this community in 2009. Nettle, broad-leaved dock and spear thistle are also present but these species are expected to decrease as the area starts to receive surface water runoff and becomes wetter.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contact any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

There were no questions within the questionnaire relating to fen/ swamp habitats.

Conclusions:

Limited information was obtained on mitigation measures to protect heathland habitats, the data collected it not detailed enough to draw any firm conclusions.

[26] Box and Stanhope (2010) Translocating wildlife habitats: a guide for civil engineers Proceedings of the ICE - Civil Engineering, Volume 163, Issue 3, pages 123 –130.

Table A3.8 Vascular plants

Literature Search:

Case Study: Blackwater Valley Relief scheme[27]

As part of the Blackwater Valley Relief scheme, a 17.6 Km new dual carriageway, a single tussock of the nationally scarce gingerbread sedge was present along the new road alignment. This plant was translocated 300m from its location into wet alder/sallow carr. The uprooted sedge was divided into two, of which one half was taken to a nursery for propagation. The remaining half was split into eight plantlets which were planted out at the new site. At the nursery, the remaining half of the plant was split into plantlets and by spring 1997 fourteen plantlets were available for replanting. Of these, four plants were added to the donor site. Three were planted in the Blackwater Valley area.

Of the twelve gingerbread sedges planted out at the donor site, nine survived, and monitoring recorded ten new plants. The translocation of this sedge appears to have been very successful; this was considered to be due to gingerbread sedge being straightforward to keep in cultivation.

Consultations:

No response was received from the Botanical Society of the British Isles. The Centre for Ecology and Hydrology (CEH) provided details of a study of railway land; this did not contact any details relating to mitigation or its effectiveness.

IEEM Questionnaire:

There were no questions within the questionnaire relating to fen/ swamp habitats.

Conclusions:

Limited information was obtained on mitigation measures to protect heathland habitats, the data collected it not detailed enough to draw any firm conclusions.

[27] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape.

Appendix 4 Species Case Studies

Table A4.1 Badger

Literature Search:

Multiple studies undertaken within Europe and North America, looking at the use of culverts and passageways beneath road and rail corridors. Assessing both those that have been installed for wildlife purposes and non-wildlife passages (i.e. designed for purposes other than to allow wildlife crossings). 12 studies were reviewed as part of this study.

A UK study of 9 road schemes, with 38 mammal tunnels, found 89% of these were used by badgers[28]. The study made the following conclusions:

- Badger use was not significantly influenced by tunnel construction material;
- Good and moderate habitat connectivity and vegetation around the entrance is more likely to result in the tunnel being used;
- Tunnels with poor drainage were never or infrequently used;
- Results suggest that a tunnel less than 600mm wide is less likely to be used.

A study in Spain assessed 82 passages beneath a road, looking at circular culverts, adapted culverts, wide underpasses, wildlife underpasses, overpasses and wildlife over passes[29]. All structures types were used by vertebrates, whether they were specifically designed for wildlife or not. Most species showed some selectivity among passageway types. Badgers were found to exclusively use underpasses rather than overpasses. Adapted culverts ranked highest, followed by wildlife underpasses, circular culverts were occasionally used. (The study did not provide specific details about the design of culverts or underpasses).

A study in Portugal assessed 57 passages along 252km of road[30]. Badgers used the crossing structures regularly and without obvious preference. Regression analyses showed the frequency of use by carnivores varied with structural, landscape, road-related features, and human disturbance with 17 of 26 (65%) attributes being significant. Larger passages with vegetation close to the passage entrances, favourable habitat in the surrounding area, and low disturbance by humans were important key features to regular use.

Natural England Research Report 178[31] provides details of the effectiveness of mitigation techniques for badgers and discusses the following:

Between 1969-1993 at least 193 underpasses for badgers were constructed in the Netherlands, however, about 65% of those examined were poorly designed. In most cases the quality of the wire netting fences guiding the badgers and the drainage of the underpasses were inadequate. Despite this at least 74% proved to be effective ecological corridors for badgers with only a few casualties along the fenced section of the underpass. In 71 % of cases the procedures for planning, management and maintenance were not satisfactory in every respect. Insufficient budget for replacement materials, a lack of regular inspections and evaluation and insufficient collaboration between land owners and the road maintenance authorities were all highlighted as casual factors for lack of effectiveness.

The population size of badgers in the Heuman/ A73 area of the Netherlands has increased from six setts in 1985 to twelve in 1995, The main reason for this growth is probably due to the success of some of the mitigation measures which have been implemented. Badger tunnels were well used by badgers (and other mammals) before the road opened to traffic, fences were

[28] Eldridge and Wynn (2011) Use of badger tunnels by mammals on Highways Agency schemes in England. Conservation Evidence 8 53-57.
[29] Mata et al (2003) Effectiveness of wildlife crossing structures and adapted culverts in North West Spain. ICOET Proceedings.
[30] Grilo, Bissonette, Adair (2008) Respond of carnivores to existing highway culverts and underpasses: implications for road planning and mitigation. Biodiversity Conservation **17 1685-1699.**
[31] Natural England (1996) Research Report 178: The significance of secondary effects from roads and road transport on nature conservation http://publications.naturalengland.org.uk/publication/50056.

lengthened, however, following road kills of badgers around the ends of the original fencing. Despite this badger kills still occur on the road and regular inspection of the fences remains a priority.

