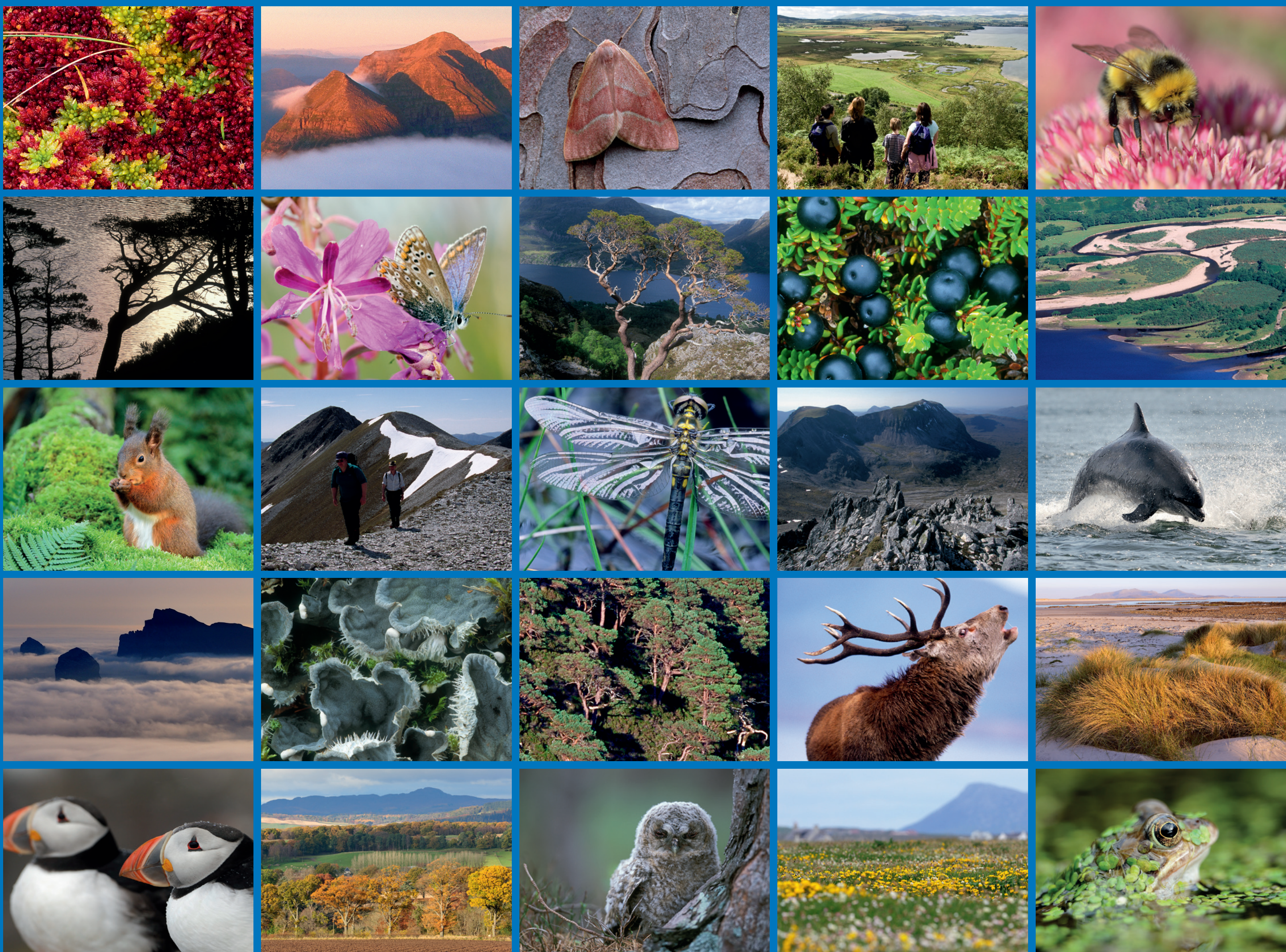
Scottish Natural Heritage
Commissioned Report No. 1003

Developing a mitigation monitoring approach for the A9 and A96 dualling projects



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COMMISSIONED REPORT

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Developing a mitigation monitoring approach for the A9 and A96 dualling projects

For further information on this report please contact:

Karen Mitchell
Scottish Natural Heritage
Battleby
Redgorton
PERTH
PH1 3EW
Telephone: 01738 444177
E-mail: karen.mitchell@snh.gov.uk

Yvette Sheppard
Transport Scotland
Buchanan House
58 Port Dundas Road
GLASGOW
G4 0HF
Telephone: 0141 2727100
Email: yvette.sheppard@transport.gov.scot

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COMMISSIONED REPORT

Summary

Developing a mitigation monitoring approach for the A9 and A96 dualling projects

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Keywords

Culvert; dualling; effectiveness; mitigation; monitoring; overpass; use; underpass.

Background

Transport Scotland is currently undertaking two large scale road improvement projects. The £3 billion A9 dualling programme will upgrade 80 miles of road between Perth and Inverness from single to dual carriageway by 2025. The £3 billion A96 dualling programme will upgrade 86 miles of single carriageway between Inverness and Aberdeen by 2030.

Very little published data exists on post-construction monitoring of upgraded roads and the effectiveness of road mitigation projects in Scotland.

Mitigation is a costly requirement of any road improvement scheme and understanding its effectiveness through mitigation monitoring is becoming a growing consideration for large infrastructure developments.

Main findings

This report outlines four different mitigation monitoring approaches that can be implemented to identify the use and/or effectiveness of road mitigation structures. It details the decision-making process and method for developing a statistically robust, standardised and replicable approach which can be applied to both online and offline dualling projects.

If taken forward the mitigation monitoring approaches could improve the temporal and spatial understanding of the environmental impact of roads and the effectiveness and use of mitigation structures.

For further information on this project contact:
Karen Mitchell, Scottish Natural Heritage, Battleby, Redgorton, Perth, PH1 3EW.
Tel: 01738 444177 or karen.mitchell@snh.gov.uk
Yvette Sheppard, Transport Scotland, Buchanan House, 58 Port Dundas Road, Glasgow, G4 0HF.
Tel: 0141 2727100 or yvette.sheppard@transport.gov.scot
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. INTRODUCTION

This report is the output of an eight month joint graduate placement project between Transport Scotland and Scottish Natural Heritage.

Transport Scotland is currently developing two large infrastructure projects to dual both the A9 between Perth and Inverness and the A96 between Inverness and Aberdeen. The A9 improvements will be an on-line dualling project whereas the A96 is likely to be largely offline.

1.1 Aims

The aim of this project is to develop a mitigation monitoring approach for the A9 and A96 dualling developments that can assess the use and/or effectiveness of mitigation provided to allow connectivity post-construction. The mitigation monitoring approach needs to be applicable to both online road upgrade and new offline road development. This has been a fundamental consideration throughout the development of the monitoring approach.

The focus is to create a statistically valid, replicable and standardised approach that ties in to the existing road development process detailed in the Design Manual for Roads and Bridges (DMRB) (DMRB, n.d.). This will ensure a cost-effective and robust method that is easily applicable for all users. Flow charts are used to clearly illustrate the process for developing mitigation monitoring.

The study has explored by literature review and consultation with both statutory and non-statutory bodies, the optimum mitigation monitoring approach to deliver the following objectives:

- Identify the current mitigation structures most commonly used and how effective they are in relation to different species;
- Identify what is and isn't known about the effectiveness of mitigation;
- Identify the current pros and cons of mitigation monitoring approaches;
- Identify current post construction monitoring applicable to the A9 and A96 dualling projects that is already carried out under STRIPE (Scottish Trunk Road Infrastructure Project Evaluation) projects;
- Identify optimum species to be surveyed resulting in the most informative output and with the minimum use of resources;
- Develop a monitoring approach that is financially viable and statistically sound.

1.2 Parameters

A number of clear parameters were set in order to focus resources on key areas of interest. Attendees of the inception meeting are listed in Annex 1 and later formed the project steering group. The parameters of the study and brief explanations as to why they were selected are detailed below.

The study considered physical mitigation structures that remain after road construction is complete and the road is operational. A complete list of included mitigation with definitions is shown in Table 1. This constraint was set because it was considered that developing a monitoring approach which investigated the longer term use of mitigation would be more valuable than considering other temporary forms of mitigation used both before and during construction. In addition, mitigation employed during construction phases tend to fit into the 'avoidance' category described in Table 2 including restrictions on night working, avoidance of scrub removal during bird nesting season, *etc*. Pre-construction mitigation such as the creation of replacement badger setts and bat roosts were also excluded from this project.

Large-scale habitat and landscape mitigation, compensation or enhancements were also not included in this study. Studying the effects of replanting, regeneration, and habitat creation, was considered to be too large a scope given the eight month project timescale. Priority was given to considering the mitigation structures and the species listed in Annex 2. This list of species was based on a document produced for the A9 Environmental Steering Group (ESG) detailing the ecological surveying extents that was agreed as part of their detailed route alignment studies. Several amendments were made after discussion with experts during the initial project inception meeting. Species highlighted as not being appropriate for mitigation monitoring including fresh water pearl mussel *Margaritifera margaritifera* (FWPM), deer and wood ants *Formica aquilonia* are removed from further study. Rare and elusive species such as capercaillie, black grouse *Lylrurus tetrix* and Scottish wildcat remain included within the list of potential target species for mitigation monitoring but their limitations are discussed fully in section 6.1.

1.3 Definitions

Throughout the literature there is a lack of consistent terminology and definitions for mitigation structures. This is primarily due to the preference of individuals. Also, the field of road ecology is relatively new, as is the consideration of many of the structures for mitigation, meaning that set definitions are yet to be established. For the purposes of this study the key types of mitigation and associated definitions are presented in Table 1. These terms have been selected due to their frequent use by statutory bodies, consultancy firms, Non-Governmental Organisations (NGOs) and individuals working on road construction in Scotland. Care has been taken to ensure that definitions and terminology follow those used within environmental assessments and other publications produced for trunk road developments as closely as possible. Additional terms and definitions are available within Annex 3.

Table 1. Key mitigation terms and definitions used in the document.

Term	Definition
Amphibian Tunnel	A culvert designed specifically for use by amphibians and reptiles to cross the road. May be enclosed or have an open grated roof to allow rainfall to soak culvert substrate. Commonly used by other small vertebrates
Culvert	Box, pipe or channel structure that allows a watercourse or excess water (surface or subsurface) to be removed by passing below the road surface. Culverts may be dry for the majority of the year thus acting as mitigation for the same species as a tunnel
Open Span Bridge	A bridge that extends far beyond the banks of a waterway leaving the immediate area unblocked and undamaged by construction and completely open for any animal to walk under
Mammal Fencing	Fencing placed along roadsides or mitigation structures to divert animals away from the road. Fencing specifications vary depending on target species
Fish Ladder	A structure to aid the movement of fish around natural or un-natural barriers
Fish Screen	A device to stop fish swimming or being drawn into pipe inlets or outlets
Green Bridge	An overpass with the primary function of providing wildlife benefit by linking habitats or populations separated by linear infrastructure with soil or other material that allows the establishment of vegetation
Hop Overs	Structure resulting from managing old or planting new vegetation or raising road verges so that bats are forced to fly above the line of traffic
Mammal Ledge	A platform fixed to a culvert for use by mammals travelling along the waterway
Multi-Use Bridge	An overpass designed for mixed human and wildlife benefit
Overpass	A bridge or other passageway over linear infrastructure
Reflectors	Reflectors placed along roadsides to divert light onto the nearby verges discouraging animals from the road surface when vehicles are nearby
Rope Bridge	A rope connecting trees on opposite sides of a barrier to help arboreal animals to cross without having to do so at ground level
Tunnel	A dry underpass, round or square, used by wildlife to travel between habitats severed by transportation infrastructure
Underpass	A passageway under infrastructure
Wire Bat Bridge (Wire Bridge/Bat Bridge/ Gantries)	A wire or mesh bridge raised above the road to encourage bats to fly above traffic at specific pre-selected crossing sites

2. BACKGROUND

As part of the project aims and objectives a literature review on mitigation monitoring and the impacts of linear infrastructure was completed investigating both published and unpublished literature and government guidance. Information considered relevant for the understanding and development of mitigation monitoring has been compiled below. It should be noted that much of the existing literature is focused on the construction of new roads.

2.1 Mitigation Monitoring

The construction and upgrade of roads and their subsequent operation has the potential to have a large impact on the local ecosystem with effects including direct mortality through collisions, habitat loss, habitat degradation, habitat fragmentation, barrier effects, edge effects, pollution (noise, chemical and light), changes to the hydrological system and microclimate, increased spread of weeds, increased human presence and population declines through species avoidance (van der Ree, 2007; Luell *et al*., 2003; Clevenger *et al*., 2000; Forman *et al*., 2003; Coffin, 2007). All of the above can cause effects for species, habitats and populations over temporary or permanent timescales at both local and regional scales. It is generally considered that the most damaging impacts are caused by habitat fragmentation as a result of the barrier effect and direct mortality through wildlife vehicle collisions (WVC) (Luell *et al*., 2003).

Over the past 15 years there has been an increase in attention to deleterious impacts of roads and traffic (Fahrig & Rytwinski, 2009). This has resulted in an increase in the amount of published literature, leading to the emergence of a new science, Road Ecology (Forman *et al*., 2003). Coffin (2007 p397) describes this new sub-discipline as being rooted in *“ecology, geography, engineering and planning…building on the mounting evidence that roads are having dramatic effects on ecosystem components, processes and structures”.* This trend has followed the expansion of the transportation network (Fahrig & Rytwinski, 2009) with 22.4% of the land mass of Europe now within 500 meters of a road or railway and 50% within 1.5 kilometres (Torres *et al*., 2016).

Organisations now assign large amounts of money to reducing the impact that roads have on our environment through the methods defined in Table 2, although costs of mitigation are small compared to the overall budget (Rtywinski *et al.,* 2015). The principal underlying reasons for mitigation are human health and safety, animal welfare and wildlife conservation (van der Grift *et al*., 2013). Increasing legislation and the consequential rise in the number of published guidance documents and literature (CIEEM, 2016a; Luell *et al*., 2003; Scottish Executive, 2005; Burns & Jackson-Matthews, 2016) all ensure that mitigation is an integral part of road design at the early stage.

The lack of understanding regarding the effectiveness of mitigation measures to provide ‘no net loss’ of biodiversity (or other ecological factors) provides one of the focal points in the field of road ecology (Roedenbeck *et al*., 2007; Chee, 2015).

Mitigation structures, especially overpasses and underpasses, are designed, constructed and maintained at great expense. It is therefore important to discern if such features are as effective as predicted (Bliss-Ketchum *et al*., 2016). Without establishing the effectiveness of mitigation, precious financial resources can be easily wasted whilst endangering local wildlife and habitats by installing structures that are ineffective (Rytwinski *et al*., 2015). Conversely, a mitigation structure may be more effective than previously thought thus requiring fewer structures to be constructed enabling significant cost savings (van der Grift *et al*., 2015).

Mitigation monitoring studies could also investigate the relative effectiveness of alternative designs for a structure. For example, an investigation into three different culvert designs could identify if the cheaper or easier to construct designs are just as effective in terms of species permeability as more expensive alternatives allowing for cost-cutting measures to be made with the knowledge that there would be no detrimental consequences (van der Grift *et al*., 2013).

Table 2. Measures to avoid or reduce environmental effect.

Principle	Definition (DMRB 11:2:5 paragraph 1.42)
Avoidance	Seek options that avoid harm to ecological features - for example, by locating on an alternative site.
Mitigation	Adverse effects should be avoided or minimised through mitigation measures, either through the design of the project or subsequent measures that can be guaranteed, for example through a condition or planning obligation.
Compensation	Where there are significant residual adverse ecological effects despite the mitigation proposed, these should be offset by appropriate compensatory measures.
Enhancements	Seek to provide net benefits for biodiversity over and above requirements for avoidance, mitigation or compensation.

There are many unanswered questions surrounding the effectiveness of road mitigation and finding valid and scientifically sound answers can ensure that detrimental ecological changes, health and safety risks and welfare issues are reduced or eliminated (van der Grift *et al*. 2013).

Understanding the effectiveness of mitigation can be complicated and costly as whilst the structure may be used by individuals it may be ineffective on a population scale. Ineffective mitigation at a population scale can result in resource inaccessibility, habitat fragmentation, higher collision risk or habitat loss (Jaeger *et al*., 2005). Similarly, a reduced population size in the vicinity of a road could be due to avoidance behaviour or high mortality rate through Wildlife Vehicle Collissions (WVCs). It is important that a mitigation monitoring study is able to identify the underlying mechanisms causing an effect and account for confounding factors otherwise the study would provide more limited information to guide future decision-making processes. Such studies waste valuable finances and resources (van der Grift *et al.*, 2013; Roedenbeck *et al.*, 2007).

The extent to which road effects can be mitigated is highly variable and dependent on the ecology of the target species, the type of mitigation, road characteristics and local habitat. Furthermore, mitigation can still fail to maintain a viable population if the population had reduced fitness or was reduced to non-viable numbers prior to mitigation construction. This could occur for a number of reasons but highlights the importance of understanding the population dynamics prior to construction since if no data existed before construction then the local extinction of a target species could be blamed on the development instead of on the pre-existing causal factors (Roedenbeck *et al*., 2007). It should be noted that wider scale population studies are not routinely regarded as necessary for the assessment of road projects.

2.2 Use versus effectiveness

There is a clear distinction to be made between the use of a mitigation structure and its effectiveness. The use of mitigation is when target species use the structure successfully for its intended purpose, for example, deer using an underpass to cross a road or fish using a fish ladder to overcome a barrier. The effectiveness of mitigation is how well the mitigation structure protects the target species from specific detrimental effects of the development, for example, to what extent is a vegetated overpass protecting the local bat population from habitat fragmentation, resource inaccessibility or WVCs (van Der Grift *et al*., 2013; van Der

Ree *et al.*, 2011; Berthinussen & Altringham, 2015; van der Grift *et al*., 2015; van Der Ree Iet al., 2007).

Investigations into the use of mitigation are usually carried out post-construction as required to comply with consenting requirements or guidelines stated through DMRB, Chartered Institute of Ecology and Environmental Management (CIEEM) or the Environmental Statement required as part of the development process (Rytwinski *et al*., 2015). Such studies are typically short term and document signs of use, damage and problems with the mitigation structure through surveying or use of remote sensing equipment. For example, under DMRB, post-construction otter surveys are recommended every week during the first month, then at six months and again after one year (DMRB Vol. 10, Section 4, Part 4). However, one year may not be considered long enough, to detect population changes or establish mitigation effectiveness although valuable information on design suitability, placement and habitat interactions can be identified through studies on mitigation use (van der Grift *et al*., 2015). The frequency and duration of surveying depends on the target species and the monitoring objectives. However, if monitoring effectiveness through changes in species abundance or viability, the impacts of the road development paired with ineffective mitigation may not be detectable in a statistically significant way for many years. Additionally, some species require time to acclimatise to mitigation and therefore use or effectiveness recorded in the first year may not be representative (van der Grift & van der Ree, 2015).

Inferential strength is "*The ability of an experiment or analysis to adequately/fully answer the question posed"* (van der Ree *et al*., 2015a, p.506; Roedenbeck *et al*., 2007). Low inferential strength means there is a high level of uncertainty regarding the results of a study. Ensuring high inferential strength is a key consideration when designing or implementing any experiment or study (Roedenbeck *et al*., 2007).

Investigating the effectiveness of a mitigation structure typically involves a larger study carried out for a longer timescale as population level changes can be cumulative, synergistic or delayed taking years or decades to become evident (van der Ree *et al*., 2015b; Berthinussen & Altringham, 2015). These factors result in significantly higher costs which are rarely viable or accounted for in the overall project budget (Van der Grift *et al*., 2013; Torres, *et al*., 2011). Additionally, many studies do not take into consideration similar experiments and most research is not planned until after the mitigation structure is operational (during construction or post-construction phases) resulting in a consistent lack of adequate baseline data for the preferred survey approach (Lesbarres & Fahrig, 2012; van der Ree *et al*., 2015b; Roedenbeck *et al*. 2007; Hardy *et al*., 2004; Rytwinski *et al*., 2015). Lesbarres & Fahrig (2012) concluded that road ecology research should be thoroughly incorporated into all stages of the road development to allow for more robust studies with greater inferential strength identifying higher order effects. In addition, they discussed how most mitigation monitoring studies are carried out by contractors or consultants with results and conclusions reported only internally. If data and conclusions were published more widely then others would be able to access and incorporate them into meta-analysis projects, an approach that would be useful considering the scale of data collection and analysis that is required for such large infrastructure projects. One additional obstacle to the consideration of similar studies and recent conclusions when implementing mitigation monitoring is that practitioners may not have access to useful articles or literature if peer reviewed journals are not openly accessible.

