Department of Transport and Main Roads

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**Manual**

# Fauna Sensitive Transport Infrastructure Delivery Chapter 3: Ecological monitoring, evaluation, reporting, and adaptive management

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## Key Points

- Monitoring and evaluation assists Transport and Main Roads with meeting commitments and expectations legally and socially, identifying risks to road users and threatened species, and increasing the efficacy of current and future projects.
- The optimal time to initiate, develop and fund a monitoring and evaluation program is during the planning and design stages of a transport project.
- Monitoring and evaluation is an integral step in the process of building an evidence-base for fauna sensitive design choices for future projects as they become business as usual across Transport and Main Roads.
- Monitoring and evaluation programs should be developed using Specific, Measurable, Achievable, Relevant, Time-framed (SMART) questions and aims.
- Strong monitoring and evaluation study designs collect data before, during and after an intervention, at multiple control and impact sites, using multiple lines of evidence and consistent survey methods.
- Information collected from monitoring and evaluation should be shared. Information can include raw monitoring data, research papers, reports, internal memos, lessons learned etc. These could be shared internally, between collaborators, and/or publicly.
- Reporting and sharing results with the community and relevant stakeholders can raise the profile of fauna sensitive transport infrastructure and build community support.
- Information learnt from monitoring and evaluation programs should be incorporated into adaptive management frameworks.

## Contents



### Tables



### Figures



### Case Studies

## 1 Introduction

Ecological monitoring and evaluation of transport projects is undertaken to determine whether the efforts to minimise, mitigate, or offset the ecological impacts of a project have been successful. Rigorous and well-conducted ecological monitoring and evaluation is increasingly a condition of project environmental approvals and is the fundamental basis for evidence-based decision-making. While often considered a relatively straightforward requirement of many projects, monitoring and evaluation programs require careful planning, preparation, and commitment to deliver reliable and useful information.

This chapter is at the start of the *Fauna Sensitive Transport Infrastructure Delivery* manual because the decision to undertake research, monitoring, and evaluation should be made as early as possible in the project lifecycle. For example, the need for monitoring and evaluation could be identified:

- During route planning when the distribution, abundance, movement patterns etc. of a threatened species is unknown.
- During the impact assessment and when the impact of a project on a threatened target species is unknown.
- During detailed design when aspects of the mitigation on its use and effectiveness are unknown, particularly if regulators determine that there is insufficient certainty on the likelihood of success of mitigation.

## 2 What is Monitoring, Evaluation, Research, Review and Reporting?

'Research' and 'monitoring' are often used interchangeably, however they have important differences[1]. In this manual:

- **Research** is the systematic collection and analysis of data or information to better understand a topic or issue.
- **Monitoring** is a specific type of research which involves the repeated measuring of certain variables using the same methods over time.
- **Evaluation** is the analysis and interpretation of the data collected during research and monitoring.
- **Review and Reporting** is the analysis and communication of the raw and/or analysed data, and typically includes reports to Transport and Main Roads, regulators, and the public. This step includes the storage of raw data with relevant metadata, and potentially publications in peer-reviewed scientific journals. It also includes updating processes and procedures as a result of the evaluation.

Monitoring in the context of this chapter is 'the periodic recording of the condition of a feature to detect or measure compliance with a pre-determined standard'[2]. There are three broadly defined types of

[1] (van der Ree et al. 2015)
[2] (Hellawell 1991)

monitoring, with some overlap in their definitions[3], all of which are undertaken to varying degrees in transport ecology:

1. **Curiosity or passive monitoring** is often done through inquisitiveness, and it typically lacks specific questions and experimental study design. The collection of Wildlife-Vehicle Collision (WVC) data by a local citizen on a regularly driven road, or monthly counts of the number of bird species in a local park, are both examples of this type of monitoring.
2. **Mandated monitoring** is a requirement stipulated by regulators and examples include:
   a. Assessing the condition of offset or rehabilitation areas over time.
   b. Quantifying the number of wildlife carcasses within a project area following installation of a crossing structure or fauna exclusion fencing.
   c. Documenting the number of fauna using an underpass or other crossing structure.

   The results of mandated monitoring are often made publicly available, such as on government agency websites.
3. **Question-driven monitoring** sets out to answer a specific question(s). The monitoring of rate of use of wildlife crossing structures by different species over time and the analysis of factors that influence this rate is an example of a common question-driven monitoring program.

Most monitoring on transportation projects in Queensland is best-described as mandated question-driven monitoring, typically required by state or federal government as a condition of approval. Requirements often look like:

- Monitoring the use and/or effectiveness of wildlife crossings on a particular project.
- Actively monitoring crossing structures to ensure connectivity or movement of the target species is maintained.
- Monitoring WVCs.
- Assessing the effectiveness of mitigation measures implemented on projects to apply to future projects or to trial new measures for certain species.