An assessment of the effectiveness of badger protection measures on ten road schemes in the south west was undertaken by Bristol Ecological Consultants (BEC) on behalf of the Highways Agency, Of the badger provisions on the ten schemes reviewed only one, the A35 Yellowham Hill Improvement appeared to be almost successful. In this case all of the purpose-built badger tunnels were being used and no other regularly used crossing points were found. Apart from one other scheme the measures to avoid or minimise badger road mortality have typically been unsuccessful. The lack of success can be largely attributed to the lengths of badger fencing installed being insufficient and fencing being installed without the provision of a crossing point.

Consultations

Details of three badger licences (licence application information and return forms) were received from the Natural England licensing team, these provided limited information and not sufficient detail to provide any degree of assessment.

IEEM Questionnaire:

The questions relating to badgers were answered by a total of 9 respondents.

100% of respondents said that fencing was a success mitigation measure.

83% of respondents answered that culverts and careful management of light were successful techniques, with 83% of responses based on monitoring.

100% of respondents agreed that exclusion zones were a successful mitigation technique, all based their response on monitoring.

100% of respondents said badgers return to setts after temporary closure, with 83% of responses based on monitoring. 60% of respondents said artificial setts were a successful technique

Conclusions:

The literature available relates to the use of mammal tunnels and culverts, from studies undertaken it has been shown that badgers will regularly use such structures. Habitat connectivity to structures, along with drainage of structures has been seen to affect the use of structures for passage. All of the IEEM respondents agreed that fencing, culverts and the management of lighting are a successful mitigation measure.

Table 4.2 Birds

Literature Search:

A study[32] in Australia looked at the use of the Compton Road Fauna Array by bird species, the array includes two large purpose-designed underpasses and three road bridges. The overpass was planted with vegetation and a detailed survey of the recreated vegetation conducted four years later detected 45 species, most of which had been planted and most of the remainder self-propagated. The structure of the vegetation closely resembled that of the dense understory of the surrounding forest and was remarkably similar to the species richness. Birds were surveyed weekly (from March 2008 until April 2010) by observing birds crossing the road away from the overpass (four 80 x 10m transects perpendicular to the road) and those using the overpass (four 20 x 10m transects positioned across the structure parallel to the road). A total of 18 species of bird were detected flying across the road independent of the overpass during the study. In contrast, a total of 30 species were detected crossing the road within the foliage on the overpass; another seven species were detected on the surface or structures of the overpass while a further four species were recorded flying directly above the vegetation. The study found virtually all of the species detected crossed the road within the foliage on the overpass were small (median 15g).

The UK COST[33] report provides limited information regarding a nest box schemes on the M40 at Gaydon where 30 kestrel chicks were raised in one year, the report however does not provide details of the purpose of the mitigation or where the nest boxes were placed.

A study by Tremblay and St. Clair[34] looked the willingness of forest songbirds to cross four types of linear features in the urban landscape of Calgary, Alberta, Canada: (1) roads of varying widths and traffic volumes, (2) conventional railways and light transit lines, (3) transportation bridges across riparian corridors, and (4) rivers. The study concluded that bird movements across linear features will be increased by limiting the gap to cross to less than 45m, especially where it bisects important habitat patches. This can be done by planting trees either side, recommending tall trees rather than shrubby ones. Birds showed a preference for flying over bridges rather than under bridges. The paper recommends bridges are flanked with trees to enhance safe movement across. Mitigation recommendations given in the paper are based on survey findings, but no evidence is provided where such mitigation has been installed and has been demonstrated to be successful.

Case Study: Blackwater Valley Relief Road[35]

As part of the Blackwater Valley Relief scheme, 17.6 Km new dual carriageway mitigation was undertaken to account for the loss of kingfisher nests. New nest sites were created within tree root plates. Monitoring however found that the sites were not used, although this may have been due to the number of alternative sites in the wider area. 21 nest boxes were also installed; monitoring found that only 13 of these remained in existence, although 10 of these were in use by house sparrows, blue and great tits. Pools were also created as part of the scheme, following gravel extraction required for road construction. Monitoring found that a number of these where used with nesting reed warblers in reed beds, however a number of the small pools were in need of management and had become choked with reedmace.