As mentioned above, the duration of the study can have a large impact on the results. A rarer target species or a low expected frequency of use of the mitigation structure will require a longer timescale to detect. The measurement end point also has to be considered in the early stages, for example, investigating population connectivity by testing for genetic isolation will take significantly longer than documenting movement rates across the road (Lesbarreres & Fahrig, 2012).

The first stage of any mitigation monitoring study is to establish the question to be answered. This should incorporate the needs and wants of the many developers, engineers, decision makers, planners and funding bodies to address a question that will have high inferential strength and applicability to any other developments that will transpire in the future. A more generalised study can provide sound evidence-based recommendations, through feedback loops, that can be implemented or considered in the future (van der Ree *et al*., 2015b; Rytwinski *et al*., 2015). Explanatory studies (investigating if species X uses mitigation Y) can be useful for understanding effects on a small local scale but can ultimately work out to be more costly if harnessed incorrectly as they may have to be repeated each time a new study is to be carried out. Larger studies can be designed to investigate broader questions that can be applied to many situations, populations, species, habitats and roads. This enables studies to continue from the insights and recommendations of the previous work and increases the accuracy of predictions made during initial road development assessment stages. This type of larger, more informative study can also impart greater influence on future decision-making processes through feedback loops. This ensures that the reasons for unsuccessful mitigation are fully identified and understood and therefore avoided in the future (Rytwinski *et al*., 2015).

An additional significant point to consider when developing a mitigation monitoring study is that the design of the study is fundamentally based on the reason for the mitigation being installed. In other words, it is necessary to define effectiveness in the context of the question to be investigated (Hardy *et al*., 2004.) During Strategic Environmental Assessment (SEA), DMRB stages and Environmental Impact Assessment (EIA) environmental considerations are discussed and investigated at length influencing route selection, design and many other factors. As part of this process the likely magnitude, severity and duration of any environmental impacts and residual impacts are estimated and if mitigation is appropriate its purpose is clearly stated, for example, *"Provision of Dry Mammal Underpass (DMU) to mitigate fragmentation of otter habitat and to increase permeability of the road"* (Transport Scotland, 2014 p8)). To continue with this example, proof of an otter crossing a road using the dry mammal underpass demonstrates use and permeability but, in wider ecology terms, it may not necessarily represent evidence of mitigation of fragmentation of otter habitat. To fully investigate the effectiveness of this would require consideration of the extent to which the dry mammal underpass mitigated the effect of habitat fragmentation and the barrier effect (Rytwinski *et al*., 2015).

With mitigation responses being species-specific, alongside the abundance of mitigation designs and purposes it is understandable why there is so much variation between monitoring studies. This adds an additional complication to the study of mitigation as data-sets differ in scope, content and format; therefore meta-analysis projects are difficult if not impossible.

Post-construction monitoring is currently completed through the Scottish Trunk Road Infrastructure Project Evaluation (STRIPE) process (CH2M, 2016). See Annex 5 for a brief overview of STRIPE.

The information discussed above provides a brief introduction to mitigation monitoring and its purpose. Supplementary information on the impacts of roads and mitigation can be found using the references within the bibliography section 14. This information has been used to create the following process for developing a mitigation monitoring approach. The next chapter introduces the desk study and processes to follow prior to step selection.

3. DESK STUDY

A desk study should be carried out to identify relevant information necessary to design a mitigation monitoring study and highlight any gaps in essential data. The key steps of the desk study are illustrated via flow chart in Annex 6

A two page start sheet is available in Annex 7. This may be used to record important information whilst progressing through the decision-making procedure. The start sheet has been designed as an overall aid but is not an essential component of the process outlined within this report. Where information is to be recorded or a similar action is to be taken this will be clearly stated within the flow chart.

The desk study flow chart refers to further information or guidance within the text where necessary. The text and flow chart run parallel to each other representing the same process.

3.1 Identifying the starting point

When initially deciding to implement a mitigation monitoring study there can be any number of starting points including mitigation type, species and experiment which form the basis of the question to be answered (see Section 5 Step Selection). The starting point should be identified in a simple sentence prior to any further investigation. It should encapsulate the basic requirements of the study and function as a base for planning the specifics of the study but does not require a great deal of detail. Examples are shown in Table 3.

Table 3. Examples of possible starting points.

Starting point	Example
Mitigation type	Using track pads to identify the species that use a high profile **green bridge**
Species	Remote sensing to investigate frequency of use of mitigation constructed for **otter**.
Approach	**Presence or absence study** to identify the time of first use after mitigation opened.

3.2 Collation of background information

3.2.1 Background information

With the starting point identified the desk study should be started to collate any information necessary to complete the decision making process for designing a mitigation monitoring study.

The list below provides examples of information that could be collated, although not all will be necessary depending on the study's specific starting point.

- Phase 1 habitat survey data;
- Copy of EIA or alternative environmental assessment if available;
- Specifications for mitigation structures including dimensions, construction material, elevation
- Location of mitigation structure, including elevation and geometry;
- List of mitigation structures that can potentially be studied;
- Full descriptions of proposed and completed works;
- List of species selected for monitoring present in the local area;
- List of species selected for monitoring associated with local habitats;
- Knowledge of priority species ecology including daily/seasonal movements;
- Knowledge of the site and mitigation structure;

- Details of land management practices in the surrounding areas;
- Details of any existing dataset that meets the essential criteria of Table 4 that could be incorporated into the study as a baseline;
- List of any constraints associated with the site/mitigation/species.

Table 4. The desirable and essential criteria to adhere to if using an existing dataset or sharing a dataset (NBN, n.d.)

Subject	Data Required	Desirability
Data Provider	The name of the organisation or person that provided the data	Essential
Data Capture Method	Detailed description of the survey methodology used to collect the data	Essential
Surveying dates	Dates and times that data collection or survey(s) took place	Essential
Survey area	Detailed surveying location(s) or geographic range of dataset	Essential
Sample Points	Details of how sample points/location(s) were selected and how many	Desirable
Equipment specifications	Detailed list of all equipment and specifications including accuracy levels or ranges (e.g. handheld GPS Make X Model Y accurate up to Z meters	Essential
Equipment Calibration	1. Details of how equipment was calibrated and how often 2. How many pieces of equipment were used	1. Desirable 2. Desirable
Surveyor	Name and experience of surveyor(s)	Essential if there were multiple surveyors or if the standard of data provider is unknown or questionable.
Confidence	Information on the quality of the dataset (e.g., were data points checked? have ambiguous data points been removed?)	Essential unless quality can be inferred from surveyor's experience or data provider
Weather	Including temperature for species where this could impact activity level or survey results (e.g., bats; camera trap data.)	Essential
Limitations	Details of anything else that could impact data quality or applicability (e.g., access problems for part of site; change in land use during survey period; unusual weather events.)	Essential unless confirmation is given that there were no limitations, in which case this should be documented.

For example, if the starting point is 'Investigate otter use of mitigation' then the necessary information to collect will include: a list of areas where otters were recorded pre-construction; habitat surveys for these areas; list of mitigation structures with otters specified as target species; specifications of the mitigation structures; details of land management practices in the surrounding area; any existing otter survey data that may be used as a baseline.

If key information is unavailable species or site specific surveying may be required in addition to the desk study to aid experimental design and influence the decision making process.

3.2.2 *Information sources*

If an EIA or alternative comprehensive assessment has been completed during the preliminary stages of the development then this will include most of the required information. This information may be out of date depending on when it was collected but can act as a rough baseline that should be updated if necessary. If no such assessment is available then the following list of organisations may hold relevant information:

- Bat Conservation Trust Scotland (BCT) or Local Bat Groups;
- Wildlife Vehicle Collision data;
- Biological Records Centre (BRC);
- Black grouse Study Groups;
- Botanical Society for Britain and Ireland (BSBI);
- British Trust for Ornithology (BTO) – Bird Atlases, Wetland Bird Surveys (WeBS), BirdTrack;
- Capercaillie Project Officer;
- Fisheries Trusts;
- Forestry Commission Scotland (FCS);
- Highland Biological Recording Group Centre (HBRG);
- Joint Nature Conservation Committee (JNCC);
- Local parks and reserves (e.g. Cairngorms National Park Authority (CNPA);
- National Biodiversity Network (NBN) Gateway / NBN Atlas Scotland. At the time of writing NBN Gateway has transitioned to NBN Atlas but both should be used as records continue to be transferred;
- North East Biodiversity Records Centre (NESBrec);
- Royal Society for the Protection of Birds (RSPB);
- Saving Scotland's Red Squirrels;
- Scottish Badgers;
- Scottish Environment Protection Agency (SEPA);
- Scottish Natural Heritage (SNH);
- Scottish Ornithologists Club (SOC) Local Recorders;
- Scottish Wildcat Association;
- Scottish Wildlife Trust (SWT);
- Wildfowl and Wetlands Trust;

The planning of a study prior to EIA will be considerably more time consuming but it provides opportunities to collect specific additional baseline data and can result in a higher quality mitigation monitoring study overall.

3.3 Existing monitoring frameworks

A requirement for mitigation monitoring may be identified through numerous pathways briefly discussed below. These may contribute data to allow for larger investigations or provide a baseline for comparisons with mitigation monitoring implemented in the future.

- An Offset Mitigation Initiative can be established to compensate for any residual impacts for species and habitats identified through the EIA process. Such 'offset' projects can include invasive species control, protected species monitoring, habitat evaluations and more. The Aberdeen Western Peripheral Route (AWPR) is an example of a large scale development that established such a programme to support the construction of a new road.

- Species Protection Plans (SPP) are created to ensure that all reasonable precautions are taken so that protected species are not disturbed, injured or killed by activities associated with the construction or operation of the development including sites used by the species for feeding, breeding, shelter or protection. An SPP may document monitoring requirements for protected species to ensure that aims have been achieved.

- Monitoring can be included as a licensing requirement or if an SPP recommending or stating mitigation monitoring requirements is used to support a licence application then this can be reflected in the terms of the licence.

- The STRIPE process can require additional data collection in years one, three and five after construction. The type and duration of surveying can vary significantly with year one rarely requiring additional data collection except where unforeseen circumstances have arisen or there is increased public interest. Years three and five may require more monitoring including analysis of WVC data, species surveys, Phase 1 habitat surveys and more. A more detailed discussion of the STRIPE process is available in Annex 5.

3.4 Existing datasets

The use of an existing dataset can introduce sources of bias and variation into the study that may have a detrimental impact on the quality of any conclusions. To avoid these complications it is necessary to obtain information on the available dataset to assess how reliable it is and if it is compatible with the current study. Table 4 lists essential and desirable criteria for a dataset. Not all subjects will be relevant to every data set, for example, data providers may not exist for a data set if the information was collected by an independent person, but if a data provider was involved in the process it is essential to identify the organisation. Knowing the identity of the data provider or person who collected the data can give an insight into the quality or confidence of the dataset. If essential criteria are not available but relevant to the dataset in question then the dataset should not be used as any sources of bias or inaccuracy may impact any mitigation monitoring output.

Table 4 also acts as a guide to identify what information should be included when recording or submitting the data, results or conclusions of a mitigation monitoring study internally and externally. This ensures that the data set can be used in the future or contribute to a meta-analysis study (See section 12.2 for further information). Table 4 adheres to the minimum requirements necessary for submitting information to the National Biodiversity Network. At the time of writing the NBN is transferring Scottish data to NBN Atlas Scotland. If submitting data to NBN Atlas Scotland check for any requirements prior to data collection or collation in case these criteria have been altered.

Data are collected throughout the pre-construction, construction and post-construction stages of development and should be thoroughly investigated to identify if it may be of use for the current study. See list below for a list of possible data sources or surveys carried out throughout the construction process that may be of use for mitigation monitoring:

Pre-construction

- Existing data collated for desk study
- Survey data collected to inform SEA, EIA, DMRB stages and Habitat Regulations Appraisal (HRA)
- Survey data collected to add to licence applications

During construction

- Data collected by Ecological Clerk of Works (ECoW)

Post-construction

- Data collected by ECoW
- STRIPE

- Offset mitigation initiative
- Licensing requirements
- Consenting requirements

3.5 Limiting resources

A limiting resource is a factor that limits the type of study that can be conducted. Exploring and identifying the limiting resource for any potential mitigation monitoring study will simplify the decision-making process considerably. Limited resources may be financial constraints, time availability, lack of experienced individuals or lack of control sites, if necessary. This list is not exhaustive but covers the most common examples. If a limited resource imposes severe restrictions on the study design or methodology it can be the sole factor used to plan and design any mitigation monitoring.

4. APPROACHES

The study developed four mitigation monitoring approaches ranging from basic to complex. Combined, the four approaches represent a spectrum of possible post construction mitigation monitoring studies that can be implemented representing a range of resource requirements, surveyor expertise and survey methodologies appropriate for most locations or possible target species. These approaches can be conducted individually or as part of a sequential process where the results of the initial study feed the design of the next.

Selecting which of the four monitoring approaches to use is fundamentally dependent on the wants and needs of the client, the available resources and the sites and species available to study. Balancing these factors requires careful consideration and knowledge of how they impact on experimental design and output.

Each of the four approaches is discussed below with examples, pros and cons and investigations of any limitations in order to demonstrate the possible outputs. It is important to understand these approaches and the aims of individual mitigation monitoring assessments before progressing to the decision-making phase. Specific survey methods appropriate for each approach are discussed fully in Step 5. The pros and cons identified for each approach are also presented in a combined table in Appendix 8 for easy comparison.

As is good practice with standard surveying, a number of explanatory variables would be collected for each approach including but not limited to, weather, date, time, location, mitigation specifications including width, height, presence of water and ledge width. This is particularly important for replicated studies.

4.1 Approach One: Presence or absence

4.1.1 Introduction

The foundation of approach one is that only the assessment of presence or absence of the target species at the mitigation structure is required. Approach one is the simplest and least resource intensive approach to investigate the use of mitigation as it requires only short surveying periods and minimal data collection. Due to the simplicity of this approach there are limitations in the way the data can be used and therefore it is only useful under specific circumstances:

- to identify number of species that use mitigation;
- to identify the delay time between mitigation completion and first use by the target species.

Approach one may also be replicated to investigate any change in the number of species using mitigation over time which may indicate changes in species range. The identification of the time of first use after mitigation goes live can also be replicated at different sites creating a large data set that can provide further information. Each of the replicated studies will require minimal statistical analysis but more than individual survey studies.

4.1.2 Limitations

Approach one presence or absence surveys that are replicated will be more informative than single surveys and should be used wherever resource and suitable site availability allows. If data comparison between years is a key component of the selected monitoring approach it is important to consider that only data collected in the same season/time period can be legitimately compared unless season or time is classed as an explanatory variable. Multiple surveys carried out at different seasons would be the most effective monitoring as this would offer more data points and provide greater statistical power, see Example 1 below. If short term presence or absence studies are carried out on only one structure then any conclusions are not relevant to other identical mitigation structures no matter how similar the situation, species or habitat. This is because there is not enough data collected to identify the circumstances where the conclusion is applicable.

Approach one may also be used to identify the time of first use of mitigation by the target species. This is an extremely useful aim as it can be used to develop peak survey periods for different species that can reduce the amount of time needed to identify use of a mitigation structure. Carrying out this method on a single mitigation structure may be beneficial in certain circumstances, e.g. where new mitigation is being trialled or where a singular high profile structure such as a green bridge has been constructed. Nevertheless, if the opportunity is available it is better to replicate this survey on as many mitigation structures as possible, see example 2 below. Examples of situations where Approach one, presence or absence studies, are not appropriate are shown in examples 3 and 4.

4.1.3 Approach One: Pros and cons

Pros	**Cons**
Simple to set up and carry out	Limited information gained
Very little or no statistical analysis (Depending on number of replicates, if any)	Only useful under restricted circumstances
Can be used to inform larger, more detailed studies	Provides no population level information
Not time consuming	
Inexpensive	
Simple to replicate	

4.1.4 Examples of Approach One

Example 1 - Good Practice: A single camera trap set up at one side of a newly extended culvert to identify the time of first use by otter after road widening. Camera trap must be in place and recording data as soon as mitigation goes live i.e. is usable by otter. Surveying can stop after first confirmed record of otter use. This can be replicated on selected culverts along the route to identify average response times to the new mitigation structure or to ensure the structure is still used after a period of disturbance, for example, if the structure is repaired or otherwise modified. These data can be used to calculate the average time of first use and the longest delay until first use. This can inform the optimum time period in which to check use in future studies. If the average and the maximum delay of first use is 26 hours and 49 hours respectively, then future studies could survey for 49 hours plus an additional X% buffer. If no use is identified this could be the threshold for implementing other studies to identify any possible underlying problems.

Note: This experiment is informative under these circumstances as data is collected to identify first use where no further conclusions are inferred. Additionally, the process can be replicated to identify averages or trends including if time of first use varies with season or habitat.

Example 2 - Good Practice: A track pad placed on a mammal ledge in a newly constructed culvert to identify the variety of species/species groups using the structure. Survey carried out repeatedly over year one and again in years three and five. This process could document the following:

- changes in species diversity over time, these could highlight changes in species range e.g. water vole recorded in a previously un-used habitat showing range expansion;

- changes in species diversity over time, these could highlight species that require further study, possibly by an external organisation e.g. pine marten recorded more or less frequently in the final year of a five year study could suggest change in abundance and further investigation through new study could explain changes;
- presence of a species previously recorded as absent from the area in EIA surveys which were completed prior to mitigation.

Example 3 - Poor Practice: Closed Circuit Television (CCTV) footage monitored to identify use of a multi-use green bridge by badgers. Surveying stopped after presence is first recorded and not repeated. Conclusions drawn that the green bridge is effective.

Note: This would identify whether badgers use the mitigation structure but would not support scientifically robust conclusions and would, therefore, be unusable as evidence in any future decision-making process due to any lack of replication. The conclusions drawn from the data are unfounded.

Example 4 - Poor Practice: A baited hair tube placed at one end of a rope bridge constructed to provide a safe crossing point for red squirrels in order to reduce WVCs and maintain habitat connectivity. The hair tube must be in place when the structure goes live so that the time of first use can be recorded. Once a red squirrel hair sample is collected then sampling can cease. Replicates can be collected at other rope bridge sites along the route to create a larger dataset for analysis.

Note: This sample method is inappropriate for identifying the presence of red squirrels at a rope bridge as the tube containing the hair trap is baited and would therefore attract animals towards mitigation thus giving inaccurate and biased results.

4.2 Approach Two: Frequency of use

4.2.1 Introduction

Approach two builds upon the theory of Approach one but instead of capturing a snapshot of mitigation use it can identify more complex interactions between species and mitigation over time. Therefore, applying approach two is more difficult and requires additional resources, time and expertise.

Data collected on frequency of use may also be compared with baseline data, if available. For example, if estimates of population size are available data on the frequency of use may infer whether a small proportion of the local population is using the mitigation structure (see Limitations). Approach two can:

- identify how often species use the mitigation structure;
- identify changes in frequency of use through time, e.g. diurnally, seasonally, or over a longer period;
- identify any unexpected changes over time that could highlight the need for additional studies connected to the road development or unconnected to the development that may be carried out by other organisations;
- identify basic behaviour towards mitigation structure;
- identify variation in frequency of use as a result of external changes e.g. short term reduction in culvert use after the road becomes operational.

As discussed previously, basic metadata or explanatory variables are to be collected for each survey.

4.2.2 Limitations

There is a clear distinction between measures of frequency of use and any conclusion referring to the local population of the species. A higher frequency of use may indicate that more individuals are using a mitigation structure but does not demonstrate effectiveness at a population level.