Evaluation, review, and reporting are critical steps in research and monitoring to ensure the results are carefully analysed, understood, and shared with relevant audiences. The timing of reporting to different audiences will vary and often include:

- Within days or weeks of data collection and/or analysis to project teams to ensure timely identification of issues and incorporation of results into routine or adaptive management.
- Six-monthly or annually to regulators.
- Annually to the public.

[3] (Lindenmayer and Likens 2010)

## 3 When is monitoring and evaluation required on transport projects?

Many transport infrastructure projects are likely to require some form of monitoring and evaluation, especially those with potentially significant impacts or when outcomes of the project or mitigation are uncertain. Monitoring and evaluation can range from simple surveys of use of a crossing structure to more complex studies that span multiple years and multiple sites.

Monitoring and evaluation programs can be used to evaluate the effectiveness of managing the priority impacts of a project as identified in the detailed assessment (Chapter 5). Priority impacts should have associated SMART goals. Often priority impacts will be associated with federal or state approvals so monitoring and evaluation will be a requirement of an approval. Priority impacts are often complex, so individual projects may not be able to collect sufficient information for a project-level evaluation, however the monitoring and evaluation should include consistent data collection from multiple projects as this will inform the effectiveness of the overall management of transport infrastructure impacts on fauna.

Monitoring and evaluation programs can also be used to evaluate the effectiveness of specific avoidance, minimisation, or mitigation measures that have been used on a project. The effectiveness of many mitigation measures is often not fully known and increased knowledge on effectiveness can inform future design choices. Where it has been identified that more information is required on the effectiveness of a mitigation measure, monitoring of that mitigation should be included for the project. Targeted research on already completed measures on other projects could also be undertaken to better inform current projects.

The timing of research and monitoring is important and should include consideration of:

- When funding decisions are being made to ensure sufficient funds are allocated and put aside to complete monitoring, even if the project has been completed and project teams disbanded.
- The need to collect data before the transport infrastructure or mitigation measure is constructed (Section 3.4.5).
- The commencement of ‘after’ construction surveys, especially when assessing use and effectiveness of crossing structures. For example, some species may take a few years to locate and begin using crossing structures, and this lag should be considered.

## 4 Implementing effective research and monitoring programs

This section describes the steps and elements to consider when implementing an ecological monitoring and evaluation and further details are available in the scientific literature[4]. Recommendations for monitoring and evaluation should be proposed by suitably qualified ecologists as part of the detailed assessment and impact management process described in Chapter 5.

[4] (Lindenmayer and Likens 2010, Van der Grift and van der Ree 2015, van der Ree et al. 2015)

### *4.1 Overview*

The following outlines the steps involved for implementing an ecological monitoring and evaluation program for transport projects. Each of the steps is described here and important considerations outlined further in Sections 3.4.2 to 3.4.10.

1. **Identify the on-ground management actions:** Chapter 5 describes the process for assessing impacts, developing SMART goals, and determining appropriate management actions (i.e. what are the avoidance, minimisation, mitigation, and offsetting actions being implemented?).
2. **Define the monitoring aims or questions:** Monitoring and evaluation that is a condition of approval will typically include the monitoring aims and/or questions to be answered. Monitoring and evaluation aims should ideally be in the form of SMART objectives and questions (Chapter 5) and this may result in approval conditions being redrafted. Conditions of approval(s) are set by government authorities and the questions are usually developed or identified by Transport and Main Roads and the project ecologist. The monitoring should also aim to collect information for any mitigation measures that currently have insufficient data as identified in Chapter 6.
3. **Develop a conceptual model:** that describes how the ecosystem and management intervention (i.e. avoidance, minimisation, mitigation, offset) operates, including the role of important internal and external drivers (e.g. climate, traffic volume, other development pressures), interactions and uncertainties. The conceptual model can range in complexity from a few dot points or flow-chart to a complex mathematical model derived from real data and/or expert opinion. The conceptual model is important to ensure that all relevant factors that can reasonably be expected to influence the outcome are identified and incorporated in the study design.
4. **Study design:** the target species and methods are identified and then the feasibility of the proposed program is assessed. If it is not feasible to measure the variable of interest with enough accuracy (e.g. target species is too cryptic and not detectable, methods are too expensive, etc.), then this step is repeated until an alternative solution (e.g. new species or survey method) is identified, or monitoring is deemed not feasible. Study designs should specify when and how data is to be collected and will be prepared by a suitably qualified ecologist.
5. **Implement monitoring:** including collection of any before, during and after construction data. An ecologist would be engaged to collect monitoring data.
6. **Data analysis, evaluation, and reporting:** analyse the collected data using appropriate statistical methods to rigorously evaluate the outcomes of the management actions (Section 3.4.9). Ensure the results are reported according to the monitoring and evaluation plan, any conditions of approval and as widely disseminated as possible (Section 3.4.9). The results should inform adaptive or routine management (Section 3.5). An ecologist with expertise in data analysis would provide analysis and a report to Transport and Main Roads for their evaluation of the findings and recommendations. Recommendations may include updates to design specifications.