Waders and wildfowl

The proceedings from the 2010 Infra Eco Network Europe (IENE) Conference detailed a project in Sweden to compensate for the for negative effects of the Bothnia Line railroad passage through

[32] Darryl Jones (2010): Vegetation structure on overpasses is critical in overcoming the road barrier effect for small birds . In: Richter, V., Puky, M. & Seiler, A. (eds): Improving connections in a changing environment. Collection of short papers from the 2010 IENE Conference. Varangy Akciócsoport Egyesület - MTA Ökológiai és Botanikai Kutatóintézete - SCOPE Ltd., Budapest - Vácrátót. 5-8.
[33] Highways Agency (2000) COST 341 Habitat Fragmentation due to transport Infrastructures - UK National State of the Art Report.
[34] Tremblay and St. Clair (2009) Factors affecting the permeability of transportation and riparian corridors to the movements of songbirds in an urban landscape. Journal of Applied Ecology 46 1314-1322.
[35] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape.

the site, large-scale restoration and construction of wetlands has been undertaken in nearby areas[36]. The railroad affects the Ume River Delta and Plains, Natura 2000 site, which is a major staging site for wetland birds along the Bothnian flyway. The aim was to create new habitats for wetland birds during spring migration, mainly Whooper Swan, Common Crane and various geese and duck species. The compensation measures included pumping of freshwater onto arable fields to create temporary spring floods, restoration of moist estuarine meadows, creation of shallow freshwater wetlands and growing of crops favoured by the birds. In total, the compensation areas cover an area of 500 hectares.

The mitigation measures (restored/created wetland habitats and their management) were completed and started in spring 2010. The monitoring program started at the same time and is still in full progress. Responsibility for the monitoring of the mitigation measures lies with the Swedish Transport Administration. Train traffic on the Bothnia Line railroad started in late autumn 2010. Commuting train traffic (passengers only) of a steadily increasing intensity has been running since then. The monitoring program, focused on migrating wetland birds, will be running during springs 2010-2015.

The site's biggest value for wetland birds (Ume River Delta area) is as a stopover site during spring (March-early May). Data has been collected from one year before train traffic (2010), as well as two years with traffic (2011-2012).

So far the mitigation measures have been very successful. Large numbers of wetland birds are concentrated to the mitigation areas. Daytime peak numbers in the mitigation areas have so far been e.g., 2000 Whooper Swan, 1500 Bean Goose, 2700 Teal, 2900 Mallard, 160 Pintail, 320 Common Crane. However, the annual variations are considerable, so further monitoring is required to confirm this evaluation.

Owls

The Barn Owl Trust report[37] on barn owls and major roads was reviewed, whilst this report provides recommendations for mitigation, it does not provide any evidence of schemes where mitigation has been implemented and has been shown to be effective.

Consultations:

Clara Grilo at the University of Lisbon was contacted. Clara presented at the 2012 IENE Conference on Mechanisms underlying the road effects on owls: moves towards mitigation[38]. Clara confirmed that she was not aware of any mitigation measures applied for owls so far, recommendations have been published, but the effectiveness of these has not been assessed.

No details of mitigation examples were provided by the RSPB and no response was received from the Barn Owl trust.

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

The data received on birds varied in terms of the aspects that were considered with studies looking at habitat creation and crossing of linear features. Given the split across the information received, there is not a sufficient weight of material to draw any firm conclusions.

[36] Lindberg and Enetjärn (2012) IENE Conference Short Papers; pg 85-87 In: Richter, V., Puky, M. & Seiler, A. (eds): Improving connections in a changing environment. Collection of short papers from the 2010 IENE Conference. Varangy Akciócsoport Egyesület - MTA Ökológiai és Botanikai Kutatóintézete - SCOPE Ltd., Budapest - Vácrátót. 5-8.
[37] Ramsden. Barn Owls and Major Roads: Results and Recommendations from a 15-year research project.
[38] IENE Conference proceedings and abstracts 2012.

Table A4.3 Deer

Literature Search:

There is a large volume of research into use by deer of wildlife specific crossing structures and of structures primarily designed for road traffic or other purposes. A report by Langbein[39] provides a useful summary of this literature and should be reviewed for detailed information on the use of crossing structures by deer. The report provides a lengthy summary of studies and evidence regarding deer use of structures and as such is not repeated in detail here. Page 8 of this report provides a useful table of dimensions of structures which have been used by deer (for which there is an evidence base) and recommendations arising from past reviews for design of overpasses or underpasses suitable for wildlife. This table is repeated below:

