Appendix 1 to the Evidence of Colin Francis John O'Donnell
Department of Conservation, Mt Messenger Bypass Hearing

Effects of land transport activities on New Zealand's endemic bat populations: reviews of ecological and regulatory literature

October 2017

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NZ Transport Agency research report 623

Contracted research organisation – Wildland Consultants Ltd

ISBN 978-1-98-851249-5 (electronic)
ISSN 1173-3764 (electronic)

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Smith, D, K Borkin, C Jones, S Lindberg, F Davies and G Eccles (2017) Effects of land transport activities on New Zealand's endemic bat populations: reviews of ecological and regulatory literature. *NZ Transport Agency research report 623.* 249pp.

Wildland Consultants Ltd was contracted by the NZ Transport Agency in 2016 to carry out this research.

Keywords: *Chalinolobus tuberculatus*, ecology, legislation, long-tailed bat, *Mystacina tuberculata*, roads, short-tailed bat

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Acknowledgements

David Greig and Carol Bannock (the NZ Transport Agency) approved this project and provided input and guidance. Members of the Steering Group are thanked for project approval and guidance: Colin O'Donnell, Brad Moore, Therese Balvert, Rachel Kelleher, Peter Simcock, and Tony Denton. Professors John Altringham and Darryl Jones are thanked for their peer review of this report. We thank Jo McQueen-Watton for support. William Shaw (Wildlands) peer reviewed earlier drafts of this report. Richard Gillies, Bruce Mackay and Brian Patrick assisted with the field work presented in appendix C.

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Executive summary

Introduction

Roads and other associated land transport activities can adversely affect indigenous animals. How impacts are identified and managed in New Zealand varies and there is currently no framework for guiding assessments or the management of these effects. In recent years the effect of roading projects on New Zealand's endemic bats has become an issue[1]. The Waikato Expressway roading project and investigations for the Hamilton Southern Links Notices of Requirement have become the first roading projects in New Zealand to attempt to address the mitigation and management of adverse effects of roading projects on long-tailed bats. Therefore, the New Zealand Transport Agency (the Transport Agency) has identified a need to develop a nationally accepted framework for research into strategies for avoiding, reducing, or mitigating negative effects of land transport activities on indigenous vertebrates, with bats being a high priority.

New Zealand has two extant species of bat: long-tailed (*Chalinolobus tuberculatus*) and lesser short-tailed (*Mystacina tuberculata*), both of which are of conservation concern. Long-tailed bats are distributed patchily, across the North Island and the South Island. They are found in indigenous forest and sometimes in exotic forest and pastoral land. Lesser short-tailed bats persist in old-growth indigenous forests at 13 known locations, 11 of which are in the North Island.

The Transport Agency commissioned Wildland Consultants, Landcare Research and AECOM to research roading effects on bats and develop a framework for managing these effects (and provide comment on how research findings may be applied to other indigenous vertebrates). More specifically:

- To undertake a review of national and international ecological literature on the impacts and mitigation of roads on bats. This included an investigation into the statutory processes governing interactions between New Zealand bats and land transport activities (Parts 1 and 2).
- To analyse an existing long-tailed bat data set to understand how weather variables may influence monitoring protocols (appendix B).
- To undertake a field study to determine how varying traffic volume affects bat activity (appendix C).
- Develop a framework for monitoring and managing the impact of roading activities on endemic bats (appendix D).

Literature review

The objectives of the literature review were to:

- Identify the key threats posed to New Zealand indigenous bat populations by land transport projects, and determine whether these are also threats to other indigenous vertebrate populations.
- Describe how regulatory planning legislation and policy statements influence requirements to assess, monitor and mitigate the effects of land transport projects on bats and other vertebrate species.
- Identify the most effective methods for managing threats that land transport projects pose to indigenous bats, and assess applicability of these findings for other indigenous terrestrial vertebrates.
- Construct a demographic model using information from the literature, to determine which long-tailed bat population parameters are most important for the survival of bat populations.

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[1] To date, a similar focus has not been applied to the other extant bat species – lesser short-tailed bat (*Mystacina tuberculata*) - as relatively little is known about their behaviour in relation to transport infrastructure.

Ecological review synopsis

Roads and road development can affect wildlife populations by causing significant permanent habitat loss, creating edge effects, causing changes in microclimate, creating noise and light pollution, mortality through vehicle collisions, weed invasion and fragmenting populations by creating barriers to dispersal.

Potential effects of roads on bat populations include:

- roost loss either directly through clearance of roost trees, or indirectly through roost abandonment
- vehicle collision mortality, particularly where roads cross established flight paths, or create edge foraging habitat by cutting through forests
- habitat loss or fragmentation.

Demonstration of whether these effects are occurring on bat populations can only be achieved by monitoring appropriately over a time-frame within which population change can be expected.

To date, studies of the effects of roads on bats have been unable to make strong inferences because they have used inappropriate metrics, such as behaviour, instead of population size and persistence. In New Zealand, most monitoring of bats and roads has used acoustic methods over short timeframes, with small sample sizes, and has mostly been insufficient to detect changes in activity or relative abundance. Monitoring of roading projects should use a before-after-control-impact design to compare population changes at road sites with other unaffected populations before and following road construction. Appropriate duration of monitoring should be determined by the life history of the bat species being considered. A biostatistician should be consulted when designing monitoring around roads. Improperly designed monitoring is costly and of no benefit, and may draw-out resource consent decisions.

International attempts to mitigate roading effects on bats have involved structures that facilitate safe movements across the road, eg height and alignment of existing flight paths. Underpasses have targeted low-flying gleaning bat species. Structures over roads try to take advantage of bats' tendencies to follow linear landscape features, but wire-bridges have been ineffective. Vegetated over-bridges might be effective but further trialling is required. There is no evidence that vegetated 'hop-overs' (high vegetation planted to provide continuous habitat over a road) are effective.

In New Zealand, mitigation measures have included: introduced predator control as an offset; protocols aimed at identifying occupied bat roosts when felling trees for road construction, and vegetated hop-overs. However, the effectiveness of these initiatives has not been properly monitored.

A demographic model using population parameters from the literature, suggests adult female survival is crucial to the survival of long-tailed bat populations. This means:

- Long-tailed bat populations will be vulnerable to events that adversely affect adult survival.
- Roost loss during road construction could be catastrophic for small remnant bat populations.
- Development of methods for mitigating flight path severance may help maintain adult survival.

Given the lack of information on mitigating the effects of roading on bats, future investment should be guided by an adaptive management framework that is justified by strong inferential, evidence-based logic; and accompanied by robust, appropriately designed monitoring.

Regulatory review synopsis

Key regulatory legislation governing the protection and conservation of wildlife in New Zealand are the Resource Management Act 1991 (RMA), Conservation Act 1987 and Wildlife Act 1953.

The RMA addresses sustainable management of natural and physical resources, and it is the Act of most relevance to land transport projects. National direction on the RMA is provided by central government, but it is implemented by regional, district and city councils. The Conservation Act is administered by the Department of Conservation with the purpose of promoting the conservation of New Zealand's natural and historic resources, and applies to land administered by the Department of Conservation. The Wildlife Act is also administered by the Department and deals with the protection and control of indigenous fauna. All land transport projects that may potentially have adverse effects on indigenous vertebrate species will require a permit under the Wildlife Act.

Approvals to undertake activities under the RMA are referred to as 'resource consents'. To obtain a resource consent an assessment of environmental effects is required. If significant adverse effects are likely to occur then options for avoiding, mitigating, compensating, or off-setting these effects are required. Concessions under the Conservation Act are guided by regionally focused Conservation Management Plans that contain specific provisions for the protection of habitat and indigenous species. The Wildlife Act requires a Wildlife Permit for projects that may disturb habitat, particularly roosts or nests, or have the potential for accidental killing of native wildlife. Permit applications must include consideration of all actual and potential adverse (or positive) effects of the proposed on indigenous wildlife.

Several land transport projects within New Zealand that interact with bats were reviewed. In general there was little or no contention regarding the need for projects to meet legislative requirements. However, there was considerable deliberation on ecological evidence and evaluation of whether the potential effects could be mitigated or offset.

Ecological research and framework development

Analysis of an existing data set demonstrated long-tailed bat activity is strongly influenced by temperature and it is suggested bat monitoring takes place when temperatures one to four hours after sunset are above 5ºC, and preferably in the 10–17ºC range. In addition, a field research project was carried out that measured bat activity between road edges and sites ≥200 metres away from the road at 57 locations throughout New Zealand where bats are known to occur. A strong negative relationship was found between bat activity on road edges and night-time traffic volume, suggesting long-tailed bats avoid or are displaced by roads with high traffic volumes.

A framework was developed to guide land transport managers, planners and ecologists through the process of getting statutory consents, ecological monitoring and mitigation of the effects of roading projects on long-tailed bats. The framework pays considerable attention to the ecological uncertainty around the potential adverse effects of land transport activities on endemic bats, and considers in some detail potential approaches for improvement of the rigour and effectiveness of ecological monitoring.

Conclusion

Ecological and legislative reviews undertaken for this project have independently identified a lack of understanding of how roads affect bats, how bats should be monitored along roads, and a lack of evidence for the effectiveness of strategies to avoid, minimise and mitigate potential adverse effects. This situation has arisen because the field of 'road ecology', which addresses the effects of roads on fauna and plants, is an emerging discipline. Lack of reliable research into the effects of roads and other linear transport infrastructure on vertebrates, particularly New Zealand bats, has meant most mitigation packages developed for roading projects and other linear transport infrastructure have been largely based on logic, intuition, best guesses and anecdotal observations.

Many opportunities to better understand both the effects of roads on bats and the methods designed to mitigate them have been lost because the monitoring that has taken place has usually been undertaken over too short a duration and has not been robustly designed. This lack of understanding of what effects occur and how these can be addressed frequently leads to indecision and conflict throughout the planning approval process required by legislation. This has been compounded by considerable variation in interpretation of legislative requirements, and their implementation, at all levels of the process: from decisions made under the RMA by regional councils and territorial authorities, through to decisions made under the Conservation Act and the Wildlife Act by the Department of Conservation.

This review and the subsequently developed framework propose a way forward based on either an iterative research-based process or strong evidence-based logic, for which the outcomes should be measured using well-designed monitoring regimes. Such an approach will expedite understanding of the effects of roading projects on bats, and the development of tools for avoiding, minimising and mitigating effects, and consequently the processes required by legislation. A similar lack of evidence of how to monitor and mitigate effects of roads and roading projects is also likely to be the case for other terrestrial indigenous vertebrate species and it is therefore appropriate that similar iterative research-based models or strong evidence-based logic models are also applied to their management.

Abstract

Roading projects may have adverse effects on indigenous wildlife. In New Zealand the effects of roading on long-tailed bats (*Chalinolobus tuberculatus*) is an issue and projects have attempted to monitor and mitigate effects on bats populations. However, how to undertake monitoring and mitigation is unclear. The New Zealand Transport Agency commissioned Wildland Consultants, Landcare Research and AECOM to: review the literature on effects and mitigation of roads on bats, and relevant statutory processes; research road effects on long tailed bats; and develop a framework for managing these effects. Roads affect bats by severing their flight paths and depleting roosting habitat by removing trees. Most bat road research has quantified effects on behaviour rather than population survival, making prediction of effects difficult. No studies have demonstrated any mitigation options to be effective for bats. Demographic modelling indicated adult female survival is vital for the survival of long-tailed bat populations, and therefore must be preserved by roading mitigation. Research showed that nightly bat emergence is related to temperature, indicating that bat monitoring should be undertaken when temperatures 1–4 hours after sunset are above 5ºC, and preferably in the 10–17ºC range. Field research also showed a negative relationship between bat activity and night-time traffic volume. A framework guiding roading projects through the process of consents, ecological monitoring, and mitigation was developed and addresses ecological uncertainty around mitigation options, and describes improved bat monitoring.

INTRODUCTION TO THIS REPORT

Roads and other associated land transport activities can affect a wide range of indigenous terrestrial vertebrate species. How these impacts are identified and managed in New Zealand varies and there is currently no national framework guiding assessments of effects or the management of effects. Regulators and land transport operators deal with these issues on a case-by-case basis, resulting in a range of outcomes and costs. In recent years the effect of roading projects on long-tailed bats (*Chalinolobus tuberculatus*) has become a particularly topical issue[2]. Implementation of the Waikato Expressway roading projects and investigations for the Hamilton Southern Links Notices of Requirement have become the first roading projects in New Zealand to attempt to address the mitigation and management of the adverse effects of roading projects on long-tailed bats. Because of these issues, the New Zealand Transport Agency (the Transport Agency) has identified a need to develop a nationally accepted framework for the study and development of management strategies for avoiding, reducing, or mitigating the adverse effects of land transport activities on indigenous vertebrates, with bats being a very high priority. Establishment of such a framework will allow potentially adverse effects to be addressed more consistently across New Zealand, and will create greater synergies and efficiencies for transport and conservation outcomes.

The Transport Agency commissioned Wildland Consultants, in collaboration with Landcare Research and AECOM, to research and develop a national framework for management of the effects of land transport activities on indigenous terrestrial vertebrate species, with particular emphasis on bats. The main body of the report covers an extensive literature review undertaken to provide information necessary for the development of the framework. The literature review is presented in two parts:

- Part 1: A review of nationally and internationally available ecological literature on the impacts of roads on bats and the relative success of various attempts to mitigate these effects.
- Part 2: A thorough investigation of the statutory processes that govern interactions between New Zealand bats and land transport activities.

The objectives of the literature review were to:

- Identify the key threats posed to New Zealand indigenous bat populations by land transport projects, and identify any commonalities between these threats and those that transport initiatives are likely to pose to other indigenous vertebrates.
- Develop a comprehensive understanding of how regulatory planning legislation and policy statements influence requirements to assess, monitor and mitigate the effects of land transport projects on bats and other vertebrate species.
- Identify the most effective and practical methods for managing (avoiding, minimising, or mitigating) threats that land transport projects pose to indigenous bats, and assess the transferability of these findings for other indigenous terrestrial vertebrates.

The literature review addressed published and unpublished material from within New Zealand and overseas. The following methodology was used to ensure the review met the project objectives:

- All literature available on the population biology of New Zealand's bats was reviewed, to establish what is known about how bat populations function, and to find parameter values suitable for use in a demographic model.

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[2] To date, a similar focus has not been applied to the other extant bat species - lesser short-tailed bat (*Mystacina tuberculata*) - as relatively little is known about their behaviour in relation to transport infrastructure.

- All literature available relating to transport projects and bats in New Zealand was reviewed to identify:
    - methods for detecting the presence of bats
    - methods for assessing, monitoring, and managing the effects of land transport activities on bat populations
    - methods used to mitigate the impacts of land transport activities on bat populations
    - evidence of the relative success of various mitigation options at reducing or removing the effects of land transport activities on bat populations.
- International literature dealing with bats and roads was reviewed to identify monitoring methods and management strategies not yet adopted in New Zealand that may be relevant and transferrable for bat species.
- A demographic model was constructed to determine which population parameters (eg fecundity, age-specific survival) are most important for the survival of bat populations. The outcome of this modelling was then used to determine the types of land transport activities that are most likely to adversely affect New Zealand bat populations.
- Key regulatory and policy issues and processes were identified that need to be addressed by land transport providers when undertaking projects where bats and other indigenous terrestrial vertebrate species are present.
- Literature relating to transport projects and bats in New Zealand (eg assessments of environmental effects, resource consent applications and regulatory decision documents) were reviewed to identify resource consent decisions and conditions pertaining to bats, which have been applied to road infrastructure projects.

In addition to the literature review in parts 1 and 2, two pieces of research are presented as appendices to this report:

1 The analysis of an existing long-tailed bat data set to see whether climatic variables, eg weather, could be used to predict favourable conditions for monitoring bats during roading projects (appendix B).

2 A field study examining the effect of road traffic volume on long-tailed bat activity along road edges in New Zealand (appendix C).

A framework for managing the effects of land transport activities on New Zealand's endemic bats is provided in appendix D. Sections within the framework also discuss its applicability to other endemic vertebrate species.

PART 1: ECOLOGICAL REVIEW

1 Introduction to Part 1

In Part 1 of this report we look at evidence from international and New Zealand studies on the effects of land transport activities on wildlife populations and address the following parameters as agreed with the NZ Transport Agency (‘the Transport Agency’).

- Complete a review of existing international and local literature covering methods used in assessing and managing impacts on vertebrate species population viability, with a focus on bat species as an example, associated with land transport systems to identify their success together with the reasons for this.
- Identify, based on factual evidence and key regulatory planning issues, which impact assessment and management techniques used for vertebrate population viability, in particular for bats, are transferrable to New Zealand and why, and for those not transferable what are suitable methods and approaches.

Note: The vast majority of land transport impact studies have focused on roads and their associated infrastructure, with little clear information on the effects of railways (see Berthinussen and Altringham 2015). Despite this, we suggest that a precautionary approach should be taken in planning mitigation of risks to wildlife, and bats in particular, from rail developments, ie assume that rail effects are similar to those of roads.

Part 1 is set out as follows. In chapter 2, we begin with a brief overview of wildlife populations and introduce some basic ecological concepts to outline how populations function in the landscape, what they need to persist, and how a range of threats can influence their viability. In chapter 3, we review how linear transport infrastructure can affect wildlife populations generally before focusing on its effects on bats in particular in chapter 4. We outline the monitoring and survey standards required to demonstrate roading impacts on bat populations, and subsequent mitigation, and describe the strengths and weaknesses of commonly-used monitoring methods in chapter 5. In chapter 6, we look at overseas evidence of the effectiveness of attempts to mitigate the impacts of roading on bats and in chapter 7; we consider what is done to mitigate effects in New Zealand. Each chapter concludes with a brief summary of key points.

In chapter 8, we demonstrate how a consideration of a species’ life-history characteristics can be used to identify the key population processes requiring protection when designing a mitigation strategy. We evaluate the current state of bat-road mitigation and propose a step-wise logic for assessing the likely impacts of planned, or existing, linear infrastructure on New Zealand bat populations, including a monitoring approach designed to provide robust evidence of whether a mitigation strategy has proved effective in minimising potential adverse effects. Chapter 9 outlines how a more generic approach can apply to the assessment of effects and their mitigation on other indigenous New Zealand vertebrate populations.

2 Wildlife populations: overview and concepts

In view of the emphasis on vertebrate species' population viability it is worthwhile outlining briefly how wildlife biologists conceptualise populations, their key components, and how these interact with, and are driven by, the environment. A **population** can be defined as a group of organisms of the same species occupying a defined space at a particular time (Krebs 1972). A population's **viability** is its ability to persist, preferably as a self-sustaining entity requiring minimal ongoing intervention. Spatial boundaries used to define populations are easy to define for species restricted to a single habitat type or isolated site (such as an island), but harder for wide-ranging species that can use a variety of habitats (Williams et al 2002). Population size is commonly expressed as abundance (the number of individuals in the population).

The abundance of a population can change through time in response to a number of internal and external drivers. Population changes can be summarised simply by the classic 'BIDE' equation:

$$N_{t+1} = N_t + B + I - D - E \qquad \text{(Equation 2.1)}$$

This indicates that the number of individuals at some point in the future (Nt+1) is the starting population (Nt) plus births (B) and immigration (I) minus deaths (D) and emigration (E). In practice, death rate (or mortality) is very hard to estimate reliably, so its complement, survival rate, is estimated. When expressed numerically, these processes are often referred to as a population's 'vital demographic rates' and each can vary according to a variety of factors. External factors affecting vital rates include resource (food, shelter) availability and predation, both of which can affect mortality/survivorship and reproductive output, or the degree of isolation of the population, which can affect immigration rate. Internal factors affecting population change include population size itself; for example, when populations grow beyond a threshold size and competition between individuals for resources such as food and mates leads to reduced survival or birth rates. At the other end of the size spectrum, small populations are vulnerable to rapid, catastrophic declines. Significant events, such as wildfires or rapid human-driven habitat loss, can cause significant short-term mortality or loss of a breeding season's young, from which a small population cannot easily recover. Small populations are also vulnerable to what ecologists term 'Allee effects', whereby population growth is limited because, for example, individuals have reduced chances of finding a suitable mate or individual predation risk might be higher because of a lack of 'safety in numbers'. Isolation of populations by the fragmentation of suitable habitats into small patches can also lead to a loss of genetic diversity in the population as immigration declines and rates of inbreeding increase. This loss of genetic diversity can make the population less able to adapt to environmental change or disease outbreaks.

The ability and speed at which a population can recover from or react to a change in conditions is also governed by the species' life-history traits. These are characteristics such as the age at which individuals first breed, the frequency of breeding, the number of offspring produced, relative survival rates of adults and offspring, and the amount of resources invested in breeding and parental care. For example, a population of rodents can characteristically respond very rapidly to a sudden increase in food resources by increasing the rate at which they produce young, leading to 'plagues' of rodents, whereas populations of long-lived, but slow-reproducing species – such as whales and seabirds – lack the ability to produce more young rapidly and may therefore take many decades to recover from population declines.

Managing a wildlife population is, in its simplest form, about managing one or more of that population's vital demographic rates so that population growth is manipulated to achieve the desired management outcome (ie increase, decrease, or maintain the population). This can best be achieved by considering the life-history strategy of the species under management so that the vital rate, or rates, that most strongly drive population change can be identified and manipulated accordingly. However, it must be stressed this requires a strong understanding of the population dynamics of the species to be managed, ideally in the location at which management is required.

In the following sections, we consider the impacts of transport infrastructure, primarily roads, on wildlife populations in general and on bats in particular. Much of the published scientific and unpublished, or ‘grey,’ literature deals with effects on individuals or groups of individuals and, later, attempts to mitigate or minimise those effects. It is important to remember such data alone should not be used to make inferences about the status of a population. Whether or not an intervention has been successful can only be determined by monitoring the response of the population itself (outcome monitoring) at an appropriate time scale based on a knowledge of the species’ life history.

2.1 Key points

- The size of a population can change through time in response to a number of internal and external drivers acting on its vital demographic rates: births, deaths, immigration and emigration.
- External factors affecting vital rates can be resource (food, shelter) availability and predation, both of which can affect mortality/survivorship and reproductive output, or the degree of isolation of the population, which can affect immigration rate.
- Internal factors affecting population change include population size itself, eg when competition between individuals for resources, such as food and mates, leads to reduced survival or birth rates.
- Small populations are vulnerable to rapid, catastrophic declines, and to other effects due to their small size, eg reduced chances of encountering a mate or increased individual exposure to predation and to loss of genetic diversity.
- Species’ life-history traits such as age at first breeding, reproductive outputs, longevity and relative parental investment dictate a population’s ability to recover from or react to a change in conditions.
- Wildlife population management is, essentially, management of key demographic rates to achieve a desired outcome.
- Management success can only be determined by monitoring the response of the population itself at an appropriate time scale based on knowledge of the species’ life history.