4.2.3 Approach Two: Pros and cons

Pros	Cons
Relatively simple to set up and carry out	Longer survey duration than Approach one
Relatively simple statistical analysis	Many confounding factors
Relatively inexpensive depending on survey methods selected (Step 5)	Low inferential strength (how well the conclusion is supported by the evidence)
Able to influence future decision making processes	Limited information gained that can be used to increase the use of mitigation or identify reasons for lack of use
Depending on methods used may be used to infer basic behavioural responses towards mitigation, e.g. camera traps to record animal behaviour towards fencing or mitigation	
Can be used to inform larger, more detailed studies	
Can work out response times for species, e.g. how long before species use a mitigation structure and whether use increases as they grow accustomed to it	
Possibly be combined with existing baseline data to gain further insight into population level interactions with the road and/or mitigation	

4.2.4 Examples

Example 5 - Good Practice: Two camera traps are placed, facing out, at either end of a multi-use underpass to record badger activity. Two camera traps are also placed at either end of funnel fencing that directs badgers towards the underpass. Camera traps are set up for one year on a one week recording, two week off, basis. The direction the animal travelled through the underpass and lengths of time taken to travel through are recorded for each pass in addition to standard metadata such as weather and time. If an individual animal is easily identified through distinguishing marks then this is noted. The same information plus whether the animal crosses or ventures onto the road surface is collected via the cameras at the fence ends. The data can then be used to identify periods of high activity during the day, season and year, as well as highlight animal behaviour towards fence ends. This can be used to identify possible WVC issues if animals are frequently crossing the road surface. It is possible that if two crossing structures are in close proximity to each other that both may be used by a badger clan. If badgers consistently travel in one direction through the underpass then it would be worthwhile also identifying the route of the return journey. Surveying can be repeated in subsequent years and compared with data collected at the same time of year.

Note: This example highlights the many possible conclusions that can be gained from this study design and where comparisons can be useful. Additionally, this study design can also be paired with a pre-existing data set.

Example 6 - Poor Practice: Camera traps set up as for Example 5 and surveying carried out for two weeks. This process is repeated six months later and the data compared to identify any changes in use.

Note: The main issue with this example is that a comparison is being made with samples taken in different seasons. Activity levels for badgers fluctuate depending on the season with males becoming more active during breeding season and juveniles becoming more active and dispersing in autumn. Comparisons cannot be made between different seasons to identify change in use but comparisons can be made between data collected at the same time of year in subsequent years as long as metadata has been collected and accounted for, for example, changes in weather.

Example 7 - Good Practice: Marble dust, fine sand or clay can be spread in a large strip across the width of a green bridge. When an animal crosses the strip the tracks are imprinted into the selected medium and can then be photographed or recorded by the surveyor. This will identify species using the structure and direction of travel. The site has to be visited every few days and then the medium is to be smoothed again. Standard metadata is also to be collected.

Note: This method is quite difficult to use in practice as rain and other weather conditions can have a detrimental impact on survey results. It has the advantage, however, that it does not require expensive equipment which can be easily damaged or stolen if the site is close to human habitation.

4.3 Approach Three: Factors influencing use

4.3.1 Introduction

Approach three can be considered as an expanded or more detailed Approach two. Both approaches investigate the frequency of use, are based on the same principles and will largely deal with similar confounding factors, constraints and limitations. Approach three, however, can incorporate a larger number of potential influencing factors (covariates or explanatory variables) and will therefore require more resources for a more complex statistical analysis and survey for the additional data points.

In addition to the possible areas of investigation listed under Approach two, Approach three can investigate how biotic and abiotic factors influence the use of a mitigation structure. More complex factors are investigated than the standard metadata discussed above in Approaches one and two. Possible factors include: type of vegetation planted around mitigation structure; traffic volume/noise; distance to nearest mitigation structure; distance to watercourse; distance to human habitation; type of artificial light and land management practices. This list is not exhaustive.

4.3.2 Limitations

The limitations of Approach three are the same as Approach two

4.3.3 Approach Three: Pros and cons

Pros	Cons
Can identify which factors may result in reduced use of mitigation, e.g. bats use multi use underpasses less if artificial light source X is present. Solution may be to remove or change light source or install sensor lights	Cannot be used for single structures, e.g. a green bridge since no replicates are available
Can identify the type of use (e.g. whether daily, seasonal, or occasional)	More complicated statistical analysis
Can identify more subtle interactions between species, mitigation and additional factors (e.g. vegetation X planted around underpass entrance	Large number of replicates needed

increases use by badger or otter display cautious behaviour and approach culvert and then avoid it)	
Could be used to infer effectiveness	Higher costs than Approaches one and two
Can identify key stages when mitigation used, e.g. juvenile dispersal; breeding seasons	Longer survey duration than Approaches one and two
Identifies key survey durations and times which can inform and reduce costs of future studies	Higher level of expertise required than for approaches one and two
Information can be used to influence future mitigation decisions	
Can identify response times for species, e.g. how long before species use mitigation structure and whether use increases with habituation	
Can be used as justification for larger, more detailed studies	
Possibly be combined with existing baseline data to gain further insight into population level interactions with the road and/or mitigation	

4.3.4 Examples

Example 8 - Good Practice: Across the selected road 20 underpasses installed for badgers are selected from similar habitats. Each mitigation structure has similar dimensions and length of badger fencing. Entrances to the underpass have one of three types of planted vegetation. Camera traps would be set up at each culvert periodically across all seasons in years one, three and five. This would be used to identify the frequency of use of each underpass and the dataset could be analysed to identify if vegetation type has an impact on frequency of use. This method would also identify other species using the underpass.

Note: This example highlights good use of replicates to understand the impact of variation over time between mitigation structures, i.e. vegetation type culvert dimensions and the presence of fencing. The statistical analysis of such a study would require statistical expertise to ensure high statistical power and establish the correct data collection method.

Example 9 - Poor Practice: Two otter culverts are selected to study factors that influence use. Basic metadata is collected including weather, date, habitat, water level, culvert dimensions and shape, proximity of human habitation, presence of mammal ledge, dimensions of mammal ledge, culvert material, traffic volume and traffic noise. Use was recorded as the number of passes through the culvert in a specific 24 hour period for eight weeks.

Note: This is a highly flawed example of how to plan and execute an Approach three study since there are not enough replicates and therefore insufficient statistical power to identify which factors influence use. Additionally, surveying the same culverts weekly and using these data to represent additional data points is an example of pseudo-replication as the same culvert and same otter or otter family have been sampled repeatedly.

4.4 Approach Four: Effectiveness of mitigation

4.4.1 Introduction

Approach four is different from the previous three approaches due to the scale and level of complexity involved in its design, implementation and analysis. There are numerous methods to investigate the effectiveness of mitigation depending on the wants and needs of the client and the resources available. It can:

- involve large scale studies investigating changes in population size, viability and movement;
- identify impacts of roads and to what extent mitigation is reducing them;
- identify the underlying mechanisms leading to changes in species range and viability through mitigation;
- gain insight into the range of detrimental impacts and how long it takes for changes in populations to demonstrably react or recover;
- be used to isolate the interacting cumulative impacts of the road from measures of the effectiveness of mitigation.

4.4.2 Limitations

The limitations of any Approach four study results from the level of complexity required to gain scientifically sound and statistically robust conclusions. Suitable controls and/or baselines will be crucial, requiring the initial planning of the study during pre-construction stages of development if control sites are unavailable. Any potential confounding factors, considerations regarding statistical power and issues of inferential strength will be specific to the study circumstances and statistical advice is essential. The increased costs and other resources required for an Approach four study mean that their occurrence will be rare and they may require to form part of larger studies focussing on broader population level issues; however, the advantages of such a study would significantly benefit the field of road ecology. Example 10 demonstrates a Before-After-Control-Impact (BACI) design amended from Rytwinski *et al* (2015) Case study 1.

4.4.3 Approach Four: Pros and cons

Pros	Cons
Can identify the impacts of road effects, e.g. genetic isolation of populations, increased stress, reduced reproductive output	Baselines require planning and/or data collection at pre-construction stages if controls are unavailable
Improved understanding of how roads and mitigation impact population viability	More sophisticated statistical analysis required
Can be used for single structures with no need for replication but a large number of data points required (consult a statistician).	Large number of replicates needed
Can identify key stages when mitigation used by e.g. juvenile dispersal, breeding seasons,	Higher costs than for Approaches one, two and three
Identifies key surveying durations and times for future studies (reducing costs)	Significantly increased survey duration than required for Approaches one, two and three
Information can be used to confidently and scientifically influence future decision making for mitigation.	

4.4.4 Examples

Example 10 – Good Practice
On the A96, on off-line sections of the road, where the road and mitigation are to be constructed simultaneously a BACI design could be applied to answer the question; what type of crossing structure allows sufficient movement of pine marten to maintain a population size similar to road free areas? Four treatments could be used including: rope bridge; wooden bridge; culvert and multi-use overpass. Data on relative population size would be collected at both control and treatment sites before and after mitigation and road construction. This could be collected using a number of methods including; mark recapture methods, genetic identification from scat, hair samples or radio tracking. Each treatment

would be replicated along the route and control sites would be located out with the Zone of Influence (ZoI).

Note: As stated above Approach four methods will generally be more costly and resource intensive and therefore will be rare but will provide a greater understanding of the effectiveness of mitigation structures on a wider scale. Such experimental studies would have greater inferential strength and power than alternative approaches. Rytwinski et al (2015) includes a number of case studies, if further examples are desired.

5. STEP SELECTION

5.1 Introduction

There are six steps to designing a mitigation monitoring study. Each requires careful consideration of a number of factors which will vary significantly between studies. Due to this variation and the numerous starting points available for a mitigation monitoring study, it is simpler to explain each of the steps independently since representing the process as a fixed sequential procedure is misleading and will potentially add unnecessary complexity. The six steps are detailed below:

- Step 1: Selecting species to study
- Step 2: Selecting mitigation structure to study
- Step 3: Selecting site to survey
- Step 4: Selecting Approach
- Step 5: Selecting surveying method
- Step 6: Selecting study design and planning statistical analysis

The starting point identified during the desk study will correspond to one of the six steps above. This should be recorded as this step will require no further investigation throughout the decision making process and thus can be regarded as complete. All steps need to be investigated and recorded although the sequence will be influenced by the starting point. For example, if the starting point is 'Investigate the effectiveness of bat bridges' then Step Two: Mitigation structure (bat bridges) is the starting step. The next step to complete will be Step One: Selecting species then Step Three: Selecting site, and so on.

After the initial identification of a starting point and which step it corresponds to then the decision making process can begin.

5.1.1 Terminology

- Start sheet: This two-page document found under Annex 7 was briefly introduced in *Desk study*, Section 3. It contains a table with priority species and mitigation structures that may be selected for a mitigation monitoring study. Additionally, Approaches 1 to 4 are listed as column headings with space to record survey method of possible experiments.

- Target species: The target species is the species selected for the mitigation monitoring study.

- Target mitigation: The specific mitigation structure or mitigation structure selected for a mitigation monitoring study.

5.2 Flow chart

The decision-making process for setting up a mitigation monitoring plan is presented here within a series of flow charts. Follow on from Flow chart 1 (Annex 6) from the desk study. The flow charts provide a reference for the relevant section within the text, where extra information or guidance can be found if required.

Annex 9 lists a range of possible mitigation monitoring study designs for the four different approaches and highlights the possible target species and survey methods applicable for each. The financial, time, expertise and statistical analysis requirements are categorised as low, medium, high or very high for each option. This categorisation is qualitative relative to the other criteria listed in the table. The number of explanatory variables to collect is indicated and it is important to note that these factors must be collected to ensure conclusions are robust and accurate. The number of explanatory variables to consider is mostly classified as high or very high although most factors will not require a large financial output to assess. The complexity of the statistical analysis generally increases with the number of explanatory variables and the complexity of the study.

Annex 9 aids selection of approach, species and/or survey method. If there is a severe limiting factor influencing the decision making process, for example, if there is a limited amount of funds available for a potential study then by using the table it is possible to identify the approaches and survey method with the lowest financial requirements. This should be chosen as a starting point and the remaining steps of the decision-making process completed using the flow charts and Annex 9 as a guide.

5.3 Survey constraints

Below is a list of possible survey constraints that will need to be considered during species, site and study design selection stages of the flow chart. This list is not exhaustive and not all points will be relevant to each situation. If a serious constraint is present in a particular situation then it may not be necessary to change species, site, *etc*. but it is always essential to account for it. In such circumstances it would be advisable to seek guidance from a statistician or experimental design specialist to guarantee that any constraints are appropriately accommodated and ensure no detrimental impact on data quality and project output.

- Land Use Change: If there is to be, or has recently been, a significant change in land use in or adjacent to the chosen survey area during the course of mitigation monitoring, not including the development itself, this could have a serious impact on the quality of the study. For example, if studying the effectiveness of culverts for badgers and woodland within the badger territory is to be felled this could have a large impact on badger behaviour, population size, territory, *etc*. Any mitigation monitoring conclusions would be inseparable from impacts of land use change unless the confounding factors were accommodated.

- Access: If access to land is difficult or withheld during certain times of the year this will affect data quality, particularly if key life history stages such as migration or juvenile dispersal will be unmonitored. Factors that may affect access include:

    - Shooting/hunting season;
    - Weather (regular flooding, landslides, snow);
    - Lambing season;
    - Forestry or construction works at access roads;
    - Health and safety of surveyor if site is dangerous/remote;
    - Sensitivity of other animals within habitat (no access to woodland survey sites/cameras during capercaillie lekking season).

- Population control: If the selected species is subject to legal control or illegal persecution then this should be taken into account. For illegal persecution this could be difficult or impossible and if so, a different species should be selected.

6. STEP 1: SELECTING SPECIES

Table 7 highlights possible survey methods and species that could be selected for each study design[1].

6.1 Rare or elusive species

Rare and/or elusive species would require special consideration when designing survey methodology due to significant impacts on the associated costs, time requirement and level of difficulty of the study. However, rare or elusive species are prime target species for mitigation monitoring as they are highly sensitive to the habitat and land use change associated with infrastructure development but they should only be selected if long term funding is guaranteed. Nationally rare or elusive species are marked on Table 5 but this does not take into consideration small localised populations which may fall into this category.

The main considerations and impacts of selecting a rare or elusive species are:

- there would likely be a lack of existing data meaning that any conclusions and data collected will be of greater value but limit the historical context of any conclusions;
- longer surveying duration due to:
  - species may be slow to respond to any change/disturbance and new mitigation measures
  - it takes longer to collect the necessary number of data points (discussed further in Section 11)
- higher financial costs: if cost is the primary limiting factor for the mitigation monitoring project it may be more beneficial to select an alternative species;
- control sites: locating and surveying replicate or control sites will be more time consuming and costly for a rare species. There is also a possibility that no control sites will be available with the necessary specifications, demanding a more complex study design and survey duration with increasing costs, time and expertise;
- limited existing datasets;
- lack of available knowledge for species:
  - population densities
  - response to roads (avoiders, non-responders)
  - size of Road Effect Zone (REZ)
  - possible lack of data on the most effective survey techniques
  - possible lack of data on the bias associated with different survey techniques
- limited qualified/experienced surveyors (e.g. for identifying hybrid vs pure bred wildcats from camera trap data) resulting in increased training time and costs or initial low quality data analysis.

[1] Deer are included in the list of species for a mitigation monitoring study but have been removed from Annex 7. There are a large number of considerations associated with such a study. Primarily, deer are not of conservation concern and therefore there are few mitigation structures installed with deer as a target species. Additionally, deer are widely managed and subject to control, making them a difficult choice for any study as observations made through mitigation monitoring have to be separated from population fluctuations and impacts from management. Deer fencing is a common form of mitigation used to reduce deer vehicle collisions and protect human health and safety and could therefore still be the subject of useful mitigation monitoring.

6.2 Surveying multiple species

Survey designs 1.1 and 1.3 identify all species using a mitigation structure, most likely through a combination of different surveying techniques. It is acceptable to select more than one target species for all other experiments. In such circumstances where multiple species are to be surveyed, the following points should be assessed:

- ensure one species will not affect the other by using the mitigation structure, e.g. predator-prey interactions

- confirm species do not respond differently to surveying equipment or methodology, e.g. one species avoids camera traps and the others do not;

- ensure species are surveyed using the same methodology (e.g. ink pads) to avoid excessive disturbance from using multiple methods. This will also reduce costs. If more than one survey method is used ensure that any behavioural consequences are fully understood and accommodated;

- if necessary, i.e. Approach four only, check that species use similar habitats to ensure any controls or replicates are valid and available;

- if necessary, i.e. Approach four only, species will each have separate mitigation goals due to any difference in population density, response/recovery times, reproductive output, *etc*.

7. STEP 2: SELECTING MITIGATION STRUCTURE

Table 5 shows which mitigation structures are or have been used by the possible species selected for monitoring. This does not mean that the identified mitigation types are constructed solely for the corresponding species, only that use has been recorded. This information was recorded as part of the literature review. Records of use that are rare or unusual are noted within the table in addition to mitigation structures proven to be ineffective.

Table 5. Mitigation structures used by species

Species	Mitigation Type												
	Green Bridge	Bat Bridge	Hop Overs	Rope Bridge	Culvert	Amphibian Tunnel	Wide Span Bridge	Fish ladder	Fish Screen	Mammal ledge	Tunnel	Reflectors	Fencing
Badger	X				X	X[2]	X			X	X		X
Bats (General)	X	X[1]	X		X		X				X		
Beaver	?				?	?[2]	X			?	?	?	X
Birds (General)	X		X				X				X		X[3]
Capercaille* & Black Grouse*	X						X				X		X[3]
Deer	X				X[2]		X				X	X[1]	X
Fish (General)					X			X	X				
Geese & Wildfowl	X						X				X		X[3]
Great Crested Newt (Amphibians General)	X				X	X	X				X		X
Otter	X				X	X[2]	X			X	X	X[1]	X
Pine Marten	X			X[1]	X	?	X			X	X		X
Red Squirrel	X			X	X[1]	?	X[1]			X	X[1]		X
Reptiles	X				X	X	X				X		X
Scottish Wildcat*	X				X	X[2]	X			X[2]	X	X[1]	X
Water Vole	X				X	X	X			X	X		X

* Rare or elusive species
[1] Recorded use of mitigation by species but limited evidence of effectiveness or mitigation proven to be ineffective.
[2] Species can use this mitigation structure if it is large enough.
[3] Mitigation can avoid collisions with traffic but may pose a collision risk itself.
? Use of mitigation structure unknown but possible considering species ecology and physiological capabilities.

8. STEP 3: SITE SELECTION

Selecting the most appropriate site(s) to survey is dependent on the species and mitigation structures chosen. The availability of replicate survey sites and the habitat of available sites will dictate what approaches are suitable for the mitigation monitoring study along the route corridor. Likewise, a selected approach will also have a considerable impact on what survey sites to select, particularly if the aim of the study requires the selection of multiple sites or a control.

Due to the close connection between Step 3: Site selection and Step 4: Approach, it should be expected that these steps may be interchangeable. For example if selecting an approach for a single mitigation structure then site will already be selected or if selecting a specific site then only one approach may be appropriate.

8.1 Selecting control site

If a control is necessary, most likely for Approach three and/or four, the control site must be similar to the primary study site in every way except one, i.e. the factor being investigated. The range of possible approaches detailed within this document makes the discussion of controls complex. As with any other aspect of experimental design the key decisions require an understanding of the study's specific circumstances. Depending on the aim of the investigation there can be two main controls:

- a control without a road which will allow comparisons to be made between 'natural' populations and the road-affected populations with mitigation;

- a control on an existing similar road or section of the same road that has no mitigation to allow comparison between unmitigated and mitigated populations.

The target species for the mitigation monitoring study will shape the required characteristics of any control site. It is possible that controls will be unavailable within the narrow route corridor particularly if the target species has a large movement range and low population density. Any control sites must be out with the zone of influence.

9. STEP 4: APPROACH SELECTION

How to select the appropriate approach for the relevant circumstances is covered within the flow charts with no need for additional explanation or the use of aids. However, as discussed in section 4.4 any Approach four studies require statistical advice. As these studies would involve the assessment of responses to mitigation it is important to create quantifiable measures of success. The framework for developing SMART (Specific, Measurable, Achievable, Reliable and Time-framed) mitigation goals is applicable here and how to develop such goals is discussed in below.

9.1 SMART Mitigation Goals

Once a target species/species group and mitigation type have been identified a testable quantifiable mitigation goal has to be created which forms the foundation of the monitoring plan. Table 6 contains examples created for offline and online developments where baseline data are available or unavailable.

It is important to consider the type of development that is being carried out or planned. Whether a road is being built online or offline will influence the SMART mitigation goal, as may the availability of an existing dataset. If construction has started or has been completed and there is no baseline data then controls can be used instead to infer any species changes. Controls and other experimental design factors are discussed fully in (Section 8 and 11 respectively).

Step 1: Identify the road impact that is being mitigated.