### *4.2 When in the project lifecycle should a monitoring and evaluation program be developed?*

Development of the monitoring and evaluation program is part of the impact assessment and should be documented in the Environmental Management Plan (Planning) (EMP(P)) as part of the proposed management of the project. It must be included in the EMP(P) for the following reasons:

- The monitoring and evaluation is based on the SMART goals and mitigations proposed.
- Uncertainty due to lack of research or prior use of mitigation measures can be used to guide what evaluation is required.
- Modifications to the design of the transport project to accommodate the monitoring and evaluation can be more cost-effectively made earlier in the project lifecycle.
- Important before or baseline data can be collected while the project is still in planning and design and before any construction commences, including across multiple seasons or years, increasing the reliability of data collected and the inferential strength of the project (Section 3.4.6).
- Additional research partners and funding can be found and 'value-add' components included when identified early in the process.
- Funds for monitoring and evaluation can be included in early business case costings for the project, ensuring sufficient funds and support are secured and available when needed.

It is important to recognise that while 'earlier is always better' when planning and commencing monitoring and evaluation, it is usually possible to still undertake a simplified form of monitoring and evaluation even when commenced later, such as after construction has finished. However, the scope, benefits and cost-effectiveness of later programs will invariably be compromised compared to projects where monitoring and evaluation is fully integrated from the earliest planning and design stages.

### *4.3 Use vs. effectiveness of mitigation measures*

Many conditions of project approvals specify that the use and effectiveness of crossing structures or other mitigation measures need to be 'monitored'. While the terms use and effectiveness are often used interchangeably, there is an important distinction between them.

The **use** of a crossing structure determines which species of animal use the structures and the rate at which they use them.
The **effectiveness** of a crossing structure is the degree to which the structure performs or achieves a pre-determined goal. Effectiveness will more often be related to priority impacts and should relate to the SMART goals for the project (Chapter 5). Use is more directly related to specific mitigation measures and their ability to be used by specific species.

Measuring the rate of use of a structure is an important first step in evaluating effectiveness. If done well, monitoring programs that measure the rate of use can:

- Determine which species are using a crossing structure, the rate at which they are using it, and whether the rate of use reflects the local population abundance.
- Correlate rates of crossing with design variables (e.g. structure width, height, etc.), landscape and environmental variables (e.g. habitat quality, topography, etc.) and road or rail features (e.g. lighting, traffic speed or volume).
- Quantify the degree of interaction among species (e.g. predator and prey species using an underpass at different times of the night) or among species and people (e.g. if use by people reduces use by wildlife).

Measuring effectiveness is the next level of analysis, and in addition to the measures of use above, it should focus on assessing whether the SMART goals of the project have been achieved. These could include:

- Has the rate of WVC and fauna mortality reduced sufficiently?
- To what extent is the population of the target species more viable after mitigation?
- Are there enough crossing structures on this project to ensure adequate movement of individuals and/or gene flow across the road or railway?

In most cases, monitoring should focus on:

- Assessing effectiveness at achieving the management priorities and objectives.
- Identifying optimal sizes, designs and management practices of mitigation measures.
- Assessing rate of use of crossing structures and other mitigation measures by rare and ‘under-studied’ species.

### *4.4 Developing and testing new innovations*

There is often some uncertainty about the most effective option to avoid, minimise, mitigate, or offset an impact. Where possible, different options should be tested as part of the project, enabling a robust comparison of the costs and effectiveness of each alternative. In some situations, new solutions can be tested off-site or on captive animals[5], and in other situations a project may be sufficiently large to implement a comprehensive program. However, many projects are too small to be able to include enough sites and thus collaboration across projects and jurisdictions is needed (Section 3.4.7).

For example, let’s assume the optimal width or height of a culvert for a certain species is unknown. It may be feasible on a project with multiple culverts to install half at the standard size and the remainder slightly taller or wider. Other culverts for drainage could potentially be modified slightly to represent a smaller size-class. Provided the study is well-designed and includes sufficient monitoring post construction, the project can meet conditions of approval (i.e. all dedicated fauna culverts are standard size or larger) as well as provide reliable evidence about the relative importance of the size of the culvert. This will reduce uncertainty on all future projects where culverts are installed for that species, and potentially inform the design for similar species. Note that due to site, species, condition etc.

[5] (Hamer et al. 2014)

variability, results may differ among projects and a level of uncertainty will remain. This uncertainty can continually be reduced with the replication of studies over time.

This experimental approach can be used in a variety of contexts, including:

- Determining how much habitat is required on the approach to crossing structures by varying mowing or pruning regimes over time.
- Investigating if koala escape poles should be made of natural salvaged trees or reclaimed power poles, and if design ‘A’ is better than design ‘B’.
- Determining how much street lighting near a land bridge, canopy bridge, or glider pole is too much and reduces use by fauna.
- Understanding if nest boxes, salvaged log hollows, carved hollows or 3D-printed hollows are preferred by a target species.