3 Effects of linear transport infrastructure on wildlife

Roads and other linear transport infrastructure can have a number of effects on wildlife. These range from direct impacts, such as mortality through vehicle collisions, to behavioural and other non-lethal changes in response to the habitat changes that result from both road construction and use. In this chapter, we summarise those effects and note how they are likely to affect population processes.

The first effect of linear transport infrastructure – habitat loss – happens during its construction and is largely permanent. Direct loss – conversion to infrastructure, including verges/shoulders, parking areas – can consume significant areas of habitat (Seiler 2001). Beyond the direct footprint of the road, habitats may be affected by changes in hydrology and microclimate following construction and by chemical, light, and noise pollution from vehicle use and by secondary effects such as weed invasion. These changes may occur to such a degree that habitats become unsuitable for use by some species, effectively adding to the net loss of habitat due to construction (Forman et al 2003). Building a road through a particular habitat also means the amount of habitat edge increases. Depending on the extent of edge-driven habitat alteration, this can lead, in turn, to even greater effective habitat loss to edge-intolerant species.

Hydrological changes due to infrastructure construction include interference with natural waterway flows and draining of aquifers. These effects, in turn, can lead to increased sediment loadings and deposition patterns, drying out of wetlands and alteration of other water-dependent habitats such as riparian zones (Findlay et al 2000; Jones et al 2000). Microclimate effects include changes in windflow, temperature, humidity and light exposure when, for example, roads are built through forested environments (Seiler 2001). Airflow and temperature patterns may even lead to the road surface becoming more attractive to species as sites for thermoregulation (by, for example, reptiles) or because the changed conditions lead to insect aggregations, thus attracting species that feed on them (Trombulak and Frissell 2000).

Road use and maintenance activities can alter the chemical environment surrounding a road. Vehicle exhaust emissions contain a number of chemical pollutants including polycyclic aromatic hydrocarbons, dioxins, carbon monoxide, sulphur dioxide, benzene and a variety of heavy metals. Contamination is greatest within 20 metres of the road, but has been detected at up to 200 metres away, with local variations depending on traffic volumes and prevailing wind direction (Hamilton and Harrison 1991; Trombulak and Frissell 2000). Accumulation of pollutants in the soil and in plant tissues can lead to changes in the local plant community with subsequent effects on wildlife that feed on those plants or use vegetation for shelter. Other documented changes include outbreaks of herbivorous insects due to increased nitrogen concentrations in vegetation lining motorways (Port and Thompson 1980). This effect could be particularly relevant to insectivorous vertebrates such as bats as increased concentrations of prey are likely to induce predators to forage closer to roads.

Noise pollution can have significant effects on a range of wildlife, particularly on species that use sound in foraging or communication (Coffin 2007). Birds seem to be particularly sensitive to noise pollution from roads, with reductions in both the density of breeding birds and the overall diversity of species with increased proximity to roads (Reijnen et al 1995; Forman et al 2002). Some species have been shown to modify the pitch of their mating calls in response to high levels of environmental noise, but others without the ability to modify call behaviour may suffer reduced reproductive output as a consequence of increased noise levels (Slabbekoorn and Peet 2003; Huffeldt and Dabelsteen 2013).

There are similar concerns about the effects of artificial lighting on wildlife. Nocturnal species' orientation and movements through the landscape may be compromised, leading to injury and mortality from collisions and increased exposure to predation. In many species, reproductive cycles are mediated through light levels and illumination periods, feeding behaviour in species using darkness to avoid predators can be affected and photophobic species may be deterred from normal commuting behaviours by increased artificial light levels (reviewed in detail by Longcore and Rich 2004).

Roads have been linked to a variety of behavioural changes in animals. These changes include both avoidance of and attraction to the road surface (Merriam et al 1989; Mulder 1999) which results in modification of individuals' home ranges. Bears (*Ursus* spp) tend to avoid roads while vultures (*Coragyps atratus*) are attracted to areas of greater road density (Trombulak and Frissell 2000). Reduced foraging ability as an indirect effect of roads' fragmentation of a landscape can mean that animals must increase their overall home range to compensate for the loss of foraging habitat. This could lead to a reduction in the density of the species and to territorial conflicts between conspecifics, as individuals affected by the road are forced into the territories of neighbours (Forman et al 2003).

A large proportion of the studies of road effects on wildlife have focused on the direct mortality of animals due to collisions with traffic. In addition to simply documenting mortality, a number of authors have looked for patterns across species to predict their relative vulnerability based on behavioural traits and local habitat characteristics. Roads represent a risk to wildlife when they are constructed through animals' home ranges/territories or across migration or commuting routes. Risk is also likely to vary according to characteristics of both the road (width, traffic volume, traffic speed, roadside vegetation) and of individual species. For example, amphibians are considered to be at high risk of road mortality because of their seasonal breeding migrations to and from wetlands and relatively slow movement (Carr and Fahrig 2001). Species' dispersal, foraging and mobility patterns are also likely to influence collision risk. Examples of these behaviours include dispersal of sub-adults to establish their own territories, which can lead to seasonal spikes in road death; the attraction of road-kill carrion to scavenging species such as Australasian harrier (kahu; *Circus approximans*); and whether species are habitat generalists (that can use a variety of habitats and are therefore less restricted in their movements) or more restricted habitat specialists that are less likely to travel widely (Trombulak and Frissell 2000; Forman et al 2003; Coffin 2007).

Although road mortality is a cause for concern, its effect on local population viability cannot be inferred based solely on observed road kill rates. High rates of road kill may simply indicate that a species is abundant in an area, and the species may be able to cope with the road induced mortality if their birth rate is high. Similarly, a temporal spike in kills may represent a seasonal effect influencing only one component of a population (eg dispersing young of one sex). The relative importance of these effects to population viability can only be understood by consideration of the species' life-history. Fahrig and Rytwinski (2009) described two general categories of species that are vulnerable to road mortality: 1) species that are either attracted to roads (eg to scavenge or thermoregulate) or do not show avoidance behaviour (eg slow-moving species such as amphibians and reptiles); 2) species that have large movement ranges and low reproductive rates, and do not avoid roads or traffic. Because animals with large home ranges and low natural densities also generally reproduce slowly (eg large carnivores), they cannot compensate rapidly for higher mortality through higher reproduction, so road mortality can lead to population declines. The authors considered the least affected species to be those that avoid going onto roads, are not disturbed by road traffic, have small home ranges, and high reproductive rates. Road avoidance and small home range size will result in low road mortality and mean that viable populations can exist within areas bounded by roads, while high reproductive rates will mean that populations can compensate for losses due to road mortality.

Habitat loss during construction, disturbance-driven behaviour change and direct mortality can lead to roads, and possibly railways, acting as barriers to animal movements at both the individual and population scales, ie interfering with normal use of a home range (commuting), migration and dispersal of independent young. This barrier effect fragments the landscape into a series of small patches with impacts at both individual and population levels for many species (summarised in Coffin 2007). At the individual level, animals may be prevented from reaching important feeding or breeding habitats, with subsequent reductions in survival rates and reproductive outputs. Fragmentation of habitat into smaller patches can lead to these containing insufficient resources to support viable wildlife populations. Even if small populations can survive in habitat fragments, they are at increased risk of local extinction through either Allee effects (see previous section), or 'chance' events such as wildfire or disease. These isolated populations may also suffer inbreeding depression, ie the loss of genetic diversity that occurs when mating opportunities are restricted to a small set of potential mates.

At the landscape scale, networks of roads can lead to increased fragmentation of the landscape, but can also lead to other, secondary, effects on wildlife populations through acting as conduits for the spread of exotic species (eg other vertebrates that may become predators or competitors, or weeds that may modify available habitat) and wildlife diseases. Furthermore, roads can also facilitate increased human use of an area which can lead to increased hunting/resource use and disturbance. For example, decreased breeding success of golden eagles (*Aquila chrysaetos*) close to roads and vehicle tracks has been attributed to increased human activity as well as the presence of the roads close to nesting sites (Watson and Dennis 1992; Steenhof et al 2014).

3.1 Key points

- Road construction causes significant and largely permanent habitat loss.
- Beyond the direct footprint of the road, habitats may become unsuitable for species due to edge effects: changes in hydrology and microclimate following construction and by chemical, light and noise pollution from vehicle use and by secondary effects such as weed invasion.
- Noise pollution can have significant effects on a range of wildlife, particularly on species that use sound in foraging or communication.
- Nocturnal species' orientation and movements through the landscape may be compromised by light pollution around roads and photophobic species may be deterred from normal commuting behaviours by increased artificial light levels.
- Roads represent a significant mortality risk to wildlife when they are constructed through animals' home ranges/territories or across migration or commuting routes. Risk is also likely to vary according to characteristics of both the road (width, traffic volume, traffic speed, roadside vegetation) and of individual species.
- Species at highest risk from vehicle collisions are those that have large movement ranges and low reproductive rates, and do not avoid roads or traffic.
- Roads act as barriers and fragment the landscape into a series of small patches with impacts at both individual and population levels for many species, interfering with normal use of a home range (commuting), migration and dispersal of independent young. This can effectively split a population into a number of smaller, more vulnerable populations.

4 International evidence for roading effects on bats

In this chapter, we first describe the basic ecological characteristics of bats as a group. This provides context for a review of overseas studies on the impacts of roads, and their use, on bats at the individual and population level.

4.1 General ecological and life-history characteristics of bats

Although only two species of bat survive currently in New Zealand, bats represent one of the most diverse groups of mammals globally. The taxonomic order Chiroptera contains over 1,200 species which are divided into 19 families. These include the large fruit-eating bats of the old world tropics, which navigate primarily by sight, and the smaller and frequently (but not exclusively) insectivorous bats that navigate and locate prey using echolocation (high-pitched sonar). The remainder of this review focuses on the small echolocating bat families for two reasons: (1) most research in Europe and North America on road impacts focuses on these species; (2) both New Zealand species of bats fall within this group.

Figure 4.1 New Zealand’s long-tailed and short-tailed bat.

Long-tailed bat, K. Borkin Collection

Short-tailed bat, K. Borkin Collection

Bat life-histories conform to a general pattern, although it is important to remember individual species will vary around this template. The following summary is based on a range of sources (Highways Agency UK 2008; SÉTRA 2009; Stone et al 2013; for more detail see Altringham 2011).

During winter in temperate zones, when insects and other foods are in short supply, bats hibernate, ie they enter extended periods of torpor (minimal activity and low metabolic rates). They seek out quiet, humid sites with low, constant temperatures where they undertake a long period of torpor, emerging occasionally to feed and drink on milder evenings when insects are active. Bat roost choice varies with their reproductive state; consequently, in winter when females are neither pregnant nor lactating and males are not making sperm, they use cooler temperature roosting sites, while in summer, when breeding female bats require warmth to enhance both the growth of their foetus in utero and milk production they live communally in warmer roosts, often accompanied by non-breeding females. In spring, they leave their winter roosts and move to their summer roosts. During the summer months, the males are generally solitary, living apart from the females in separate roosts. Females frequently continue to use communal roosts that are separate from males when pregnant and lactating.

Bats spend the daylight hours resting inside a roost and may even enter torpor during part of the day, emerging to feed at, or soon after, dusk. Their nocturnal habits are likely to a means of avoiding avian predators. The timing of their emergence from the roost is critical, as delayed emergence will reduce the amount of time available to forage at the time when the abundance of crepuscular insects is at its greatest. Generally, bat species that are more light-tolerant tend to emerge earlier than light-sensitive species.

Male and female bats share breeding roosts together in the autumn in order to mate. Female gestation is temporarily halted by delaying fertilisation (storage of sperm) or by halting the development of the embryo until the next spring. During the spring and summer period, female bats gather together into maternity roosts for a few weeks to give birth and rear their young (called pups). Usually only one pup is born each year and is looked after carefully and suckled for between four and six weeks until it is old enough to fly and hunt independently (Mitchell-Jones 2004). A sign of their limited energy budget is that every year females produce only one, or exceptionally, two pups. During this period, the females need to hunt intensively and generally return to the roost several times a night to feed their young. Once the pups are independent, the communal roost breaks up and the bats generally move to other roosts. Bats may gather together from far flung locations to form these maternity roosts, so any disturbance or destruction of these roosts can affect bats over a large spatial scale (Mitchell-Jones 2004). Many of these maternity roosts are used every summer as bats have a strong tradition of returning to the same site year after year.

The activity of flying between roosts and foraging areas is known as commuting. Individual bats use the same routes regularly for commuting, which are known as commuting corridors, flight paths or fly-ways. Alteration of these linear features can cause increased energetic costs to bats in finding, possibly longer, alternative routes to feeding areas and can therefore lead to reduced foraging time.

The shape of a bat's wing influences its manoeuvrability and thus the type of prey and habitat in which it forages (Norberg and Rayner 1987). Some bats ('gleaning' foragers) with wider, more rounded wings are better able to fly in cluttered environments, such as forests, taking prey from vegetation, while other 'aerial hawking' species with narrower, more pointed wings forage on flying insects in open uncluttered spaces.

Many species of small echo-locating bats globally are at risk of extinction (Mickleburgh et al 2002), with the primary threats being habitat degradation and loss, human hunting and the impacts of introduced predators to islands. Studies of the factors likely to predict extinction risk have identified restricted geographic range and wing shape as key factors (Jones et al 2003; Safi and Kerth 2004). Bats with wings adapted to foraging in cluttered forest habitats are at higher risk of extinction because their survival is more critically linked to the existence of suitable habitat and because their wing shapes are not adapted to long-distance migratory flights. In essence, as habitats are lost, so are bats. More recently, Sagot and Chaverri (2015) linked roost specialisation to extinction risk, with those bat species able to utilise a greater range of roost types predicted to be at lower risk.

New Zealand has two remaining species of bat, long-tailed (*Chalinolobus tuberculatus*) and lesser short-tailed (*Mystacina tuberculata*), both of which are considered of conservation concern (O'Donnell et al 2013), primarily from the effects of habitat fragmentation and loss and from the impacts of introduced mammalian predators. Key information on both species is summarised in table 4.1, and we direct the reader to O'Donnell (2005) and Lloyd (2005) for more detailed accounts.

Table 4.1 Summary of key ecological and life- history information for extant New Zealand bat species. Data from O'Donnell (2005) and Lloyd (2005) unless cited otherwise. Note that behaviour and life- history traits may vary between populations.

	Long- tailed bat (*Chalinolobus tuberculatus)*	**Lesser short- tailed bat (*Mystacina tuberculate)***
Status (DOC 2013)	Nationally vulnerable (North Island form). Nationally critical (South Island form).	Nationally endangered (northern and South Island forms). Nationally vulnerable (central form).
Distribution	Wide, patchy distribution – North Island. Few isolated populations on West Coast of South Island. Declining nationally, compared with historical records.	13 known populations: 11 North Island; also Eglinton Valley (South Island) and Whenua Hou/Codfish Island. Core ranges of all populations in fully-protected indigenous forests.
Habitat	Indigenous forest and some exotic plantations – use edges and gaps to move/forage. In open landscapes, use riparian zones, cliff edges and other linear landscape features. Several known populations in urban areas, eg Hamilton, Temuka, Auckland. Generally considered an edge-adapted species.	Largest populations in mature, unmodified lowland indigenous forest. Require old, large tree stands for roosts. May forage in adjacent habitats including exotic forest, but generally avoid open/edge habitats except for commuting between forest patches. Can commute over 10 kilometres between day roosts and foraging areas.
Home range size	Median estimates (Eglinton Valley): Males – 1,589 hectares Females – 1,361 hectares (post-lactation) 360 hectares (lactation). Juveniles >2 weeks independent – 2,006 hectares. Concentrate activity in small core areas.	Eglinton Valley: range 130–6,220 hectares; median 480. Ranges smaller in mixed-habitat mosaic (Toth et al 2015). Concentrate activity in small core areas.
Life history	Insectivorous. Mate late summer/autumn; pregnancy delayed until spring. Births: November to mid-December. Dates vary between populations. Females produce one young/year after 2–3 years old in indigenous forest; may breed earlier in other habitats. Adult survival in South Island forest variable; inversely proportional to introduced predator abundance. Form distinct social groups, which have distinct roosting, but foraging areas that overlap between social groups.	Primarily insectivorous, but also eat nectar, pollen and fruit. No population parameters estimated – lack of suitable safe marking method. Mate late summer; pregnancy delayed until spring. Single young born mid-December to mid-January. Around 80% of mature females breed annually – likely to vary according to local conditions.

	Long- tailed bat (*Chalinolobus tuberculatus)*	**Lesser short- tailed bat (*Mystacina tuberculate)***
Foraging habit	Wing morphology typical of aerial-hawking, moderate/fast-flying species. Primarily forages in forest edge/gap habitats; activity high over water bodies.	Wing morphology suggests gleaning habit. Mixed foraging strategy, some hawking, but mainly gleaning and terrestrial hunting for invertebrates using passive listening. Commute at high speed between forest canopy layer and understory, but reported as foraging within 2 metres of the forest floor (Lloyd 2001). Capable of high manoeuvrability in cluttered environments.
Emergence	Usually from up to one hour before to 30 minutes after sunset; influenced by temperature, humidity, invertebrate activity and light levels. May be later in winter or when roosting alone.	Only at full darkness; return to day roosts 30 minutes before dawn twilight.
Roosting	Shift roosts frequently where sufficient available sites; in other habitats roost occupancy times are longer and roost switching less frequent. Utilise cavities (with high, small entrances), peeling bark, fissures and splits in trunk/large limbs of large, old trees. Fewer cavities are available in many exotic tree species. May use rock cavities/fissures if insufficient trees are available.	Primarily small cavities in trunks of large, mature trees, but use variety of similar spaces May have 20–30 colonial roosts within 10,000–13,000 hectares of forest. Visit roosts intermittently during the night. In summer, whole colonial groups move every few days between roosts, kilometres apart. In habitat mosaics, active in range of habitats, but all known roosts are in old-growth indigenous forests.

4.2 Effects of roads on bats

4.2.1 Overview

When roads and associated infrastructure are built, the first potential effect on local bat populations is the loss of habitat when existing land cover is cleared. The UK Highways Agency (2008) summarised these effects as, 'the permanent direct loss of bat habitats, such as roosts, foraging areas and landscape features used for commuting', and went on to list a number of secondary effects:

- Consequential development associated with some new roads may result in further permanent loss of bat habitats and fragmentation of remaining areas; adjacent land use may change because of the effect of the new road on field size and management of agricultural land.
- Wetland foraging habitats are likely to change if the local hydrology is disrupted by road construction or if polluted by run-off.
- The viability of roosts may be affected by physical/noise/light disturbance (both during construction and operation).
- Roosts can be isolated or their microclimate altered by removal of shelter, for example, adjacent vegetation.
- Routine maintenance operations on the road network can also result in permanent and direct habitat loss and degradation.
- The removal of vegetation on the soft estate, particularly woody species, may result in the loss of important foraging areas or even roosts within trees.
- Structure or building repair work, in addition to potentially disturbing or killing roosting bats, may also result in the exclusion of bats or a change in conditions, causing bats to abandon the roost.
- Structure inspections can potentially disturb roosting bats.
- Pollution of wetland foraging habitats, from road run-off or accidental spillage resulting from road crashes, may reduce their invertebrate abundance and value to bats.
- Lighting during night-work that spills onto adjacent foraging habitats or roosts may temporarily deter bats or cause bats to abandon roosts, or to emerge later than is optimal for foraging.

4.2.2 Habitat loss

The direct effects of habitat loss will depend on the particular bat species' requirements and the type of habitat removed, eg if wetlands are removed this will affect wetland-foraging species. Loss of foraging habitat means that individual bats may need to increase their home range to compensate, but this, in turn increases the energetic cost of foraging. Clearly, at some point a threshold of habitat loss will be unsustainable for individuals, leading to reduced survival rates and reproductive outputs. These effects would subsequently affect the viability of a local bat population, but identifying such a limit would require detailed, long-term research of a type that has not yet been carried out for any species anywhere in the world.

Loss of roosts is likely to be critical to bat populations given the important functional roles they play in breeding (described above). This will be particularly so when they are occupied by females and young during the breeding season, but loss of both breeding and hibernation roosts will be highly detrimental for any species that show long-term fidelity to the same roosts. Impacts of roost loss will become more pronounced when roosts are restricted to certain rare habitat types. Habitat around roosts is also critical to continued use of roosts; Davidson-Watts (2007) found *Pipistrellus* species selected roosts primarily due to the presence of habitats around the roost. Impacts on these features can lead to roost loss. Although roost-loss from road development has not been the subject of any published studies, the effects of more general land-use change have been considered. Roost loss can force bats to expend excess energy in finding and or commuting to new roost and replacement roosts may be of poorer quality (eg reduced thermal insulation; O'Donnell and Sedgeley 2006), leading, via lower survival and reproductive rates, to smaller populations (Brigham and Fenton 1986; Borkin et al 2011). For many bat species, older trees have much greater value as roost sites than other trees, so loss of the former can have a disproportionately greater impact than loss of younger trees (Burgar et al 2015). Direct mortality from the felling of roost trees is also a significant risk when forest areas are cleared for development meaning that torpid bats and pregnant or nursing females and their dependent young are likely to be at the greatest risk because of their limited ability to escape (Borkin and Parsons 2010b). The risk of this to populations will vary seasonally, but, to a small population or social group of bats, the loss of one or more communal roosts may have significant consequences to long-term viability.

4.2.3 Noise, light and pollution

In addition to the loss of suitable habitat, remaining habitat adjacent to roads may be changed by the presence of the road, its associated infrastructure and by the effects of the vehicles using it. As animals that depend heavily on hearing to navigate and to detect prey, it is not surprising that several studies have identified the negative effects of noise on bats. Early studies examined bat foraging ability under different experimental noise treatments: Schaub et al (2008) showed that simulated traffic noise levels deterred greater mouse-eared bats (*Myotis myotis*), which detect prey by 'passive listening,' from foraging effectively and, later, Siemers and Schaub (2011) described a decline in the speed and success of foraging by the same species with increasing road noise. In a study of road-avoidance behaviour by commuting bats, the frequency at which bats changed their flight path to avoid roads increased with road noise levels with an apparent threshold of 88 dB suggested (Bennett and Zurcher 2013). The same study also showed bats avoided roads at locations where noise levels were greatest. By looking at the effects of noise on different aspects of the foraging behaviour of echolocating Daubenton's bats (*Myotis daubentonii*), Luo et al (2015) suggested their observed reduction in foraging efficiency was because, although bats could detect prey, they avoided loud noise levels.