A) If a mitigation plan for the development has been created then the specific reason for the mitigation will be discussed, e.g. DMU to mitigate fragmentation of otter habitat and increase permeability of the road.

B) If this information is unavailable then there is an opportunity to select whichever road impact mitigated by the structure would be of greatest interest or where there is an existing dataset or other feature. For example, an existing dataset documenting movements of species A would provide a possibility of testing the impact of a new DMU on movement patterns and the barrier effect.

Step 2: Quantify the expected reduction in road impact.[2]

A) Refer to development publications for any generalist (e.g. limited net loss, no net loss) or quantifiable mitigation goal (X% decrease in collisions). Use these goals to check or create (see Step 2B) a specific and realistic target level that will be used to judge the success or failure of mitigation.

B) Using expert opinion based on population estimates/surveys, habitat surveys and species ecology, create a quantitative target that mitigation should achieve. Be aware that this goal should be species and site specific. For example, a ten per cent reduction in badger populations after road construction may be acceptable for a large population but unsustainable for a small population of a species of higher conservation concern.

[2] Care must be taken when setting numerically based targets in relation to road projects. The approach requires detailed understanding of population level issues prior to the project construction and establishment of a fully evidenced baseline against which to measure any change which is unlikely to be routinely available in many cases. Any comparison of before/after scenarios will also require to account for factors unrelated to the road construction that have the potential to cause an impact and how these will be accounted for should be agreed prior to setting the target.

Step 3: Specify goal timescale

A) Create a realistic survey timescale over which to observe population and/or behavioural changes caused by the mitigation. This should be as long as possible with consideration given to financial and resource availability. The shorter the timescale the less chance there is of detecting any impact of the mitigation. Long-lived species with a slow reproductive output may need decades to acclimatise and/or respond to mitigation. Short-lived species with a high reproductive output will generally respond more quickly. Survey duration should be a minimum of three years (Luell, 2003) or longer if species require a long period to adapt to change.

Table 6. Examples of SMART mitigation goals for Approach four mitigation monitoring

Road effect	Target Level in Road Mitigation
Vehicle Collisions[3]	In year X after mitigation has been constructed vehicle collisions with species A have reduced by Y% or are Y% or lower than control or baseline levels
Barrier effect	In year X after road species A uses territory severed by infrastructure the same as or Y% of pre upgrade levels
	In year X after road and mitigation construction has been completed as part of online dualling species A uses mitigation Y% or more than previously recorded before dualling.
Reduced population density	In year X after road or mitigation upgrade has been completed activity of bat species A in proximity to the road is y% of pre-upgrade or control levels

[3] Using collision data or surveying animal casualties can be unreliable and care must be taken to ensure that estimates account for non-fatal collisions, animals fleeing and dying elsewhere, and/or carcass removal or destruction by scavengers or traffic. Such estimates are difficult to accurately predict or calculate and even in carefully designed studies there may still be significant inaccuracies or biases which may reduce the reliability of conclusions. If collision data is to be used advice should be sought from a statistician and a species specialist to ensure biases and confounding factors are minimised or negated. SNH (2009b) provides guidance on calculating carcass removal rates and accounting for search bias. Existing collision data is unlikely to be usable but collision data collected specifically for mitigation monitoring where the above constraints have been accounted for would be useful.

10. STEP 5: SURVEY METHOD SELECTION

Selecting the most appropriate survey method will depend on the species and mitigation structure to be surveyed. Table 8 states the most commonly used survey methods for the selected species and can be used to guide survey method selection.

Best practice survey guidelines for the selected species are covered extensively elsewhere (see references in Table 7). Guidelines or information sources for additional survey methods and technologies that may be appropriate for mitigation monitoring such as the use of eDNA and Unmanned Aerial Vehicles (UAV) are also listed in Table 7. Survey methods and guidance are constantly updated and are therefore not discussed in detail within this report to avoid the need for frequent review. Table 9 illustrates optimum survey times for the range of species. This calendar is a rough guide only as seasons may vary depending on local climate. For example, there is expected to be variation in seasonal windows between the A96 in the north and the southern stretches of the A9.

Completing a literature search to identify the most current survey methods and study designs will increase the overall quality of mitigation monitoring. References listed within the bibliography Section 14 provide an introduction to mitigation monitoring survey methods from within the scientific literature and a starting point for research targeted towards a specific species or mitigation structure *etc.* The following section provides additional notes and considerations as examples of information to record and look for during an initial literature search.

10.1 Additional Notes

Baited survey methods cannot be used for mitigation monitoring studies as they draw animals into or towards mitigation giving a false view of its normal use. Unfortunately, this rules out the use of hair traps to monitor use of mitigation by red squirrels. This is usually a favoured survey method for squirrels as it allows for quick and effective distinctions to be made between native red squirrels and invasive greys. Squirrels are unlikely to travel through hair traps without encouragement and the difference between baited and unbaited traps has not been investigated sufficiently to be able to account for the resulting bias which this could have on the survey results.

Basic bait marking surveys for badger can be carried out as part of initial survey during the environmental assessment stages of a development to determine the social group belonging to a sett or territory feature. Such assessments of territory boundaries are not common and are only carried out when necessary to inform decision-making processes or possibly when replacement setts are to be created. Such studies and corresponding data records are, however, sometimes carried out by local NGOs and this could be a useful dataset to utilise, particularly if a direct comparison could be made between pre construction and post construction territory boundaries. It should be remembered that territory marking behaviour alters throughout the seasons and so any survey investigating territory size or changes would have to consider these variations.

Natural and unnatural variation in the population densities of target species between years, habitats and locations can have a large impact on any study output if not accounted for. For example, a long delay between mitigation going live and the time of first use may be due to ineffective mitigation or due to a low population caused by control.

Eldridge and Wynn (2011) observed that prints left in a clay tracking pad sometimes showed tracks in one direction. This means that badgers may cross a road through one underpass and return through another or may not return the same night at all, sheltering in outlier or subsidiary setts. This should be considered when monitoring mitigation which is in close proximity to other similar structures providing the same function such as culverts or underpasses. If this behaviour is observed during the pilot study the survey method or design may need to be altered (see Section 11 for discussion on pilot study). If alternative crossing structures are in close proximity to the structure being investigated it may be useful to record the distance to the nearest alternative structures as an explanatory variable.

Table 7. References of best practice guidance for survey

Species/ Species Group	**Survey guidelines and resources**
Amphibians	Gent, T. & Gibson, S. eds. 2003. *Herpetofauna Workers Manual 2nd Ed.* Joint Nature Conservation Committee JNCC Peterbourgh. Sewell, D., Griffiths, R.A., Beebee, T.J.C., Foster, J. & Wilkinson, J.W. 2013. *Survey protocols for the British Herpetofauna: Version 1.0.* Available from: http://www.narrs.org.uk/documents/Survey_protocols_for_the_British_herpetofauna.pdf [Accessed on 13 February 2017].
Badger	SNH, 2003. Best Practice Guidance - Badger Surveys. Inverness Badger Survey 2003. *Scottish Natural Heritage Commissioned Report No. 096*. SNH, n.d. *Best practice badger survey guidance note*. Available from: http://www.snh.gov.uk/docs/B957619.pdf [Accessed 30 November 2016].
Bats (General)	Mitchell-Jones, A.J. & McLeish, A.P. eds. 2004. *Bat Workers Manual 3rd ed*. Joint Nature Conservation Committee, Peterborough. Collins, J. 2016. *Bat Surveys for Professional Ecologists: Good Practice Guidelines 3rd ed.* Bat Conservation Trust.
Beaver	Campbell-Palmer, R., Gow, D., Campbell, R., Dickinson, H., Girling, S., Gurnell, J., Halley, D., Jones, S., Lisle, S., Parker, H., Schwab, G. & Rosell, F. 2016. *The Eurasian beaver handbook: ecology and management of* Castor fiber. Pelagic Publishing, Exeter.
Birds (General)	SNH, 2014. *Guidance: Recommended bird survey methods to inform impact assessment of onshore wind farms.* Available from: http://www.snh.gov.uk/docs/C278917.pdf [Accessed 31 March 2017].
Capercaillie & black grouse	Haysom, S. 2013. *Guidance: Capercaillie survey methods.* SNH. Available from: http://www.snh.gov.uk/docs/A863292.pdf [Accessed 30 November 2016]
Deer	Best Practice Guidance, n.d. *Index to all guides. Available from:* http://www.bestpracticeguides.org.uk/guides [Accessed 14 February 2017].
Fish (General)	Fisheries and Aquaculture Management Division, n.d. *Guidelines for sampling fish in inland waters.* Food and Agriculture Organisation of the United Nations (FAO).
Freshwater pearl mussel	Cosgrove, P., Hastie, L., MacDougall, K. & Kelly, A. 2007. Development of a remote deep-water survey method for freshwater pearl mussels*. Scottish Natural Heritage Commissioned Report No. 263.* SNH, n.d. *Freshwater pearl mussel survey protocol for use in site-specific projects.* Available from: http://www.snh.gov.uk/docs/A372955.pdf [Accessed 3 November 2016].
Geese & other wildfowl	SNH, 2014. *Guidance: Recommended bird survey methods to inform impact assessment of onshore wind farms.* Available from: http://www.snh.gov.uk/docs/C278917.pdf [Accessed 31 March 2017].
Great crested newt	Gent, T. & Gibson, S. eds. 2003. *Herpetofauna Workers Manual 2nd Ed.* Joint Nature Conservation Committee JNCC Peterbourgh. SNH, n.d. *Guidelines for trapping Great Crested Newts (Triturus cristatus). Available from:* http://www.snh.gov.uk/docs/C210988.pdf [Accessed 9 January 2017]. Sewell, D., Griffiths, R.A., Beebee, T.J.C., Foster, J. & Wilkinson, J.W. 2013. *Survey*

	protocols for the British herpetofauna: Version 1.0. Available from: http://www.narrs.org.uk/documents/Survey_protocols_for_the_British_herpetofauna.pdf [Accessed 13 February 2017].
Otter	Chanin, P. 2003. *Monitoring the Otter Lutra lutra*. Conserving Natura 2000. Rivers Monitoring Series No 10. English Nature, Peterborough. Chanin, P. 2005. *Otter surveillance in SACs: testing the protocol*. English Nature Research Report No 664. English Nature, Peterborough. SNH, n.d. *Scottish Wildlife Series: Otters and Development- Mitigation.* Available from: http://www.snh.org.uk/publications/on-line/wildlife/otters/mitigation.asp [Accessed 10 November 2016]. Ogada, M.O. 2004. Scats and glue – a cheap and accurate method for mapping African Clawless Otter *Aonyx capensis* (Schinz, 1821) territories in riverine habitat. *IUCN Otter Specialist Group Bulletin*, 21(1): 36-39.
Pine marten	Croose, E., Birks, J.D.S. & Schofield, H.W. 2013. Expansion zone survey of pine marten (*Martes martes*) distribution in Scotland*. Scottish Natural Heritage Commissioned Report No. 520.* SNH, n.d. *The pine marten.* Available from: http://www.snh.gov.uk/docs/A253114.pdf [Accessed 30 November 2016].
Red squirrel	Gurnell, J., Lurz, P. & Pepper, H. 2001. *Practical Techniques for Surveying and Monitoring Squirrels*, Forestry Commission Practice Note. Lurz, P.W.W. & Garson, P.J. 1997. *Red squirrel monitoring: the potential of hair-tubes for estimating squirrel abundance. Practice Note*. Forestry Commission, Edinburgh.
Reptiles	Gent, T. & Gibson, S. eds. 2003. *Herpetofauna Workers Manual 2nd Ed.* Joint Nature Conservation Committee JNCC Peterbourgh. Sewell, D., Griffiths, R.A., Beebee, T.J.C., Foster, J. & Wilkinson, J.W. 2013. *Survey protocols for the British herpetofauna: Version 1.0. Available from:* http://www.narrs.org.uk/documents/Survey_protocols_for_the_British_herpetofauna.pdf [Accessed 13 February 2017].
Scottish wildcat	Kilshaw, K. & Macdonald, D.W. 2011. The use of camera trapping as a method to survey for the Scottish wildcat*. Scottish Natural Heritage Commissioned Report No. 479*. SNH, n.d. *Scottish Wildcat Surveys.* Available from: http://www.snh.gov.uk/docs/A1267895.pdf [Accessed 21 April 2017]. Davis, A.R. & Gray, D. 2010. The distribution of Scottish wildcats (*Felis silvestris*) in Scotland (2006-2008). Scottish Natural Heritage Commissioned Report No. 360.
Water vole	The Mammal Society, 2016. *Water Vole Mitigation Handbook*. Available from: http://www.snh.gov.uk/docs/A1959339.pdf [Accessed 5 April 2017].
Wood ant	Hughes, J. & Broome, A. 2007. *Forests and Wood Ants in Scotland: Information Note.* Forestry Commission, Edinburgh. Available from: https://www.forestry.gov.uk/pdf/fcin090.pdf/$FILE/fcin090.pdf [Accessed 30 November 2016].
eDNA	Freshwater Habitats Trust, n.d. *What is eDNA?* Available from: http://freshwaterhabitats.org.uk/projects/edna/edna/ [Accessed 1st March 2017]. PondNet, Freshwater Habitats Trust, n.d. *How to: Collect an eDNA sample.* Available from: http://freshwaterhabitats.org.uk/wpcontent/uploads/2015/03/eDNA-method-protocol.pdf [Accessed 18 January 2017].
UAV	Hodgson, J.C., Baylis, S.M., Mott, R., Heron, A. & Clarke, R.H. 2016. Precision wildlife monitoring using unmanned aerial vehicles. *Scientific Reports,* DOI: 10.1038/srep22574.
Genetic Tagging	Williams, B.W., Etter, D.R., Linden, D.W., Millenbah, K.F., Winterstein, S.R. & Scribner, K.T. 2009. Noninvasive hair sampling and genetic tagging of co-distributed fishers and American martens. *The Journal of Wildlife Management,* 73(1), 26-34.

Table 8. Survey methods

	Remote Sensing								Direct Observation	eDNA/ Genetic identification	Tracks/ Signs	Drone and Aerial surveys
	Camera Trap	Track Pads	Hair Traps	Bat Detector	Night Vision Scopes	Infra-Red Cameras	CCTV	Heat Sensors				
Amphibians	✓	✓							✓	✓	✓	
Badger	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Bats (General)				✓	✓	✓	v	✓	✓	✓	✓	
Beaver	✓	✓	✓		✓				✓	✓	✓	✓
Birds (General)	✓								✓	✓	✓	
Capercaillie & Black Grouse							✓		✓	✓	✓	✓
Fish (General)									✓	✓		
Geese & Wildfowl	✓						✓		✓	✓	✓	✓
Great Crested Newt	✓	✓							✓	✓	✓	
Otter	✓	✓	✓		✓	✓	✓		✓	✓	✓	
Pine Marten	✓	✓	✓		✓		✓		✓	✓	✓	
Red Squirrel	✓	✓	✓		✓		✓		✓	✓	✓	
Reptiles	✓	✓							✓	✓	✓	
Scottish Wildcat	✓	✓	✓		✓		✓		✓	✓	✓	
Water Vole	✓	✓	✓		✓		✓		✓	✓	✓	

Table 9. Example survey calendar. (Amended from SNH n.d.)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Amphibians	Newts hibernating		Pond surveys for adults/ terrestrial surveys/ egg surveys March to mid-June/ Larvae surveys from mid-April				Larvae and refuge surveys			Refuge surveys	Newts hibernating	
Badgers	Limited sett/bait surveys	Sett surveys and bait marking			Sett monitoring				Sett surveys and bait marking			Limited sett/bait surveys
Bats	Inspection of hibernation, tree and building roosts			Limited activity	Summer roost emergence and activity surveys. Maternity roosts start to form in May, females give birth in June; Mating starts in September.					Limited activity	Inspection of hibernation, tree and building roosts	
Beaver	Reduced activity	Optimum survey period for field signs			Surveys possible but signs may be obscured by vegetation				Optimum survey period for field signs			Reduced activity
Capercaillie and Black Grouse	Peak activity			Lekking surveys (May be earlier in warm weather)		Surveys can be constructed all year round, (weather permitting) depending on the type of survey.						
Fish (General	For coastal, river and stream dwelling species the timing of the surveys will depend on the migration pattern of the species concerned Where surveys require information on breeding, the timing of surveys will need to coincide with the breeding period which is species - specific											
Great Crested Newt	Newts hibernating		Pond surveys for adults/ terrestrial surveys/ egg surveys April to mid-June/ larvae surveys from mid-April				Terrestrial habitat and larvae surveys		Terrestrial habitat surveys		Newts hibernating	
Otter	Limited by vegetation cover and weather conditions rather than season											
Pine Marten	Surveys may be constructed all year round weather permitting. Optimum time is spring and summer. Surveys for breeding dens from March to May											
Red Squirrel	Surveys may be constructed all year round weather permitting. Optimum time is spring and summer. Surveys for breeding females from December to September											
Reptiles	Reptiles hibernating		Basking refugia surveys. Peak survey months are April and May				Reduced basking time reduces effectiveness of refugia survey		Peak survey month	Limited activity	Reptiles hibernating	
Scottish Wildcat	Surveys may be constructed all year round weather permitting.											
Water Vole	Low activity	Initial habitat survey	Habitat and field signs / activity surveys. May be limited by vegetation cover and weather May to September in upland areas								Initial habitat survey	Low activity

Optimal Survey Period

Limited Survey Period

Surveys not possible

11. STEP 6: STUDY DESIGN AND STATISTICAL ANALYSIS

11.1 Study design

As suggested throughout, but with particular reference to Approaches 3 and 4, it is important to consult a statistician and species specialist when developing a study design to ensure adequate inferential strength and statistical power. Identifying the number of data points and method of statistical analysis are essential steps when designing any study and should be identified and confirmed prior to any data collection (see bibliography for introductory literature on the subject).

Pilot studies are an essential component to most studies and should be completed as part of mitigation monitoring where appropriate. Some approaches and study designs discussed previously are not compatible with a traditional pilot study such as monitoring to identify the time of first use of a mitigation structure. As the survey has to start when mitigation goes live there is not time to complete a pilot study using live mitigation. However a similar mitigation structure could be used to check the positioning of survey equipment, data recording methods and identify any unforeseen complications.

Most explanatory variables would be recorded at the beginning of every standard survey e.g. date, time, weather, habitat, location, and name(s) of surveyors. There are certain features, however, that may influence use or species activity that would also have to be recorded. For example, if studying culverts then the following factors are considered to be explanatory variables: culvert shape; size (length, width, area and openness); culvert material and finish; presence or absence of water or vegetation; water depth; percentage cover of water; proximity to human habitation; habitat and features up to a 500m radius of culvert. This is in addition to standard measurements or other variables including traffic volume, distance to alternative crossing structures, *etc*. (Serronha *et al*., 2012; Clevenger *et al*., 2001). The greater the number of explanatory variables incorporated into the study design the more replicates or data points required. If there are not enough replicates or data points then explanatory variables can be reduced. A thorough literature search should highlight variables most likely to influence use. The bibliography section 14 provides a starting point for a literature search.

11.2 Study Timing and Duration

The duration and frequency for mitigation monitoring will vary depending on the mitigation objectives, monitoring objectives and species ecology.

The duration of monitoring within the published literature ranges from 4 days to eight years (van der Ree *et al., 2007)*. The longer the survey duration the more robust the conclusions as natural variation is more likely to be understood and able to be standardised. If investigating the effectiveness of mitigation structures then the factor being recorded will influence survey duration, for example if studying population viability, genetic differentiation or similar, then the response time from mitigation construction to an observable effect will be greater.

If mitigation has been constructed to maintain a juvenile dispersal route then monitoring may be justifiably limited to that period or if mitigation is constructed to maintain daily commuting corridors then use should be monitored throughout the year. Additionally if the species life cycle identifies periods of inactivity or absence then these periods may also be excluded from survey for example, during seasonal migrations or hibernation. It should be remembered that data collected within a specific season cannot be compared to data collected during an alternative season due to this natural variation in activity.

Luell *et al.* (2003) recommend that monitoring should cover a period of three years minimum because the evaluation of effectiveness should not incorporate data collected immediately after the mitigation structure is usable. This is because animals will need a chance to become accustomed to the mitigation structure and adapt to any wider habit changes associated with the development. Evidently, this will not include approaches aimed at identifying mitigation use, for example, time of first use or how frequency of use changes over time.