### *4.5 Scientific study design*

The most informative monitoring and evaluation programs have scientifically rigorous study designs that maximise inferential strength. Inferential strength (also referred to as statistical power) is the ability to identify an impact or response from the collected data if such an effect exists. Good study designs measure the variable of interest (e.g. population size, crossing rate, mortality rate, etc) Before and After an intervention (e.g. before or after road or rail construction) at both Control and Impact sites. Impact sites are those where the intervention occurs (e.g. where the crossing structure or other mitigation measure is installed) and Control sites (also known as reference sites) are areas that are as similar as possible to the impact site but are otherwise unaffected by the intervention. Control and reference sites may vary depending on the design of the monitoring program and could include areas of similar habitat with no roads, existing smaller roads, existing smaller culverts etc. Measurements may also be taken During an intervention. These are often referred to as Before During After Control Impact (B(D)ACI) study designs. A critical step in all Before and After studies is to gather enough data using identical methods before and after the management action has occurred.

THE CHALLENGES OF USING RESULTS FROM PLANNING INVESTIGATIONS WHEN EVALUATING MITIGATION EFFECTIVENESS

It is rare that data collected during planning and investigation stages of projects can be used as the ‘Before’ data in a before-after evaluation program because:

- The objectives of planning studies and monitoring and evaluation are usually very different, and unlikely to use identical methods.
- Timing: there may be several years between planning and when construction starts, and conditions may change.
- Replication: planning studies are typically focussed on locations that inform project planning and design, and replication and control sites for long-term monitoring are not typically considered.
- Key uncertainties that inform the monitoring are often identified through the planning and design, usually after the surveys have been completed.

The following tips may assist in using data collected during planning and design as ‘before’ or ‘baseline’ data:

- If possible, identify uncertainties before commencing field surveys, and design the field survey AND the monitoring and evaluation program to be complimentary and be part of the same program.
- Conduct fauna surveys during planning investigations using standard field techniques, and carefully document survey effort, enabling others to replicate methods more closely.
- There are statistical methods which enable greater use of already-collected data, such as Bayesian approaches and the use of meta-analyses. Engage ecological statisticians for expert advice.
- Potentially suitable baseline data may be available from other locations, studies, or projects. Engage broadly with consultants, researchers, academics, Transport and Main Roads, and regulators to identify potentially suitable existing data sets.

Another key consideration in study design is to have Control or reference sites, which remain unimpacted by the treatment or intervention (e.g. road construction, installation of a crossing structure, fencing). Control sites are very helpful when identifying changes that occur due to the intervention compared to changes that occur due to background environmental factors. In the following hypothetical example, a suite of existing drainage culverts was modified with ledges to allow terrestrial wildlife to use them. Monitoring was conducted before and after the ledges were installed and showed a doubling of the rate of use. However, the study coincided with the breaking of a long-term drought and culverts without ledges were also being used by wildlife to cross beneath roads. Without control or reference sites (i.e. culverts where ledges were not installed), an incorrect conclusion about the effectiveness of ledges would be drawn.

Identifying and managing control or reference sites for the duration of the monitoring program can be challenging along railways and major roads because:

- Maintenance requirements to maintain safety standards may over-ride the needs of the monitoring.
- Road reserves are also used by other utilities such as powerlines and pipelines, and maintaining those will likely take precedence over the design of the monitoring.
- Numerous random events can also occur, such as wildfires, interference by community members, management mistakes, etc.

Despite these challenges, control and reference sites in monitoring and evaluation are immensely valuable and attempts should be made to identify and maintain them to increase the reliability of the outcomes. Where controls are not feasible, collection of before and after data becomes more important, as does the value of replication.

Replication (i.e. number of sites) is also critical in improving the reliability and transferability of the results and insights. For example, if only one culvert was studied and no animals were found to use it, the researcher is not able to confidently determine if the problem is associated with the design of that single culvert, its location, or something else. However, conclusions can be drawn about the suitability of the failed culvert if multiple culverts were studied and the occurrence of the target species in adjacent habitat was also investigated. The results can also be more confidently applied to other scenarios.

Much has been written about study designs in transport ecology[6] and more detailed guidance is available.

### *4.6 Optimal methods and survey effort*

There are often many ways to collect data to answer the questions posed and each method has different costs, efficacy, and accuracy (see Appendix A). For example, the rate of use of a wildlife crossing structure can be measured using cameras, PIT tags, sand-tracking, inkpads, radio / GPS tracking, capture-mark-recapture, genetic analyses, etc. Emerging technologies, such as artificial intelligence, drones, eDNA etc. could also potentially be used. The cost and accuracy of each method varies, and all options should be considered before deciding. Appendix A describes the various field survey techniques that can be used and some of the pros and cons of each technique.