Increased levels of illumination from artificial light sources on and around roads has also been identified as a factor likely to affect bats' nocturnal behaviour patterns. Some more light-tolerant bats may be attracted to the aggregations of insect prey around white street lights (Blake et al 1994; Rydell and Racey 1995). This behaviour has been observed in New Zealand where long-tailed bats were seen feeding on moths around street lights near Borland Lodge, Fiordland (Des Smith, pers comm). Evidence of the negative effects of lighting effects was first provided by Kuijper et al (2008) who compared pond bats' (*Myotis dasycneme*) commuting behaviour under dark and illuminated conditions. Light had two main effects: it reduced the number of 'feeding buzzes' (characteristic echolocation sounds produced when attacking prey) by 60% despite insect abundance increasing; it also induced bats to turn away from their normal commuting route, even at relatively low illumination levels. Much of the subsequent evidence on the effects of lighting has come from Bristol University's 'Bats and Lighting' project. Stone et al (2009) described marked reductions in slow-flying bats' normal use of hedgerows that were illuminated artificially with high-pressure sodium lights compared with those that were unlit. Bats also delayed their normal activity under lit conditions. This is likely to have two effects on individual fitness: alteration of commuting routes creates increased energy demands and both altered commuting behaviour and delayed emergence serve to reduce the time available to forage. A similar effect was found on slow-flying species when both light-emitting diode (LED) and metal halide street lights were trialled, although no effect was detected on faster-flying species commuting behaviour

(Stone et al 2012; 2015a). Faster species were more attracted to metal halide lamps than to older sodium lamps. Matthews et al (2015) found that increased activity at street lamps was only significant when tree cover was also present. Lighting effects on bats are therefore likely to vary by species and according to local habitat characteristics. Fast-flying species may be attracted to the increased foraging opportunities presented by insects around street lights, but this behaviour may also increase the risk of motor vehicle collisions, particularly to juveniles that may not have learned avoidance behaviours (Stone et al 2015b). Slower-flying, clutter-adapted species seem more likely to avoid artificial lighting, possibly to reduce predation risk, but in Hamilton, Dekrout (2009) found a negative relationship between intensity of street lighting and activity of long-tailed bats, which are not a gleaning species.

Chemical pollution is also likely to occur, particularly in the habitats immediately adjacent to, or downwind from, busy roads. Heavy metal pollution in air and soil was most apparent up to 10 metres from the road edge (Muskett and Jones 1980). In a recent review, Muñoz et al (2014) concluded that, although road-derived pollutants affect insects, there was still insufficient evidence of impacts on wider populations or on those species that feed on them, which includes bats.

4.2.4 Edge effects

One of the most obvious effects of road construction on habitats is the creation of new edges in what was previously contiguous habitat. The creation of more habitat edge with the associated reduction in cover, shade and humidity and increased light, wind and exposure can have mixed effects depending on individual species' requirements. In North America, Morris et al (2010) compared the activity of local bat species in and around managed pine plantations. They found aerial hawking species were much more active along edges than in forest interiors while gleaning, clutter-adapted Myotis species avoided edges. In a related study, bats were recorded as flying predominantly parallel to the forest edge with very few feeding 'buzzes' recorded, suggesting the edges were being used as linear landscape elements to facilitate commuting (Kalcounis-Rueppell et al 2013). In contrast, Jantzen and Fenton (2013) found edge use to be similar across bats of all foraging types, although the most clutter-adapted species of those studied had significantly lower levels of activity outside the forest than species classified as 'edge' or 'open' foragers.

Where commuting or foraging bats cross roads, they risk collision with vehicles, and this is likely to be fatal. Two analyses of bat road-kill records have sought to explain observed differences in the composition of bat species in data sets from different areas (Lesinski 2007; 2008). First, the relative abundance of different species in the habitats surrounding roads will be reflected in road-kill statistics, but species' behaviour also has an influence. Characteristically low-, slow-flying, gleaning species may show disproportionately high mortality rates whereas fast, high-flying species are relatively rarely encountered. Where a road crosses a flyway, casualties are also likely to be higher and even higher-flying species may be guided into traffic (Lesinski et al 2011). Seasonal effects were also apparent in the data, with peak mortality recorded during periods of migration to different seasonal roosts and during the dispersal of newly independent young. These effects have since been confirmed by other studies (Gaisler et al 2009; Russell et al 2009; Lesinski et al 2011; Semrl et al 2012). There is also increasing evidence that characteristics of both the road and the surrounding landscape can influence the risk of road mortality to bats. In a study of the impact of a main road in Austria on bat mortality, Gaisler et al (2009) noted that significantly more carcasses were detected where the road ran between two lakes. In Poland, twice as many road-kills were recorded on one stretch of a same road than at another bordering the same forest, but 10 kilometres away (Lesinski et al 2011). The authors suggested local habitat variation (commuting bats were 'funnelled' by forest lanes onto the road), and vehicle numbers and speed were key factors. Similarly, Medinas et al (2013) found landscape features were the most important of a range of factors in predicting bat road casualty rates. More road-kills occurred where roads crossed high-use habitats such as dense woodland, water bodies and riparian zones. They also recorded higher mortality rates of female bats in early summer, corresponding to the energetically demanding late pregnancy and lactation periods of the life cycle when females must forage more frequently, but are likely to be less manoeuvrable.

In considering road mortality data as an indicator of population impacts, two important points must be considered. The first is that surveys are likely to underestimate true mortality rates significantly because of difficulties in detecting road-killed carcasses (Slater 2002; Santos et al 2011; Teixeira et al 2013). The small size of bat carcasses means they may be thrown some distance from the point of impact or be retained on the vehicle; even if they land at the roadside, they are likely to be hard to detect in vegetation or could be scavenged and removed before the survey takes place. Second, although road mortality has the potential to contribute to population change, this cannot be inferred reliably without knowledge of the proportion of the population affected, the demographic classes (sex, age, reproductive status) to which they belong and the relative impact of this mortality in the context of the population's other vital demographic processes.

4.2.5 Bat behavioural effects

In addition to direct mortality effects, roads have been shown to affect the behaviour of commuting and foraging bats although different species can have quite different responses. Kerth and Melber (2009) radio-tracked individuals of two species of bat near a motorway during foraging and seasonal roost switching. An aerial hawking species that characteristically flew in open spaces crossed the motorway readily during both periods, but a gleaning species very rarely crossed the motorway and, when it did, individuals used an underpass. This was in spite of the motorway lying within the species' normal commuting range. As well as avoiding crossing the motorway, bats of the gleaning species had smaller than normal foraging ranges – a factor linked to significantly lower reproductive success. Road avoidance behaviour may be due, in part, to the deterrent effect of traffic to some species; for example, around twice as many commuting Myotis bats in the USA reversed their course away from a road crossing their commuting route when traffic was present compared with when it was absent (Zurcher et al 2010). One possible explanation for this effect is the avoidance of noise described above. Characteristics of habitats adjacent to the road also influence bat behaviour; bats' typical use of linear landscape elements to navigate across a landscape can lead them onto roads, but they may be more reluctant to cross the road because it creates a break in the linear landscape element (Russell et al 2009; Abbott et al 2012a; Bennett and Zurcher 2013).

Whether because of direct mortality or behavioural avoidance of the road due to light, noise, or traffic movement, roads can be barriers to bats' foraging, commuting and migration. This can have impacts on both populations and assemblages (groups of species living within defined areas) of bats in an area. In a transect-based study in the north of England, total bat activity and the diversity of recorded species declined dramatically with proximity to a motorway, particularly in areas of lower canopy cover (Berthinussen and Altringham 2012a). Two more recent studies confirmed these findings: in northern California, Kitzes and Merenlender (2014) found total bat activity to be reduced by about half adjacent to a road compared with 300 metres away, and that the effect was greater on cooler nights than warmer, suggesting habitat alteration may play a part in driving the observed behaviour. A survey of five British roads undertaken as part of the development of generic methodologies showed declines in both bat activity and diversity with increasing proximity to the roads (Berthinussen and Altringham 2015). Given that long-tailed bats in New Zealand are distributed patchily across a landscape, there is a strong possibility that local populations may be maintained by immigration from other patches. Barrier effects of roads are likely to interfere with this process making small isolated sub-populations more vulnerable to local impacts.

The effects of the impacts described above on the viability of bat populations can be inferred from published evidence, but can only be demonstrated from monitoring a population using an appropriate survey design, scale and methods, and for monitoring over the time-frame at which a population change can be detected reliably, or at which changes in vital rates can be measured. Individual species' vulnerability and responses to roads vary according to characteristics of their flight, foraging and ranging behaviours and any prediction of likely impacts must be based on a thorough understanding of these traits. The design of methods and strategies aimed at mitigation of impacts on a local population should be based on a firm understanding of that species population vital rates and life-history traits. If such information is lacking then collection of data on it should be prioritised before monitoring is properly designed.

4.3 Key points

- New Zealand has two remaining species of bat, long-tailed and lesser short-tailed, both of which are considered of conservation concern, primarily from the effects of habitat fragmentation and loss and from the impacts of introduced mammalian predators.
- Small echolocating bats hibernate in communal roosts during winter, when insects and other foods are in short supply. During the summer months, the males are generally solitary, living apart from the females in separate roosts. Females frequently continue to use communal roosts that are separate from males when pregnant and lactating.
- Bats spend the daylight hours resting inside a roost, emerging to feed at, or soon after, dusk; species that are more light-tolerant tend to emerge earlier than light-sensitive species.
- Usually, only one pup is born per female per year. Pups are looked after carefully and suckled for between four and six weeks until old enough to fly and hunt independently. Females need to hunt intensively during the suckling period and generally return to the roost several times a night to feed their pups.
- Bats may gather together from far flung locations to form these maternity roosts, so any disturbance or destruction of these roosts can affect bats over a large spatial scale.
- Individual bats use the same routes regularly for commuting between roosts and foraging areas.
- Some bats ('gleaning' foragers) with wider, more rounded wings are better able to fly in cluttered environments, such as forests, taking prey from vegetation, while other 'aerial hawking' species with narrower, more pointed wings forage on flying insects in open uncluttered spaces.
- Bats with wings adapted to foraging in cluttered forest habitats are at higher risk of extinction because their survival is more critically linked to the existence of suitable habitat and because their wing shapes are not adapted to long-distance migratory flights.
- Long-tailed bats are distributed patchily, but widely across the North Island and in a few places on the South Island. They are found primarily in indigenous forest and some exotic plantations, using edges and gaps to move/forage. They are insectivorous with wing morphology typical of aerial-hawking, moderate/fast-flying species. Roosts are in cavities (with high, small entrances), peeling bark, fissures and splits in trunk/large limbs of large, old trees. Emergence is usually from just before until 30 minutes after sunset, although this may be later in winter or when bats roost alone.

- Lesser short-tailed bats persist in old-growth indigenous forests at 13 locations, 11 of which are in the North Island. Their rounded wing shape suggests a gleaning habit, but they show a mixed foraging strategy; some hawking, but mainly gleaning and terrestrial hunting for invertebrates using passive listening. They also feed on nectar, pollen and fruit. Roosts are primarily in small cavities in trunks of large, mature trees and the bats only emerge when fully dark and return before sunrise.
- Likely roading impacts (with effects on demographic processes) on bat populations include:
  - roost loss during construction and from indirect effects, eg noise light, habitat clearance in local area of roost (direct mortality; loss of reproductive output if occupied; impaired energetic budgets due to need to establish replacements if unoccupied)
  - vehicle collision mortality where roads cross established flight paths (reduced survival rates)
  - habitat change through lighting, noise and physical severance of flight paths (barrier effects cause fragmentation, leading to increased foraging costs and lower foraging efficiency, therefore reduced survival and reproductive outputs. Potential for reductions in immigration and local genetic diversity)
  - creation of increased habitat edge may benefit edge-foraging long-tailed bats at some sites, but may also interact with increased road mortality risk.
- The effects of these impacts can only be demonstrated from monitoring a population using an appropriate survey design and methods, and by monitoring over the time-frame at which a population change can be detected reliably.
- Individual species' vulnerability and responses to roads vary according to characteristics of their flight, foraging and ranging behaviours and any prediction of likely impacts must be based on a thorough understanding of these traits.

5 Survey design and monitoring methods

In this section, we review the requirements for the design of a survey to either demonstrate an impact on bats from linear transport infrastructure or to provide robust and reliable evidence of the effectiveness of mitigation. We then review the methods used to survey and monitor bats in such studies with a particular emphasis on methodologies available in New Zealand. The section concludes by describing recently developed generic survey protocols for detecting landscape-scale effects on bat populations and for examining the effectiveness of mitigation attempts related to roading projects. Although we focus on the collection of evidence for assessing impacts and the effectiveness of mitigation, we note that in advance of any road construction, general assessments of likely ecological effects are required. Part of this general process will be a 'baseline' survey to detect the presence of indigenous species, such as bats, that may be affected by the road. Ideally, further work to identify key resources, such as roosts and foraging habitats, and species' activity patterns in and around those resources should also be carried out to predict the likely impacts of the road's development. Managers must then decide whether to instigate monitoring to quantify the predicted impacts or, if mitigation is planned, to test its effectiveness.

5.1 General design principles

In applied wildlife management, it is an unfortunate commonality that much more time and money is spent on 'doing things' than on monitoring the effectiveness of those interventions. Although this is understandable given the strong socio-economic drivers behind many development projects, including roads, a lack of robustly designed and sufficient monitoring means there is frequently no evidence available to allow management decisions to be made in the planning stage of a project and, later, no evidence that a management intervention has been effective and therefore cost effective. Yoccoz et al (2001) suggested monitoring design should be driven by three simple questions: (1) why monitor; (2) what should be monitored, and; (3) how should monitoring be carried out? The answer to the first question depends on the context of the project and the existence of clearly-defined 'SMART' (specific, measurable, achievable, relevant and time-bound) goals or objectives. This should then lead, logically, to the identification of what to monitor, ie what will tell you if you have achieved the project's desired outcome? Identification of the key variables of interest will then guide monitoring requirements, including the choice of the most appropriate methods to be used.

Rodenbeck et al (2007) noted that studies on the ecological effects of roads are rarely able to make strong inferences for two main reasons: 1) they are often focused on measuring an inappropriate 'end-point' such as movement rates across roads rather than the key variable of population persistence, and; 2) an absence of monitoring both before and after a road is built or a mitigation put into place. The authors emphasised that the most robust study design is a before-after-control-impact (BACI) design in which both the site of interest and a similar comparison site are monitored before and after an intervention. Post-effect monitoring must be of sufficient duration to detect an effect of interest based on the ecology and life-history of the species of interest. In a BACI monitoring design, the 'before' (pre-construction baseline) and 'after' (post-construction) states of a variable are compared, both at an 'impact' site (where an intervention is to take place) and at a 'control' (reference site). Before and after sampling will determine how the intervention changes the measured variable through time from its baseline condition. Control and impact sampling will allow the effects of actions to be discerned from natural variability, chance events and underlying trends in the larger area. For example, a before vs after comparison may detect a change in a key variable, such as a species' survival rate, but, if that effect is due to a more widespread factor, such as climate or food availability, comparison of the impact and control site data should reveal this. A control site which has identical conditions to the impact site is not typically available. Therefore, the term "reference site" can be used to describe a similar area near the site at which an intervention takes place, but that is not part of the impact area, or population, affected directly by the actions. The intervention and reference sites are typically monitored using identical methods and survey designs to allow direct comparisons of data (Smith et al 1993; Turner et al 2012).

If a full BACI design is not feasible, power analysis models suggest simple, but replicated before-after comparisons carry greater inferential strength than control-impact (ie sites with and without the intervention) comparisons (Rodenbeck et al 2007). Weaknesses in survey design meant that, of 30 studies of the effectiveness of wildlife road-crossing structures reviewed by Taylor and Goldingay (2010), only one was able to draw robust conclusions about the affected species' population viability. In a review of attempts to mitigate roading impacts on European protected species, Ward et al (2015) noted: 'In the majority of studies in which the benefits of road crossing structures were quantified, we found definitions of effectiveness to be inadequate. Many studies focussed on the use frequency of road crossing structures or changes in the absolute numbers of animals killed without accounting for pre-road movement rates, for changes in road crossing away from structures, for changes in population mortality rates (including within and between ages or sexes) and for population-level benefits'.

Other key questions in the design of a monitoring programme to determine the effects of a road or mitigation intervention on a wildlife population include how long monitoring should be undertaken and its extent (how many sites do you need to monitor at). The first question can best be answered by thorough consideration of the life history and ecology of the species of interest; for example, a programme aimed at monitoring changes at the population level of slow breeding, long-lived species such as bats would likely require decades of data to detect a significant change reliably, but one aimed at detecting changes in behaviour or mortality at a road would likely require a shorter duration defined by predictable seasonal or annual patterns of behaviour and a knowledge of their inherent variability.

All natural systems are variable and complex. Monitoring programmes rarely record data on every member of a population. More often we monitor only a sample of the population, and when interpreting the results, we assume the sample is representative of the whole population. Important questions are: 1) how big should that sample be, ie how many individuals' activity do we need to observe; 2) how many surveys do we need to be confident the data represents the population and its inherent variability reliably? This is particularly important when examining the effect of an intervention when we have to be sure any resulting change is able to be detected above the normal background variability. If we take too small a sample, we may not detect a real difference, too large and we waste valuable resources on monitoring. Scientists deal with this issue by estimating the 'statistical power' of a proposed monitoring programme. Power is an estimate of the probability of detecting a real effect and is influenced by the variability in what is being measured, the size of the effect that managers wish to detect, the duration and frequency of monitoring and the number of surveys or samples that are taken. Put simply, power analysis answers the question, 'how much survey/monitoring effort is required to be reasonably sure a real effect/difference can be detected'?

Mitigation of roading effects on wildlife will incur a cost to the agency building the road. The only way to be confident any investment in mitigation is cost effective is to monitor the effectiveness of various mitigation strategies in reducing impacts on a population. If monitoring is not designed appropriately to provide the necessary information, it imposes an additional cost from which little benefit is derived, and the uncertainty created by weak monitoring data may lead to drawn-out resource-consent decision-making processes.

5.2 Monitoring of bats in New Zealand

There are multiple challenges with monitoring of bats. Most are related to the fact that bats are small nocturnal flying animals that use cryptic roosts and produce calls largely outside the hearing range of humans (Weller 2007). The small number of methods used to monitor bats can be defined broadly into three categories depending on their aims: activity patterns from the detection of echolocation calls using either handheld bat detectors or automated bat monitoring (ABM) devices; behaviour patterns determined using radio telemetry, and population assessments estimated from mark-recapture methods. The majority of bat monitoring taking place in New Zealand is based on surveys of bat activity.

Before deciding upon what kind of monitoring is required, ecologists need to determine the monitoring objectives which, in turn, identify the most appropriate variables to measure to achieve these objectives (Hayes et al 2009; Meyer 2015). Monitoring programmes must provide sufficient baseline, and ongoing data for the accurate assessment of the effects of development, management activities and mitigation measures. For projects that require bat monitoring to assess changes in activity and behaviour related to a particular development, it will be necessary for monitoring to take place before work begins to ensure prior activity patterns are available for post-development comparisons and therefore assessments of any effects on bat movements.

5.2.1 Establishing bat presence

When a site is being considered for development, the first step is to determine the presence or absence of bats. Typically, a literature search is undertaken to check whether the site falls within the known distribution of bats. If bats are known to be within the general area then presence/absence surveys do not always take place; if they have not been recorded within the local area then surveys should take place. The literature search can be followed by acoustic surveys using ABMs. If there is any detection, or record of bats within the vicinity of a project footprint it is prudent to assume bats are likely to use the project footprint at least occasionally, unless proven otherwise. It is important that presence surveys are comprehensive; detection rates can be very low if bats are rare. Short-tailed bat calls are produced at relatively low intensity and attenuate quickly, so a bat must pass a few metres from a microphone to have a chance of detection (Parsons, unpublished data cited in Borkin and Parsons 2010a). Furthermore, activity and detectability can vary with environmental conditions, so these must be taken into account when surveys are designed.

If bats have been detected within several home range spans of a project, it is close enough to consider bats may possibly use the area. Home range is the area within which a bat moves when performing its normal activities, and home range span is the furthest distance from one edge of the home range to the other (Burt 1943; Harris et al 1990). In New Zealand, long-tailed bat median home ranges have been calculated to be as large as 2,006 hectares (juvenile bats independent for greater than two weeks, measured as 100% minimum convex polygons (MCPs); O'Donnell 2001) and to have range spans as wide as 10.85 kilometres in Fiordland forest habitats (adult male bats; O'Donnell 2001). The median home ranges for long-tailed bats in Kinleith Plantation Forest, central North Island, were in excess of 1,800 hectares with median range spans in excess of seven kilometres (both for juvenile bats, 100% MCP, Borkin and Parsons 2011a). In comparison, short-tailed bats in the same forest had median home ranges (100% MCPs) of 1,255 hectares and median range spans of 10.9 kilometres (post-lactating females), with the largest range span being 23 kilometres (Christie and O'Donnell 2014). In Pureora, central North Island, within mature podocarp-hardwood/plantation/pasture mosaic short-tailed bat median home range was somewhat smaller at 159.8 hectares and 258.9 hectares for female and male bats respectively (100% MCP, Toth et al 2015a). There is currently no official standard or best practice for the recommended level of input required to detect New Zealand bats. The Australian government's guidelines for surveys of indigenous bats provide some useful general advice on survey design and implementation (Department of the Environment, Water, Heritage and the Arts 2010).

In addition to surveying for the presence of active bats within the road project's footprint, areas planned for vegetation clearance are generally surveyed for the presence of bat roosts before any work begins. We address roost surveys and tree removal protocols as mitigation approaches in more detail in section 7.3.

5.2.2 When to monitor for bats

Bat activity is generally considered to increase with increasing overnight temperature (Kuenzi and Morrison 2003; O'Donnell 2000a; Scanlon and Petit 2008). Therefore, to be most effective at detecting bat presence, monitoring sessions should be planned for warm periods with little or no rain. For this reason, monitoring should take place between November and April, the period over which peak activity occurs (Borkin 2010). Specific climatic guidelines, based on research into the interaction between bat activity and climate, should be developed to determine the conditions most suitable for bat surveys.

5.2.3 Bat monitoring programme design

As with any monitoring programme aimed at answering questions about effects on wildlife and populations, bat monitoring should be planned to answer the critical 'why,' 'what,' and 'how' questions outlined in section 5.1 above. For example, if the question, 'does the construction of a road through a certain area reduce population size?' is important, some form of population estimation is required. Alternatively, if the question, 'does the removal of trees from an area result in behavioural changes?' is important, behavioural monitoring may be sufficient. In most situations, the ultimate goal of monitoring will be to establish whether land transport activities are having a negative effect on bat population abundance and long-term viability, and whether mitigation measures lead to long-term population sustainability. However, as described in subsequent sections, it can be difficult and costly to estimate population abundance. Therefore, measures of activity, eg numbers of bat passes detected by ABMs, are often relied on, inappropriately, to infer changes in population status. Activity indices are unable to provide any reliable indication of population size or viability simply because it is impossible to tell whether an observed level of activity results from single passes from many bats or multiple passes by few bats. Furthermore, indices of abundance are commonly flawed as they are often reliant on both activity – which varies by individual, habit, and season – and an assumption that a consistent linear relationship exists between the index and true abundance, which is very rarely the case. This requires that the focal species' detectability remains constant, both spatially and over time (Williams et al 2002). If this is not the case, differences in index values may be attributable to changes in population size, in detectability, or to some combination of the two. Without additional information on how detection probability changes according to variables such as season, habitat, weather or previous experience of the index method, it is impossible to know the relative effect of a change in population size on the measured index value (Williams et al 2002).