The survey timescale used to complete STRIPE during years one, three and five is appropriate for mitigation monitoring, ensuring that monitoring is completed over a long enough time frame to gain usable conclusions but with a reduced cost. It is acceptable to carry out monitoring periodically for example collecting camera trap data for one week then stopping for two weeks.

If it is necessary to collect a certain number of data points to ensure statistical power and significance then a longer survey period will be required for rare species. Conversely, if the species is common the survey period may be shorter.

12. POST-SURVEY

12.1 Publication of results

As discussed earlier a key constraint to furthering the scientific understanding of mitigation structures is the absence of adequately collected monitoring data. To negate this problem any conclusions of a mitigation monitoring study should be compiled into a widely available report or other publication. Unpublished data should, if possible, also be transferred to a data centre such as NBN Atlas Scotland. This ensures data is processed and stored correctly and available for future use. Table 4 shows the minimum information required to accompany a dataset.

12.2 Meta-analysis

If mitigation monitoring is implemented repeatedly and the data is available, there is the possibility that the data sets could be combined to contribute to a meta-analysis study. Meta-analysis combines and analyses existing datasets to extrapolate further conclusions and gain deeper understanding of a subject with little or no addition data collection. Such a study could be carried out by independent researchers, non-statutory bodies and other organsiations.

12.3 Feedback loops

If a mitigation monitoring study is executed appropriately any conclusions will be able to identify various interactions between the selected species and mitigation structures. The applicability of such conclusions may be limited, however, depending on the study's design. The limitations of any conclusions should be clearly stated to ensure that the risk of misinterpretation is reduced. A statistician and/or species specialist should confirm the scope of any conclusions.

If appropriate, robust conclusions may be used to aid future decision-making processes conducted as part of the development and mitigation design procedures in addition to the equivalent for mitigation monitoring studies. Future changes to legislation, guidance and best practice as well as improvements to our scientific understanding of the subject may impact the development process documented within this report. It is therefore important to updated and streamline this process when necessary.

13. REFERENCES

Berthinussen, A. & Altringham, J. 2015. *Development of a cost effective method for monitoring the effectiveness of mitigation for bats crossing linear transport infrastructure.* School of Biology, University of Leeds, Leeds. Report Reference: WC1060.

Best Practice Guidance, n.d. Index to all guides. Available from: //www.bestpracticeguides.org.uk/guides [Accessed 14 February 2017].

Bliss-Ketchum, L.L., de Rivera, C.E., Turner, B.C & Weisbaum, D.M. 2016. The effect of artificial light on wildlife use of a passage structure. *Biological Conservation,* 199, 25-28.

Burns, O. & Jackson-Matthews, S. 2016. *Environmental Clerks of Works: Good Practice Guidelines for Planning Authorities*. The Association of Environmental & Ecological Clerks of Works, Glasgow.

Campbell-Palmer, R., Gow, D., Campbell, R., Dickinson, H., Girling, S., Gurnell, J., Halley, D., Jones, S., Lisle, S., Parker, H., Schwab, G. & Rosell, F. 2016. *The Eurasian beaver handbook: ecology and management of* Castor fiber. Pelagic Publishing, Exeter.

CH2M, 2016. *Scottish Trunk Road Infrastructure Project Evaluation. (STRIPE): Final Guidance.* Transport Scotland, Glasgow.

Chanin, P. 2003. Monitoring the Otter *Lutra lutra*. Conserving Natura 2000 Rivers Monitoring Series No 10.

Chanin, P. 2005. Otter surveillance in SACs: testing the protocol. English Nature Research Report No 664. English Nature, Peterborough.

Chee, Y.E. 2015. Principles underpinning biodiversity offsets and guidance on their use. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester, England, Wiley Blackwell, pp 51-59.

CIEEM, 2016. *Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal, 2nd Edition*. Chartered Institute of Ecology and Environmental Management, Winchester. pp 2.

Clevenger, A.P., Chruszcz, B. & Gunson, K. 2001. Drainage culverts as habitat linkages and factors affecting passage by animals. *Journal of Applied Ecology,* 38, 1340-1349.

Coffin, A. 2007. From road kill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography,* 15, 396-406.

Collins, J. 2016. *Bat Surveys for Professional Ecologists: Good Practice Guidelines 3rd ed*. Bat Conservation Trust.

Cosgrove, P., Hastie, L., MacDougall, K. & Kelly, A. 2007. Development of a remote deep-water survey method for freshwater pearl mussels*. Scottish Natural Heritage Commissioned Report No. 263.*

Croose, E., Birks, J.D.S. & Schofield, H.W. 2013. Expansion zone survey of pine marten (*Martes martes*) distribution in Scotland. *Scottish Natural Heritage Commissioned Report No. 520.*

Davis, A.R. & Gray, D. 2010. The distribution of Scottish wildcats (*Felis silvestris*) in Scotland (2006-2008). *Scottish Natural Heritage Commissioned Report No. 360.*

DMRB, (Design Manual for Roads and Bridges) n.d. *Design Manual for Roads and Bridges.* Available from: http://www.standardsforhighways.co.uk/ha/standards/dmrb/ [Accessed 6 September 2016].

Eldridge, B. & Wynn, J. 2011. Use of badger tunnels by mammals on highways agency schemes in England. *Conservation Evidence,* 8, 53-57.

Fahrig, L. & Rytwinski, T. 2009. Effects of roads on animal abundance: An empirical review and synthesis. *Ecology and Society,* 14(1), 21. Available from: http://www.ecologyandsociety.org/vol14/iss1/art21/ [Accessed 17 October 2016].

Fisheries and Aquaculture Management Division, n.d. *Guidelines for sampling fish in inland waters*. Food and Agriculture Organisation of the United Nations (FAO).

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T. & Winter, T.C. 2003. *Road ecology. Science and solutions*. Island Press, Washington, DC.

Freshwater Habitats Trust, n.d. *What is eDNA?* Available from: http://freshwaterhabitats.org.uk/projects/edna/edna/ [Accessed 1 March 2017].

Gent, T. & Gibson, S. eds. 2003. *Herpetofauna Workers Manual 2nd Ed*. Joint Nature Conservation Committee, Peterbourgh.

Gurnell, J., Lurz, P., McDonald, R. & Pepper, H. 2009. Practical Techniques for Surveying and Monitoring Squirrels. Forestry Commission Practice Note.

Hardy, A., Clevenger, A.P., Marcel, H. & Graham, N. 2004. An overview of methods and approaches for evaluating the effectiveness of wildlife crossing structures: emphasizing the science in applied science. In: Irwin, C.L., Garrett, P. & McDermott, K.P. eds. *Proceedings of the 2003 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Arkansas, USA*, pp 319-330.

Haysom, S. 2013. *Guidance: Capercaillie survey methods*. SNH. Available from: http://www.snh.gov.uk/docs/A863292.pdf [Accessed 30 November 2016].

Henley, M. Licencing Officer. Personal Communication 20 January 2017.

Hodgson, J.C., Baylis, S.M., Mott, R., Heron, A. & Clarke, R.H. 2016. Precision wildlife monitoring using unmanned aerial vehicles. *Scientific Reports,* 6. DOI: 10.1038/srep22574. [Accessed 21 April 2017].

Hughes, J. & Broome, A. 2007. Forests and Wood Ants in Scotland: Information Note. Forestry Commission, Edinburgh. Available from: https://www.forestry.gov.uk/pdf/fcin090.pdf/$FILE/fcin090.pdf [Accessed 30 November 2016].

Huijser, M.P. & Bergers, P.J.M. 2000. The effect of roads and traffic on hedgehog (*Erinaceus europaeus)* populations. *Biological Conservation,* 95, 111-116.

Kilshaw, K. & Macdonald, D.W. 2011. The use of camera trapping as a method to survey for the Scottish wildcat. *Scottish Natural Heritage Commissioned Report No. 479.*

Lesbarrères, D. & Fahrig, L. 2012. Measures to reduce population fragmentation by roads: What has worked and how do we know? *Trends in Ecology and Evolution,* 27(7), 374-380.

Luell, B., Bekker, G.J., Cuperus, R., Dufek, J., Fry, G., Hicks, C., Hlaváč, V., Keller, V., Rosell, C., Sangwine, T., Tørsløv, N. & Wandall, B.M. eds. 2003. Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions. KNNV Publishers, Brussels, Belgium.

Lurz, P.W.W. & Garson, P.J. 1997. Red squirrel monitoring: the potential of hair-tubes for estimating squirrel abundance. Practice Note. Forestry Commission, Edinburgh.

Mitchell-Jones, A.J. & McLeish, A.P. eds. 2004. *Bat Workers Manual 3rd ed.* Joint Nature Conservation Committee, Peterborough.

NBN, n.d. *Metadata Standards.* Available from: https://nbn.org.uk/record-share-explore-data/share-your-data/prepare-your-data/ [Accessed 14 March 2017].

Ogada, M.O. 2004. Scats and glue – a cheap and accurate method for mapping African Clawless Otter *Aonyx capensis* (Schinz, 1821) territories in riverine habitat. *IUCN Otter Specialist Group Bulletin*, 21(1), 36-39.

PondNet: Freshwater Habitats Trust, n.d. *How to: Collect an eDNA sample*. Available from: http://freshwaterhabitats.org.uk/wpcontent/uploads/2015/03/eDNA-method-protocol.pdf [Accessed 18 January 2017].

Roedenbeck, I.A., Fahrig, L., Findlay, S.C., Houlahan, J.E., Jaeger, J.A.G., Klar, N., Kramer-Schadt, S. & van der Grift, E.A. 2007. The Rauischholzhausen agenda for road ecology. *Ecology and Society,* 12(1), 11. Available from: http://www.ecologyandsociety.org/vol12/iss1/art11/ [Accessed 30 August 2016].

Rytwinski, T., van der Ree, R., Cunnington, G.M., Fahrig, L., Findlay, C.S., Houlahan, J., Jaeger, J.A.G., Soanes, K. & van der Grift, A. 2015. Experimental study designs to improve the evaluation of road mitigation measures for wildlife. *Journal of Environmental Management,* 154, 48-64.

Scottish Executive, Welsh Assembly Government & Department of the Environment, Northern Ireland, 2005. *A Practical Guide to the Strategic Environmental Assessment Directive: Practical guidance on applying European Directive 2001/42/EC "on the assessment of the effects of certain plans and programmes on the environment"* Office of the Deputy Prime Minister: London. Reference Number 05 PD 03311.

SNH, 2003. Best Practice Guidance - *Badger Surveys.* Inverness Badger Survey 2003. *Scottish Natural Heritage Commissioned Report No. 096.*

SNH, 2009. *Guidance Note: Guidance on methods for monitoring bird populations at onshore wind farms - January 2009.* Available from: http://www.snh.gov.uk/docs/C205417.pdf [Accessed 11 April 2017].

SNH, 2014. Guidance: *Recommended bird survey methods to inform impact assessment of onshore wind farms.* Available from: http://www.snh.gov.uk/docs/C278917.pdf [Accessed 31 March 2017].

SNH, n.d. Scottish Wildlife Series: *Otters and Development- Mitigation*. Available from: http://www.snh.org.uk/publications/on-line/wildlife/otters/mitigation.asp [Accessed 10 November 2016].

SNH, n.d. *The pine marten.* Available from: http://www.snh.gov.uk/docs/A253114.pdf [Accessed 30 November 2016].

SNH, n.d. *Scottish Wildcat Surveys*. Available from: http://www.snh.gov.uk/docs/A1267895.pdf [Accessed 21 April 2017].

SNH, n.d. *Best practice badger survey guidance note*. Available from: http://www.snh.gov.uk/docs/B957619.pdf [Accessed 30th November 2016].

SNH, n.d. *Freshwater pearl mussel survey protocol for use in site-specific projects.* Available from: http://www.snh.gov.uk/docs/A372955.pdf [Accessed 3 November 2016].

SNH, n.d. *Guidelines for trapping Great Crested Newts* (Triturus cristatus). Available from: http://www.snh.gov.uk/docs/C210988.pdf [Accessed 9 January 2017].

SNH, n.d. *Survey Calendar.* Available from: http://www.snh.gov.uk/docs/A1308161.pdf. [Accessed 17 February 2017].

Serronha, A.M., Mateus, A.R.A., Eaton. F., Santos-Reis, M. & Grilo, C. 2013. Towards effective culvert design: monitoring seasonal use and behaviour by Mediterranean mesocarnivores. *Environmental Monitoring and Assessment,* 185(3), 6235-6246.

Sewell, D., Griffiths, R.A., Beebee, T.J.C., Foster, J. & Wilkinson, J.W. 2013. *Survey protocols for the British Herpetofauna: Version 1.0.* Available from: http://www.narrs.org.uk/documents/Survey_protocols_for_the_British_herpetofauna.pdf [Accessed on 13 February 2017].

The Mammal Society, 2016. *Water Vole Mitigation Handbook.* Available from: http://www.snh.gov.uk/docs/A1959339.pdf [Accessed 5 April 2017].

Transport Scotland, 2014. *A9 Dualling: Luncarty to Pass of Birnam DMRB Stage 3 Environmental Statement Appendix A10.6:* Terrestrial and Freshwater Ecology – Impacts and Mitigation Table 1 page 8.

Torres, A., Jaeger, J.A.G. & Alonso, J.C. 2016. Assessing large scale wildlife responses to human infrastructure development. *PNAS,* 13(30), 8472-8477. Available from: DOI:10.1073/pnas.1522488113 [Accessed 12 September 2016].

Torres, A., Palacin, C., Seoane, J. & Alonso, J.C. 2011. Assessing the effects of a highway on a threatened species using a Before-During-After and Before-During-After-Control-Impact designs. *Biological Conservation,* 144, 2223-2232.

van der Grift, E.A., van der Ree, R., Fahrig, L., Findlay, S., Houlahan, J., Jaeger, J.A.G., Klar, N., Mandriñan, L.F. & Olson, L. 2013. Evaluating the effectiveness of road mitigation measures. *Biodiversity and Conservation,* 22, 425-448.

van der Grift, E.A. & van der Ree, R. 2015a. Guidelines for evaluating use of wildlife crossing structures. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester , England, Wiley Blackwell, pp119-128.

van der Grift, E.A., van der Ree, R. & Jaeger, J.A.G. 2015. Guidelines for evaluating the effectiveness of road mitigation measures. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester , England, Wiley Blackwell, pp 129-137.

van der Ree. R., Smith. D.J. & Grilo. C. 2015a. eds. *Handbook of Road Ecology.* Chichester, England, Wiley Blackwell.

van der Ree, R., Gagnon, J.W. & Smith, D.J. 2015b. Fencing: A valuable tool for reducing wildlife-vehicle collisions and funnelling fauna to crossing structures. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester, England, Wiley Blackwell, pp 159-171.

van der Ree, R., Jaeger, J.A.G., van der Grift, E.A. & Clevenger, A.P. 2011. Effects of roads and traffic on wildlife populations and landscape function: road ecology is moving towards larger scales. *Ecology and Society,* 16(1), 48. Available from: http://www.ecologyandsociety.org/vol16/iss1/art48/ [Accessed 5 September 2016].

van der Ree, R., van der Grift, E., Mata, C. & Suarez, F. 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. In: Irwin, C. L., Nelson, D. & McDermott, K. P. eds. *International Conference on Ecology and Transportation. Center for Transportation and the Environment*, North Carolina State University, Arkansas, USA, pp 423-431.

Williams, B.W., Etter, D.R., Linden, D.W., Millenbah, K.F., Winterstein, S.R. & Scribner. K.T. 2009. Noninvasive hair sampling and genetic tagging of co-distributed fishers and American martens. *The Journal of Wildlife Management*, 73(1), 26-34.

14. BIBLIOGRAPHY

Abbott, I.M., Berthinussen, A., Stone, A., Boonman, M., Melber, M. & Altringham, J. 2015. Bats and Roads. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester , England, Wiley Blackwell, pp 290-300.

ALGE, n.d. *Biodiversity: Planning Toolkit.* Available from: http://www.biodiversityplanningtoolkit.com/default.asp [Accessed 30 August 2016].

Barber, J.R., Crooks, K.R. & Fistrup, K.M. 2009. The costs of chronic noise exposure for terrestrial organisms. *Trends in Evolution and Ecology,* 25(3). DOI:10.1016/j.tree.2009.08.002 [Accessed 7 October 2016].

Barrueto, M., Ford, A.T. & Clevenger, A.P. 2014. Anthropogenic effects on activity patterns of wildlife at crossing structures. *Ecosphere*, 5(3), 27. Available from: http://dx.doi.org/10.1890/ES13-00382.1 [Accessed 7 October 2016].

Bautista, L.M., García, J.T., Calmaestra, R.G., Palacín, C., Martín, C.A., Morales, M.B., Bonal, R. & Viñuela, J. 2004. Effect of weekend road traffic on the use of space by raptors. *Conservation Biology,* 18(3), 726-732.

Beebee, T.J.C. 2013. Effects of road mortality and mitigation measures on amphibian populations. *Conservation Biology,* 27(4), 657-668.

Benítez- López, A., Alkmade, R. & Verweij, P.A. 2010. The impacts of roads and other linear infrastructure on mammal and bird populations: A meta-analysis. *Biological Conservation,* 143, 1307-1316.

Bissonette, J.A. & Rosa, S.A. 2009. Road zone effects in small-mammal communities. *Ecology and Society,* 14(1), 27. Available at: http://www.ecologyandsociety.org/vol14/iss1/art27/ [Accessed 12 September 2016].

British Standards Institution, 2013. BS 42020 2013. Biodiversity: Code of practice for planning and development. London, BSI.

Butler, L.K., Ries, L., Bisson, I.A., Hayden, T.J., Wikelski, M.M. & Romero. L.M. 2013. Opposite but analogous effects of road density on songbirds with contrasting habitat preferences. *Animal Conservation, 16(1), 77-85.* DOI:10.1111/j.1469-1795.2012.00576.x. [Accessed 14 October 2016].

Červinka, J., Riegert, J., Grill, S. & Šálek, M. 2015. Large scale evaluation of carnivore road mortality: The effect of landscape and local scale characteristics. *Mammal Research,* 60, 233-243. DOI: 10.1007/s13364-015-0226-0 [Accessed 14 October 2016].

Chen, H.L. & Koprowski, J.L. 2016. Barrier effects of roads on an endangered forest obligate: influences of traffic, road edges and gaps. *Biological Conservation,* 199, 33-40.

CIEEM, 2015. *Guidelines for ecological report writing*. Chartered Institute of Ecology and Environmental Management, Winchester.

Clevenger, A.P. & Waltho, N. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology,* 14(1), 47-56.

Coelho, I.P., Teixeira, F.Z., Colombo, P. & Kindel, A. 2012. Anuran road kills neighbouring a pen-urban reserve in Atlantic Forest, Brazil. *Journal of Environmental Management,* 112, 17-26.

Colino-Rabanal, V.J. & Linzana, M. 2012. Herpetofauna and roads: A review. *Basic and applied Herpetology,* 26, 5-31.

Conroy, J.W.H., Chanin, P., Lafontaine, L. & Yoxon, P. 2007. Mitigation for a safer otter habitat: Report of the IUCN otter specialist group workshop 10 -12 April. Available from: http://www.otterspecialistgroup.org/OM/Biblio/ConroyEtAl_2007_DutchReintroduction.pdf [Accessed 20 October 2016].

Conservation Evidence, n.d. Conservation Evidence: Providing evidence to improve practice. Available from: http://www.conservationevidence.com/ [Accessed 5 September 2016].

Creswell, W.J., Birks, J.D.S., Dean, M., Pacheco, M., Trewhella, W.J., Wells, D. & Wray, S. 2012. *UK BAP mammals: Interim guidance for survey methodologies, impact assessment and mitigation.* The Mammal Society, Southampton.

Cosentin, B.J., Marsh, D.M., Jones, K.S., Apodaca, J.J., Bates, C., Beach, J., Beard, K.H., Backlin, K., Bell, J.M., Crockett, C., Fawson, G., Fjelsted, J., Forys, E.A., Genet, K.S., Grover, M., Holmes, J., Indeck, K., Karraker, N.E., Kilpatrick, E.S., Langen, T.A., Mugel, S.G., Molina, A., Vonesh, J.R., Weaver, R.J. & Willey, A. 2014. Citizen science reveals widespread negative effects of roads on amphibian distributions. *Biological Conservation,* 180, 31-38.

Cunnington, G.M. & Fahrig, L. 2010. Plasticity in the vocalisations of anurans in response to traffic noise. *Acta Oecologica,* 36(5), 463-470.