Many monitoring programs fail to meet their objectives because insufficient data was collected to confidently draw conclusions. While inferential strength (Section 4.5) is largely dependent on study design, survey effort is also relevant. For example:

- One roadkill survey per month may be insufficient to detect mortality of a cryptic species that are difficult to see on the road – twice-weekly may be required to account for removal of carcasses by scavengers.
- Surveys may need to be undertaken each season to ensure the population is adequately sampled.

[6] (Rytwinski et al. 2015, Van der Grift et al. 2015, Van der Grift and van der Ree 2015, van der Ree et al. 2015)

- Multiple survey techniques will be required to detect all species groups (e. g. mammals, birds, reptiles, amphibians, invertebrates) using a crossing structure.
- Multiple survey techniques may be required to decrease the risk of failure of the monitoring and evaluation program (Case Study 3.).

***Case Study 3 – Using multiple approaches to evaluate the effectiveness of canopy bridges for squirrel gliders***

Highways are a major barrier and cause of mortality to arboreal animals, including squirrel gliders *Petaurus norfolcensis*[7]. In response, hundreds of canopy bridges and glider pole arrays have been built for arboreal animals across Australia. The simplest approach to measure use by fauna is to install cameras on one or both ends of the bridge and count the number of times a possum or glider is detected. With a focus on the threatened squirrel glider, researchers worked with VicRoads (now Major Roads Projects Victoria (MRPV)) and the NSW Roads and Maritime Services (now Transport for NSW (TfNSW)) to evaluate the use and effectiveness of multiple canopy bridges and glider poles. They used the following survey techniques in a replicated before-during-after-control-impact study over seven years:

- Remotely-triggered cameras on canopy bridges and glider poles to record crossings.
- Radiotracking of individuals to measure movements and home range size.
- Collection of genetic material to determine the dispersal of individuals and changes in gene flow.
- PIT tag readers installed on canopy bridges to detect use by micro-chipped individuals.
- Capture-mark-recapture using cage-trapping at sites with and without crossing structures to estimate population density and relate this to crossing rates.

The results[8] demonstrated that:

- Large trees in the centre median were more effective at maintaining connectivity than canopy bridges or glider poles.
- Multiple individuals frequently crossed most canopy bridges and glider poles over a five-year period.
- Gene flow increased after mitigation.
- Few (if any) instances of successful predation of animals using the crossing structures were detected.
- Crossings were part of home range movements as well as dispersal movements.
- Adult survival rates were similar at highway sites and low-volume gravel roads.

One of the many strengths of this research was the use of multiple survey techniques. Combined, these techniques present an overwhelming body of evidence to guide future

[7] (McCall et al. 2010, van der Ree et al. 2010)
[8] (Soanes et al. 2013, Soanes et al. 2015, Soanes et al. 2017, Soanes et al. 2018)

mitigation for possums and small gliders, including the maintenance of canopy connectivity, and installation of canopy bridges and glider poles to facilitate crossings across wide roads.

***Figure 4.6 – Survey techniques installed on glider poles and canopy bridges (left) a passive infra-red camera; (middle) an active infra-red camera and (right) a PIT scanner.***

Source: © Rodney van der Ree, WSP.

### *4.7 Collaborating across projects and jurisdictions*

Many transport infrastructure projects are relatively short in length and the number and diversity of mitigation measures per project are constrained by the size and design of the project, which limits replication and statistical power. One way to increase the robustness of monitoring and evaluation is to collaborate across projects and jurisdictions. For example, the monitoring programs of two transport projects with five wildlife underpasses each is relatively small, but when combined they have a sample size of ten underpasses, increasing inferential strength.

When monitoring and evaluation programs are being developed for a project, completed and ongoing monitoring at other locations should be reviewed to ensure that subsequent programs are collecting compatible data for combining into larger datasets.

All monitoring data collected on Transport and Main Roads projects will be centrally stored by Transport and Main Roads. This data will be made available to external parties on demand.

Where monitoring and evaluation priorities align and are well understood, collaboration can also take place across jurisdictions, such as across state boundaries, levels of government and even among contractors. Many local governments in Queensland are actively implementing Fauna Sensitive Transport Infrastructure Delivery (FSTID) projects and opportunities exist to co-design and cost-effectively undertake research and monitoring.

### *4.8 Monitoring program logistics*

Many long-term monitoring and evaluation programs struggle because the basics have not been managed appropriately. These include:

- Ensuring the program has both a ‘champion’ and a ‘committed team’ within Transport and Main Roads to oversee the program. This is important to ensure Transport and Main Roads meets their approval obligations and to support research that sits outside a project approval.
- Ensure the fieldwork, data storage and analysis are carried out to a high and consistent standard over time.
- Ensure the methods are clearly documented and strictly followed to ensure identical methods are used to collect all data. Where possible, the same people should be engaged to collect the data for the same reasons.

- Having external expert review of study designs prior to commencement to identify any issues or shortcomings.
- Allocating sufficient resources to the project, including time, funding, and sites for the life of the monitoring period.
- Ensuring there is regular and frequent reporting and dissemination of results, enabling rapid integration of findings into management and to inform future projects.