Monitoring programmes need to be sufficiently robust to meet project objectives, ie they will collect sufficient quality and quantity data to be able to detect a change in abundance or activity with a given degree of confidence.

To give an example, if a road is planned for an area where bats are known to be resident, the following questions might be asked:

1. What are the potential impacts on bats?
2. Are behavioural changes (eg in habitat use or movements because of road construction) likely?

3. What are the likely effects on population size or status that may occur (as a consequence of these impacts)?
4. Can impacts/effects be avoided through design changes – if not, then what mitigation or compensation measures might be required?
5. What is the most appropriate survey design for answering these questions?

Answering the first question, and to a degree, the second, depends on the results of the initial ecological impact survey to detect the presence of bats and their roosts in combination with detailed knowledge of species' ecological requirements. For the second question, a radio-tracking survey could be used to identify family group movement patterns clearly, and therefore identify road avoidance behaviour. However, ABMs could also be used to address this question, albeit far more crudely, although this would be best used as part of a wider suite of surveys. This would require setting up ABM arrays using a before, after, treatment, control (BACI) design. To do this at least two sites are required, one where the road is going to go, and one that will remain without a road, but which also has bat activity (the 'control' site). ABMs would then be used to establish activity patterns at both sites prior to road construction. Following construction, ABMs would be used to determine whether bat activity still occurs along/across the road, or whether activity patterns have been altered by the road. Changes in bat activity would then be compared to bat activity at the control site and to pre-road conditions.

The third question requires a knowledge of the relative effects on key demographic processes (eg survival, reproduction) and therefore on population growth of the most likely impacts of the development. This is best addressed using intensively collected mark-recapture data. Mark-recapture theory uses ratios of marked versus unmarked individuals and records of their captures through time to estimate probability of detection, abundance and apparent survival. These values can then be used in models to estimate population growth rates (see section 8.1 for an example).

The ecological component of the fourth question is best answered using robust evidence of the effectiveness of potential mitigation approaches or from trials of novel methods that are designed appropriately to provide sufficient good quality data. In the context of population viability, the third question is by far the most important to answer given that it would provide information regarding the likelihood of the persistence of a local bat population post-road construction. However, to our knowledge, this question has never been answered for a roading project in New Zealand. Instead, acoustic monitoring of activity data has taken place with the unsupported assumption that this reflects population status or is a direct measure of abundance.

When planning monitoring, some thought is required in relation to potential thresholds (such as a trend or absolute change in population size or survival) that monitoring needs to detect and of the optimal monitoring design (using power analysis) to detect that magnitude of change. Identification of this change, if negative, should trigger a change in management, otherwise the purpose of monitoring may be void. Identifying intervention thresholds or trigger points can help inform the level of precision and accuracy required in a monitoring programme and also assists with the choice of methods used (Hayes et al 2009). While adaptive management (changing management interventions in response to monitoring data) is at least occasionally discussed within Bat Management Plans (BMPs) (such as for the Huntly section of the Waikato Expressway; Connolly 2015a) there has been no formal identification of thresholds that would trigger a change in management or additional actions. Neither has there been identification of possible actions that may take place if trigger points are breached, nor the promise of making monitoring data publicly available to inform design of subsequent projects.

5.3 Activity monitoring using acoustic methods

Acoustic monitoring is a widely used monitoring tool for determining the presence of bats (Ahlen and Baagoøe 1999; Furey et al 2009; Harrison et al 2012) and examining their activity patterns (Hayes 1997). Acoustic monitoring is possible in New Zealand because the two extant species echolocate (Parsons 1997), that is they produce ultrasound or use biosonar, to 'visualise' their environment and navigate through it (Jones and Teeling 2006). Acoustic monitoring devices detect bat echolocation calls, record these in some form, and, with interpretation from the user, can confirm that a bat has been within the vicinity of the detector or ABM unit. Bat detectors, including those used in ABMs, have a relatively short range of detection and detectability varies between species (Hayes et al 2009). Early ABMs used in New Zealand were only able to detect long-tailed bats when they flew within 50 metres of the device and short-tailed bats within 25 metres (O'Donnell and Sedgeley 1994); consequently, the detection of bats using this method is limited to a relatively small area (Parsons 1996). At the time of writing, the most recent ABMs built by the Department of Conservation's (DOC's) Electronics Unit are expected to detect bats between 30 and 50 metres from units (S Cockburn, DOC, Wellington, New Zealand, pers comm, 29 October 2015). Nonetheless this provides a relatively low-cost method of detection because equipment is small and light, and an improvement in battery life means they can be placed in the field for relatively long periods for low labour input. An alternative method to the placement of stationery units is a walking transect with a handheld bat detector, although this can rely heavily on the skill of the user in identifying bat calls quickly in the field. It can also require higher labour input, and potentially fail to detect bats, due to transects either taking place at times when the bats are using other parts of their home range or moving away from the user in response to their presence.

Acoustic monitoring is useful for determining the presence of bats but, as with other methods, failure to detect bats does not confirm their absence in a specific area although this is commonly and mistakenly interpreted as such. For example, non-detection of long-tailed bats in the northern part of the Huntly section of the Waikato Expressway project footprint was interpreted as absence by Tonkin and Taylor (2014), but later surveys found bats were using the area (Tonkin and Taylor 2015). 'Non-detections' may result because ABMs are placed in locations where bats are unlikely to fly, or do not fly during the course of the survey, or because there are potential differences in the ability to detect bats in different habitat types (Patriquin et al 2003). Non-detections may also be due to the fast attenuation of some frequencies of calls, particularly around short-tailed bat peak call amplitude (O'Donnell and Sedgeley 1994; Patriquin et al 2003); the survey taking place during a period when bats are least likely to be flying, eg during heavy rain or other inclement weather (O'Donnell 2002a; Griffiths 2007); insufficient survey duration; equipment failure; or because, indeed, bats are absent from the area. Repetitions of surveys may result in detections of bats where these were not previously recorded (Borkin and Parsons 2010a) or could be used to estimate the probability of detection from which the probability of non-detection, given presence, can be established using occupancy modelling (MacKenzie et al 2002).

Although acoustic monitoring is used commonly it has several major disadvantages related to its passive nature. Firstly, it is currently impossible to determine whether one bat has been detected flying past an ABM many times or many bats were detected flying past once (Hayes 1997). Consequently, this method cannot be used for population monitoring, and relative abundance can only be estimated very coarsely (eg as 'relatively common', 'uncommon', or 'rare'; Sedgeley and O'Donnell 2012). This, again, highlights the importance of designing a survey appropriately to answer a specific question. If, for infrastructure development, the aim of mitigation is to maintain or increase the levels of 'activity' or use of a mitigation measure, then sufficient pre- and post-construction activity monitoring may be sufficient, based on the assumption that if no effect or a positive effect is detected, then the overall effect on the population is minimal.

The value of acoustic monitoring for evaluation of habitat use would be increased greatly if the calls of individual bats could be differentiated and the numbers of bats using each habitat type could be determined (Lacki et al 2007). Further, behaviour can only be inferred from acoustic monitoring, whereas more active monitoring, such as radio-tracking of individual bats, can determine with far more accuracy the type(s) of behaviour taking place, including during periods when bats are not echolocating (Hayes et al 2009; Morris et al 2011). With well-designed acoustic monitoring programmes, limited information about habitat use and changes in use over time can be inferred (Hayes et al 2009). However, this may be confined to information such as whether more or less foraging activity is taking place in a specific location within 25 to 50 metres of ABM equipment (O'Donnell and Sedgeley 1994). Acoustic monitoring can only provide information about bats in situations when they are producing ultrasound within the range of detection of ABM equipment (both frequency and area). Information about roosting behaviour can be difficult to tease out using acoustic monitoring (Hayes et al 2009). This is because activity patterns around roosts are not well studied for New Zealand bats (Sedgeley and O'Donnell 2012). Nevertheless, acoustic monitoring has been used with success within New Zealand to improve understanding of the presence of bats (Sedgeley 2012), their habitat use (O'Donnell et al 2006), and to create a model that predicts bat distribution and improved survey success (Greaves et al 2006). To understand behaviour and population status more thoroughly a more rigorous method of monitoring is required.

Most infrastructure projects within New Zealand undertaking monitoring for bats use acoustic monitoring. This is a valid way of establishing broad measures of bat activity and identifying, in the first instance, those areas where further survey effort should be targeted. Generally though, most pre-infrastructure surveys have taken place over short timeframes, and sample sizes have been small, which means little confidence can be placed in their ability to detect changes in relative activity reliably or in relative abundance at all. These monitoring programmes have generally designed surveys that are more likely to detect long-tailed bats than short-tailed bats. This is because monitoring sites have largely been placed along edges of forest stands and waterways along which long-tailed bats are most likely to be detected (Borkin and Parsons 2009; O'Donnell et al 2006) and short-tailed bats are generally considered to be restricted to certain habitat types (but see Toth et al 2015a, and Borkin and Parsons 2010a). Bat activity can vary from day to day and between seasons due to many factors including climatic conditions (Turbill 2008), reproductive activity (Russ et al 2003), the distance between roosts and foraging areas (Ciechanowski et al 2007), and invertebrate availability (O'Donnell 2000a), resulting in wide sample variance and consequently requiring large sample sizes for precise estimates of activity (Hayes 1997). O'Donnell and Langton (2003), when using counts of bat passes along line transects, noted large sample sizes and/or long monitoring programmes are required to obtain sufficient power to detect changes in relative abundance because long-tailed bat activity is inherently variable, even with standardised survey methods. A more recent analysis suggests that monitoring for fewer than 10 years would provide insufficient statistical power to infer changes in populations reliably, particularly changes of small magnitude (Meyer 2015). As discussed previously, statistical power refers to the ability to use monitoring data to measure trends that are present. Insufficient or highly variable data may not detect population trends that are actually occurring. It is essential that a power analysis be undertaken during the design phase of a monitoring programme. The power analysis should demonstrate that the monitoring programme is capable of producing sufficient data to answer questions pertinent to project goals. The use of power analyses to assess the ability of bat monitoring programmes to determine trends is increasing (Meyer 2015). If sites are sampled inadequately there is greater probability of incorrect or ambiguous inferences being drawn (Hayes 1997). For example, if a monitoring programme has low statistical power then it may fail to detect a change in bat abundance that has actually occurred, and therefore falsely conclude there is no change. Power analyses use known or predicted samples sizes, and data variance, to estimate the likelihood of detecting various changes in population sizes, eg a 10% reduction in bats over five years. Consequently, power analyses can be used to guide the design of monitoring programmes by identifying the level of sampling necessary to detect a change in population of a certain size. As an example, O'Donnell and Langton (2003) suggested that in most situations monitoring programmes should aim to achieve 80–90 percent statistical power to detect population changes in the order of 3–10 percent per year. They estimated that achievement of this level of statistical power would require monitoring 50–100 sites once per year for >10 years. In contrast, Scott and Altringham (2014) estimated one to nine repeated surveys at a site would be required to detect the presence of a range of British woodland bat species reliably and that between 22 and 126 sites should be surveyed annually to detect a 50 percent change in occupancy. Required sample sizes for each species differed according to species' detectability and relative abundances. The analytical methods used by Scott and Altringham (2014) can be adapted for use in other surveys and the authors provide instructions and software code to facilitate this.

The use of statistical modelling techniques, particularly those that take into account the probability of detecting bats given they are present, can greatly improve monitoring programmes along with a well-balanced design and highly standardised sampling (Meyer 2015). Unfortunately, there are no formal guidelines describing sampling effort for acoustic monitoring of New Zealand bats using ABMs (Sedgeley 2012). The development of such guidelines is essential and should be based on power analyses that make use of existing data.

It is important to consider the type of data analyses required to answer the key research question when designing a monitoring programme. In this context, not all data is of equal value. For example, if monitoring is put in place to investigate a change in bat behaviour through time, then repeated measures using the same method, in the same places, at the same time of year are required, whereas data requirements for spatial comparisons or for a full BACI design are different. Consultation with a biostatistician or a scientist with experience of experimental design during the planning stage of a monitoring programme is strongly recommended to avoid wasting resources on a programme that is unable to answer a key management question because data were not collected appropriately.

5.4 Population monitoring

Population monitoring is the only type of monitoring that can inform ecologists directly about survival, productivity and abundance, and consequently any population changes. To our knowledge the only population monitoring undertaken for New Zealand bat species is carried out by DOC (Pryde et al 2005; 2006) and in limited cases during research by various universities. Although population monitoring is the method that would assist best with understanding the direct and indirect impacts of road development projects, a search of the literature suggests no population monitoring has been undertaken in relation to New Zealand infrastructure projects. This is because population monitoring is costly and labour intensive, even though it produces high-quality data, and also perhaps because project managers have been unaware of its value.

Population monitoring involves the capture of individual bats, attaching radio-transmitters to them to enable location of their roosts by radio-telemetry which, in turn, facilitates a systematic programme of regular resurveys of the population. Population size can be estimated using a variety of methods with a range of precision and reliability. 'Minimum number alive (MNA)' techniques have been used to estimate population size from the capture histories of long-tailed female bats (Eglinton Valley, Pryde et al 2005), and from roost emergence counts using infrared cameras and counting at a later time (as for the Rangataua Conservation Area short-tailed bat studies, Morrison and Beath 2012). Using MNA methods is generally discouraged as they tend to underestimate true population size (Pryde et al 2006). This is because it is impossible to estimate the unobserved proportion of the population that is distributed over several roosts at any one time, some of which may be unknown. An alternative and more robust technique is capture-mark-recapture and this has been used in studies in the Eglinton Valley, Geraldine and Grand Canyon Cave (Pryde et al 2005; 2006). The latter study concluded that the use of MNA underestimated long-tailed bat population size significantly at Grand Canyon Cave in comparison with mark-recapture estimates.

Methods that estimate population size assume a population is 'closed', ie no or little mortality, births, immigration and emigration between capture sessions, and therefore data must be collected over a short period to avoid violating this assumption. The lack of movement between populations may be a reasonable assumption for New Zealand's long-tailed bats – except during juvenile dispersal – given that they appear relatively loyal to traditional home ranges (Borkin and Parsons 2014) and roosts (O'Donnell and Sedgeley 1999) and maintain relatively stable social groups (O'Donnell 2000b). Less is known about short-tailed bats (Christie and O'Donnell 2014, Toth et al 2015a), although they appear to reuse roosts over multiple summers (Sedgeley 2003; Morrison and Beath 2012). Depending on the capture location and methods used, there may be some capture bias towards bats of either sex or of specific reproductive status, although this heterogeneity in capture probability can be accounted for during analysis of the capture data. Many capture-based studies are biased towards reproductive females and juveniles. This is because both long-tailed bats and short-tailed bats generally roost in large maternity day roosts (O'Donnell and Sedgeley 1999; Sedgeley 2003) and switch social groups less often (long-tailed bats, O'Donnell 2000b) over summer, when most studies are undertaken. In contrast, adult males and non-reproductive females are generally captured less often as they more frequently roost away from maternity roosts (O'Donnell and Sedgeley 1999; Sedgeley 2003) and switch social groups (long-tailed bats, O'Donnell 2000b) and therefore are less likely to be captured at communal roosts and included in radio-telemetry studies. The choice of a night roost as a capture site reduced bias during one study and this may be a useful technique; however, night roosts are often unknown and hard to locate (Pryde et al 2006). As a general rule, when undertaking population size estimations it is important to define the geographical limits of the population being assessed (Hayes et al 2009).

Difficulties with population monitoring can be related to the capture method involved. Capture methods include the setting of large mist-nets or smaller harp traps across flightpaths, or at roost sites, or using hand nets to capture bats as they emerge from roosts (see Patrick et al 2014 for a brief review and Sedgeley et al 2012 for greater detail). Capturing bats is labour-intensive, and capture rates are often low, because bats are rare and can detect mist-nets (less than 0.01 bats/net/hour in O'Donnell and Sedgeley 1999). When roosts and effective capture sites are known, capture rates increase (Sedgeley et al 2012).

5.5 Permanent marking of bats

Long-tailed bats are typically ringed or banded with an individually numbered metal bat band on the forearm (Sedgeley et al 2012), but this method has been linked to injuries in short-tailed bats. Passive integrated transponder (PIT) tags are increasingly being used in New Zealand for monitoring of short-tailed bat populations, and this is currently the only method that is approved by DOC for the species (Sedgeley et al 2012). PIT tagging involves the insertion of a permanent tag under the skin of individuals. Tags can be read electronically using loop antennae placed around known roost entrances. These offer potential improvements to programmes that aim to estimate survival rates, because once captured animals are marked, bias caused by harp trap avoidance can be ignored (Kunz et al 2009). Once a large proportion of the population is pit-tagged long-term survival information can be collected without capturing additional bats (Sedgeley et al 2012). PIT tagging also provides opportunities for gathering behavioural data including roost use of short-tailed bats (Toth et al 2015b).

5.6 Behavioural monitoring

Monitoring of behavioural changes could be useful to help understand effects of specific management actions on bat activity within or near infrastructure projects. For example, if greater understanding of a specific action is required, and a question is posed such as: 'Does planting promote or facilitate crossing of roads by bats?', or: 'Are original flyways maintained?' then monitoring of individual bat behaviour is required. Acoustic monitoring is unlikely to answer such questions in isolation because it can only provide presence-absence data and does not provide information on whether an individual bat crossed a road. A range of behavioural monitoring methods are used within New Zealand although, as for population monitoring, this is largely undertaken by DOC and by university researchers. There has been limited use in relation to infrastructure projects, eg some direct observations of long-tailed bats were undertaken during baseline monitoring for the Cambridge Section of the Waikato Expressway (Connolly 2013) and the use of thermal imaging is being investigated for use within the Huntly Section of the same expressway (Connolly 2015). Monitoring aspects of bat behaviour may have the potential to guide mitigation associated with infrastructure projects in a more precise manner than acoustic monitoring because of the higher quality information that can be gathered, dependent on the method used.

Monitoring methods that involve the capture of bats are currently the only option that provides information about individuals of known age, sex, and reproductive status. Studies that have previously taken place in New Zealand using capture and radio-tracking of individual bats have expanded our knowledge of home range (O'Donnell 2001, Christie and O'Donnell 2014), habitat selection (Borkin and Parsons 2011a, Toth et al 2015a), individual activity patterns (O'Donnell 2002b), roost use and selection (Sedgeley and O'Donnell 1999, Sedgeley 2003), social group dynamics (O'Donnell 2000b), genetics (O'Donnell et al 2015), and breeding systems (Toth et al 2015b).

The most commonly-used method of gaining this information involves capture of bats, the attachment of a radio-transmitter, and the use of radio-telemetry to locate roosts and obtain information about bat habits. Radio-telemetry's advantage over acoustic monitoring when investigating habitat selection is that locations for bats can be obtained regardless of their behaviour, and even when they are not echolocating (Morris et al 2011). There are some concerns about the effect of adding mass in the form of transmitters to bats (Aldridge and Brigham 1998). Consequently, researchers try to keep transmitter weights to 5% or less of animal weights, to minimise any potential adverse effects (Lacki et al 2007). However, evidence suggests that bats are able to carry greater than 5% of their body weight with little effect on future reproductive success, condition, survival (Neubaum et al 2005), and foraging efficiency (Hickey 1992).

The success of a radio-telemetry-based investigation depends on the ability to capture bats, and track locations, as well as the skill of personnel. The ability with which locations can be tracked is affected by terrain, access, weather, movement, and triangulation error (Lacki et al 2007). Short battery life of transmitters (one to three weeks) and the ability of bats to remove transmitters at least occasionally (K. Borkin personal observation) mean that full home ranges and roost use may not be determined without recapture and transmitter replacement. These factors, as well as the sample sizes required to answer questions and the likelihood of attaining these, should be taken into account when designing programmes. A pilot study can be worthwhile to assist the design of larger programmes by investigating, for example, autocorrelation and designing a regime of data collection which minimises its effect, whilst gaining enough information to estimate an individual's home range (Harris et al 1990).

Chemiluminescent tags (light tags) also have been used to investigate habitat use of short-tailed bats with some success (Christie 2003, Sedgeley et al 2012). However, their use is limited by the need to stay in visual contact with the bat, the short-time visible due to the presence of clutter (Christie 2003), the short life-time of the tags (a few hours Sedgeley et al 2012), and the number of observers required (Lacki et al 2007). There is also minimal ability to distinguish between individually-tagged bats (Lacki et al 2007, Sedgeley et al 2012).

5.7 Future horizons for behavioural monitoring

Technological advances related to radio-telemetry, such as satellite and GPS tracking, may be of use in the future, but devices are currently too large or heavy to be used for small insectivorous bats (Lacki et al 2007), such as those that occur in New Zealand.

Direct observations of bats may be useful in elucidating behaviour at specific locations. Observations can, in some cases, provide information about species that use a specific area, a measure of the use of habitat, the position and direction of common flight paths, as well as some information about roost use (Hayes et al 2009). However, visual observations that are not supported with night-vision equipment or thermal imaging cameras can be limited to a small field of view and a short period of the night within which bats are visible to the naked eye (Hayes et al 2009). Direct observations are generally subjective and as such may be less useful when answering more complex questions. When using direct observations, such as watching for bats at street lights, it is not possible to differentiate between individual bats and therefore determine individual bat behaviour or the total number of bats using specific features and their interactions.

Recent technological developments in infrared thermal imaging have improved the information that can be gathered using direct observations, although at present these still remain most useful over a short range and are relatively high cost (Weller 2007, Hayes et al 2009). Advantages of this technique include its non-invasive nature, its ability to eliminate visibility bias, and reduced observer fatigue (Havens and Sharp 2016). Thermal imaging can detect bats over a far greater distance than ABMs. Bats have been easily recorded at 500 metres and in some cases at up to one kilometre, in comparison with ABMs approximately 30–50 metres detection range (S Cockburn, DOC, Wellington, New Zealand, pers comm, 29 October 2015). Thermal imaging may be most effective where relatively warm animals are able to be silhouetted against a homogeneous, cooler, background, such as the sky (Weller 2007), or forest floor, particularly in the early morning when the background has come to thermal equilibrium (Havens and Sharp 2016). Thermal imaging surveys may be even more successful after several days of minimal solar loading (ie dull, overcast weather) because this will ensure a greater contrast in temperatures between the target and their surrounds (Havens and Sharp 2016). Thermal imaging techniques may be useful at some roost sites for use in emergence counts, particularly when images are recorded so bats can be counted later, and may provide more accurate counts than those undertaken solely by human observers (Hayes et al 2009; Havens and Sharp 2016). Cavities that provide potential tree roosts may also be identified with thermal imaging during day or night because the interior of trees can be warmer than their exterior, therefore providing contrasting temperatures (Havens and Sharp 2016), but may not determine whether bats are present. A combination of thermal imaging and light detection and ranging systems has recently provided information regarding the flight behaviour of individual bats and the avoidance of obstacles (Yang et al 2014). These techniques could be potentially useful for the investigation of bat behaviour around roads.