Cunnington, G.M., Garrah, E., Eberhardt, E. & Fahrig, L. 2014. Culverts alone do not reduce road mortality in anurans. *Ecoscience,* 21(1), 69-78.

D'Amico, M., Román, J., de los Reyes, L. & Revilla, E. 2015. Vertebrate road kill patterns in Mediterranean habitats: Who, when and where. *Biological Conservation,* 191, 234-242.

D'Anunciação, P.E.R., Lucas, P. & Bager, R. 2013. Road ecology and Neotropical amphibians: Contributions for future studies. *Acto Herpetologica,* 8(2), 129-140. DOI: 10.13128/Acta_Herpetol-12331 [Accessed 5 September 2016].

Dowding, C.V., Harris, S. & Poulton, S. 2010. Nocturnal ranging behaviour of urban hedgehogs *Erinaceus europaeus,* in relation to risk and reward. *Animal Behaviour,* 80, 13-21.

Elmiger, C. & Trocmé, M. 2007. Developing fauna-friendly transport structures: Analysis of the impact of specific road engineering structures on wildlife mortality and mobility. In: Irwin, C.L., Nelson, D. & McDermott, K.P. eds. *International Conference on Ecology and Transportation* Centre for Transportation and the Environment, North Carolina State University, North Carolina and Little Rock, Arkansas, USA pp 212 – 219.

Fahrig, L., Pedlar, J.H., Pope, S.E., Taylor, P.D. & Wegner, J.F. 1995. Effect of road traffic on amphibian density. *Biological Conservation,* 73, 177-182.

Fietz, J., Tomiuk, J., Loeschcke, V., Weis-Dootz, T. & Segelbacher, G. 2014. Genetic Consequences of Forest Fragmentation for a Highly Specialized Arboreal Mammal - The Edible Dormouse. *PLoS ONE,* 9(2), e88092. DOI: 10.1371/journal.pone.0088092 [Accessed 17 October 2016].

Foppen, R.P.B. & Deuzeman, S. 2007. De Grote karekiet in de noordelijke randmeren; een dilemma voor natuurontwikkelingsplannen!? *De Levende Natuur*, 108, 20-26.

Franklin, J.F. 1993. Preserving Biodiversity: Species, Ecosystems or Landscapes? *Ecological Applications,* 3(2), 202-205.

Fraser, H.L., Henry, H.A.L., Carlyle, C.N., White, S.R., Beierkuhnlein, C., Cahill, Jr. J.F., Casper, B.B., Cleland, E., Collins, S.L., Dukes, J.S., Knapp, A.K., Lind, E., Long, R., Luo, Y., Reich, P.B., Smith, M.D., Sternberg, M. & Turkington, R. 2013. Co-ordinated distribution experiments: an emerging tool for testing global hypotheses in ecology and environmental science. *Frontiers in Ecology and the Environment,* 11(3), 147-155.

Fuller, R.A., Warren, P.H. & Gaston, K.J. 2007. Daytime noise predicts nocturnal singing in urban robins. *Biology Letters,* 3, 368-370.

Gordon, K.M., McKinstry, M.C. & Anderson, S.H. 2004. Motorists response to a deer-sensing warning system. *Wildlife Society Bulletin,* 32(2), 565-573.

Grogan, A., Philcox, C. & Macdonald, D. 2001. *Nature conservation and roads: Advice in relation to otters.* Wildlife Conservation Research Unit, Oxford.

Grogan, A., Green, R. & Rushton, S. 2013. The Impacts of Roads on Eurasian Otters (*Lutra lutra*). *IUCN Otter Specialist Group Bulletin*, 30(1), 44-57.

Groot Bruinderink, G.W.T.A & Hazebroek, E. 1996. Ungulate Traffic Collisions in Europe 1996. *Conservation Biology,* 10 (4), 1059-1067.

Guinard, E., Prodon. R. & Barbraud, C. 2015. Case Study: A robust method to obtain defendable data on wildlife mortality. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester, England, Wiley Blackwell, pp 159-171.

Gunson, K., Mountrakis, G. & Quackenbush, L. 2011. Spatial wildlife-vehicle collision models: A review of current work and its application to transportation mitigation projects. *Journal of Environmental Management,* 92(4), 1074-1082.

Hill, D. 2001. *Highways and Birds: A Best Practice Guide.* Ecoscope Applied Ecologists, Cambridgeshire.

Hill, D. & Arnold, R. 2012. Building the evidence base for ecological impact assessment and mitigation. *Journal of Applied Ecology,* 49, 6-9.

Hess, G.R & King, T.J. 2002. Planning open spaces for wildlife 1. Selecting focal species using a Delphi survey approach. *Landscape and Urban planning*, 58, 25-40.

Huijser, M.P., Wagner, M.E., Hardy, A. & Clevenger, A.P. 2007. Animal-vehicle collision data collection throughout the United States and Canada. In: Irwin. C. L., Nelson. D. & McDermott. K.P. eds. *Proceedings of the 2007 International Conference on Ecology and Transportation, Center for Transportation and the Environment, North Carolina State University, Arkansas, USA*, pp. 387-391.

Huijser, M.P., Fairbank, E.R., Camel-Means, W., Graham, J., Watson, V., Basting, P. & Becker, D. 2016. Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife-vehicle collisions and providing safe crossing opportunities for large mammals. *Biological Conservation,* 197, 61-68.

Huijser, M.P., Mosler-Berger, C., Olsson, M. & Strein, M. 2015. Wildlife warning signs and animal detection systems aimed at reducing Wildlife-Vehicle Collisions. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester , England, Wiley Blackwell, pp 198-212.

Ibisch, P.L., Hoffmann, M.T., Kreft, S., Pe'er, G., Kati, V., Bieber-Freudenberger, L., DellaSala, D.A., Vale, M.M., Hobson, P.R. & Selva, N. 2016. A global map of roadless areas and their conservation status. *Science,* 354(6318), 1423-1427.

Jackson, S.D. 1996. Underpass systems for amphibians. In: Evink, G.L., Garrett, P., Zeigler, D. & Berry, J. eds. *Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar.* State of Florida Department of Transportation, Tallahassee pp 4.

Jacobson, S.L., Bliss-Ketchum, L.L., de Rivera, C.E. & Smith, W.P. 2016. A behaviour-based framework for assessing barrier effects to wildlife from vehicle traffic volume. *Ecosphere,* 7(4). Available from: http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1345/full [Accessed 1 November 2016].

Jaeger, J.AG., Bowman, J., Brennan, J., Fahrig, L., Bert, D., Bouchard, J., Charbonneau, N., Frank, K., Gruber, B. & von Toschanowitz, K.T. 2005. Predicting when animal populations are at risk from roads: an interactive model of road avoidance behavior. *Ecological Modelling,* 185, 329-348.

Jaeger, J.A.G., Fahrig, L. & Ewald, K.C. 2006. Does the configuration of road networks influence the degree to which roads affect wildlife populations? In: Irwin, C.L., Garrett, P. & McDermott, K.P. eds. *International Conference on Ecology and Transportation. Center for Transportation and the Environment*, North Carolina State University, Arkansas, USA, pp 151-163.

Jones, D.N. & Pickvance, J. 2013. Forest birds use vegetated fauna overpass to cross multi-lane road. *Oecologia Australis,* 17(1), 147-156.

Keller, V., Bauer, H., Ley, H. & Pfister, H. 1996. Bedeutung von grünbrücken uber autobahn für vögel. *Der orithologische beobachter*, 93, 249-258.

Kilshaw, K. 2011. *Scottish Wildcats: Naturally Scottish*. Scottish Natural Heritage, Battleby.

Klar, N., Herrmann, M. & Kramer-Schadt, S. 2009. Effects and mitigation of road impacts on individual movement behaviour of wildcats. *Journal of wildlife Management,* 73(5), 631-638. DOI: 10.2193/2007-574. [Accessed 14 November 2016].

Kociolek, A.V., Clevenger, A.P., St.Clair, C.C. & Proppe, D.S. 2011. Effects of road networks on bird populations. *Conservation Biology,* 25(2), 241-249.

Kuitunen, M. & Rossi, E. 2003. Impact of busy roads on breeding success in Pied Flycatchers *Ficedula hypoleuca. Environmental Management,* 31(1), 79-85.

Langbein, J. 2011. *Deer Vehicle Collisions in Scotland Monitoring Project 2008-2011. Deer* Initiative Research Report. 11/2.

Lesiński, G. 2007. Bat road casualties and factors determining their number. *Mammalia,* 71(3), 134-147.

Lurz, P. 2010. *Red squirrels: Naturally Scottish.* Scottish Natural Heritage, Battleby.

Madsen, A.B. 1996. Otter *Lutra lutra* mortality in relation to traffic, and experience with newly established fauna passages at existing road bridges. *Lutra*, 39, 76-89.

Magintan, D. 2012. *Mitigation of road related impacts on wildlife.* Dissertation, Wildlife Institute of India.

Massemin, S., Le Maho, Y. & Handrich, Y. 2008. Seasonal pattern in age, sex and body condition of Barn Owls *Tyto alba* killed on motorways. *Ibis,* 140(1), 70-75.

Mata, C., Bencini, R., Chambers, B.K. & Malo, J.E. 2015. Predator-prey interactions at wildlife crossing structures: Between myth and reality. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester, England, Wiley Blackwell, 190-197.

Mata, C., Hervàs, I., Herranz, J., Suàrez, F. & Malo, J.E. 2004. Effectiveness of wildlife crossing structures and adapted culverts in a highway in Northwest Spain. In: Irwin, C.L., Garrett, P. & McDermott, K.P. eds. *Proceedings of the 2003 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Arkansas, USA*, pp 265-276.

Meisingset, E.L., Loe, L.E., Brekkum, Ø., van Moorter, B. & Mysterud, A. 2014. Targeting mitigation efforts: The role of speed limit and road edge clearance for deer-vehicle collisions. *The Journal of Wildlife Management,* 78(4), 679-688.

Meisingset, E.L., Loe, L.E., Brekkum, Ø., van Moorter, B. & Mysterud, A. 2013. Red deer habitat selection and movement in relation to roads. *The Journal of Wildlife Management,* 77(1), 181-191.

Merrow, J. 2007. Effectiveness of amphibian mitigation measures along a new highway. In: Irwin, C.L., Nelson, D. & McDermott, K.P. eds. *International Conference on Ecology and Transportation. Center for Transportation and the Environment*, North Carolina State University, Arkansas, USA, pp 409-421.

NARRS, n.d. *Great Crested Newt Habitat Suitability Index*. Available from: http://www.narrs.org.uk/documents/HSI%20guidance.pdf [Accessed 6 December 2016].

Neumann, W., Ericsson, G., Dettki, H., Bunnefeld, N., Keuler, N.S., Helmers, D.P. & Radeloff, V.C. 2012. *Biological Conservation,* 145, 70-78.

Orlowski, G. 2007. Spatial distribution and seasonal pattern in road mortality of the common toad *Bufo bufo* in an agricultural landscape of south-western Poland. *Amphibia-Reptilia,* 28(1), 25-31.

Oxford, M. 2000. *Developing Naturally: A handbook for incorporating the natural environment into planning and development.* The association of Local Government Ecologists (ALGE).

Pariss, K.M. & Schneider, A. 2008. Impacts of traffic noise and traffic volume on birds of roadside habitats. *Ecology and Society,* 14(1), 29. Available from: http://www.ecologyandsociety.org/vol14/iss1/art29/ [Accessed 14 October 2016].

Philcox, C.K., Grogan, A.L. & Macdonald, D.W. 1999. Patterns of otter *Lutra lutra* road mortality in Britain. *Journal of Applied Ecology,* 36, 748-761.

Putman, R., Langbein, J., Green, P. & Watson, P. 2011. Identifying threshold densities for wild deer in the UK above which negative impacts may occur. *Mammal Review,* 41(3), 175-196.

Quinn, J.L., Whittingham, M.J., Butler, S.J. & Cresswell, B.W. 2006. Noise, predation risk compensation and vigilance in the chaffinch *Fringilla coelebs*. *Journal of Avian Biology*, 37, 601-608.

Ramsden, D.J. n.d. *Barn Owls and Major Roads: Results and recommendations from a 15-year research project.* The Barn Owl Trust.

Reijnen, R., Foppen, R.P.B. & Veenbaas, G. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. *Biodiversity and Conservation,* 6, 567-581.

Reijnen, R., Foppen, R.P.B., Braak, C.T. & Thissen, J. 1995. The effects of car traffic on breeding populations in woodland. Reduction of density in relation to the proximity of main roads. *Journal of Applied Ecology,* 32(1), 187-202.

Rheindt, F.E. 2003. The impact of roads on birds: does song frequency play a role in determining susceptibility to noise pollution? *Journal für Ornithologie*, 144, 295-306.

Ruxton, G.D. & Colegrave, N. 2006. *Experimental design for the life sciences.* Oxford University Press, Oxford.

Rytwinski, T. & Fahrig, L. 2012. Do species life history traits explain population responses to roads? A meta-analysis. *Biological Conservation,* 147, 87-98.

Sawyer, H., Lebeau, C. & Hart, T. 2012. Mitigating roadway impacts to migratory mule deer – a case study with underpasses and continuous fencing. *Wildlife Society Bulletin,* 36(3), 492-498.

Scottish Government, 2010. *SEA Guidance.* Available from: http://www.gov.scot/Topics/Environment/environmentalassessment/sea/guidance/SEAGuidance/basicguidance [Accessed on 6 December 2016].

SNH, 2016. *Wind farm impacts on bird guidance.* Available from: http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/windfarm-impacts-on-birds-guidance/ [Accessed 3 November 2016].

SNH, 2013. *A handbook on environmental impact assessment: Guidance for competent authorities, consultees and others involved in the environmental impact assessment process in Scotland.* 4th Edition. Scottish Natural Heritage, Inverness.

SNH, 2009. *Guidance Note: Monitoring the impact of onshore wind farms on birds - January 2009.* Available from: http://www.snh.gov.uk/docs/C205416.pdf [Accessed 30 August 2016].

Senzaki, M., Yumaura, Y., Francis, C.D. & Nakamura, F. 2016. Traffic noise reduces foraging efficiency in owls. *Scientific Reports,* 6, 30602. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4989872/ [Accessed 9 December 2016].

Servheen, C., Shoemaker, R. & Basting, P. 2007. Measuring the success of wildlife linkage efforts. In: Irwin, C.L., Nelson, D. & McDermott, K.P. eds. *International Conference on Ecology and Transportation. Center for Transportation and the Environment*, North Carolina State University, Arkansas, USA, pp 409-421.

Shilling, F., Perkins, S.E. & Collinson, W. 2015. Wildlife/Roadkill observation and reporting systems. In: van der Ree, R., Smith, D.J. & Grilo, C. eds. *Handbook of Road Ecology.* Chichester , England, Wiley Blackwell, pp 492-501.

Simpson, J. 2016. BS 42020:2013 – Cracking the Code. *Bulletin of the Chartered Institute of Ecology and Environmental Management: In Practice, 92.* Available from: http://www.cieem.net/data/files/Resource_Library/In_Practice/InPractice92_Jun2016_Simpson.pdf [Accessed 21 November 2016].

Slabbekoorn, H. & Ripmeester, E.A. 2008. Birdsong and anthropogenic noise: implications and applications for conservation. *Molecular Biology, 17(1), 72-83.* DOI: 10.1111/j.1365-294X.2007.03487.x [Accessed 14 October 2016].

Taylor, B.D. & Goldingay, R.L. 2010. Roads and Wildlife: Impacts, mitigation and implications for wildlife management in Australia. *Wildlife Research,* 37, 320-331.

van der Ree, R., Heinze, D., McCarthy, M. & Mansergh, I. 2009. Wildlife tunnel enhances population viability. *Ecology and Society,* 14(2), 7. Available from: http://www.ecologyandsociety.org/vol14/iss2/art7/ [Accessed 28 September 2016].

Ware, H.E., McClure, C.J.W., Carlisle, J.D. & Barber, J.R. 2015. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. *PNAS*, 112(39), 12105-12109.

Wiącek, J., Polak, M., Kucharczyk, M. & Bohatkiewicz, J. 2015. The influence of road traffic on birds during autumn period: Implications for planning and management of road network. *Landscape and Urban Planning*, 134, 76-82.

Wildlife and Roads, n.d. *Wildlife and Roads: A resource for mitigating the effects of roads on wildlife using wildlife crossings such as overpasses, underpasses, and crosswalks.* Available from: http://www.wildlifeandroads.org/ [Accessed 05 September 2016].

Williams, B.W., Etter, D.R., Linden, D.W., Millenbah, K.F., Winterstein, S.R. & Scribner, K.T. 2009. Non-invasive hair sampling and genetic tagging of co-distributed fishers and American martens. *The Journal of Wildlife Management,* 73(1), 26-34.

15. GLOSSARY

Active space	The distance from the sender at which a signal can be detected by a receiver
Confounding factor	A factor that can adversely affect the relationship between the independent and dependent variables
Explanatory variable	A type of independent variable...When a variable is independent, it is not affected at all by any other variables. When a variable isn't independent for certain, it's an explanatory variable
Inferential strength	The ability of an experiment or analysis to adequately / fully answer the question posed
Meta-analysis	The statistical analysis of data collected from multiple studies
Pseudoreplication	When replicated data points are not independent of each other
Zone of influence (ZoI)	The area surrounding a road subject to ecological effects. Also known as the Road Effect Zone (REZ)
Feedback loop	When the output of a process is taken into consideration and used to adjust and improve its performance and response
Biotic	Derived from living organisms
Abiotic	Not derived from living organisms
On line dualling	When a road upgrade conforms to the existing route
Off line dualling	When a road upgrade does not conform to the existing route and a new road is constructed

16. ABBREVIATIONS

AWPR	Aberdeen Western Peripheral Route
BACI	Before After Control Impact
BCT	Bat Conservation Trust
BRC	Biological Records Centre
BSBI	Botanical Society for Britain and Ireland
BTO	British Trust for Ornithology
CCTV	Closed Circuit Television
CEMP	Construction Environmental Management Plan
CI	Control Impact
CIEEM	Chartered Institute of Ecology and Environmental Management
CNPA	Cairngorms National Park Authority
DMRB	Design Manual for Roads and Bridges
DMU	Dry Mammal Underpass
DVC	Deer Vehicle Collisions
EA	Environmental Assessment
ECoW	Ecological Clerk of Works
eDNA	Environmental DNA
EIA	Environmental Impact Assessment
EMS	Environmental Management System
ESG	Environmental Steering Group
FCS	Forestry Commission Scotland
FWPM	Fresh Water Pearl Mussel
HBRG	Highland Biological Recording Group Centre
HRA	Habitat Regulations Appraisal
JNCC	Joint Nature Conservation Committee
NBN	National Biodiversity Network
NESBrec	North East Biodiversity Records Centre
NGO	Non-Governmental Organisation
REZ	Road Effect Zone
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SMART	Specific Measurable Achievable Reliable and Time-framed
SPA	Special Protection Area
SPP	Species Protection Plan
STRIPE	Scottish Trunk Road Infrastructure Project Evaluation
UAV	Unmanned Aerial Vehicle
WeBS	Wetland Bird Surveys
WVC	Wildlife Vehicle Collisions
ZoI	Zone of Influence

ANNEX 1: STEERING GROUP MEMBERS

Name	Organisation	Job Title
Sarah Macdonald-Smart	Scottish Natural Heritage	A9/A96 graduate placement
Yvette Sheppard	Transport Scotland	Environment & Sustainability Manager, Glasgow
Karen Mitchell	Scottish Natural Heritage	Operations Officer, Battleby – covering A9
Nathan McLaughlin	Scottish Natural Heritage	Operations Officer, Dingwall – covering A9 & A96
Keith Duncan	Scottish Natural Heritage	Operations Officer, Aviemore – covering A9
Darren Hemsley	Scottish Natural Heritage	Senior Casework Manager and SNH A9 lead
Sue Haysom	Scottish Natural Heritage	Policy & Advice officer – Ornithologist, Inverness
Rob Raynor	Scottish Natural Heritage	Policy & Advice officer – Mammals, Inverness
Shirley Reid	Scottish Natural Heritage	Operations Officer, Elgin – covering A96
John Altringham	Leeds University	Professor of Animal Ecology & Conservation
Peter Gilchrist	Jacobs Engineering	Director of Operations, Edinburgh