### *4.9 Evaluating, reporting, and using the findings*

All research and monitoring programs should include data evaluation and reporting to ensure conclusions are accurately drawn and disseminated to relevant stakeholders. Relevant stakeholders can include Transport and Main Roads, researchers, consultants, government regulators, community members, and special interest groups.

Data evaluation should use contemporary analysis and modelling approaches to ensure the findings reflect the data. Deep insights and understanding are possible if a project has a scientifically robust study design, adequate replication, and reliable analytical techniques. However, analytical methods also need to be understood by stakeholders to maximise effectiveness and a balance between the complexity of analysis, and applicability of findings needs to be struck. This challenge can be overcome by effective science communication from researchers.

The minimum reporting requirements should be specified in the monitoring plan and at a minimum should include:

- Raw data.
- Survey and analytical methods.
- Summarised results and findings.
- Discussion of what the results mean and recommendations.

Where consultants and researchers (including students) are engaged, they should be encouraged to publish the findings in peer-reviewed journals, thereby ensuring a minimum acceptable scientific standard and importantly, dissemination of the findings to a global audience. This dissemination can be useful for future projects even outside of linear transport and Australian contexts (e.g. species abundance estimates can be useful for future infrastructure projects in the area, crossing structure designs could be implemented in other countries etc.).

Publications could include:

- Scientific peer-reviewed papers.
- Transport and Main Roads documents such as project reports, guidance notes, manuals.
- Raw data.

These can be published to:

- Scientific journals, public-facing websites, news articles.
- Shared databases including BioNet, Wildnet, etc.
- Internal and external reports
- Social media stories, lessons learnt and outreach.

A key determinant of the success of monitoring programs is the regular and frequent use of findings. Regular reporting and interrogation of research and monitoring results increases the profile of the project among decision-makers, reducing the likelihood that funding may be cut. The regular integration of findings into routine and/or adaptive management reinforces the utility and value of research and monitoring, thereby increasing the likelihood that future projects will be supported. Most importantly, the findings should be used to update best-practise and ensure future projects implement the most cost-effective approaches and methods to achieve fauna-sensitive transport infrastructure.

### *4.10 Data sharing and meta-analysis*

All research and monitoring should be published with enough detail to enable its use in research including meta-analyses. A meta-analysis is where the results of many studies on a similar topic are identified, systematically reviewed, and combined into a single data set for a larger analysis or synthesis. Meta-analysis is not a simple review where the number of studies showing different results is summarised. Rather, each result in the many studies becomes a new data point in a larger study and new analysis. For example, a recent study[9] used meta-analysis to evaluate the effectiveness of road mitigation at reducing roadkill. They extracted and analysed data from 50 relevant studies from around the world and concluded that fencing and crossing structures led to an 83% reduction in roadkill of large mammals. In contrast, they found reflectors achieved a 1% reduction in roadkill.

Not all published studies can be included in a meta-analysis. Out of 140 studies they found[10], only 50 were an appropriate study design and provided enough information and data to be used in the formal meta-analysis. And for many species groups and mitigation types, there was insufficient data to conduct meaningful tests. To improve future meta-analyses, they recommend:

- All future studies include the collection of data before and after the intervention.
- Before-After studies should have a minimum duration of four years (and not necessarily in the first 4 years immediately after construction, to allow time for vegetation to become re-established and fauna to become accustomed to the structures) and ideally longer.
- B(D)ACI studies run for a minimum of four years and ideally longer or have at least four sites.
- At a minimum, studies should include the sample size, means, and associated variances (e.g. standard deviation, standard error).
- Raw data sets are saved in online repositories.
- Detailed descriptions of the methods, road and traffic conditions, mitigation measures, landscape, etc. are provided.
- Consistent survey methods are used among studies to increase data comparability, and whichever methods are used are fully described, including survey method and effort, duration, target species, etc.

## 5 Adaptive and routine management

Information learnt through monitoring and evaluation should be used to inform adaptive and/or routine management. Adaptive management is a formalised approach to monitoring and evaluation that

[9] (Rytwinski et al. 2016)
[10] (Rytwinski et al. 2016)

includes a feedback loop to update and improve project or program management. There is an expectation in adaptive management that the results will trigger an evaluation of management effectiveness and result in an update of what is considered ‘best-practice’. Example scenarios of when adaptive management might be used are provided in Table 5.

In contrast, routine or ‘business as usual’ management is where the results of monitoring trigger a management response, such as fence repair, revegetation, re-attaching a canopy bridge feeder rope after failure, or de-silting a culvert. Monitoring and evaluation that informs routine management may result in improvements to practice based on anecdotal findings, but it typically lacks the rigour to trigger adaptive management because formal learning is not explicitly a goal.