The use of radar to monitor bat activity and behaviour is infrequent, and to our knowledge this has not yet taken place in New Zealand. However, it has been used internationally to measure use of habitat, and the position and direction of flight paths as well as their speed and altitude (Hayes et al 2009). A recent trial showed there is promise for this technique to assist in the investigation of bat behaviour near linear infrastructure, although further development is required prior to it becoming an effective survey tool (Berthinussen and Altringham 2015). While radar has relatively long-range capabilities and can collect data in many directions at once, its use may be limited in a New Zealand context because it is ineffective in areas with strong topographical relief, or with dense vegetation cover. There are also difficulties separating small birds and bats, and individuals flying in close proximity (Hayes et al 2009).

Another recent monitoring development involves the use of a 3-D microphone network and associated GIS analysis to plot the position of a bat call accurately in three-dimensional space (Tasse and Pouchelle 2014). This, allied with a species identification algorithm, allows bat flight movements to be mapped and their use of mitigation structures such as bridges and underpasses to be investigated.

5.8 A generic bat survey protocol for bat activity around roading projects

In a recent report for the UK Department for Environmental Food & Rural Affairs (DEFRA), Berthinussen and Altringham (2015) developed survey protocols for bats at two spatial scales around roads:

- A large-scale transect study to detect changes in bat activity and diversity across the landscape that can be related to the building or upgrading of major roads and railways, and can determine likely effects on bat populations
- Observational studies at a local scale along linear habitat features and bat crossing points to assess the success and cost effectiveness of mitigation measures currently used to take bats safely over or under roads or railways.

The methodologies described in the DEFRA report may be applicable to New Zealand requirements, but it is relevant to reiterate the authors' caveat that they:

> *should be conducted in addition to other preconstruction desk and field-based surveys that are used in the early stages of road or rail route planning to identify bat roosts, foraging habitats and commuting routes that may be destroyed or disturbed by the scheme. Particular attention should be given to rare and vulnerable species and to points where they cross the proposed road, since it is at these points that mitigation effort should be concentrated.*

The report supplies detailed methodologies for both surveys as on-line appendices which also include protocols for analysing the data collected. The recommendations are summarised below and further information can be obtained from:

- Landscape-scale protocol: http://sciencesearch.defra.gov.uk/Document.aspx?Document=12714_WC1060AppendixE.pdf
- Mitigation/crossing-point protocol: http://sciencesearch.defra.gov.uk/Document.aspx?Document=12715_WC1060AppendixG.pdf

The landscape scale survey is based on a series of 10, one kilometre-long transects lying perpendicular to the road (or proposed road) and on which handheld bat detectors are used at regular intervals for 10 minutes to detect the presence of foraging bats. The distance between monitoring points will depend on the range at which the available bat detectors are functional. At each monitoring point, climate and habitat variables can be recorded and related later to bat activity, although the authors limited surveys to those weather conditions when bats are most likely to be detected, ie avoiding rain, and windy (>20 kilometres/hour) or cold (<7°C) nights. The authors' caveat above is particularly appropriate in the New Zealand context given the potential for at least one indigenous species, lesser short-tailed bats, to be restricted to habitat fragments and for long-tailed bats' tendency to utilise habitat edges for foraging. A local survey design would need to consider such behaviours and it is strongly recommended this protocol is tested in a New Zealand landscape, particularly given the relative rarity and more sparse distribution of New Zealand bats compared with their European counterparts.

To examine bat activity and behaviour at existing and proposed road-crossing points/mitigation structures, the DEFRA report suggests six observational surveys undertaken one hour after sunset and one hour before sunrise at each location of interest. Bats are detected and identified using bat detectors, but observers note behavioural characteristics at the crossing point. In a trial, the authors focused on existing mitigation structures and recorded the proportion of bats crossing the road/railway safely, and the effectiveness of the structure in guiding bats safely over or under the road/railway. For 'over-the-road' structures, they estimated the position (relative to the crossing structure) and flight height of all bats crossing the road/railway in the vicinity of such structures. For underpasses, they determined the proportion of bats flying safely through the underpass compared to those crossing the road above, safely or unsafely (relative to traffic height).

'Safe' and 'unsafe' crossing heights were defined as above or below five metres above the road surface, respectively.

Among a set of best practice measures, the authors suggest:

1 For assessment of landscape scale effects:

  a Undertake the transect survey protocol prior to construction to provide baseline data. This should be done over at least two seasons (other than winter) where possible.

  b Repeat the transect survey protocol during and after construction. We advise surveying for a minimum of three years post-construction. Frequency of survey will depend upon the project goals but the effects of linear infrastructure on bats may persist for many years, and long-term monitoring is important.

  c A minimum of 10 transects of one kilometre length (with 10-minute spot checks at 100 metre intervals) must be completed per site, at the same time each year (ideally late summer). More transects may be needed if specific bat species are of interest, particularly those that are less common.

  d Compare pre-construction data with during and/or post-construction data using appropriate statistical tests (such as t-tests or one-way analyses of variance) to look for changes in bat activity over time. If bat activity (either total and/or for individual species) has significantly declined, the infrastructure has had a negative effect since construction.

  e Analyse post-construction data using the suggested statistical method to look for changes in total bat activity in proximity to the infrastructure, and repeat the analyses for all species with sufficient data. The analysis may also be repeated for bat diversity.

  f If the effect of distance from the infrastructure is positive (with a statistical significance level of $P < 0.05$) or bat activity (either total and/or for individual species) is predicted to increase by at least 20% (regardless of statistical significance) between zero and one kilometre from the infrastructure, the effect is considered to be detrimental to local bat populations. Rare or vulnerable populations may need special consideration. We note that the authors' use of a 20% decline in activity with proximity to a road was suggested as a precautionary threshold that allows for intrinsic behavioural variability.

2 For local scale and mitigation surveys:

   a Identify bat commuting routes that will be severed by the scheme prior to construction to inform the placement of mitigation structures.

   b Before construction, complete a minimum of six 60-minute dusk or dawn surveys at each location where mitigation is to be installed. Longer surveys, running later into the night, may be necessary if vulnerable, woodland-adapted species are involved.

   c Repeat the local scale survey protocol at each location where mitigation is installed at the same time each year during construction and post-construction. We advise surveying for a minimum of three years post-construction (frequency of survey will depend upon the project goals but the effects of linear infrastructure on bats may persist for many years, and long-term monitoring is important).

   d For schemes that have already been completed, surveys may be carried out post-construction only to provide a basic assessment of the mitigation. However, this will not give a complete picture of effectiveness or the impact of the scheme and is insufficient for future schemes.

   e Compare the total number of bats crossing at each site before, during and after construction, and the number of bats considered to be using the mitigation structure in question (according to set definition of 'use'), and the number crossing the scheme at risk of collision with traffic.

   f Mitigation structures are considered effective when the number of bats using the commuting route has not declined substantially (by a statistically significant decline of 10% or more) since construction, and at least 90% of crossing bats are using the structure to cross safely. Special consideration will need to be given to rare and vulnerable populations. Not all species may be affected in the same way. As with the landscape-scale survey, the 10% threshold is the authors' suggestion of a safety criterion, based on the precautionary assumption that a crossing structure should only be considered effective if at least 90% of bats use it to cross a road safely.

5.9 Key points

- Studies on the ecological effects of roads are rarely able to make strong inferences because they are often focused on measuring an inappropriate 'end-point', such as movement rates across roads rather than the key variable of population persistence, and they do not monitor both before and after a road is built or mitigation is put into place. Post-effect monitoring must be of sufficient duration to detect an effect of interest based on the ecology and life-history of the species of interest.
- The most robust study design is a before-after-control-impact (BACI) design where the 'before' (pre-construction baseline) and 'after' (post-construction) states of a variable are compared, both at an 'impact' site (where an intervention is to take place) and at a 'control' (reference site). Before and after sampling will determine how the intervention changes the measured variable through time from its baseline condition. Control and impact sampling will allow the effects of actions to be discerned from natural variability, chance events and underlying trends in the larger area.
- Duration of monitoring should be determined by the life history of the species being monitored – populations of long-lived, slow-breeding species will take longer to respond to an intervention, so a monitoring programme will need to last longer to detect changes reliably.
- Extent of a monitoring programme should be planned using power analysis; a statistical method that addresses the question of how much survey/monitoring effort is required to be reasonably sure a real effect/difference can be detected.

- If monitoring is not designed appropriately to provide the necessary information, it imposes an additional cost from which little benefit is derived, and the uncertainty created by weak monitoring data may lead to drawn-out resource-consent decision processes.
- Consultation with a biostatistician or a scientist with experience of experimental design during the planning stage of a monitoring programme is strongly recommended, to avoid wasting resources on a programme that is unable to answer a key management question because data were not collected appropriately.
- Field methods for monitoring bats fall into three categories: presence/absence and activity patterns from automated bat monitors; population assessments estimated from mark-recapture methods, and; behavioural patterns determined using radio telemetry.
- Monitoring should reflect a survey's objectives, but measures of activity, eg numbers of bat passes detected by ABMs are often relied on, inappropriately, to infer changes in population status.
- Most infrastructure-related monitoring in New Zealand uses acoustic methods. Generally, these have taken place over short timeframes, and sample sizes have been small, which means little confidence can be placed in their ability to detect changes in relative activity reliably or in relative abundance at all.
- Population monitoring is not used in infrastructure-related surveys; it is costly and labour intensive, even though it produces high-quality data.
- Monitoring aspects of bat behaviour may have the potential to guide mitigation associated with infrastructure projects more precisely than acoustic monitoring because of the higher-quality information that can be gathered, subject to the method used.
- Radio telemetry and direct observation methods are used most commonly to monitor behaviour, but new technologies such as infrared thermal imaging, light detection and ranging systems, horizontally-scanning x-band radar and 3-D acoustic plotting have shown promise, but need further investigation.
- A recent British template for surveying bat protocols at landscape and local (crossing-point) scales has great potential for use in New Zealand, but it should be trialled to test its suitability for the New Zealand landscape and for New Zealand's rarer and patchily distributed bat populations, which are likely to require larger sample sizes than those recommended for most British species.

6 Mitigation: overseas evidence

Following the identification of the threats presented to bats by roads and their associated infrastructure, a range of mitigation approaches have been developed, primarily in Europe. In this section, we review published evidence on bat behaviour around mitigation structures, to determine their effectiveness. Most attempts to mitigate adverse effects have been based on incorporation of structures into road design, to facilitate safe movements across the road.

6.1 Underpasses

Bats' use of under-road structures to move from one side to the other was first recorded in a series of observational studies in central Europe (Bach et al 2004). At around the same time, a new highway scheme in Wales incorporated two culverts at pre-existing bat crossing points, specifically to facilitate safe crossing of the new road by bats. Although use was low during road construction, a number of species of bats used the culverts increasingly following the road opening, although some were observed to alter their behaviour away from more well-lit areas near the culverts (Wray et al 2006). Kerth and Melber's (2009) study of the effects of a motorway on bat behaviour revealed a variety of species used underpasses to cross safely, but encounters were dominated by characteristically low-flying, gleaning species. Research then focused on the characteristics of crossing structures that might influence their use by bats. Boonman (2011) investigated bat use of 54 culverts under Dutch roads. Use was dominated by low-flying, gleaning species and by over-water foragers where the culvert carried a water flow. Bats used all culverts of cross-sectional area greater than 4 m2 and use increased with cross-sectional area above that threshold. Clutter-adapted foraging species were the only bats to use narrow drainage pipes to traverse a road in Ireland, but a greater variety of bats used a large underpass nearby (Abbot et al 2012b). In both the Irish and Dutch studies, the height of the underpass was the most important component of the cross-sectional area in determining bat use. Bat use of three underpasses in the north of England varied depending on the underpasses' location (Berthinussen and Altringham 2012b). At only one of the three, sited on a pre-road construction commuting route, did the majority (96%) of bats observed use it to cross the road. At the other two underpasses – not aligned to commuting routes – more bats crossed over the road, at traffic height, than used them, despite landscaping attempts to divert their flight paths towards the underpasses. A subsequent study of three more underpasses by the same authors showed that up to two-thirds of bats observed using the structures at two and the vast majority at the third (Berthinussen and Altringham 2015). The most used underpass was the widest and highest and maintained a pre-existing commuting route. The other two, smaller underpasses maintained some characteristics of the original flight paths, but not all.

6.2 Over-road mitigation structures

Because of bats' tendency to use linear landscape elements as commuting routes, over-road mitigation structures have been used to attempt to take advantage of this behaviour in guiding bats above the traffic flow. Perhaps the method used most commonly is the bat bridge or gantry which consists of a series of horizontal wires strung over a road with mesh or plastic spheres attached to the wires to increase their echolocation profile. Despite their extensive use and high cost (equivalent to around NZ$280,000 each[3]), there appears to have been little evidence of their effectiveness used in deciding to utilise them, other than assumptions based on what was known about bat behaviour.

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[3] Source BBC News Online, 22 October 2009, http://news.bbc.co.uk/2/hi/uk_news/england/cornwall/ 8320610.stm (accessed 29 October 2015)

In the first robust assessment of their usefulness, Berthinussen and Altringham (2012b) compared the proportions of bats observed using four gantries with those crossing the road at unsafe heights and found the majority of bats at all sites avoided using the gantries, even one that had been in place for nine years prior to the survey. Most bats crossed the roads at pre-existing commuting routes at heights that placed them in danger of vehicle collision. In a subsequent study at three more gantry sites, one of which was yet to be completed by having wires attached, bat use of the gantries was negligible and most crossed roads at unsafe heights nearby (Berthinussen and Altringham 2015). The overwhelming conclusion is that bat gantries are ineffective at guiding bats across roads at safe heights. Similarly, we could find no evidence of the effectiveness of vegetated 'hop-overs,' where high vegetation is planted or manipulated to provide continuous habitat over a road. O'Connor and Green (2011) reported that around half of bats observed crossing a road in the UK used a hop-over at a 'safe' height, but no data was available to evaluate either before or after use or the proportion of bats crossing safely.

Other studies have recorded or investigated bat use of other over-road structures, including minor road- and foot-bridges and purpose-built 'green bridges.' Few bats were recorded using overbridges spanning motorways relative to crossing the motorways at other sites or using underpasses in two separate studies (Bach et al 2004; Abbott et al 2012a). Berthinussen and Altringham (2015), in developing their survey design, also recorded minimal use of a minor-road-carrying overbridge with no vegetation and no connectivity to linear habitat features. The same authors also looked at two over-road structures designed specifically to aid wildlife crossing of major roads. These were an 'environmental overbridge' with high sides and a row of planted vegetation, over which 80% of observed bats crossed, and a 'green bridge' described as, 'a relatively wide, substantial structure and although it carries a paved minor road, it is well vegetated with dense and continuous mature trees and shrubs along each side that are well connected with treelines and surrounding woodland'. Ninety-seven percent of observed bats used this structure to cross the road. Other features of the bridge, including its connectivity to pre-existing habitat on both sides and its placement at commuting height, may have influenced its effectiveness.

6.3 Mitigation of roost loss

Although not specific to road effects, the use and effectiveness of mitigation of roost loss has also been considered in relation to bat conservation in Europe. Roosts may be lost during habitat clearance when constructing a road, along with other important habitat components. Replacement roosts made from artificial structures may be considered as a mitigation approach. Provision of artificial roost boxes has been used with success internationally, with the aim of providing additional potential roosts and enhancing biodiversity in a variety of habitats including farm forests (Smith and Agnew 2002), plantation forests (Ciechanowski 2005), indigenous reserve areas (Bender 2009), and mosaics of deciduous forests with agricultural, residential, and commercial developments (Brittingham and Williams 2000). However, there are few published studies documenting their efficacy (Hayes and Loeb 2007) and, as with other types of mitigation, we caution that evidence of some use does not translate to effectiveness in mitigating an adverse effect at the population level.

There is some overseas evidence to suggest, in areas where natural roosts are limited in number, bat uptake of roost boxes may be higher (Smith and Agnew 2002, Ciechanowski 2005). Roost boxes may also be more effective when placed near the roosts they are to replace (White 2004) and when their aspect orientation is considered in relation to sunlight (Dillingham et al 2003). However, they should only be considered as a temporary solution for areas undergoing restoration and that currently have few suitable roost trees. It is generally recommended long-term strategies focus instead on provision of natural roosting structures (Hayes and Loeb 2007, Popa-Lisseanu et al 2009). This is because artificial roost boxes are far less efficient at buffering and delaying temperature fluctuations than natural cavities, and bats are therefore likely to prefer natural cavities if they are available (De Bruyn et al 2003). Artificial roosting structures probably rarely meet the full suite of bats' roosting needs, which vary with species, reproductive condition, season, and roost function (Hayes and Loeb 2007). In a survey of permits (derogation licences) allowing building and renovation that might result in roost-loss to take place in England, Stone et al (2013) noted that most mitigation methods were based on anecdotal evidence of their effectiveness and that post-development monitoring data was inadequate to tell whether or not the mitigation attempts had been effective.

In summary, the efficacy of bat roost boxes for New Zealand species has not been demonstrated and their use as a mitigation strategy cannot be justified without evidence of their effectiveness in providing supplementary roosts for bats.

6.4 Lighting management

To date, there are no published studies on the effectiveness of different lighting regimes in reducing impacts on bats at roads. Stone et al (2015b) provide a series of recommendations to minimise impacts, including interconnected light-exclusion zones along known flight-lines, dimming or switching off lights during critical bat movement periods, reducing overall light intensity (although species-specific thresholds are unknown), and avoidance use of lights with short-wavelength (blue to ultra-violet) outputs to which bats and some insects may be more sensitive. More recently, Rowse et al (2016) detected no difference in aerial-hawking species' activity between low-pressure sodium and newer LED street lights, although slow-flying, gleaning species were encountered only rarely under either lighting regime.

6.5 Key points

- Most international attempts to mitigate roading impacts on bats have been based on incorporating structures into road design to facilitate safe movements across a road.
- Use of underpasses is dominated by low-flying, gleaning species. Use appears to increase with cross-sectional area, underpass height and alignment with existing flight paths.
- Over-road structures have tried to take advantage of bats' tendencies to follow linear landscape features when commuting.
- Wire-bridges or 'bat gantries' have been shown to be ineffective in guiding commuting bats safely across roads, despite their frequent installation in Europe.
- Vegetated over-bridges that maintain existing flight paths may be effective in mitigating road-crossing impacts on bats, but further trials are required before any robust assessment of their effectiveness can be made.
- We could find no evidence of the effectiveness of vegetated 'hop-overs,' where high vegetation is planted or manipulated to provide continuous habitat over a road.
- Use of artificial roost boxes to replace natural roosts lost during road construction has not been assessed adequately and limited evidence of their use elsewhere suggests that use is minimal or may take many years to have any significant benefits.
- Impacts of artificial lighting may be minimised by interconnected light-exclusion zones along known flight-lines or dimming or switching-off lights during critical bat movement periods, reducing overall light intensity, but these methods have not been tested formally.

- A common thread among mitigation approaches that facilitate safe crossing of roads is they maintain both the height and alignment of existing flight paths.

7 Mitigation of potential adverse effects in New Zealand

7.1 Overview

In this section, we review the evidence for mitigation of roading effects on bats in New Zealand and address the following key questions:

- What has been done to mitigate/compensate for road effects in New Zealand?
- What was the logic or justification for what was done?
- What monitoring of these mitigation efforts has taken place?
- Is there evidence that this mitigation worked?

The use of mitigation, minimisation and avoidance approaches related to New Zealand bats in infrastructure projects has been limited until recent years. Current research into long-tailed bat ecology in and around the Waikato region, as well as the establishment of Project Echo in 2010, has highlighted bat presence outside unlogged indigenous forests (Dekrout 2009; Borkin 2010; Le Roux 2010), resulting in consideration of bats when planning such projects within the rohe of Waikato Regional Council. Project Echo is a multi-agency initiative that aims to increase awareness of bats (Project Echo 2015). These developments have meant roading projects are increasingly required to avoid, minimise and mitigate potential adverse effects on long-tailed bats.

It has been suggested predator control aimed at improving breeding success and survival, planting indigenous vegetation to improve foraging habitats, and providing artificial roost boxes, are methods that may improve the likelihood of persistence of long-tailed bats (Pryde et al 2006). As a result of these recommendations, BMPs, which are required by regional councils for resource consents, and in designation conditions of district councils, have focused on these potential mitigation methods. However, the lack of research into potential mitigation tools and any clear evidence for their effectiveness for New Zealand bats has resulted in the development of BMPs being protracted (and therefore expensive), and even after completion, remaining contentious. For example, BMPs associated with the Huntly Section of the Waikato Expressway project were under review for over a year before approval, and plans associated with the Cambridge Section were still being altered two years after first submission to Waikato Regional Council. It is important to note that any impacts of roading infrastructure development on a population and subsequent mitigation approaches must be considered as a whole and that assumptions that one approach will compensate for a range of impacts are unlikely to be justifiable. For example, predator control would not provide effective mitigation for a bat population if all available tree roosts had been removed.

7.2 Control of introduced mammalian predators

Control of introduced predators is the only potential mitigation approach used in New Zealand that has been investigated systematically with regard to its effects on bat populations, for long-tailed bats (Pryde et al 2005) and short-tailed bats (O'Donnell et al 2011). Predator control could be considered a compensatory or offsetting tool, not one that directly mitigates potential adverse effects of infrastructure projects, and it is important to note that its effectiveness in this context has never been investigated. New Zealand bats are thought to be preyed upon by cats (*Felis catus*; Scrimgeour et al 2012), brush-tailed possums (*Trichosurus vulpecula*; O'Donnell 2000c), rats (*Rattus* spp), and stoats (*Mustela ermine*); Pryde et al 2005, O'Donnell et al

2011). In years of high rat and stoat abundance, survival of long-tailed bats was low; conversely when rat and stoat abundance was low, survival rates of long-tailed bats were higher in the Eglinton Valley, in Fiordland (Pryde et al 2005). Increasing the survival of individual bats increases the likelihood of persistence of a population and may reverse declines in populations and the possibility of local extinction due to predation, but long-term population monitoring is required to ensure predator control is having the desired effect (Pryde et al 2006). This is because the level to which predator populations must be suppressed in order for bat recovery to occur has not been established and because there is concern regarding the effects of some control methods on bats due to the potential for either direct or secondary poisoning (O'Donnell et al 2011; Dennis and Gartrell 2015). Consequently, it is advised to evaluate the risk of poisoning on short-tailed bats, at least, prior to predator control taking place.