ANNEX 2: SPECIES/GROUPS FOR MITIGATION MONITORING STUDY

Species/Group	Scientific name
Amphibians (General)	*Lissamphibia*
Badger	*Meles meles*
Bats (General)	*Chiroptera*
Beavers	*Castor fiber*
Birds (General)	*Aves*
Capercaillie & Black Grouse	*Tetrao urogallus & Lyrurus tetrix*
Deer	*Capreolus capreolus (Roe) and Cervus elaphus (Red)*
Fresh Water Pearl Mussel	*Margaritifera margaritifera*
Fish (General)	*Osteichthyes*
Geese/Wildfowl (General)	*Ansemni/ Anseriformes*
Great Crested Newt	*Triturus cristatus*
Otter	*Lutra lutra*
Pine Marten	*Martes martes*
Red Squirrel	*Sciurus vulgaris*
Reptiles (General)	*Reptilia*
Scottish Wildcat	*Felis silvestris grampia*
Water Vole	*Arvicola amphibius*
Wood Ant	*Formica aquilonia*

ANNEX 3: DEFINITIONS OF MITIGATION STRUCTURES

Mitigation	Definition
Badger Pipe	A tunnel designed for use by badgers with various specifications and construction materials.
Batrachian Passage	See 'Amphibian Passage' definition.
Box Culvert	A square or rectangular shaped culvert of varying size usually made from concrete.
Culvert	A buried box, pipe or channel structure that allows a watercourse or excess water (surface or subsurface) to pass under infrastructure. Use of structure by animals can vary throughout the year depending on presence or absence of water. Commonly paired with a mammal ledge to ensure safe dry passage at all times of the year.
Dry Ledge	See 'mammal ledge' definition.
Dry Mammal Underpass	A dry tunnel of any shape or size used by most animals (depending on the size).
Sheep/Cattle Creep	See ‘Multi Use Underpass’ definition.
Multi use underpass	A dry underpass used primarily for farm access and livestock with a road or track.
Amphibian Passage	A culvert designed specifically for use by amphibians and reptiles to cross road. May be enclosed or have an open grated roof to allow rainfall to soak culvert substrate. Commonly used by other small vertebrates.
Eco Bridge	See 'Green Bridge' definition
Ecoduct	See 'Green Bridge' definition
Environmental Bridge	See 'Green Bridge' definition
Open Span Bridge	A bridge that extends far beyond the banks of a waterway leaving the immediate area unblocked and undamaged by construction and completely open for any animal to walk under.
Fauna Passage	See 'Tunnel' description.
Fencing	Fencing placed along roadsides or mitigation structures to divert animals away from the road. Fencing specifications vary depending on target species.
Fish Ladder	A fish pass which aids the movement of fish around natural or un-natural barriers.
Fish Passes	A device/structure that ensures the safe and successful passage of fish at all life-cycle stages whilst migrating either upstream or downstream.
Fish Screen	A device to stop fish swimming or being drawn into pipe inlets or outlets.
Gantries	See 'Bat Bridge' definition. Gantries is also a term used to describe a different feature in road construction. Due to this the term gantries will not be used in this report to avoid possible confusion although it is important to note that it remains a

	common and widely used term within ecology, conservation and scientific literature
Green Bridge	An overpass with the primary function of providing wildlife benefit by linking habitats or populations separated by linear infrastructure with soil or other material that allows the establishment of vegetation.
Hop Overs	Mitigation that forces bats to fly over the height of traffic through managing old or planting new vegetation or raising road verges.
Land Bridge	See 'Green Bridge' definition
Landscape Bridge	A Green Bridge over 80 meters wide created solely for wildlife to cross infrastructure with the surface covered or partially covered with vegetation.
Mammal Ledge	A platform fixed to a culvert for use by mammals travelling along the waterway.
Multi Use Overpass	An overpass designed for mixed human and wildlife benefit.
Multi Use Underpass	An underpass designed for mixed human and wildlife use, possibly incorporating a road or track. Commonly used for farm access or for moving livestock.
Overpass	A bridge or other passageway over linear infrastructure
Pipe Culvert	A round culvert of varying size and material.
Reflectors	Reflectors placed along roadsides to divert light onto the nearby verges discouraging animals from the road surface when vehicles are nearby.
Rope Bridge	A rope connecting trees on opposite sides of a barrier to facilitate arboreal animals crossing without having to do so at ground level.
Small Mammal Underpass	A tunnel designed for use by small mammals with various specifications and construction materials.
Tunnel	A dry underpass, round or square, used by wildlife to travel between habitats severed by transportation infrastructure.
Underpass	A passageway under infrastructure
Vegetated Overpass	See 'Landscape Bridge' definition
Viaduct	See ‘Extended Stream Crossing’ definition.
Watergate	A barrier placed across a waterway to prevent livestock and deer from traveling through it.
Wildlife Overpass	The same definition as for a landscape bridge but smaller in size.
Wildlife Shelf	See 'mammal ledge' definition.
Wire Bat Bridge (Wire Bridge/Bat Bridge/ Gantries)	A wire or mesh bridge raised above the road to encourage bats to fly above traffic at specific pre-selected crossing sites.

ANNEX 5: AN INTRODUCTION TO STRIPE

The Scottish Trunk Road Infrastructure Project Evaluation (STRIPE) is a guidance document developed by Transport Scotland for assessment of development projects included within the Scottish Motorway and Trunk Road Programme. STRIPE ensures that post-construction monitoring is carried out on the project in order to highlight any maintenance/construction issues or remediation measures that may require attention, and provides a review framework for the project as a whole. It also provides a method for evaluating the project forecasts, predictions and objectives against actual data collected post-opening. In summary, the STRIPE document acts as a management plan for any trunk road or motorway development. It allows for the review and evaluation of project predictions and outcomes which are fed back into the process through feedback loops to avoid repetition of mistakes.

The STRIPE plan is incorporated into the design process early on and is updated as the project progresses. This makes sure that data collection, funding and other requirements are accommodated. The guidance allows for three separate reviews, if required, one, three and five years after the road is opened. The guidance is split up into sections or objectives, with the environmental objective containing numerous sub-objectives including biodiversity and habitats that investigate mitigation (CH2M HILL, 2016). Most sub-objectives are revisited as part of the Environmental Statement, particularly when a moderate or significant impact was identified or occurred but was initially unforeseen.

The one-year evaluation investigates whether the mitigation measures advised in the Environmental Statement for construction/installation were implemented, if they are performing as expected and if any further action is required. These investigations may not require further data collection except under certain circumstances where public interest is high or initial investigations identify unforeseen problems that require further investigation or remediation.

Evaluations in years three and five may, in some circumstances, require protected species surveys, site inspections, Phase 1 habitat surveys, repeated standard assessments to determine other trends and analysis on WVC data for deer, otter, badger, red squirrel, barn owl, fox, hedgehog or domestic animals (CH2M HILL, 2016). However, this requirement is rarely necessary.

ANNEX 6: START SHEET

Details	Notes
Starting Point	
Starting Step	
Limiting Resource	
Relevant guidance notes or tables	
Other	

Site number (Name & Location)	Species															Mitigation														Approach and Survey Number			
	Amphibians	Badger	Bats (General)	Beaver	Birds (General)	Capercaillie & Black Grouse	Fish (General)	Geese & Wildfowl	Great Crested Newt	Otter	Pine Marten	Red Squirrel	Reptiles	Scottish Wildcat	Water Vole	Green Bridge	Wire Bat Bridge	Hop Overs	Rope Bridge	Culvert	Amphibian Tunnel	Wide Span Bridge	Fish ladder	Fish Screen	Mammal ledge	Tunnel	Reflectors	Fencing	Other:	Approach 1	Approach 2	Approach 3	Approach 4
1																																	
2																																	
3																																	
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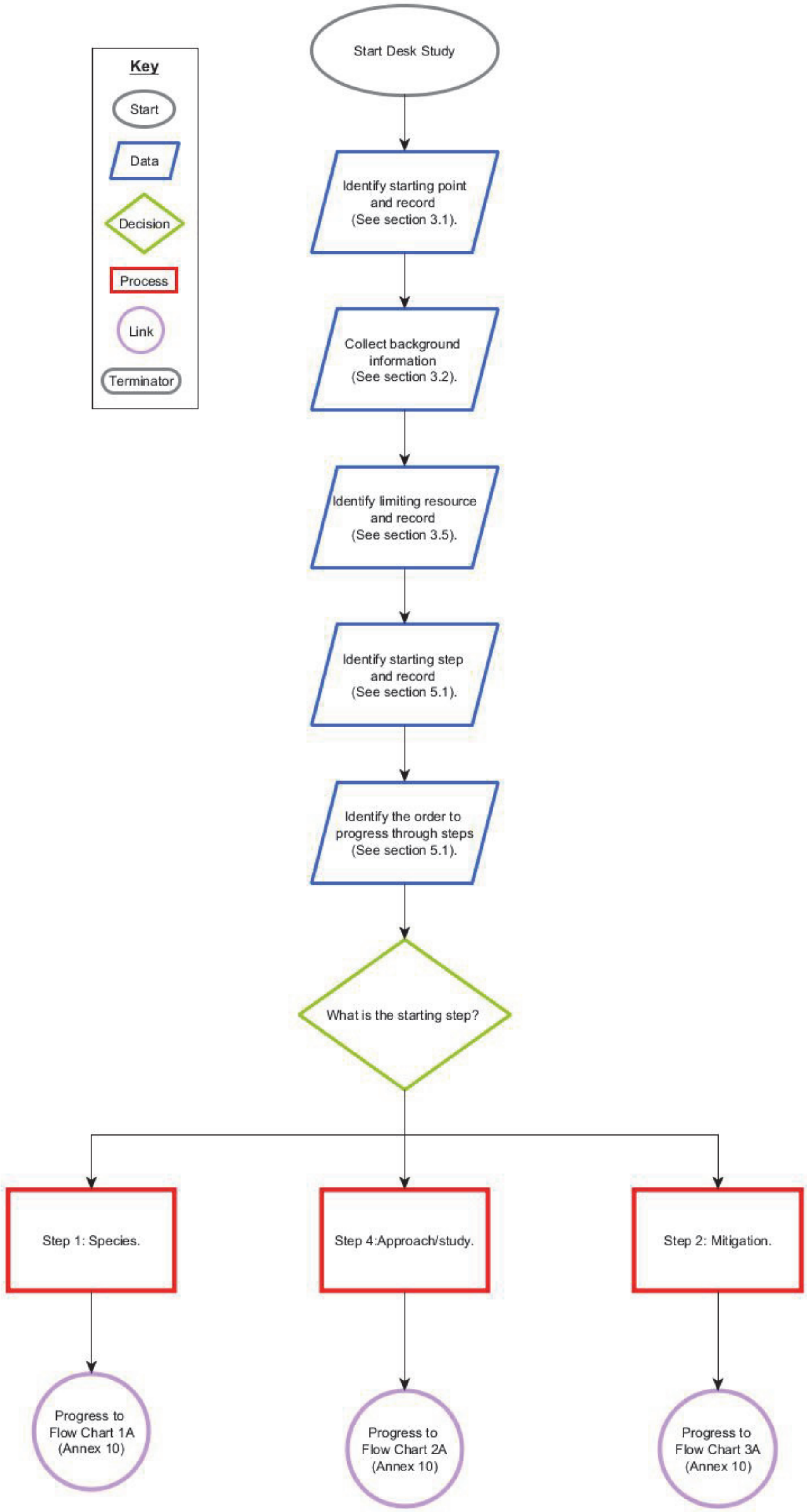
ANNEX 7: DESK STUDY FLOW CHART



ANNEX 8: PROS AND CONS FOR EACH APPROACH

Approach	Pros	Cons
Approach 1	Simple to set up and carry out	Little information gained
	Very little or no statistical analysis (Depending on number of replicates, if any)	Only useful under restricted circumstances
	Can be used as justification for larger, more detailed studies	Provides no population level information
	Not time consuming	
	Inexpensive	
	Simple to replicate	
Approach 2	Relatively simple to set up and carry out	Longer survey duration than Approach one
	Relatively simple statistical analysis	Many confounding factors
	Relatively inexpensive depending on survey methods selected (Step 5)	Low inferential strength (how well the conclusion is supported by the evidence)
	Able to influence future decision making processes	Little information gained that can be used to increase the use of mitigation or identify reasons for lack of use
	Depending on methods used may be used to infer basic behavioural responses towards mitigation, e.g. camera traps to record animal behaviour towards fencing or mitigation	
	Can be used as justification for larger, more detailed studies if desired.	
	Can work out response times for species, e.g. how long before species use a mitigation structure and whether use increases as they grow accustomed to it?	
	Possibly be combined with existing baseline data to gain further insight into population level interactions with the road and/or mitigation	
Approach 3	Can identify which factors may result in reduced use of mitigation, e.g. bats use mixed use underpasses less if artificial light source X is present. Solution may be to remove or change light source or install sensor lights	Cannot be used for single structures, e.g. a green bridge since no replicates are available
	Can identify the type of use (e.g. whether daily, seasonal, or occasional)	More complicated statistical analysis
	Can identify more subtle interactions between species, mitigation and additional factors (e.g. vegetation X planted around underpass entrance increases use by badger or otter display cautious behaviour and approach culvert and then avoid it, etc.)	Large number of replicates needed
	Could be used to infer effectiveness	Higher costs than Approaches one and two
	Can identify key stages when mitigation used, e.g. juvenile dispersal; breeding seasons	Longer survey duration than Approaches one and two
	Identifies key survey durations and times which can inform and reduce costs of future studies	Higher level of expertise required than for approaches one and two
	Information can be used to influence future mitigation decisions	
	Can identify response times for species, e.g. how long before species use mitigation structure and whether use increases with habituation	

	Can be used as justification for larger, more detailed studies	
	Possibly be combined with existing baseline data to gain further insight into population level interactions with the road and/or mitigation	
Approach 4	Can identify the impacts of road effects, e.g. genetic isolation of populations, increased stress, reduced reproductive output	Baselines require planning and/or data collection at pre-construction stages if controls are unavailable
	Improved understanding of how roads and mitigation impact population viability	More sophisticated statistical analysis required
	Can be used for single structures with no need for replication but a large number of data points required (consult a statistician).	Large number of replicates needed
	Can identify key stages when mitigation used by e.g. juvenile dispersal, breeding seasons,	Higher costs than for Approaches one, two and three
	Identifies key surveying durations and times for future studies (reducing costs)	Significantly increased survey duration than required for Approaches one, two and three
	Information can be used to confidently and scientifically influence future decision making for mitigation.	

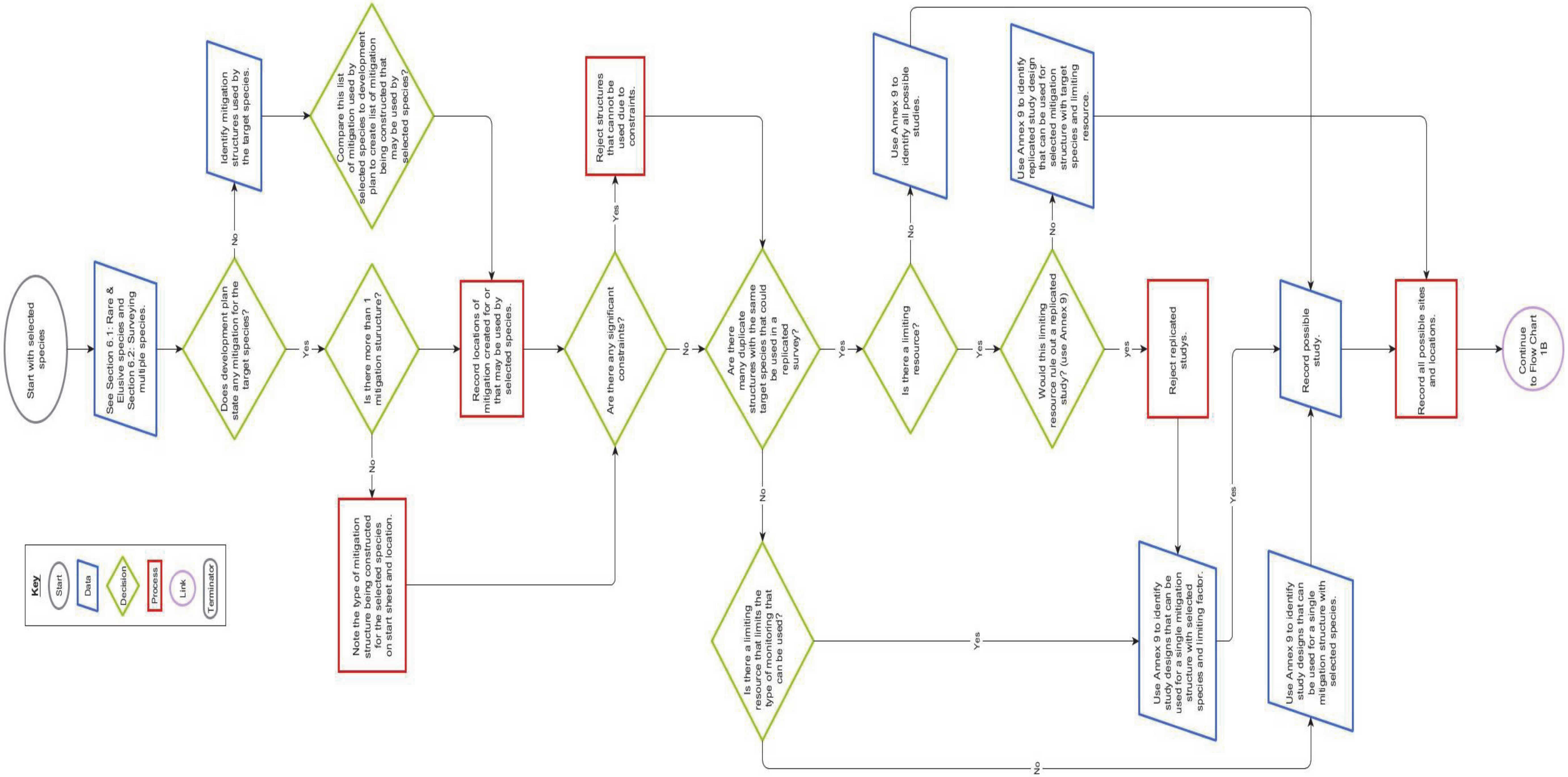
ANNEX 9: GUIDE FOR FLOW CHART

Approach	Study	Survey Number	Definition/Aim	Can Experiment be replicated	Beaver	Scottish Wildcat *	Capercaillie* / Black Grouse*	Reptiles	Water Vole	Geese/ Wildfowl	Fish	Pine Marten	Red Squirrel	Great Crested Newt	Amphibians	Bats	Otter	Badger	Survey Method: Remote Sensing	Track Pads	Hair Traps	Bat Box	eDNA	Other	Experimental Elements: Time Requirement	Financial Requirement	Level of Expertise	Level of Statistical Analysis	Number of Explanatory Variables	Controls or Baseline
Approach 1	Identify Number of Species	1.1	Identify the number of priority species that use the mitigation structure	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Low	Low	Low	Low	Low	N/A
	Identify First Use	1.2	Identify the time between mitigation completion and the first recorded use of the structure by the target species	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Low	Low	Low	Low	Low	N/A
	Replicated Number of Species	1.3	Survey 1.1 repeated to identify if there has been any change in species diversity that could highlight change in species range, recovery of species or local decline/extinction	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Medium	Medium	Low	Low	Medium	Can be compared to pre construction data but not necessary
	Replicated First Use	1.4	Survey 1.2 replicated to gain general averages for time of first use of mitigation for the selected priority species	Y: Can compare the average time of first use between different mitigation structures. This will increase the experimental elements required.	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Low	Low	Low	Medium	High	N/A
Approach 2	Frequency of use	2.1	Identify how often the priority species uses the mitigation structure	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Low	Low	Low	Medium	Medium	N/A
	Behaviour towards mitigation	2.2	Identify how the priority species behaves around the mitigation structure e.g. avoidance	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Medium	Medium	Medium	Medium	Medium	N/A
	Replicated frequency of use	2.3	Survey 2.1 replicated to identify how the frequency of use changes over time e.g. around the clock, seasonally throughout the year	Y: Can compare the average frequency of use between different mitigation structures. This will increase the experimental elements required.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	High	Medium	Low	Medium	High	N/A
	Replicated frequency of use to identify change	2.4	Survey 2.3 but identifying how frequency of use changes in response to stress or other external factor e.g. if mitigation structure undergoes maintenance or traffic speed limit increased	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Medium	Low	Medium	High	High	N/A
	Replicated long term frequency of use	2.5	Survey 2.3 but carried out over a longer period of time to highlight any unexpected changes in frequency of use that may require further investigation	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Medium	Medium	Medium	High	High	Can be compared to pre construction/ historical data but not necessary
Approach 3	Factors that Influence use	3.1	Identifying factors that influence the use of mitigation	Y: Can compare different mitigation structures. Will increase the experimental elements required.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	High	High	High	Very High	Very High	N/A
	Factors that influence behaviour	3.2	Identifying factors that influence the behaviour of a priority species towards mitigation	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	High	High	High	Very High	Very High	N/A
Approach 4	Effects of Roads	4.1	Identifying the effects of roads by monitoring changes in population viability or distribution	Y: Can compare different mitigation structures. Will significantly increase the experimental elements required.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Very High	Very High	Very High	Very High	Very High	Control or baseline will be necessary, both would be preferable
	Effectiveness of mitigation	4.2	Identifying how well mitigation negates the effects of roads	Y: Can compare different mitigation structures. Will significantly increase the experimental elements required.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Very High	Very High	Very High	Very High	Very High	