Changes to management activities are sometimes called ‘adaptive management’ when a problem or opportunity to improve was informally identified by chance. For example, an ecologist may notice an area for improvement and after informing Transport and Main Roads, a change in management is made. This results in an adapted management procedure, but it falls outside the formal ‘adaptive management’ cycle because the need to adapt management was informally identified. Whilst an absence of previous monitoring may make it more difficult to identify the required changes, a flexible management approach is likely to yield the most successful results and should be considered.

***Table 5 – Examples of when adaptive management may be required.***

| WHEN ADAPTIVE MANAGEMENT MAY BE REQUIRED | EXAMPLE SCENARIO AND POTENTIAL ADAPTIVE MANAGEMENT APPROACH |
|---|---|
| When the objectives and priorities of management are not being met. | A crossing structure has not been successful at facilitating the movement of the target species as predicted. Adaptive management might involve changing the environment around the crossing structure (i.e. modifying a street light to reduce levels of Artificial Light at Night (ALAN) or adding features to the crossing structure (i.e. habitat furniture in a culvert). |
| When objectives are met but there is room for improvement. | A fence constructed along a road has reduced, but not eliminated, the rate of WVC. To reduce the number of WVC even further, adaptive management may consider alterations to the fence design to make it better suited to its intended purpose. |
| When there are unexpected findings that were not previously considered. | Monitoring reveals that a road underpass is facilitating the movement of a target species, as well as a predatory species. Adaptive management may consider trapping regimes to reduce the number of predators in the area, or alterations to the underpass that will provide more protection to the target species. |
| When new technology, data, information or research becomes available that would benefit the monitoring program. | Over time, new research may discover a better way of creating an underpass that produces more successful results. Such discoveries should be incorporated into ongoing management to ensure the best possible outcomes are being achieved. |

## 6 Monitoring and evaluation checklist and scenario testing

Use the checklist in Table 6 prior to commissioning or commencing a monitoring and evaluation program to ensure it meets all the necessary requirements to be successful and meets the needs of Transport and Main Roads. The checklists should also be used by ecologists developing and/or implementing monitoring and evaluation to ensure they achieve their objectives.

The checklist was used to develop a monitoring and evaluation program for the following hypothetical situation: An existing two-lane road which passes through a protected area that contains greater gliders, is being upgraded to four lanes with a wide grassy median. The size of the gap in canopy after the road widening will be approximately 80 metres, which exceeds the glide capability of the greater glider. The project is likely to fragment the population of greater gliders and lead to increased mortality from WVC as gliders attempt to glide across the road. A condition of approval was the inclusion of eight arrays of glider poles along the 1 km section of road, and they be monitored for three years to evaluate success.

An ecological consultant was appointed halfway during construction to undertake the monitoring as per the condition of approval. The following checklist describes the many considerations, decisions, and compromises the consultant made to implement the monitoring and evaluation program.

The checklist is a useful due-diligence process and should be documented and provided to Transport and Main Roads when proposing a monitoring and evaluation program.

***Table 6 – Example of the use of a due diligence checklist prior to commencing a monitoring and evaluation program and at hold points to evaluate the success of a mitigation program for greater gliders***

| CRITERIA | NOTES |
|---|---|
| **Monitoring and evaluation planning and design** | |
| Has an impact assessment and conceptual model of the system prepared? | Yes. Three ecologists with expertise in greater gliders prepared the impact assessment, which included the following conceptual model of how greater gliders live around major roads. Greater gliders are expected to be able to live in habitat near the road. Major threats are mortality from WVC (gap-crossing distance estimated to be 40 metres) and inbreeding due to fragmentation. Greater gliders are expected to use the glider poles, but use of glider poles to cross roads has not been demonstrated. The road is expected to form home range boundaries because greater gliders eat eucalypt leaves which are distributed evenly across the forest and they are not expected to need to cross the road daily. |
| Are the aims / objectives / questions sensible, important, and necessary? | The specified aim is to determine if the mitigation was 'successful'. Success was not defined in the condition of approval or the planning documentation, but it was interpreted to mean "do Greater Gliders use the glider poles to cross the road?" It is an important and sensible question to ask because little is known about the use of crossing structures by greater gliders. |
| Are the aims / objectives / questions clearly articulated? | No. The consultant refined the project objective to be: greater gliders regularly and safely cross the road using the glider poles. This is to be measured by use of the poles and no reduction in the density of gliders anywhere across the forest area. |
| Is the program determining the 'use' or 'effectiveness' of mitigation, or both? Has scaling up to assess effectiveness been considered? | The condition of approval was just to focus on measuring the rate of use of glider poles by greater gliders. However, greater gliders may be crossing the road elsewhere, potentially unsuccessfully and resulting in WVC. Transport and Main Roads have agreed that it is important to understand if gliders are crossing and/or dying elsewhere along the road. |