	Existing structures for which deer use reported	**Recommended design characteristics to encourage regular use by deer**
Underpasses (UP)		
Internal height (m)	2.4 – 8.0 (Georgii et. al, 2007) 3.0 - 4.0 (Halcrow, 2002) 4.0 - 7.0 (Langbein, 2008)	>4.0 (Olbrich, 1984) >3.0 for roe deer (SETRA, 1993) >4.0 red deer (SETRA, 1993) >8.0 (Georgii et al. 2007)
Width (m)	4.0 (Olbrich, 1984, Halcrow, 2002, Langbein,2008) 8.0 (Ballon,1985)	>4.0 (Olbrich, 1984) >12.0 for red deer (SETRA, 1993) >7.0 roe deer (SETRA, 1993)
Length (m)	up to 48 (Langbein 2007b, 2008)	Variable depending on height / width
Openness index (*width times height divided by length)*	0.5 (Langbein, 2008)	for roe deer ratio >0.75 for red deer >1.5 (Olbrich, 1984)
Overpasses (OP)		
Accessible width (m)	6.0 (CTGREF, 1978) 3.5 – 7.0 (Langbein, 2007b, 2008)	>6.0 (CTGREF, 1978) >7.0 (Olbrich, 1984) >25m (Berthoud et al. 2000)
Length (span) (m)	85 -106 (Langbein, 2007b, 2008)	
Openness (*width divided by length)*	0.05 - 0.06 (Langbein, 2007b)	ratio >0.1 (CTGREF, 1978)
Purpose-built Green Bridges / Wildlife Overpasses		>40 m or at least 20 m at narrowest point with wider entrances (see reviews Iuell et al. 2003; Georgii et al. 2007).

A study into the use of highway underpasses by large mammals in Virginia and factors influencing their effectiveness, reviewed 7 underpass sites over 1 year[40]. The study focused on white tailed deer. The study concluded that only underpasses 12^{ft} or greater in height were successful at facilitating deer passage. This attribute alone, however, was not sufficient to guarantee the success of a crossing.

In California, 15 underpasses and drainage culverts were monitored for wildlife movements[41]. The study found that passages were used by a variety of species, including carnivores, mule deer, small mammals, and reptiles. Many types of underpasses were utilised, indicating that passages beneath highways, even when not originally designed for wildlife, can provide important safe avenues for animals to cross roads.

The 2010 IENE Conference Papers details a short paper on the effectiveness of wildlife fences in preventing collisions with wild ungulates[42]. A study compared the number of collisions with

[39] J. Langbein (2010) Pilot study to assess the potential of selected existing structures on the A30 and A38 trunk roads to provide safer crossing places for deer.
[40] Donaldson (2005) The use of highway underpasses by large mammals in Virginia and factors influencing their effectiveness. Report for the Virginia Transportation Research Council.
[41] Ng et al (2004) The use of highway crossings by wildlife in Southern California. Biological Conservation 115 449-507.
[42] M.Niemi, A.Martin, A.Tanskanen and P.Nummi Improving connections in a changing environment. Collection of short papers from the 2010 IENE Conference. Varangy Akciócsoport Egyesület - MTA Ökológiai és Botanikai Kutatóintézete - SCOPE Ltd., Budapest - Vácrátót. 5-8.

moose and deer on a highway and its parallel road in southern Finland before and after the fencing of the highway. After fencing, the number of collisions decreased however at the same time the number of collisions on the parallel road increased. Based on these observations the paper concludes that fencing of highways can alter the distribution of vehicle-ungulate collisions. To avoid this, the use of wildlife passageways is recommended when constructing fences.

A report for the Deer Commission Scotland[43] provides a review of mitigation measures and their costs and cost effectiveness, this report was produced based on a review of literature and studies (and as such is based on previous documented evidence). The report concludes for motorway and high-speed trunk roads, highway fencing remains the most effective measure against accidents (with appropriate one-way gates to permit escape of animals trapped on the carriageway). The report recommends that such fencing should whenever possible be combined with the provision of dedicated crossing places (overpasses, underpasses, or well-signed crossing areas/cross-walks) to avoid producing absolute barriers to animal movement and fragmentation of populations. On more minor roads, or where deer fencing is not a feasible option for landscape or other reasons, mitigation measures should in the first instance be targeted at reduction of driver speeds in areas of known high deer collision risk. The report details that mitigation measures appropriate for consideration in planning of new road schemes expected to be of low traffic volume will be similar to those already outlined for existing roads – simply because of the high costs involved in more complex provision, which will not be justifiable on relatively minor roads. For roads of high traffic volume, barrier fencing on both sides of the carriageway should be coupled with adequate provision of underpasses or green bridges at regular intervals. In addition, all additional bridges or tunnels required for other purposes (footpaths, minor roads crossing the carriageway, machinery tunnels, culverts etc.) – other than those specifically dedicated as wildlife passages, above - should be designed and built as dual-purpose structures (this finding is in keep with other articles review for this project).

Studies have been undertaken into the effectiveness of wildlife warning reflectors in reducing deer-vehicle collisions, a study[44] examining the habituation of deer to repeatedly occurring light reflections found that the habituation of deer and technical limitation so the reflectors, such as limited angle and low light intensity of reflection means that reflectors are not reliable as a method to reduce the number of deer vehicle collisions.

***Consultations**:*

No information was received.