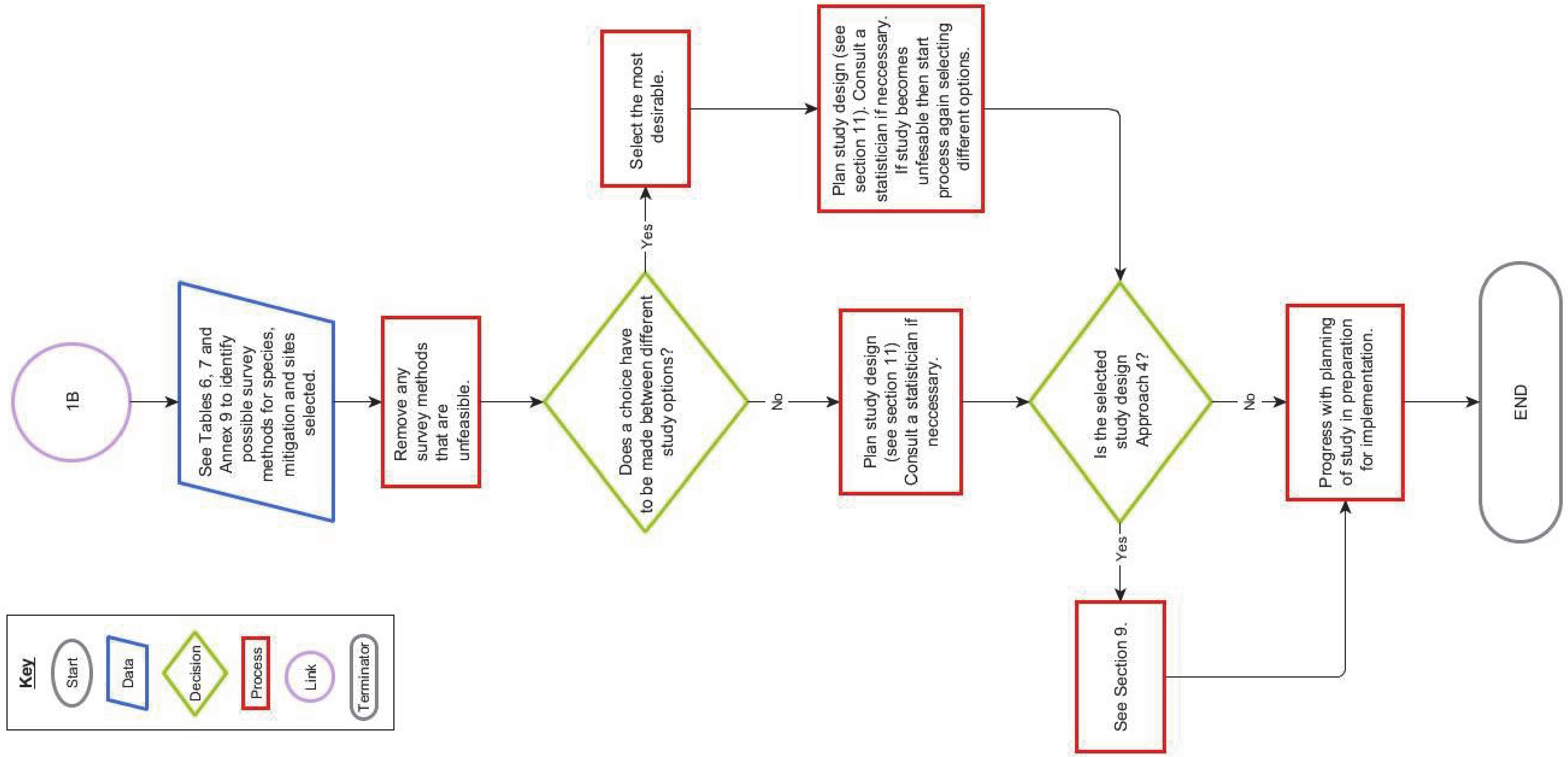
*Species could be used for the selected surveys but their rare and elusive nature would significantly increase the level of resources and expertise with little chance of gaining any robust data or conclusions

ANNEX 10: FLOW CHARTS

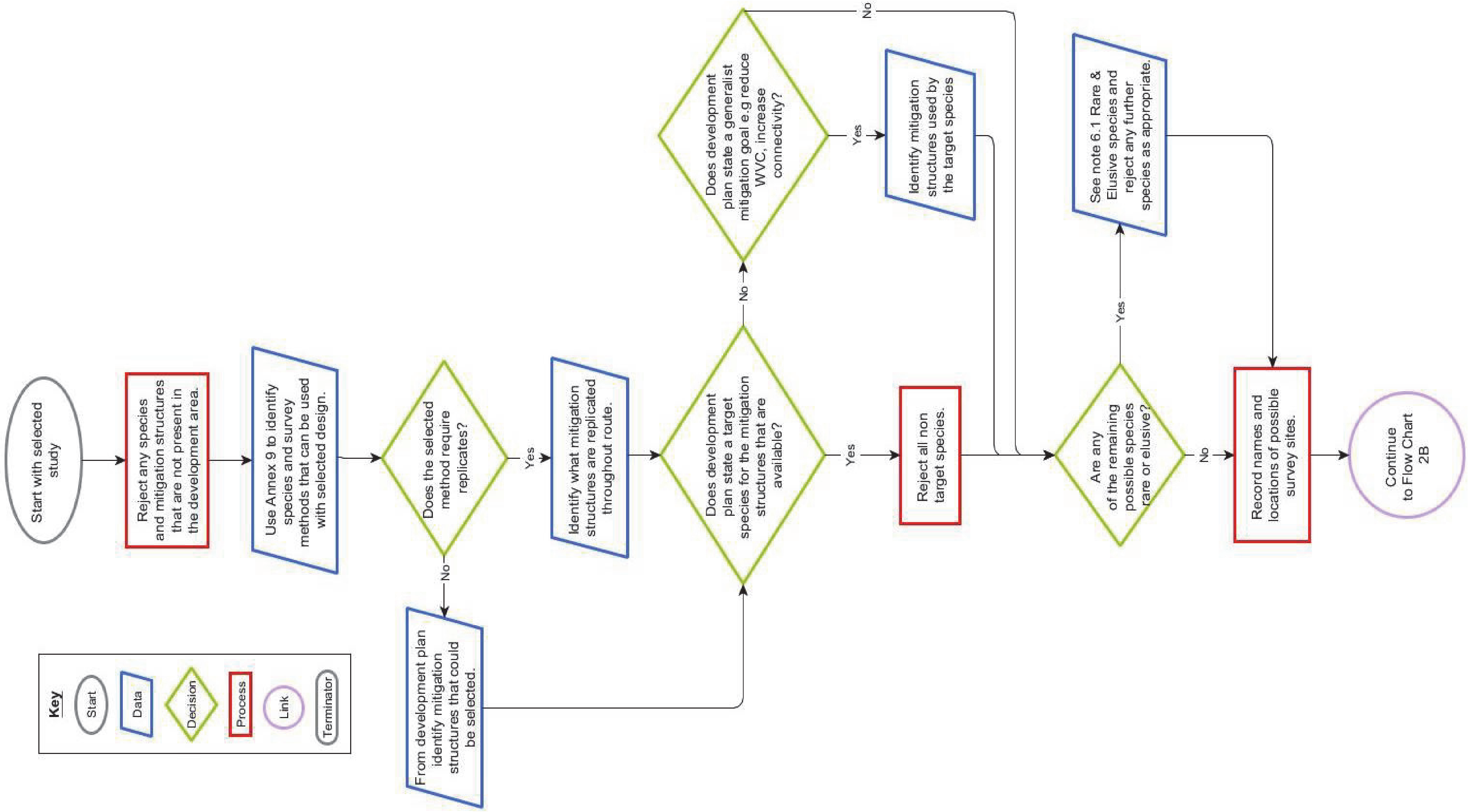
Flow Chart 1A



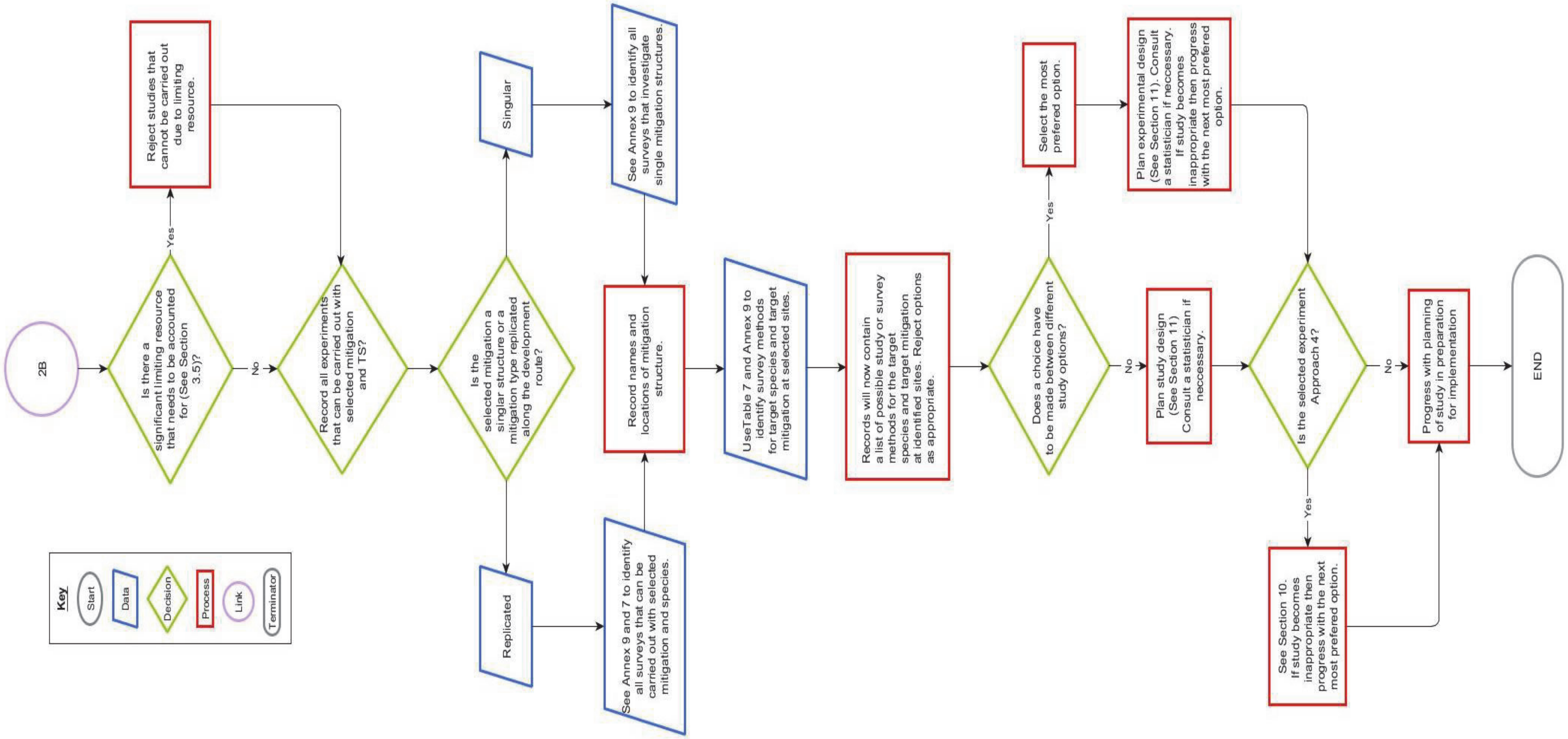
Flow Chart 1B



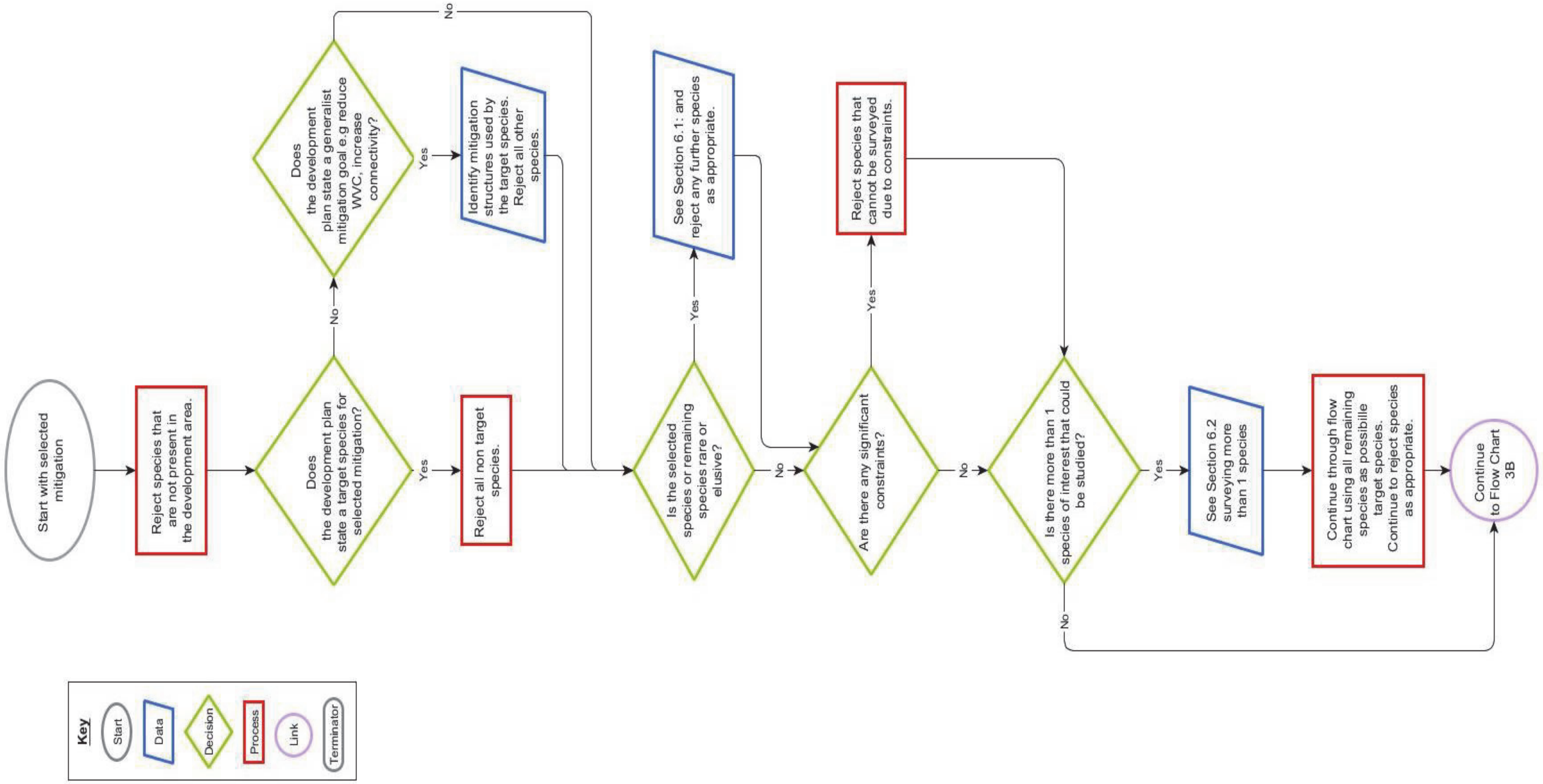
Flow Chart 2A



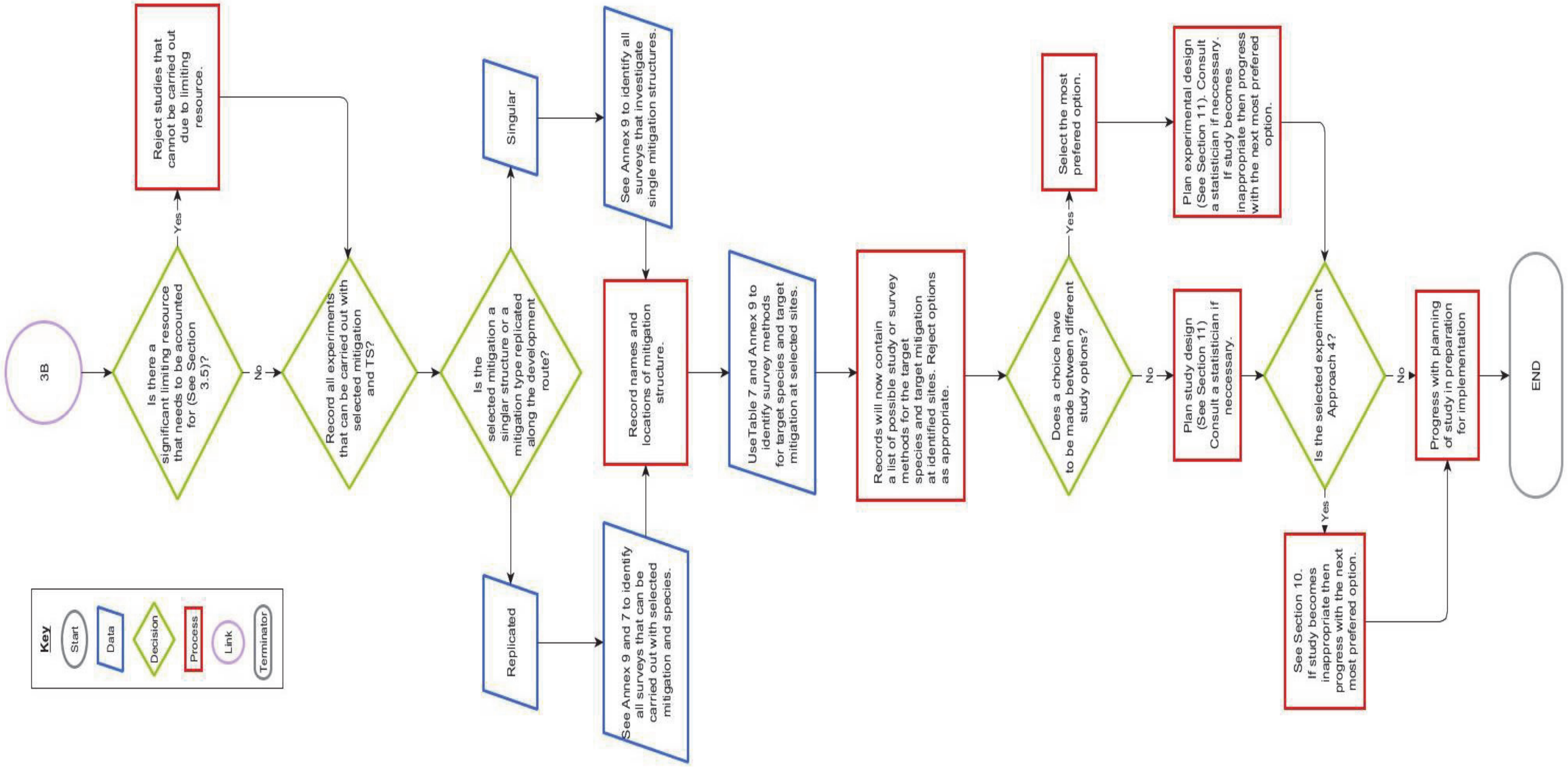
Flow Chart 2B



Flow Chart 3A



Flow Chart 3B



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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
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