Mammalian predator control to protect bats has been planned as a compensatory mitigation approach for the Huntly section of the Waikato Expressway. For this project, control of rats and possums has been required by resource consent conditions and details are given in the ecological management plan for their implementation (Connolly 2015a; 2015b). Predator control is scheduled to begin in 2016 in Taupiri Scenic Reserve, but the likelihood of success of this mitigation method is currently unknown. Taupiri Scenic Reserve is 399 hectares and predator control is planned to be undertaken over its entire area. However, it is worth noting this is a very small area given the size of endemic bats home ranges, which can be in excess of 1,800 hectares (juvenile long-tailed bats in North Island exotic forest (Borkin and Parsons 2011a), and the potential distribution of their populations. A recommendation made by DOC for the protection of long-tailed bat colonies is control of predators over large forest areas, eg a minimum of 1,000 hectares but preferably several thousand hectares (O'Donnell 2014). This is because long-tailed bat colonies can use many roosts over the course of one year, and only a proportion of these may be protected by small areas of predator control. Monitoring for the Huntly section of the Waikato Expressway is required to take place for 15 years from completion of the road, but the monitoring programme is only required 'to be able to identify changes and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Huntly section of the Waikato Expressway' (Consent condition clause 28e viii, Huntly section). Consequently, monitoring will be unable to ascertain population-level responses to predator control, and whether this has succeeded in mitigating the effects of the construction and operation of this part of the expressway.

Other clauses within the consent for the Huntly section include:

28 d) Mammalian predator control within the Taupiri Scientific Reserve which shall include and comply with the following:

- *i. Every 3 years a possum and rat control operation covering an area of approximately 399 hectares of the Taupiri Scientific Reserve. The operation shall ensure possums are reduced to 5% or lower Residual Trap Catch (RTC) or equivalent Bite Mark Index (BMI) [or equivalent National Possum Control Authority (NPCA) approved index] by the 1st of October of the year of operation for a minimum term of 10 years. For the avoidance of doubt, the possum and rat control operations in d) i. Shall continue for a term of at least 10 years, but shall be extended if necessary to ensure that operational targets and intended outcomes as set out in the detailed Ecological Management Plan and Bat Management Plan have been met.*
- *ii. An annual possum and rat control operation covering an area of approximately 241 hectares surrounding the Te Iringa Wetland within the Taupiri Scientific Reserve. The operation shall ensure possums are reduced to 5% or lower Residual Trap Catch (RTC) or equivalent Bite Mark Index (BMI) [or equivalent NPCA approved index] by the 1st of October of the year of operation for a minimum term of 10 years. Rats are to be reduced to 5% or lower Tracking Tunnel Index*

> *by the 1st of October of the year of operation and until the last day of the following February, for a minimum term of 10 years.*
>
> *For the avoidance of doubt, the annual possum and rat control operations in d) ii. shall continue for a term of at least 10 years, but shall be extended if necessary to ensure that operational targets and intended outcomes as set out in the detailed Ecological Management Plan and the Bat Management Plan have been met.*

Control of cats, rats, stoats, and possums was agreed in the Waikato Expressway: Tamahere – Cambridge section bat management plan (stage one: enabling works) (Davies et al 2013). This plan was approved by Waikato Regional Council in August 2013 (Matthews 2015). The area within which predator control is likely to take place is unlikely to protect entire colonies of long-tailed bats (O'Donnell 2014). Predator control was recommended 'to improve overall bat survival rates over the course of' construction. Acoustic monitoring required to be undertaken throughout this section of the expressway will be inadequate to determine effects on population-level survival because it records only relative changes in levels of activity. Only an extended mark-recapture programme with permanent marking of individual bats would be able to determine changes in survival rates (O'Donnell 2009).

The Transport Agency is committed to biosecurity and the management of introduced mammalian predators, where necessary, on land it manages. However, because predator control needs to occur over large areas to be successful, it requires a coordinated effort between the Transport Agency and other landowners.

7.3 Protection when felling trees and removing vegetation: tree removal protocols

Both New Zealand bat species shelter during the day within roosts that may be in trees, caves, rock crevices, or buildings (Daniel and Williams 1983; 1984). Roosts are also used during the night between foraging bouts (O'Donnell 2002a). Bats are known to remain within trees as they are felled and consequently may be injured or killed when this occurs (Cheeseman 1893; Borkin and Parsons 2010b), resulting in smaller colony sizes (Borkin et al 2011b). In Australia, artificial flaps have been developed that can be placed over tree roost entrances and will allow bats to leave a roost, but prevent them from returning (C O'Donnell, DOC, pers comm). These methods have the potential to greatly reduce bat mortality associated with tree felling, but to be effective they require accurate identification of roost trees, and alternative roosting habitat must be available.

In recent years, various regional councils have required projects that fell trees and clear other vegetation to undertake intensive monitoring in locations where long-tailed bats have been previously detected, in order to prevent bat injury or mortality (Auckland Regional Council; Waikato Regional Council, Davies et al 2013, Connolly 2015a). This process is governed by 'tree removal protocols' and involves the use of a professional ecologist to identify potential roosts, using knowledge of features associated with roosts, such as cavities, and acoustic bat monitoring devices (ABMs). Following this, tree felling will only take place if the ecologist determines the trees are not being used by bats at that time. If ABM monitoring is equivocal then an arborist is often required to inspect tree cavities and other potential roost locations within the tree. If this inspection does not locate bats then felling may take place. These protocols have largely targeted long-tailed bats, and have not yet been applied to short-tailed bats. Such tree removal protocols are being implemented as a consent condition for a number of projects the Transport Agency is involved with in the Waikato Region, including the Cambridge, Hamilton, and Huntly sections of the Waikato Expressway (Davies et al 2013; Connolly 2015).

These protocols overlook the use of ‘non-tree’ vegetation as roosts and do not protect these. For example, long-tailed bats are known to use dead tree ferns as roosts (Borkin and Parsons 2011b), but these generally remain unprotected in tree removal protocols (Connolly 2015; Matthews 2015). However, a recent consent application within Hamilton required the monitoring of tree ferns for bats prior to felling (see the tree and tree fern removal protocols related to tracks and boreholes within gullies in the Hamilton section for an example; roading and tracking activities APP135120 held by the Transport Agency).

To our knowledge, active bat roosts have not been located in the thousands of trees felled (both potential bat roosts and other trees which do not have features that make them potential bat roosts) using these protocols nor have any bats been located during post-felling inspections. Although implementation of tree removal protocols adds considerable cost to each project, the accuracy of these protocols for identifying bat roosts remains untested. Therefore the effectiveness of these protocols as a mitigation method remains unknown and, as such, a formal test of the current protocol’s ability to detect a roost, where present, is required.

7.4 Planting of vegetation to improve habitat and maintain population linkages/reduce habitat fragmentation

Maintaining the connectivity of bat populations requires ‘functional connectivity’ of habitats; that is, individuals must be able to move between resource patches within the landscape (Hale et al 2012). Critical resources for bats include both roosts and foraging areas. For species such as long-tailed bats that commute along tree networks and other linear landscape features, such as forest and road edges (O’Donnell 2000a; Borkin and Parsons 2009), population connectivity requires the maintenance of structural connectivity between areas (Hale et al 2012), and of both roosts and foraging habitat between social groups of bats.

Construction of a new road is likely to interrupt population linkages because some recent overseas studies show that at least some bat species will avoid a busy road rather than fly across it (Bennett and Zurcher 2013). Removal of vegetation is also likely to increase fragmentation of populations in the case of long-tailed bats because their colony sizes and home ranges are smaller in areas where tree felling has taken place (Borkin et al 2011; Borkin and Parsons 2014). Smaller home ranges and colony sizes that occur subsequent to tree felling and vegetation removal may also result in increased colony isolation and increased vulnerability of local populations to extinction (Borkin et al 2011; Borkin and Parsons 2014). When this occurs, genetic diversity may also be reduced.

Planting of vegetation has been recommended as a tool to improve foraging habitat (Pryde et al 2006), and to maintain connectivity between local bat populations (Matthews 2015). This is because, in the long term, planted areas may provide potential roosting and foraging opportunities over areas where vegetation has been previously removed. The effectiveness of this approach in the short to medium term has not been demonstrated and Borkin (2010) found relatively low use of young indigenous vegetation replantings by long-tailed bats compared with other habitat types.

Planting programmes are planned for the Cambridge and Huntly sections of the Waikato Expressway, with the aim of mitigation effects of road construction on bats (Matthews 2015; Connolly 2015b). Some of the species included in the planting plans for each of these sections may form potential roosts in the long term (60–80 years, Tim Martin, Wildland Consultants, pers comm, 21 September 2015); however, they do not address the loss of roosts in the short term. Maintaining as many trees as possible on the northern side of the designation of the Cambridge section of the Waikato Expressway and establishment of fast-growing tree species on the southern side of the designation has been the focus of mitigation effort for this section in relation to potential decreases in connectivity between colonies and population fragmentation (Matthews 2015). Monitoring planned to take place in both these sections may help our understanding of whether the areas that are planted as part of the mitigation packages are still used by bats. However, because acoustic monitoring is the only monitoring planned, the monitoring programmes will be unable to determine whether populations remain sufficiently linked to maintain population viability and genetic diversity.

7.5 Planting of vegetation to provide traffic 'hop-overs' and reduce likelihood of bat-vehicle collisions

There are anecdotal reports of collisions between long-tailed bats and vehicles, when moving (Moore 2001) and stationary (SPCA Officer, Putaruru, New Zealand, pers comm, 2006) in New Zealand. These cases have resulted in bats either dying immediately or later due to their injuries, because they could not fly and therefore were unable to locate food or water (K Borkin, personal observation). Both New Zealand bat species fly at heights that mean they can interact with vehicles. Long-tailed bats have been noted flying between 3 and 60 metres above the ground (Borkin 2010). Le Roux et al (2013) compared detection rates at various heights within one tree stand and most commonly detected long-tailed bats between 4–6 metres above the ground (when compared with ABMs placed 15–30 metres above the forest floor although ABMs were not placed at ground level to compare detection rates at the forest floor). In comparison, Scrimgeour et al (2013) found short-tailed bats were detected most frequently 10–12 metres from the forest floor (when compared with ABMs placed at 22–25 metres and 1.5–2 metres within podocarp and beech forest). It has been suggested by Lloyd (2001) that short-tailed bats commonly fly within two metres of the forest floor. Because of this variability in reported behaviour and the potential for significant barrier and mortality effects at road crossings, we suggest research is urgently required to investigate bat flight behaviour over and near existing and planned New Zealand roads.

In some cases, specific sites have been identified as important road crossing points for bats prior to projects beginning, eg Cambridge (Connolly 2013). In one case, within the Cambridge section of the Waikato Expressway (at the Lloyd property) long-tailed bats were observed crossing the road several times in close proximity to tall oak trees that were at right angles to the road (Connolly 2013). In response, a vegetated hop-over is intended to be created over the expressway traffic at that site by using tall, fast-growing trees (Matthews 2015). This hop-over is designed with the aim of encouraging bats to fly high above the traffic and thus avoid collisions (Matthews 2015). Whether monitoring will be undertaken to determine whether the use of this site to cross the expressway is continued post-construction is unclear and its effectiveness is therefore currently unknown.

With the aim of reducing the likelihood of bat-vehicle collisions along the extent of the Cambridge section of the Waikato Expressway the following measures were also recommended:

> *Tall planting that is adjacent to the Expressway will be set back from the carriageway as far as possible within the land owned by NZTA to encourage bats to fly further away from the Expressway alignment and thus avoid collisions. A relatively wide verge of low vegetation (grass/low shrubs) will be maintained adjacent to the carriageway wherever possible to discourage bats from foraging along the roadside. (Matthews 2015)*

As for the above examples, it is not clear whether monitoring will be undertaken to determine the effectiveness of this planting at minimising bat-vehicle collisions, once the expressway section is operational. If no monitoring takes place then the relative effectiveness of this mitigation measure will remain unknown.

7.6 Provision of artificial roost boxes

Gould's wattled bat (*Chalinolobus gouldii*), an Australian species in the same genus as the long-tailed bat, commonly uses roost boxes (Bender 2009). Therefore, it was suspected that long-tailed bats may also use roost boxes. If long-tailed bats use roost boxes at a specific location, then it is likely that their use may take some years to be observed (Moira Pryde, DOC, pers comm, 12 October 2015), as is the case for Gould's wattled bat (Bender 2009).

There is some, albeit limited, evidence of long-tailed bats using artificial roost boxes. A short-term trial of artificial roost boxes began in 2003 in Kakahu Bush, near Geraldine, South Canterbury to determine whether they would provide potential roosting opportunities for the resident long-tailed bat population, which was in rapid decline (Pryde et al 2006). Approximately 25% of natural roosts were lost within four years of study because of either natural attrition or tree felling for firewood (Pryde et al 2006). The remaining roosts were considered to be of poor quality because of their low insulating properties and large entrances which potentially exposed inhabitants to unstable microclimates and increased the risk of predation. Provision of roost boxes was considered a potential tool to mitigate this loss (Sedgeley and O'Donnell 2004).

The roost boxes were installed in 2003. They were first known to be used by bats less than two years after installation and were still in use five years after installation. Boxes were used by bats at least occasionally; two bats were found in one box and guano was found in multiple boxes. Subsequent checks have not detected use by bats and reasons for this are not certain. Some roost boxes were no longer available to the bats as they were full of nesting materials placed there by rifleman and other bird species, and the long periods between checks may have meant the bat guano had disintegrated (Colin O'Donnell, DOC, pers comm, 19 October 2015). Subsequent recommendations have suggested roost boxes require frequent emptying so they remain available for use by bats (Moira Pryde, DOC, pers comm, 12 October 2015). This trial indicated that the use of the roost boxes required consistent monitoring over several years.

Provision of artificial roost boxes was approved as a mitigation measure in the Bat Management Plan (Enabling Works) for the Cambridge section of the Waikato Expressway (Davies et al 2013). To our knowledge, however, this has not yet been implemented nor has monitoring been planned to determine whether they are being used. A later plan suggested that roost boxes would not be used as a mitigation method because their effectiveness was questioned during a project workshop (Matthews 2015).

A long-term investigation into the use of artificial roost boxes by long-tailed bats is required to address questions regarding bat use of these structures. Most research into roost use by New Zealand bats has focussed on female-dominated maternity colonies (Sedgeley and O'Donnell 1999; Sedgeley 2003), although those roosts differ from those used by male bats (Borkin and Parsons 2011). Consequently, more detailed research into the roosts used by male bats is also required, so that artificial roost boxes can emulate roosts used by males as well as those used by female-dominated maternity colonies.

7.7 Minimisation of night work and lighting

The effect of lighting on New Zealand bats remains little studied, with most work having taken place within Hamilton City. After undertaking an extensive acoustic monitoring survey, Le Roux and Le Roux (2012) considered that the effect of lighting and other anthropogenic variables on long-tailed bats appeared to explain why apparently otherwise suitable habitat remains unused within Hamilton City. In particular, lighting appears to form a barrier to use of habitat by long-tailed bats (Dekrout 2009; Le Roux and Le Roux 2012). In comparison with upstream, little activity appears to occur downstream of the first major well-lit bridge along the Waikato River corridor (Le Roux and Le Roux 2012). Within Hamilton City, bat activity is also correlated negatively with street light density (Dekrout et al 2014). However, in contrast, anecdotal reports suggest that at least occasionally long-tailed bats will forage around or above street lights (Connolly 2013). Le Roux and Le Roux (2012) suggested that experimental research is required to better elucidate the effect of light and roads on bat behaviour, so more targeted mitigation and management techniques can be developed, and this should be undertaken.

Le Roux and Le Roux (2012) also made suggestions that aimed to create a landscape that was more 'permeable' to bat movement, including the implementation of low-impact road and bridge lighting regimes. Subsequently, recommendations have been made to minimise lighting, and therefore by association night work, where long-tailed bats are present in several roading projects within the Waikato Expressway (Cambridge – Davies et al 2013; Huntly – Connolly 2015a), including traffic bridges: Karapiro Gully Bridge, Cambridge (Davies et al 2013). The effects of lighting on bats were considered within one pedestrian bridge project – the Allan Turner Memorial Bridge, Hamilton – where it was recommended to minimise light spill and use motion-activated sensors so lights were only activated when users were approaching and on the bridge, in order to minimise potential effects on long-tailed bats (Turner 2014). No monitoring of bat activity, behaviour, or population-size was apparently recommended, or has taken place, to determine the success of these mitigation measures, and their success or failure therefore remains unknown.

7.8 Key points

- In New Zealand, the proposed control of introduced mammalian predators could be considered a compensatory, or offsetting, tool, not one that mitigates adverse effects of infrastructure projects directly and it is important to note that its effectiveness in this context has never been investigated.
- Tree removal protocols are implemented to identify bat roosts prior to felling for road construction. Although no active bat roosts have been located in trees to be felled or any bats located during post-felling inspections, the efficacy of these protocols for identifying bat roosts remains untested. Testing of these protocols is required.
- Planting of vegetation has been suggested as a tool to improve foraging habitat and maintain connectivity between local bat populations, but this is unlikely to have any effect in the short-to-medium term. Monitoring planned in association with replanting is unlikely to shed any light on the effectiveness of the technique for mitigating roading effects.
- Bat use of mitigation structures (crossing aid, artificial roost) is not evidence of a structure's effectiveness in mitigating direct impacts, or in sustaining the population. This can only be inferred by comparative, well-designed surveys using an appropriate metric.
- In New Zealand, there has been little or no post-construction monitoring to ascertain whether these mitigation approaches are effective.

8 Protection of bats from the potential adverse effects of roads

In this section, we use a simple demographic model to demonstrate the relative effects of changes in vital population rates on population persistence and use the results to prioritise mitigation approaches. Using this information, we consider the effectiveness of current strategies, from both New Zealand and overseas, for maintaining the population viability of New Zealand bats likely to be affected by roading projects and propose a step-wise process for prioritising of future mitigation and monitoring.

8.1 Using life-history to prioritise interventions

If sufficient information about a species' life-history, including reliable estimates of vital demographic rates, is available, management of that species can be guided by considering the relative contribution of each rate to population growth. This can allow managers to identify and prioritise management of those rates most likely to achieve a desired conservation or control outcome (Dixon et al 1996). To illustrate this approach, we constructed a simple population matrix model for a population of long-tailed bats using published estimates of vital rates and life-history parameters (table 8.1). We then used a standard analytical method – elasticity analysis (van Groenendael et al 1988) – to look at the relative importance of each parameter in driving population growth. We focus on long-tailed bats because estimates of vital rates for short-tailed bats are not yet available.

We assumed a simplified long-tailed bat life-cycle composed of four age-classes: juveniles (from independence to one year of age), yearlings, two-year-olds and adults aged three and over. We assumed that only two-year olds and adults could breed with annual breeding probabilities increasing with age class (O'Donnell 2002). The model considered females only, which is common practice for species where males contribute little to post-mating parental investment. The model was constructed in a standard spreadsheet and population growth rate was estimated as the ratio of total population size in one year to that in the previous year.

Table 8.1 Input values and elasticity coefficients of long- tailed bat demographic parameters used in population model. Elasticity coefficients illustrate the relative contribution of parameters to population growth; parameters with higher values have greater influence on population growth rate.

Parameter	Notation	Value	Source	Elasticity coefficient
Annual survival of adults aged 3 and over	S^{3+}	0.79	Pryde et al (2005)	0.491
Annual survival of 1-year olds	S^{1}	0.79	Pryde et al (2005)	0.186
Annual survival of juveniles	S^{J}	0.53	O'Donnell (2002)	0.179
Annual survival of 2-year olds	S^{2}	0.79	Pryde et al (2005)	0.141
Fecundity of adults aged 3 and over	F^{3+}	1.00	O'Donnell (2002)	0.141
Fecundity of 2-year olds	F^{2}	0.60	O'Donnell (2002)	0.047

The population is 'sampled' assuming a post-breeding census and transitions between life-history stages are described by the following equations:

$$NJt = [N2t \times F2] + [N3+t \times F3+] \qquad \text{(Equation 8.1)}$$

$$N1t+1 = NJt \times SJ$$

$$N2t+1 = N1t \times S1$$

$$N3+t+1 = [N2t \times S2] + [N3+t \times S3+]$$

Where: Nit = number of individuals in age class i at time t

Si = annual probability of survival of individuals in class i

Fi = annual fecundity rate (probability of breeding x number of young produced per breeding attempt) of individuals in class i

Ntotalt = NJt + N1t + N2t + N3+t

λ = population growth rate, given by: Ntotalt+1/ Ntotalt

The model was deterministic in that we used a single mean (‘average’) value for each parameter. Again, this is standard practice for assessing the relative effects of parameters and management interventions on population growth (Beissinger et al 2006), but is not suitable for making probabilistic predictions about the size or viability of populations under management i.e. we are assuming a generic long-tailed bat population. Predictive modelling requires more detail about a specific population under study, particularly a reliable estimate of its size and estimates of the variability around its vital rates. Once the model had been constructed, we carried out a simple perturbation analysis to help identify which parameters have the greatest effect on population growth rate (Caswell 1989). This type of analysis involves making small perturbations to vital rates and assessing the resulting impact on overall population growth. We used “elasticity analysis” which compares the relative effects of proportional changes in parameters on population growth rate (van Groenendael et al 1988; Caswell 2000; Heppell et al 1996). The mean value of each parameter in turn was reduced by 5% whilst keeping all others fixed at their mean values so that the elasticity of population growth rate, ep, to an input parameter, p, is given by:

$$ep = (\Delta\lambda/\lambda) / (\Delta p/p) \qquad \text{(Equation 8.2)}$$

The model suggested an annual population growth rate of just below one percent which is within the range of what might be expected for a deterministic assessment of a long-lived species with low annual reproductive output. The estimated elasticity coefficients for key parameters are shown in table 8.1. It is clear that maintaining survival rates of adult female bats would have the greatest effect on maintaining population growth. This result agrees with similar assessments of bat population growth models internationally (eg O’Shea et al 2011).

Information such as this allows managers to prioritise their interventions, particularly where resources are limited. In our example of a bat population under threat from a number of potential impacts, we can suggest the following logic:

- If a population is small it is likely to be very vulnerable to chance catastrophic impacts and other small-population effects.
- Growth of all populations will be most sensitive to reduced adult survival; given that even a healthy bat population is likely to grow slowly, any impact on adult survival should be regarded as a threat to population viability.

- Because adult survival is the most important contributing parameter to population growth, larger populations are likely to be less vulnerable to short-term reductions in the productivity of young, although longer-term impacts will restrict population growth.