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

A large volume of work has been undertaken with respect to deer and vehicle collisions and the use of underpasses and overpasses. Studies have found that high roadside fencing reduces deer collisions and is successful where it channels animals to safe crossing points. Deer are known to use structures of relatively modest size not specifically built for wildlife to cross under and over roads. Structures that have been found to be used by deer vary widely in terms of substrate, location, joint use by motorised traffic and other disturbance.

[43] Putman, Langbein and Staines (2004) Deer and road traffic accidents: A Review of mitigation measures: costs and cost effectiveness.

[44] Ujvari, Baagoe, Madsen (1998) Effectiveness of wildlife warning reflectors in reducing deer-vehicle collisions: A behavioural study. Journal of Wildlife management **62 (3)** 1094-1099.

Table 4.4 Dormice

Literature Search:

An article by Pat Morris in British Wildlife[45] provides details on the Lamberhurst bridge; this is the first example of a green bridge in the UK. This bridge was built to compensate for the loss of National Trust land and to reduce the barrier effect on wildlife (notably dormice.) from the new bypass. The bridge has a single lane with raised banks either side planted with woody shrubs. The shrubs include tree stumps removed from the path of the bypass. Four years after bridge completion, seven species of mammal were recorded using the bridge and in 2011 dormice bred on the bridge in nest boxes. The article also detailed crossings used by small mammals to cross roads in Japan, with details of a steel gantry adapted carrying overhead road traffic signs adapted for animal use. The gantry had Japanese dormice breeding within it, four weeks following construction. Small arboreal pathways based on suspended cables have also been used and CCTV footage, showed use 800 times in three months. The article did not provide details of the design of these structures or detailed evidence of use.

Case Studies: A2/M2 Cobham to Junction 4 Widening scheme[46]

Mitigation included woodland enhancements for dormice, relocation of dormice, creating habitat linkages for dormice.

Woodland supporting dormice was lost as a result of the scheme and mitigation was undertaken to create habitat and to reconnect fragmented and isolated woodlands. Woodland management plans were designed to enhance the value of the retained woodland for dormice. Dormice boxes were installed. Dormice occurring in isolated areas affected by the scheme were relocated to suitable release site in existing woodlands nearby, which were also subject to management to improve their suitability for dormice.

The area of created woodland habitat developed to provide optimal resources for dormice. The presence of dormice in the created woodland demonstrated that the linkages between woodland blocks were successfully recreated and that habitat creation and enhancement for dormice had been achieved. The habitat creation at Cossington Fields (see details in woodland section above) was successful with confirmed breeding and 50% of nest boxes containing dormice evidence.

Consultations:

No information was received

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

Studies have shown that creating dormouse habitat and linkages between woodland habitat can be successful in preserving dormice populations. Green bridges have also been demonstrated as being successful.

[45] Pat Morris and Shasaku Minato (February 2012) Wildlife Bridges for small mammals British Wildlife **153-157.**
[46] HyderCresswell (2013) A2/M2 Cobham to Junction 4 Widening Strategy, 10 year Ecological Monitoring Strategy 2000-2009 Final Monitoring Report.

Table A4.5 Invertebrates

Literature Search:

Case Study: A2/M2 Cobham to Junction 4 Widening scheme[47]

Woodland creation undertaken to mitigate for the loss of ancient woodland.

Invertebrate surveys were undertaken to assess the development of deadwood habitats. Flight inception traps were used within areas of new woodland and in areas of retained woodlands. Coleoptera and hymenoptera were used as indicator taxa. Pitfall trapping was undertaken to determine the success of translocation of ground dwelling invertebrates. Pitfall traps looked at coleoptera, araneae and mollusca as indicator taxa.

Analysis of the ground dwelling invertebrate data found that two of the soil receptor areas have developed an invertebrate fauna that is increasing similar to the donor sites and the invertebrate fauna is developing towards a woodland community. The study concluded that it is highly likely that the development of specialist invertebrate fauna is a direct consequence of donation of soil from existing woodlands.

Case Study: A564 Foston Hatton Hilton bypass[48]

Between 1993 and 1995 the A456 bypass was constructed across part of a SSSI, resulting in the loss of one pond, birch woodland, willow scrub and grassland. The site was important for the emerald damselfly and the ruddy darter. Three new ponds were excavated in advance of the works in 1992. The site was surveyed in 1996 to assess the effectiveness of the mitigation. The new pond complex and surrounding terrestrial vegetation were found to provide excellent breeding and foraging habitat for dragonflies. Both the ruddy darter and emerald damselfly were present. The monitoring identified that management of the ponds was required to prevent them becoming too shaded.