| | |
|---|---|
| Has review of existing studies been conducted? Is monitoring necessary? | Yes. A review of the peer-reviewed and grey literature confirmed that while crossing structures for greater gliders have been built on a small number of projects, there has been no comprehensive evaluation of the use of those structures by greater gliders. Therefore, information from this monitoring and evaluation program is important to evaluate success of this project and inform the planning and design of future projects. |
| Has the target species for mitigation and for monitoring and evaluation been identified? | Yes – greater gliders are the focus of mitigation and the monitoring and evaluation. In this project, the population of greater gliders adjacent to the road is high, and thus there are lots of animals to study. If the greater glider population was small, a surrogate species (perhaps squirrel gliders) might need to be used as an indicator. If there are no other glider species, and the greater glider population is very small, some aspects of the monitoring and evaluation program may not be feasible. |
| Has sufficient funding and resources been allocated to all aspects of the monitoring and evaluation? | Yes – because it is an endangered species, Transport and Main Roads have committed to obtaining high-quality data for a long enough period of time. |
| **Survey methods** | |
| Are the field methods appropriate (e.g. timing and duration of surveys, optimal survey technique for target species and questions posed). | Greater gliders can be detected on the glider poles using remotely-triggered cameras. Cameras are solar powered and will send images via the cellular network. Greater gliders can be surveyed in the forest around the road using spotlighting and/or thermal cameras on drones to estimate population size / density and whether there is an effect of road presence on density. DNA samples will be collected by climbing den trees and placing double-sided tape around hollow entrances to estimate gene flow and relatedness over time across the road. If enough gliders can be captured (this is uncertain), tracking using GPS transmitters to measure the rate and location of road-crossing is feasible. Surveys of mortality from WVC are not feasible because:<br>• A low-likelihood of WVC occurring.<br>• Dead gliders are difficult to detect because they may be thrown off the road, attached to the front of vehicles or quickly damaged.<br>• The road will have high traffic volume and speed, meaning surveys on foot or from slow-moving vehicle are not safe to conduct. |
| **Study design** | |
| Is the study design robust? Can conclusions be confidently drawn? (e.g. experiments, B(D)ACI, adequate replication, peer review of study design). | No ‘before upgrade’ data on population size was collected so a B(D)ACI design is not feasible. However, there are other areas of similar forest type and area that contains greater gliders that can function as control areas for comparisons of population density and glider movement patterns – thus enabling a control-impact study design. |
| Have opportunities to collaborate with other jurisdictions to improve study design been considered and explored? | There are numerous road and rail projects interstate and the responsible agencies there have agreed to use the exact same methods. Despite the monitoring being conducted by different consultants and commence at different times, the results can be pooled for subsequent meta-analysis. |

| **Evaluation** | |
|---|---|
| Are the data analysis methods adequate / state of the art? Does the project team have adequate data analysis expertise? | Yes. The consultant has engaged an experienced bio-statistician who reviewed the study design and data being collected and has confirmed that the data will be able to answer the questions being posed. The same bio-statistician will be engaged throughout the project to analyse the data using current techniques. |
| **Reporting** | |
| Are the reporting timelines and methods adequate? Can results be made available to inform management in timely manner? | Reports to Transport and Main Roads and the regulator are required at 6- and 12-monthly intervals, respectively. This is adequate to ensure any declines in population size can be detected and additional mitigation measures implemented. |
| Have the minimum standards for data reporting been stipulated? | Transport and Main Roads have stipulated that the reporting is to include supply of the raw data along with all necessary metadata to enable meta-analysis at a later date. |
| Will the findings be written as a report, scientific paper, or both? | The consultant will prepare reports to Transport and Main Roads and the cost to prepare a peer-reviewed will be shared by the consultant and Transport and Main Roads. |
| Has storage of raw data and meta-data been planned and agreed? | Yes. Raw data will be uploaded to I-naturalist, Qld fauna database and provided to Transport and Main Roads. The final payment for the project is contingent upon this being done. |
| **Management** | |
| Have the routine or adaptive management responses to different results been identified? | Yes. Routine maintenance will include structural assessments of the glider poles. Adaptative management will depend on the impact that has been identified. For example, mortality away from glider poles will be addressed by installing additional poles. Alternative design options for poles have been identified. |
| If adaptive management, has the full adaptive management cycle been developed? | Not fully. It is unknown what the minimum population density or crossing rate is required to maintain a viable population. Results from this project, plus the two additional projects in other states will be combined to inform future projects. |
| Have the responsible Transport and Main Roads reps for management response been identified (local, head office)? | Yes – the local project office for management, in consultation with head office. |

## 7 Audits and surveillance monitoring

Audits and surveillance monitoring is different to ecological monitoring and evaluation and is intended to answer questions about whether a specific construction or maintenance standard has been achieved. These questions could include:

- Is the mitigation measure built as planned and designed?
- Has all clearing been within approved clearing limits?
- Is sedimentation fencing and temporary construction fencing intact and functioning?
- Are Tree Protection Zones (TPZ) being complied with?

- Is the fauna fencing being inspected and maintained as required?
- Have the poles for the canopy bridges and glider poles been inspected as specified?

These are described fully in Chapter 7 and Chapter 8.

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