If we consider the major effects of roads on bats in terms of impacts on population processes, vehicle collisions lead to reduced survival rates. Habitat changes can affect bats' ability to forage efficiently, either through limiting resources directly (habitat loss/alteration) or through limiting access to key resources (barrier effects). This is likely to have two effects: reductions in survival rates and reduced reproductive output (as pregnancy and lactation are very energetically demanding). Roost loss during habitat clearance for road construction has the potential to be catastrophic if hibernation and, particularly, maternity roosts are destroyed with impacts on adult survival rate and reproductive output. Road effects as barriers to movement can also affect dispersal of newly independent young, leading, in the longer term, to reduced genetic diversity within a population and, at the landscape scale, reduced ability to re-populate areas where local populations have declined.

8.2 Bat-road mitigation: the current state

Our reviews of mitigation approaches, both internationally and within New Zealand, revealed a range of potential methods, but with little empirical evidence of their effectiveness in reducing specific impacts and no evidence whatsoever of effects on population viability. The most commonly used structure aimed at minimising bat vulnerability to vehicle collisions in Europe, the bat-bridge or gantry, has been shown to be both costly and ineffective. Bats with gleaning, clutter-adapted foraging behaviour have been shown to use underpasses to cross roads, where those underpasses are of sufficient size and lie on existing flight paths. One study described bats using a 'green' bridge over a road. The bridge maintained an existing bat commuting route, meaning no deviation from bats' normal behaviour was necessary. This suggests that some methods have potential to minimise impacts on some species, but also that they require appropriate testing before any commitment to their adoption in New Zealand.

Of the approaches used in New Zealand, there is no evidence that any of them minimise adverse effects of roads on bats or help to maintain bat population viability, despite their frequent use in mitigation plans. To explain this apparent criticism it is important to consider what we mean by 'effectiveness'. Take, for example, a study or survey result describing bats' use of a road-crossing structure. We could interpret this finding as follows: bats use the structure to cross the road, therefore it is reducing road mortality, and therefore it is contributing to population viability. But, we should also ask the following questions to be confident of the reported 'success.'

- What proportion of the local bat population are using the structure to cross the road safely, and what proportion are crossing the road unsafely?
- How does the proportion of bats crossing the road safely compare with pre-road movements?
- By how much did the structure reduce road mortality?
- Is the remaining road mortality sustainable: how does it affect population viability?

In giving evidence to an enquiry into a British road development project, Altringham (2008) noted, correctly, that it is, 'important to distinguish between use and effectiveness. This is linked with the distinction between assessing mitigation at the individual and population levels. Conservation is the protection of species and ecosystems at the population level: maintaining favourable conservation status means maintaining stable populations. Assessment at the individual level is not a guide to what is happening at the population level'. This is because an individual's behaviour may not always conform with, or represent reliably, the behaviour of most other members of the population. Indeed, caution must be used when extrapolating measures of activity to infer the status of a population. Even if activity or use is maintained at a development site, mechanisms other than 'no effect' may be operating. For example, a consistent post-development level of activity may result from fewer bats being more active, from new bats moving into a habitat because mortality of residents has made local resources more available, or from a declining population being forced to increase their use of remnant sub-optimal habitat.

Using this logic, we considered the suggested or commonly used mitigation approaches in table 8.2. Partly due to the relative novelty of the research area, there is no evidence of the effectiveness of any mitigation strategy in maintaining the viability of an affected bat population, in either New Zealand or internationally. This would require monitoring of a population's size for a period of years both before and after a strategy is implemented. Monitoring of surrogate variables (survival, productivity of young) from samples of the population may suffice if the resulting data is of a sufficient standard for use in predictive population modelling.

Evidence of the effectiveness of a strategy in mitigating a particular impact on a component of a bat population can only be obtained using an appropriate survey design, which requires consideration of the scale and duration of monitoring effort, and measurement of an appropriate metric. Such monitoring should begin, ideally, before a road is built so before-during-after comparisons can be made, ideally alongside a nearby, similar, but unaffected reference site (ie before, after, control, impact). We, again, emphasize that evidence of use only is not evidence of effectiveness without estimates of the reduction in risk to the wider population.

It is a concern that much of the mitigation currently incorporated into roading planning in New Zealand, at a financial cost to the projects, appears to be based on opinion, anecdote, assumption and a reliance on certain methods with little, if any, evidence of their effectiveness. Techniques appear to become accepted practice based on their use in another project and not on robust evidence of their effectiveness. Monitoring is heavily reliant on documenting bat use of, or levels of activity within, particular habitats or areas using automated detectors with little evidence of monitoring plans that have been designed formally to test for subsequent changes or effects using the criteria outlined above. Given an increasing international and national emphasis on evidence-based conservation and on justifying expenditure in terms of demonstrated conservation outcomes, the implementation of mitigation without appropriate monitoring of its effectiveness and an associated commitment to modify management appropriately in response to monitoring data does not represent cost-effective use of limited funding.

Table 8.2 Summary of evidence of effectiveness of strategies used to mitigate the effects of roading development on bat populations, internationally and in New Zealand. Strategies used in New Zealand are identified with an asterisk.

Mitigation	Target effect	Effectiveness on target	Effectiveness on population viability	Notes
Underpass/culvert	Reduced risk of vehicle collisions by guiding bat movements below road. Increased road permeability leading to reduced barrier effect.	Use by primarily gleaning species demonstrated, but no evidence of effectiveness in reducing overall road mortality due to lack of controlled studies.	Not demonstrated.	Larger cross-sectional area and greater height linked to increasing use. Must maintain pre-development flight paths.
Bat-bridge/gantry	Reduced risk of vehicle collisions by guiding bat movements above traffic height. Increased road permeability leading to reduced barrier effect.	None.	Not demonstrated.	Use is to be avoided - high cost and no benefits to bats.
Unvegetated road/foot-bridge	Reduced risk of vehicle collisions by guiding bat movements above traffic height. Increased road permeability leading to reduced barrier effect.	Minimal use recorded in Europe, but no evidence of effectiveness.	Not demonstrated.	
Vegetated “green” bridge	Reduced risk of vehicle collisions by guiding bat movements above traffic height. Increased road permeability leading to reduced barrier effect.	Effectiveness for some species demonstrated in one European study.	Not demonstrated.	Effective structure maintained alignment/height of existing flight path; good continuity with roadside bat habitats.
Lighting management	Deterrence of photo-phobic species away from roads to reduce collision risk. Avoidance of illumination of flight paths and roosts.	None – requires testing.	Not demonstrated.	Use of deterrence effect must be balanced carefully against concurrent increase in a ‘barrier’ effect.
Artificial roost provision*	Compensation for loss of natural roosts during road construction.	Some evidence of use by long-tailed bats in New Zealand and overseas species, but no evidence of effectiveness.	Not demonstrated.	

Mitigation	Target effect	Effectiveness on target	Effectiveness on population viability	Notes
Introduced predator control*	Assumed to increase bat survival rates as compensation for reduction in survival due to roading impacts.	Evidence of higher bat survival in indigenous forest during years of lower predator abundance, but no evidence of effectiveness in mitigating road-induced mortality.	Not demonstrated.	Limited spatial and temporal scale of control may limit effectiveness.
Tree-removal protocols*	Prevention of mortality of roosting bats during habitat clearance.	Effectiveness unknown as accuracy of roost identification remains untested.	Not demonstrated.	Current protocols rarely include surveys of non-tree vegetation as roost sites.
Replanting*	Maintenance of functional connectivity of habitats; compensation for roost loss during road construction; provision of foraging habitat.	Use based on limited observational studies from overseas. Effectiveness unproven.	Not demonstrated.	Potential roost trees may take 60–80 years to mature sufficiently.
'Hop-over'	Reduced risk of vehicle collisions by guiding bat movements above traffic height.	None - untested.	Not demonstrated.	Based on suggestion in European study. May work if provides continuity of flight path for higher-flying species. Lag between planting and trees/vegetation reaching sufficient effective height.
Road margin/verge design*	Discourage bats' use of areas close to roadside. Raised verges may encourage commuting bats to fly higher across road.	None – untested. Some evidence of required behaviour from Europe, but effectiveness in management untested.	Not demonstrated.	Even if effective, may be time lag before any benefits accrue.

8.3 Bat-road mitigation in New Zealand: a way forward

While acknowledging there is no immediate 'off the shelf' solution to the likely effects of roading developments on New Zealand bat populations, it is possible to integrate findings from our review of likely impacts and evidence of potential mitigation approaches and their effectiveness to suggest a way forward.

Likely roading impacts – with effects on demographic processes – on bat populations include:

- roost loss during construction (direct mortality; loss of reproductive output if occupied; impaired energetic budgets due to the need to establish replacements if unoccupied)
- vehicle collision mortality where roads cross established flight paths (reduced survival rates).
- habitat change through lighting, noise and physical severance of flight paths; barrier effects cause fragmentation, leading to increased foraging costs and lower foraging efficiency, therefore reduced survival and reproductive outputs. Potential for reductions in immigration and local genetic diversity. Creation of increased habitat edge may benefit edge-foraging long-tailed bats at some sites, but may also interact with increased road mortality risk.

New Zealand bat populations exist in already-fragmented habitats. Some populations are likely to be very small and therefore particularly vulnerable. In addition to small-population effects, population growth is most strongly influenced by survival rates of breeding adult bats. Because of bats' inherent life-history characteristics, population growth is slow, even under good conditions. Recovery of populations from significant perturbations is therefore likely to be slow.

If an impact due to the development of roading infrastructure is considered likely, or even of significant risk to a bat population, the first consideration should be to examine whether that impact can be avoided by shifting the planned footprint of the development. If this is not feasible, mitigation should be considered.

Investment in mitigation of roading effects on bats should be based, ideally, on previous evidence of effectiveness. This is rarely available, so investment should therefore be: 1) justified by strong inferential, evidence-based logic, and 2) accompanied by robust, appropriately designed monitoring that is planned, in advance, to allow an objective assessment of a method's effectiveness in mitigating an impact.

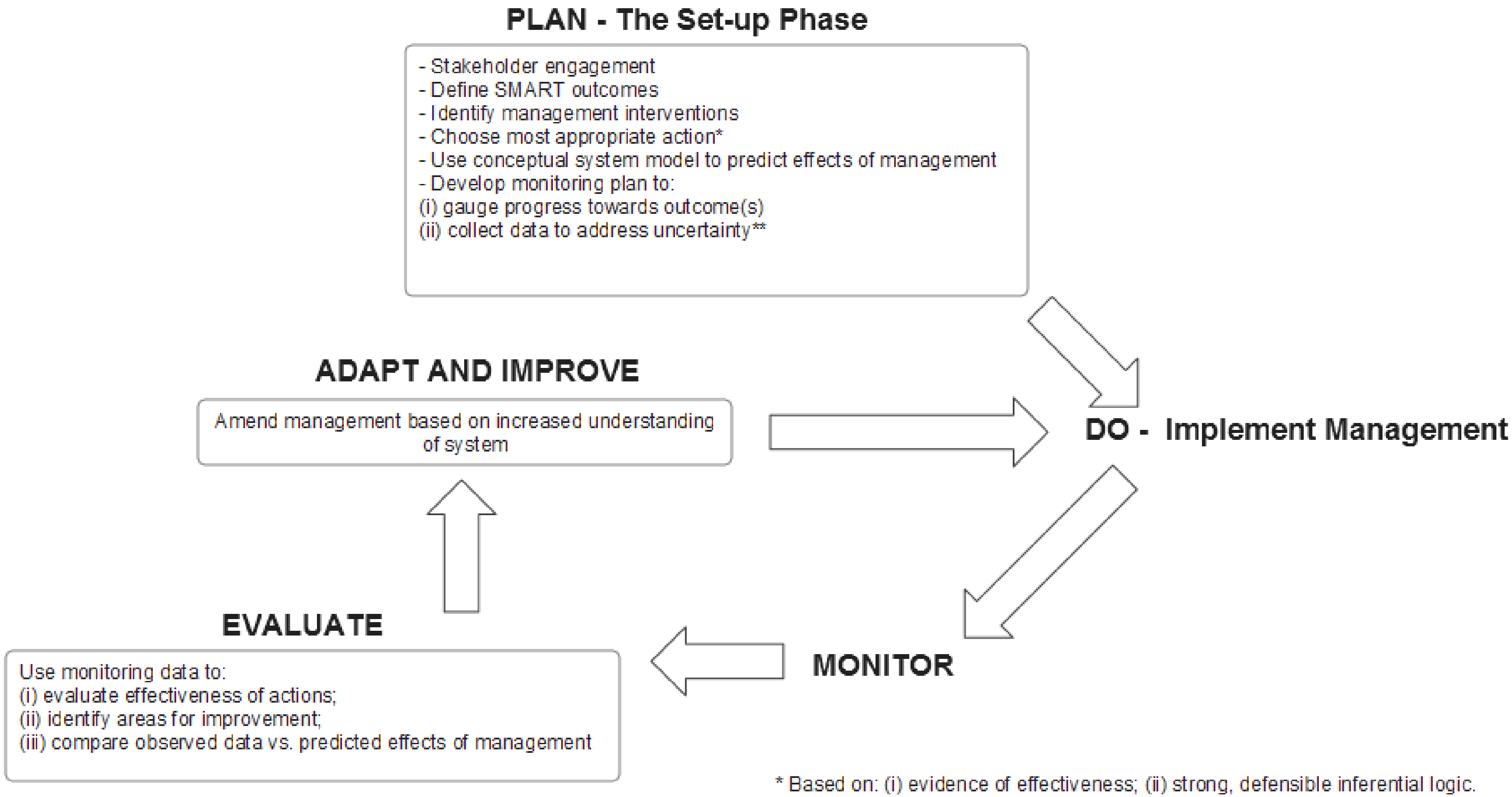
Effectiveness of mitigation in sustaining population viability can only be assessed by monitoring characteristics of the population (size, density, growth rate) or demographic vital rates (annual survival, reproductive output) which can be used in population models. Such monitoring may be beyond what a single development project can realistically achieve. The most immediate need for individual projects, or groups of linked projects, is to identify localised risks to vital bat population processes and focus on mitigating those risks. For mitigation approaches at road crossings, evidence of use is not evidence of effectiveness, so monitoring should be designed, ideally, to compare crossing safety with pre-road conditions or, consider relative proportions of safe versus unsafe crossings by bats. The use versus effectiveness logic also applies to other mitigation approaches such as the installation of artificial roost boxes.

Evaluation of a mitigation approach should include the following components (based on van der Grift et al 2013):

- A clearly-defined SMART (specific, measurable, achievable, relevant, time-bound) goal against which project results can be evaluated.

- Selection of appropriate measurement endpoints that will inform managers of the project's effectiveness.
- A survey design that is capable of detecting real effects where they exist. This will ideally include an assessment of statistical power and subsequent identification of sampling requirements (number of surveys and their duration).
- Identification of appropriate survey/monitoring methods.
- Robust analysis of data and feedback of monitoring results in an appropriate format for managers to make decisions with confidence. This process is known as active adaptive management and uses monitoring data to both evaluate the effectiveness of a project in achieving its outcomes and compare observed data with predicted effects. This allows managers to evaluate their management interventions and to modify future actions based on robust evidence (figure 8.1).

Figure 8.1 Simplified adaptive management cycle. Planning involves the development of clear outcomes, identifying the actions considered most likely to achieve them and deciding on what to monitor to best inform on the project's performance. Monitoring data are then used to evaluate the effectiveness of the project and to allow evidenced- based adjustments of actions to improve performance.



PLAN - The Set-up Phase

- Stakeholder engagement
- Define SMART outcomes
- Identify management interventions
- Choose most appropriate action*
- Use conceptual system model to predict effects of management
- Develop monitoring plan to:
(i) gauge progress towards outcome(s)
(ii) collect data to address uncertainty**

DO - Implement Management

MONITOR

EVALUATE

Use monitoring data to:
(i) evaluate effectiveness of actions;
(ii) identify areas for improvement;
(iii) compare observed data vs. predicted effects of management

ADAPT AND IMPROVE

Amend management based on increased understanding of system

* Based on: (i) evidence of effectiveness; (ii) strong, defensible inferential logic.
** E.g. trial of new methodology

- Clearly, some mitigation approaches, such as crossing structures, may be difficult to modify to improve their effectiveness following construction. To overcome this, a centrally coordinated adaptive management process can be used to modify new structures based on evidence of the effectiveness of others. Aggregated information from more than one project will be much more powerful and useful than that from a single project.
- Landscape- and road crossing-scale monitoring designs developed for the UK's DEFRA agency are a very useful template and should be considered for trial in New Zealand. We note that these designs: 1) should follow appropriate pre-construction surveys, and 2) are likely to require some amendments to account for New Zealand conditions and indigenous bat species' rarity, and sparse distributions compared with European species.

Given the vulnerabilities of bats to even small reductions in adult survival because of their slow population growth rates, mitigation must help almost immediately. Mitigation approaches based on revegetation are unproven and are likely to take many years to be effective, if at all. While we cannot discount their usefulness, they are unlikely to mitigate immediate impacts on bat populations. This includes the planting of trees as 'hop-overs' to facilitate safe road crossings and as replacements for mature roost trees lost during road construction. These methods, if used, should form part of a wider strategy that also includes measures to mitigate immediate impacts.

Because of the importance to New Zealand bat populations of maintaining adult survival, we suggest methods of mitigating flight path severance should be investigated as a priority. Identification of the most appropriate method requires knowledge of how – where, when and at what height – bats travel through a landscape in which a road is planned. This would then allow identification of a mitigation approach, ie whether an under- or over-road structure would be most appropriate. Any structure should seek to maintain existing flight paths (alignment and height). Of the over-road structures considered overseas, vegetated bridges appear to have the greatest potential to mitigate impacts, but further evaluation is needed. We therefore recommend that flight behaviour characteristics of New Zealand bats are investigated with some urgency, particularly at sites where planned roads are likely to cross existing flight paths.

The loss of an occupied maternity roost due to tree felling may be significant to a small local bat population, particularly because of the potential impacts of the loss of breeding-age females. Although current tree-removal protocols generally prohibit tree removal during winter, or when temperatures are below a threshold (to avoid loss of hibernation roosts), the risk to maternity roosts is often dependent on the ability to detect them in trees prior to felling. This risk remains unquantified because the accuracy of current survey methods remains untested. A robust assessment of current protocols is therefore required.

The additional cost of mitigation, monitoring, and associated research to already-expensive roading projects is an international issue. For example, between 7.5 and 10 percent of roading project budgets overseas have been dedicated to mitigating impacts on wildlife (van der Grift et al 2013). Given the national importance of this issue and the threatened status of many of the wildlife species that are likely to be affected by roading developments, a collaborative funding model should be developed for supporting the testing and creation of mitigation methods. This could include the Transport Agency, consenting agencies, Department of Conservation and the roading industry. Research support for individual projects may be available via other sources such as Envirolink funding to regional councils. This would spread the costs and support the collection of data consistently across projects, thus facilitating the meta-analysis of data to provide stronger inference about effectiveness. An alternative approach may be to stipulate the conditions for monitoring the effectiveness of mitigation within contracts. Projects currently suffer the costs of delays due to prolonged litigation during the consent process, often because of debate and uncertainty as to the likely effectiveness of mitigation methodologies, and significant sums are spent on implementing mostly untested mitigation approaches. An investment in developing an evidence-based mitigation strategy, while requiring upfront financial input, will likely reduce costs and delays in the long term. Our priorities are summarised in table 8.3.

Table 8.3 Priority activities for developing mitigation strategies that protect indigenous bat species from the impacts of roading infrastructure

Activity	Outcome	Timeframe
Assessment of ability of roost-identification protocols to detect roost presence reliably.	Improved protection of maternity and over-winter roosts to increase adult female survival and productivity rates.	Short term
Research into flight-path behaviour of New Zealand bat species, ie how (where, when and at what height) bats travel through a landscape in which a road is planned.	Guidance for development of measures to reduce barrier effect of roads and to reduce direct mortality of bats at crossings.	Short term
Test of applicability of UK DEFRA landscape and crossing-point monitoring protocols for New Zealand species and environments. Or develop other potential monitoring methods.	Improved ability to monitor New Zealand bat species' distribution and activity around roads, before, during and after development.	Short term
Test of methods of mitigation of flight-path severance (under- and over-road) linked to research findings on bat flight behaviours.	Reduction/mitigation of barrier effect and direct mortality at road crossings.	Medium term
Establishment of common monitoring protocols to enable data sharing from road development projects.	Collection of appropriate quality and quantity of data to allow individual projects to contribute to a greater pool of data that will allow robust decision-making and evidence-based adaptive management without a single project bearing the cost of collecting the required volume of data.	Medium term
Establishment of a cross-agency collaborative funding model for supporting the research and development of mitigation methods.	Critical research into bat behaviour, roading impacts and effectiveness of potential mitigation approaches is supported.	Medium term
Explore potential for common stipulation of requirements for: 1) standards for monitoring the effectiveness of mitigation, and; 2) evidence-based justification of investment in mitigation methods, when roading developments are consented.	Investments into avoiding and mitigating the biodiversity impacts of roading developments are made using robust evidence and become progressively more cost effective as evidence-driven decisions reduce the requirements for prolonged litigation.	Medium term

9 Generic approach for other vertebrate groups

Although the primary focus of Part 1 of this report has been on the effects of roading on New Zealand bat populations and their mitigation, it is possible to derive a set of general principles for assessing the impacts of roading and thereby prioritising mitigation strategies for any indigenous vertebrate population. We suggest the following, step-wise, logical approach that builds on current practices and emphasises the use of robust evidence-guided decision making:

1. Within and around the planned (or existing) infrastructure footprint, consider topography, hydrology, and habitat type in association with existing species distribution records, habitat use data and landscape modelling to identify indigenous vertebrate species that may be affected by the development. Where local records are not up to date, survey for potentially affected species using appropriate methods.
2. Where species' presence is confirmed, assess potential impacts of roading, taking into account, for each species:
   a Known habitat requirements, including foraging and other behaviour
   b Conservation and protection status and district/regional significance
   c Population size and distribution (habitat type, distance from road footprint)
   d Life history, demographic vital rates (used to assess critical vital rates and seasons for the species of concern)
   e If sufficient data is available, use population modelling to prioritise vital rates for protection
   f Likely impacts of development on these demographic processes, eg habitat loss, habitat change, habitat fragmentation, direct mortality, behavioural changes.
3. Use the information above to identify the most likely effects on each species, including likely effects on vital demographic processes and therefore on population dynamics.
4. Determine whether predicted adverse effects can be avoided by, for example, relocating the project away from the impact area.
5. If avoidance is not possible, prioritise mitigation of those impacts considered likely to have the greatest effects on population growth and viability.
6. Use robust evidence (not anecdotal or 'accepted', but untested practice) to identify potential mitigation approaches.
7. Prioritise mitigation methods based on:
   a Robust scientific evidence of success when used on the species to be protected in similar locations or habitats. Robust evidence should include demonstration of sufficient statistical power and some quantification of effect magnitude
   b Peer-reviewed scientific evidence of successful use on the species to be protected in other location/habitat type(s)
   c Peer-reviewed scientific evidence of successful use on related or similar (species in other location/habitat type(s).