Case Study: M40[49]

The route of the M40 resulted in the loss of an area of Shabbington Wood SSSI, an ancient semi-natural woodland, rich in invertebrates, including the Black Hairstreak butterfly. The route was found to effect the locations of Black Hairstreak colonies and habitat creation was undertaken to mitigate for this loss. The fields (arable and grass ley) were planted with suitable food plants, blackthorn (larval food plant for Black and Brown Hairstreaks) and goat willow and wych elm (food plants of purple emperor and White Letter Hairstreak, respectively). The design for the shrub planting was a maze of dense, sheltered but unshaded scrub, with many south facing aspects. Some of the blackthorn was propagated from suckers of local bushes on Otmoor rifle range. Bushes with a small number of overwintering larvae were transplanted to the site. Wildflower glades were created between the bands of trees and shrubs. The topsoil from the arable field was stripped and used to make low mounds on which the trees and shrubs were planted. The wildflower seed source was taken from a traditionally managed local hay crop. In total 25,000 forestry transplants were planted, (60% blackthorn) over 11,100m^2 and grassland area covered 17,500m^2 (60% seeded with hay meadow mix.). The site was fenced to protect against rabbit and deer grazing.

The site was monitored between 1989 and 1997 (the road was opened in 1991). Monitoring in 1990 found a high proportion of the blackthorn had failed; this appeared to be due to the herbicide application for weed control. These were replaced in second and subsequent years as necessary. After 5 years the planted blackthorn was well established. Monitoring found that a strong colony of Brown Hairstreak had established, but not the Black Hairstreak. Planted elms failed, but the management to encourage elm suckering resulted in the arrival of White Letter Hairstreak. The monitoring following habitat creation demonstrated the success of the mitigation

[47] HyderCresswell (2013) A2/M2 Cobham to Junction 4 Widening Strategy, 10 year Ecological Monitoring Strategy 2000-2009 Final Monitoring Report.
[48] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.
[49] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.

and allowed appropriate action to be taken where necessary.

Case Study: M3[50]

The route of the M3 result in the loss of part of St Catherine's Hill SSSI and the Itchen Valley SSSI. The road was constructed between 1992 and 1994. The Itchen Valley SSSI comprises flood plain with species rich meadows and St Catherine's Hill is designated for its chalk grassland scrub. To mitigate for the loss of habitat, new areas of downland were created for butterflies, including the chalk blue. A receptor site to mitigate for the loss of an area of flood meadow was selected; this was prepared by removing low quality turves and laying the new turves from the donor site at the same hydrological level as where they were taken from. The turves cut measured 2.4mx1.2m and up to 30cm thick. From cutting to relaying took about 1.5 hours. To create the areas of downland the topsoil was removed to create thin nutrient poor soil. Herb rich turf from the donor site was cut by hand and translocated. During turf translocation 500m^2 of herb rich turf was moved by traditional hand methods. The areas not turfed were reseeded. 31,000 pot plants of seven downland species where planted, the majority being grown from local seed or cutting. 200 juniper plants were planted in rabbit and stock proof enclosures. Another area of habitat creation was at the old A33, the road was broken up and cutting faces and banks were cleared of scrub. Chalk was used to fill the site, and a thin layer (75mm) of topsoil spread over the area to become downland and a thicker layer was spread over the area where trees and shrubs were to be planted. The area was seeded with a downland mix of 51 species. 45,000 plants of 8 downland species were planted. A total of 7ha of downland was created. The site was monitoring in years 1,2,3,4,6,8 and 10 following creation.

Turves were successfully translocated. The turves moved by machine were successful in retaining species; those moved by hand were less successful due to some drying out. Three distinct colonies of the Chalkhill blue butterfly were established. The project demonstrated that is possible to create butterfly habitat, and in particular habitat for the Chalkhill blue on former arable land.

The Butterfly Handbook[51] details that the numbers of Chalkhill Blues increased in the first 3 years following the opening of the M3, with a few individuals flying across the road, indicting the metapopulation structure in the area has been improved as a result of mitigation. Full details of the monitoring are not provided in the handbook, but it is understood this knowledge is based on post construction monitoring.

Case Study: A30 Bodmin to Indian Queens Road Improvements[52]

This scheme which opened in July 2007 is detailed as a case study in the Butterfly Handbook. The first year, Post Open Project Evaluation (POPE)[53] report has been reviewed to assess if the mitigation measures detailed within the Handbook were successful. The project evaluation report includes the Natural England comment that downgrading the old A30 provided the opportunity for access to areas of Goss Moor for management of habitat which it is hoped will encourage the Marsh Fritillary. A breeding colony has been noted in the area. But details of monitoring are not provided. Cornwall Council commented that it did not have the resources to offer an evidence based assessment of the effectiveness of the mitigation. It had very limited involvement with the application process and has no baseline data nor carried out any monitoring. The case study within the Butterfly Handbook states it to be important that monitoring should take place within the first year with detailed monitoring beginning two to three years after construction. The case study states that 'monitoring should take place in order to inform future road design elsewhere in Britain and particularly to establish best practice for creating suitable habitat conditions for the Marsh Fritillary'. From the information made available to POPE it does not appear that specific monitoring has been undertaken as part of the scheme. The first year POPE states it is too soon to evaluate the effectiveness of the mitigation measures which should be considered as part of

[50] Chinn, Hughes, Lewis (1999) Mitigation of the effects of road construction on sites of high ecological interest, TRL.
[51] English Nature (2005) The butterfly handbook – general advice note on mitigation the impacts of roads on butterfly populations.
[52] Highways Agency (2009) Post Opening Project Evaluation A30 Bodmin to Indian Queen Improvement 1year after study.
[53] Highways Agency (2009) Post Opening Project Evaluation A30 Bodmin to Indian Queen Improvement 1year after study.

the five year after report when the on-going monitoring information would be available which would help inform the evaluation of the effectiveness of the ecological mitigation measures for both habitats and species. It is unknown if the five year POPE has yet been published.

Case Study: Black Water Valley Relief Road[54]

As part of the Blackwater Valley Relief scheme, a 17.6 Km new dual carriageway mitigation new water bodies were created to mitigate for the loss of ponds. Post construction surveys on newly created pond habitat found after three years, 22 species of dragonfly present, with 14 of these breeding at the site. It is considered that the reason for the success of this habitat creation was due to the transplantation of turves from the ponds which were lost, which allowed the flora to quickly establish.

Consultations:

No information was provided through consultation.

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

There are a number of case studies where habitat translocation and creation have been shown to be successful in creating habitat for butterflies. These have been well monitored with a strong evidence base, and papers detail the mitigation techniques used.

Table A4.6 Otter

Literature Search:

Several papers relating to otters and roads were reviewed; however none of these provided evidence relating to the success of mitigation approaches, beyond authors' opinions. A paper[55] by Chanin details guidance for the use of tunnels and ledges, ramps, fencing, but does not provide evidence in support of this.

Consultations:

A paper[56] was provided by otter expert Paul Chanin, this presents his opinions on mitigation for otter, but does not provide details of evidence to support the proposed mitigation.

IEEM Questionnaire:

The questions relating to otter were answered by a total of 8 respondents, although only two of the questions were answered by over 5 people.

87% of respondents said that fencing was a successful mitigation measure, with 83% basing this on monitoring.

100% of respondents said that culverts were a successful mitigation measure; all responses were based on monitoring.

Conclusions:

There are a number of well-known mitigation techniques for otters, however no evidenced based studies were found during the literature review. The majority of IEEM respondents agreed that fencing was a successful mitigation, and all responded that culverts were a successful measure.

[54] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape.
[55] P Chanin (2006) Otter Road CasualtiesCasualities *Hystric It J. Mammals* **17 (1)** 79-90.
[56] P Chanin (2006) Otter Road CasualtiesCasualities *Hystric It J. Mammals* **17 (1)** 79-90.

Table A4.7 Reptiles

Literature Search:

Case Study: Flood defence works, Horsey

An article by Whiting and Booth[57] provides details of mitigation for a flood defence scheme, but the methods used are also applicable to road and rail schemes where reptiles are present. The project provided mitigation for an adder population effected by flood defence works at Horsey in 2010 to mitigate any temporary loss of hibernation and natal den sites. An adder bank (hibernacula) was constructed in the autumn 2009 and reptile fencing was erected around the adder banks and some adjacent grazing marshes to create reptile enclosures. During March to May 2010, 119 adders were moved to the adder banks from the flood banks that were then stripped of vegetation and topsoil to discourage animals from re-entering the working corridor. Sections of the adder fencing were removed in mid-May to allow animals to disperse to their summer foraging grounds. Surveys during summer 2010 indicated breeding success within the banks. Pre hibernation surveys in 2010 recorded a peak count of 22 animals, and a spring emergence survey of the adder bank in 2011 identified 17 individual adders. A further four were recorded using an adjacent store of rush bales. Monitoring through summer and autumn 2011 identified a further 16 individual animals on or close to the adder bank, including six gravid adders. Eighteen out of the 33 adders recorded using the adder banks in 2011 were recaptures. Fifteen 'new' adders (i.e. not relocated during the 2010 mitigation) were subsequently identified as using the adder banks to hibernate or give birth. The total cost of constructing the adder banks and erecting/dismantling the reptile fencing was £63,500; the article provides a detailed breakdown of costs and timescales. The article provides a detailed methodology for the creation of adder banks. Common lizards and grass snakes were also observed using the adder banks when monitored.

Case Study: South Lowestoft Relief Road[58]

Prior to partial clearance for a road development (South Lowestoft Relief Road), an area of grassland and gorse dominated scrub was identified as supporting a small population of common or viviparous lizards Lacerta (Zootoca) vivipara. The area supporting common lizards covered about 3 ha, with about one fifth to be lost to a road development.

One core area comprising an old man-made bank constructed of large blocks of hard core and rubble which had become partly vegetated over, appeared especially favoured by lizards and was undoubtedly used as a hibernation site. The bank however lay within the new road line and was therefore going to be completely destroyed but the remaining area of grass and scrub was to be retained and a nature conservation area created. Three new hibernacula were created within the conservation area and lizards translocated to these. Details of the hibernacula design are provided within the article.

About 70 lizards were caught in total in autumn 2004 and spring 2005 and released around the hibernacula. Observations undertaken from March 2005 onwards have revealed that each of the hibernacula has a number of resident common lizards and it is normally fairly easy to spot one or two if weather conditions are reasonable. Both adult and immature lizards have been observed basking on them. It is not known if these were the lizards that were translocated or whether these are individuals that were already present in the area. Either way the hibernacula are being used by at least some lizards and it is hoped that with time numbers using them will increase. Small numbers of common frogs have also been observed using the hibernacula as refugia. The article does not provide details of precise monitoring.

[57] Whiting and Booth (2012) Adder *Vipera berus* hibernacula construction as part of a mitigation scheme, Norfolk, England Conservation Evidence **9** 9-16.
[58] Showler, Aldus and Parmenter (2005) Creating hibernacular for common lizard *Lacerta vivipara*, the Ham, Lowestofy, Suffolk, England Conservation Evidence **2** 96-98.

Case Study: Black Water Valley Relief Road[59]

As part of the Blackwater Valley Relief scheme, 17.6 Km new dual carriageway mitigation was undertaken for reptiles. A large number of reptiles (2500+) were rescued from the site and moved in to enclosed locations. Following construction the enclosures were removed. Post construction monitoring found a good population of reptiles still to be present, however due to the lack of pre-construction survey data it is not possible to draw any firm conclusions on success.

Consultations:

Jim Foster, the Conservation Director at Amphibian & Reptile Conservation provided details of road schemes he was aware of where reptile mitigation had been implemented, A338 Bournemouth Spur Road; A3 near Lightwater and Thursley; A31 New Forest; Liverpool/Crobsy/Southport railway line and M6 in Cumbria. No data was received on these schemes, but follow up is recommended.

IEEM Questionnaire:

Less than 5 responses were received.

Conclusions:

Two examples of successful mitigation techniques were found, detailing translocation and habitat creation.

[59] Blackwater Valley Countryside Partnership/ Atkins (undated) The Blackwater Valley Road – Shaping the Landscape

Table A4.8 Water Vole

Literature Search:

The Water Vole Conservation Handbook[60] (Third edition. Strachan, Moorhouse & Gelling 2011 published by WildCRU) devotes a chapter on Development and Mitigation that discusses potential impacts such as habitat loss, habitat deterioration, fragmentation of habitat and populations and barriers to dispersal. The handbook includes several mitigation case studies, where post construction monitoring found mitigation techniques to be successful including:

- Translocation at Reading Sewage Treatment works
- Displacement for the Channel Tunnel Rail Link at Swanscombe
- Relation at the River Leen Vole Facility, Papplewick

A paper by Bennet, Watson and Hill[61] details mitigation undertaken at Cabot Park in Avonmouth. Road crossings were required over watercourses (rhines) where water voles were present and a number of mitigation measures were applied including, large box culverts, length of culverts kept to a minimum on rhines known to support water voles, gabions installed in culverts above mean water level to allow passage, disturbed banks and gabions hydro-seeded to encourage rapid regeneration of vegetation. Fencing was placed around water vole habitats to prevent inadvertent damage. Displacement by strimming was used in some locations of the site, and trapping and translocation in another where the area was too great for displacement by strimming to be successful. Initial monitoring of the site shows little change in population levels between the first site surveys and the annual monitoring. An area of diverted salty rhine showed signs of water vole activity but was not fully colonised.

Consultations:

Rob Strachan from the Environment Agency confirmed that no detailed research has been carried out on the impacts of roads/rail infrastructure on water voles and the success (or otherwise) of any mitigation measures. Comment was also provided that box culverts under roads or railways are thought to be better for water voles than pipe culverts as pipe culverts have diminishing headroom when filling with water. It therefore follows that the preferred option to allow passage under roads is for an over-sized culvert for watercourses and ditches to encourage the animals through the structure. The length of culvert could restrict dispersal, with water voles reluctant to pass through excessively long tunnels, however, this has not been researched and a maximum length has not been identified.

IEEM Questionnaire:

For the majority of the questions relating to water voles, less than five responses were received. Three questions had 5 respondents.

All respondents said that displacement through habitat manipulation was a successful mitigation technique and all responses were based on monitoring. 80% of respondents said that maintaining or creating habitat connectivity was a successful mitigation technique and 100% of respondents said that the use of exclusion zones was a successful technique.

Conclusions:

There is evidence based studies into water vole mitigation, as detailed in the water vole conservation handbook. However no detailed research has been carried out on the impacts of roads/rail infrastructure on water voles and the success (or otherwise) of any mitigation measures. From the IEEM questionnaire, the majority of respondents agreed that creating habitat connectivity was a successful mitigation technique and the use of exclusion zones was successful.

[60] Strachan and Moorhouse (2006) Water Vole Conservation Handbook 2nd Edition.
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