8 If reliable evidence of mitigation is not available, identify likely approaches based on published research and consider trials of those methods. Trials must be designed using the criteria suggested in the previous section above, to allow objective and robust assessment of effectiveness and should take into account the caveats also set out in the previous section. Expert thinking could be involved here, particularly if the published literature is lacking, but the key thing is to set up the monitoring appropriately, and spread risk across a number of mitigation options, being prepared to quickly drop/modify options that produce poor results, ie an adaptive management framework.

9 Establish a robust monitoring programme to evaluate the effectiveness of the mitigation method used.

10 Data collected at individual projects should be publicly available, so other similar data sets can be compared in a meta-analytical approach to assess the effectiveness of mitigation methods on a wider scale.

PART 2: REGULATORY REVIEW

10 Introduction to Part 2

10.1 Background

In New Zealand, regulatory approvals of land transport projects and their associated environmental impact assessments are largely approved at the local government level. At the national level, regional and local planning instruments often play an important role in project approval decisions and the level of environmental mitigation required. This leads to both regulators and land transport operators assessing and managing impacts on a case-by-case basis, resulting in a range of outcomes and costs.

10.2 Purpose and methodology

In order to develop a Vertebrate/Bat Management Framework it is necessary to first have a comprehensive understanding of how regulatory planning legislation and policy statements influence the requirements to assess, monitor and mitigate the effects of land transport projects on bats and other vertebrate species. Therefore the purpose of this regulatory review is to identify and assess key legislation, policy, and planning documents and processes that need to be addressed by land transport providers to gain regulatory approval to undertake projects in areas where bats and other indigenous vertebrate species are present.

Chapter 11 examines New Zealand's legal and planning instruments used by regulatory authorities to assess land transport projects in areas where bats and other endemic vertebrate species are present.

Chapter 12 explores how the key legislation, policy and planning documents and processes are being applied at the project level by reviewing a selection of recent land transport planning reports. This part of the review summarises key ecological issues with respect to assessing impacts specifically on indigenous bats, and the differences and similarities in the conditions placed on regulatory approvals, such as the type of mitigation measures and degree of monitoring required.

11 Key documents

11.1 Legislation

The key regulatory legislation that governs the management of natural and physical resources and the conservation and protection of wildlife in New Zealand are the:

- Resource Management Act 1991
- Conservation Act 1987
- Wildlife Act 1953.

These Acts and their statutory processes need to be considered in developing a framework for assessing and mitigating effects of linear infrastructure on bats and other endemic vertebrates.

Approvals will likely be required by land transport providers under one or several of these Acts; however, as can be seen from the discussion that follows, the issues needing to be addressed under each Act are similar in focus and intent.

11.1.1 Resource Management Act 1991

The Resource Management Act 1991 (RMA) is the statute that land transport projects in New Zealand will most commonly interact with in terms of the need for authorisations.

11.1.1.1 Purpose and key principles

The purpose of the RMA is defined by section 5 of the Act as the sustainable management of natural and physical resources. Natural and physical resources in the RMA are defined as including:

> *…land, water, air, soil, minerals, and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures*

while the environment in the RMA is defined as including:

> *(a) ecosystems and their constituent parts, including people and communities; and*
>
> *(b) all natural and physical resources; and*
>
> *(c) amenity values; and*
>
> *(d) the social, economic, aesthetic, and cultural conditions which affect the matters stated in paragraphs (a) to (c) or which are affected by those matters.*

The purpose of the Act, amongst other things, means managing the use, development, and protection of natural and physical resources while avoiding, remedying or mitigating any adverse effects on the environment.

In regards to the specific protection of indigenous fauna, section 6 of the Act states:

> *In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:…*
>
> *6c the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna"*

While the purpose and principles of the RMA give importance to ecosystems and significant habitats of indigenous fauna, the RMA does not provide specific protection or require specific regard to threatened or vulnerable fauna (vertebrates or other), rather this is implicit by way of protecting habitats. The RMA does not define 'significant' in regards to habitats of indigenous fauna.

It should also be noted that section 6 of the RMA lists a number of 'matters of national importance' and these matters as well as the matters in sections 7 and 8 are accessory to the RMA's purpose as stated in section 5 of the RMA.

11.1.1.2 Implementation and application of the RMA

National direction on the implementation and application of the RMA is provided by central government, but it is usually the responsibility of local authorities[4] to implement the RMA unless matters are referred to the Minister for the Environment or the Minister of Conservation. The responsibility for local authority implementation is divided between regional councils, unitary authorities and territorial authorities (either district or city councils).

The main mechanisms by which the purpose and principles of the RMA are given effect to, is through a cascading regime of policy documents as follows:

- national policy statements (NPS) (prepared by the Ministry for the Environment)
- regional policy statements (prepared by regional councils)
- regional plans (prepared by regional councils)
- district plans (prepared by territorial authorities)
- other statutory or non-statutory documents such as iwi management plans.

All regional councils must have a regional policy statement with regional plans then giving effect to regional policy statements. District plans must give effect to regional policy statements and cannot be inconsistent with regional plans. The weighting and influence of these documents as they relate to gaining authorisation for land transport or other infrastructure projects are discussed further in sections 11.2, 11.3, and 11.5 of this review.

In regards to indigenous biological diversity, section 30 of the RMA specifies the functions, powers and duties of regional councils:

> *Every regional council shall have the following functions for the purpose of giving effect to this Act in its region:... (ga) the establishment, implementation, and review of objectives, policies, and methods for maintaining indigenous biological diversity*

Similarly, section 31 of the RMA specifies the functions of territorial authorities in regard to indigenous biological diversity under the Act:

> *Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:*
>
> *(b) the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of—*
>
> *(iii) the maintenance of indigenous biological diversity.*

The maintenance of indigenous biological diversity therefore comes under the jurisdiction of both regional councils and territorial authorities, albeit with a slightly different emphasis.

Biological diversity is defined in the RMA as 'the variability among living organisms, and the ecological complexes of which they are a part, including diversity within species, between species, and of ecosystems'.

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[4] 'Local authorities' is the term used to describe both regional councils, unitary authorities and territorial authorities.

These functions for maintaining indigenous biodiversity or controlling the effects of land use for the purpose of maintaining indigenous biodiversity are given effect through the regional policy statements and plans and district plans prepared and administered by regional councils and territorial authorities, respectively. These documents are discussed further in section 11.5 of this review.

11.1.1.3 Approvals required for infrastructure projects under the RMA

Permitting requirements for an infrastructure project are determined by Part 3 of the RMA and the relevant rules in the district and or regional plan.

In general, approval to undertake land use activities, such as roading, is required from the territorial council, while approval for discharges, works in, on or above watercourses, take or disturbance to groundwater, or works in the coastal marine area is required from the regional council. In the case of a Unitary Authority, such as Auckland, they do both. Activities such as earthworks and vegetation clearance can be administered by territorial authorities and regional councils. The approvals under the RMA are referred to as resource consents[5] and a large land transport project will typically require a number of different kinds of resource consent. However in many cases 'designations' are established, which allows the work to be undertaken without the need for a land use consent from the territorial authority. This is discussed in further detail below as it affects the type of information that must be provided in order to gain approval for a land transport project.

Resource consents

Where a resource consent is required an 'environmental impacts assessment' must be completed. In New Zealand this is referred to as an assessment of effects on the environment (AEE). Schedule 4 of the RMA defines what must be included in an AEE.

Schedule 4 of the RMA specifies that assessed 'effects' are to include actual and potential, cumulative, temporary and permanent, as well as effects of low probability which have a high potential impact. The level of effect should be identified within the AEE, and if effects are considered 'likely' to be 'significant', then any possible alternative locations or methods should be identified. The term 'significant' is not defined in the Act, and relies upon provisions such as criteria in the national policy statements and local and regional plans, as well as input from specialists during the assessment process.

In the management of adverse effects on the environment, the RMA establishes a hierarchy of avoid, remedy or mitigate (eg sections 5, 17, 30, 68, and 76 of the RMA) and affords a general duty on every person to avoid, remedy or mitigate any adverse effect on the environment arising from an activity (section 17 of the RMA).

Section 104 of the RMA states when considering an application for a resource consent and any submissions received, the consent 'authority must, subject to Part 2, have regard to:

> *(a) any actual and potential effects on the environment of allowing the activity; and*
>
> *(b) any relevant provisions of—*
>
> *(i) a national environmental standard: (ii) other regulations: (iii) a national policy statement: (iv) a New Zealand coastal policy statement: (v) a regional policy statement or proposed regional policy statement: (vi) a plan or proposed plan;....*

Although the content of an AEE is led by schedule 4, this is 'subject to the contents of any policy statement or plan', which means aspects such as matters of control or discretion by the local/regional

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[5] Term covers different types of resource consent including: land use consent, subdivision consent, coastal permit, water permit and discharge permit (refer Section 87 RMA, 1991)

council will differ according to the applicable plan or policy, thus impacting what needs to be assessed in the AEE. Councils through their plans can specify matters to be included in an AEE. While these may not be material, these regional and district variances should be considered so an assessment framework for impacts on vertebrates from land transportation projects can be applied across the country.

Designations and notice of requirement

Designations authorise a requiring authority's[6] work and activity without the need for land use consent (resource consent) from the relevant territorial authority. While no land use consent is required, the work is still subject to restrictions in relation to air, water, and the coastal marine area, as such regional council resource consents are usually also required.

Designations are often used to provide long-term protection for routes for land transport projects. Irrespective of land ownership, a designation restricts anyone other than the requiring authority from carrying out work on the designated land that will prevent or hinder the project or work to which the designation relates, without first obtaining the requiring authority's permission.

Rather than a resource consent application, to obtain a designation, a notice of requirement (NOR) is prepared. A NOR does not need to include an AEE in accordance with Schedule 4 of the RMA but does need to include 'details of the effect that the proposed work will have on the environment, and the proposed mitigation measures as well as additional information (if any) as required by regional or district plans or regulations'. The contents therefore of the NOR effects assessment are less prescribed than with a resource consent application.

Section 171(1) of the RMA requires the territorial authority, subject to Part 2, to consider the effects on the environment of allowing the NOR, having particular regard to:

> *a) any relevant provisions of a national policy statement, the New Zealand Coastal Policy Statement, a regional policy statement or proposed regional policy statement and a plan or proposed*

In addition to the AEE not being subject to schedule 4 of the RMA, another key difference in making a decision on a NOR compared with a resource consent is the phrase 'having particular regard to' (section 171 of the RMA – NOR) compared with 'have regard to' (section 104 of the RMA – resource consent) in terms of policy statements and plans. In practice, this slight difference in wording has little implication.

Another difference in practice between the assessment of a NOR and a resource consent is the explicit requirement in section 171(b) of the RMA for a territorial authority, when considering a NOR, to have particular regard to whether a requiring authority has given adequate consideration to alternative sites, routes or methods of undertaking the work if:

- the requiring authority does not have an interest in the land sufficient for undertaking the work, or
- it is likely the work will have a significant adverse effect on the environment.[7]

Where endemic vertebrate species are present within a linear infrastructure project area, then by virtue of section 171(b) of the RMA, it can be expected that significant attention will be paid by decision makers to

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[6] A requiring authority may be a Minister of the Crown; or a local authority; or a network utility operator approved as a requiring authority. Examples of network utility operators are water supply/wastewater operators, airports, telecommunications providers, electricity operators, road or rail operators.

[7] Resource consent applications must contain a description of any possible alternative locations or methods for undertaking the activity if it is likely the activity will result in any significant adverse effect on the environment; however, this is not explicitly listed as a matter to have regard to when considering an application for a resource consent.

the alternative routes that were considered during the route development phase. Ecological considerations should therefore be one of the criteria in deciding route selection.

Finally, it should be highlighted that territorial authorities do not approve NORs, rather they make a recommendation to the requiring authority. The requiring authority (eg the Transport Agency) ultimately decides whether to accept or reject the territorial authority's recommendations (including recommended conditions). In practice, for a major infrastructure project, the conditions to apply to the designation will likely have been through an iterative process of development through the consultation, submission and hearing process. This means wholesale changes to conditions as part of the requiring authority decision have become uncommon in practice.

Direct referrals

The Environment Court hears appeals on decisions made by local councils; however, notified resource consent applications, alteration to consent conditions, designations and alterations to designations may be directly referred to the Environment Court. This 'direct referral' process follows the traditional process to the point of receiving submissions. Instead of continuing onto a council hearing, the applicant requests the council to refer the matter directly to the Environment Court for hearing and determination.

Proposals of national significance

The RMA provides for the Minister for the Environment and/or the Minister of Conservation to refer proposals of national significance[8] to a board of inquiry or the Environment Court for a decision. Applications (for example, resource consent applications or NORs) required for a proposal of national significance are lodged with the Environmental Protection Authority (EPA). The EPA functions as a statutory office, operating within the Ministry for the Environment under the Secretary for the Environment. The EPA administers and makes recommendations to the Minister for the Environment regarding the processing of nationally significant consent applications, plan changes and NORs. The board of inquiry or Environment Court covers the role of the territorial authority in these cases.

The NZ Transport Agency (2013) *Consenting strategy approvals and pathways guide* summarises the different approval types (eg plan changes, consents, designations, direct referrals to Environment Court) required for land transport projects and the way these can be gained as well as a brief discussions on disadvantages and advantages of each process.

Emergency works provision

Section 330 of the RMA permits emergency works or other activities to be undertaken under certain circumstances by utility operators and local authorities (and their representatives) without a resource consent, when one would have otherwise been needed. These certain circumstances include where an adverse effect on the environment requires immediate preventative or remedial measures; or when there is a sudden event causing or likely to cause loss of life, injury, or serious damage to property. An example could be indigenous vegetation clearance to prevent spread of a fire or removing a scheduled tree that is about to fall and damage a utility structure such as power or telephone lines.

A consent condition could be breached using the emergency works provision but the reasons for undertaking the work would need to meet the requirements of section 330 of the RMA. An example of this may be the need to remove a tree for safety reasons that meant tree removal protocol conditions could not be complied with.

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[8] Section 142(3) of the RMA sets out criteria for considering whether a proposal is nationally significant.

Retrospective approval to gain resource consent for emergency works needs to be applied for under section 330A of the RMA if those works have ongoing adverse effects. For example, if a bat roost was removed as a result of the tree removal example above, this permanent adverse effect on bat habitat could be considered as 'ongoing' (because it is permanent) and the action require a retrospective resource consent application. Prior approval for a wildlife permit under the Wildlife Act (refer to section 13.1.3) would theoretically still be required for emergency works in relevant circumstances.

11.1.1.4 RMA – key points for land transport projects in regard to vertebrate impacts

- The RMA is a key piece of legislation and land transport projects are required to gain authorisation under this Act.
- The RMA stipulates protecting areas of 'significant habitats of indigenous fauna' is a matter of national importance and local authorities have responsibilities for maintaining biological diversity (either directly or via land use control). No specific emphasis is given to rare, threatened, or endangered species such as indigenous bats.
- A key component of the consideration of consents and designations applied for under the RMA is whether the actual and potential adverse effects of the proposal are avoided, remedied or mitigated and to what level. Inherent in this assessment is the need to have sufficient knowledge and information about the effect being considered.
- In addition to considering actual or potential effects, when considering land transport projects, regard must be had to relevant planning documents (ie policy statements and plans) or, in the case of NORs, particular regard.
- Section 171(1)(b) of the RMA requires that notices of requirements give adequate consideration to alternative sites, routes or methods of undertaking the work. As such, the presence of endemic vertebrates such as indigenous bats should be one of the criteria in route selection and should influence decision makers to review the alternative routes that were considered during the route development phase. For resource consent applications, the assessment of the activity's effects on the environment must include a description of any possible alternative locations or methods for undertaking the activity, if it is likely the activity will result in any significant adverse effect on the environment.
- There is the potential for variable interpretation and implementation of how local authorities (regional, unitary and territorial) meet the requirement to maintain 'indigenous biological diversity' (sections 30 and 31 of the RMA). This has the potential to affect the way authorisations are granted and has the potential to result in inconsistent consent conditions from regional and territorial councils for the same project in relation to the management of impacts on vertebrate species (eg refer to section 12.2.2 of this review). However, this risk is mitigated in practice through the use of joint/combined hearings where all the necessary approvals (ie regional and district) for a project are considered at the same time and inconsistencies in consent conditions can be identified and remedied. It is also worth noting that unitary authorities can work through conditions well in advance of a hearing.
- If a project meets the criteria of nationally significant, resource consent and NORs can be lodged with the EPA and decided by a board of inquiry, or directly referred to the Environment Court. However, regional and district planning documents are still considered. Alternatively the project can still be considered at local level through the standard 'two-step' process.
- Emergency works may be undertaken under section 330 of the RMA in the event that safety or the effectiveness of key infrastructure is compromised. A consent condition could be breached using the emergency works provision but the reasons for undertaking the work would need to meet the

requirements of section 330 of the RMA. As such there is a possibility bat protection provisions could be overridden in emergency situations.

11.1.2 Conservation Act 1987

The Conservation Act (CA) is administered by DOC. The purpose of the CA is to promote the conservation of New Zealand's natural and historic resources.

The significant mechanisms in the CA for managing conservation are as follows:

- Conservation Management Strategies
- Conservation Management Plans
- New Zealand Coastal Policy Statement.

These documents establish policies and objectives for the integrated management of natural and historic resources, which may or may not include the protection of specific species. Conservation strategies and plans are discussed in section 11.4 of this review.

Section 6 of the CA outlines the functions of DOC to manage for conservation purposes, all land and all other natural and historic resources[9], for the time being held under this Act, and all other land and natural and historic resources whose owner agrees with the Minister they should be managed by DOC.

Under the CA, areas can be protected for their conservation values including ecological areas, sanctuary areas, and wildlife management areas. The CA also contains mechanisms for protection on Māori land, which may include ecological values. Concessions are required for activities on conservation land and applications need to be supported by specific information including effects and actions to avoid, remedy or mitigate effects. The Minister can also request an environmental impact assessment, which takes the form of an RMA Schedule 4 AEE.

11.1.2.1 Threat classification system

DOC maintains a 'New Zealand Threat Classification System' listing. This listing is not established by legislation but is a tool to assist in natural resource decisions and conservation management. The conservation status of the long-tailed bat (*Chalinolobus tuberculatus*) and the lesser short-tailed bat (*Mystacina tuberculata*) was reassessed in 2012 and these species, and their various sub-species, are now classified as threatened or at risk (O'Donnell et al 2013)

The conservation status of a species is part of considering the potential effects of a project, but the presence of a threatened species has no specific legal requirements (other than those afforded to all species protected under the Wildlife Act discussed in section 11.1.3 of this review).

11.1.2.2 Conservation Act 1987 – key points for land transport projects in relation to vertebrate impacts

The CA applies directly to land transport projects which pass through or are adjacent to conservation land in that a concession would need to be gained to carry out any activities on that land. If the land is subject to a Conservation Management Plan, this plan will need to be considered before the concession is granted.

New Zealand Threat Classification System ratings are one consideration in assessing effects on indigenous vertebrate species from a proposed project.

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[9] Defined as: (a) plants and animals of all kinds; and (b) the air, water, and soil in or on which any plant or animal lives or may live; and (c) landscape and landform; and (d) geological features; and (e) systems of interacting living organisms, and their environment.

Conservation Management Plans often contain specific provisions for protecting habitat and endemic vertebrate species. The CA also can apply indirectly, in that territorial authorities can take into account any relevant Conservation Management Strategy when considering an application for a resource consent.

Where roading authorities are promoting projects that affect DOC's estate, the purpose of the land in question should be clarified and any conservation strategies or plans taken into account.

11.1.3 Wildlife Act 1953

The Wildlife Act (1953) is administered by DOC and deals with the protection and control of wild animals and the management of game.

Protection of wildlife through the Act ranges from absolute protection, to partial, to non-protected. Most species of wildlife (including mammals, birds, reptiles and amphibians), indigenous or introduced, are absolutely protected under the Act.

Section 3 of the Act outlines that all wildlife (except in the case of wildlife being specified in Schedules 1-5) is subject to the Act and is absolutely protected throughout New Zealand and New Zealand fisheries waters, and that no one is to kill or have in their possession any wildlife unless they have a permit.

The definition of hunt or kill within the Act, states 'in relation to any wildlife, includes the hunting, killing, taking, trapping, or capturing of wildlife by any means; and also includes pursuing, disturbing, or molesting any wildlife'. As such, permits are required for the following activities:

- catching, handling and releasing wildlife at one site
- disturbing or killing wildlife or their eggs
- exporting live/dead wildlife
- catching and/or holding wildlife for rehabilitation
- holding dead specimen (eg any part of the wildlife)
- transferring captive wildlife from one facility to another
- catching protected wildlife for holding in captivity
- releasing captive wildlife into the wild
- catching wildlife in the wild and moving them to another wild location into which they are released.

Any land transport project involving wildlife capture, temporary captivity and release either to the same site or another site, may require a permit under the Wildlife Act (wildlife permit). Reporting of accidental or incidental death or injury is also required under the Wildlife Act. Wildlife permits are also required for disturbing nests/roosts or eggs and may be required for habitat destruction that may result in accidental killing.

Assessments are required in order to gain approval for these permits. There is no specified method for undertaking assessments and liaison with DOC staff is required. Unlike the RMA, which provides guidance on how resource consent applications are to be considered and how decisions are made, the Wildlife Act provides no such details.

The department has developed some permit application guidance which requests that applications include:

- the activity being carried out and its purpose
- threat classification of the species (if relevant)
- activity timeframes
- number to be caught, held or killed

- methods of capture
- land access
- captive management programmes details and effects (‘list all actual and potential adverse (or positive) effects of the proposed activity at the site, including effects on the target species, other indigenous species and the ecosystems at the site. Where adverse effects are identified please state what methods will be used to manage those effects’).

Conditions may be imposed directly from DOC via the wildlife permit. As such, a different and a possibly more stringent set of conditions may result than those determined during the RMA consenting process (ie resource consent or designation conditions) for that project.

11.1.3.1 Wildlife Act 1953 – key points for land transport projects in regard to vertebrate impacts

Bats and other vertebrate species are protected by the Act as they are not included in any of the exclusion schedules (Schedules 1, 2, 3, 4, or 5). The default of the Act is that mammals, birds, reptiles and amphibians are protected unless otherwise specified.

The Wildlife Act requires a wildlife permit for projects proposing capture and relocation of species. In addition, projects that may knowingly or unknowingly disturb habitat, particularly roosts or nests, or have the potential for accidental killing as a result of habitat destruction also require permits. For example a wildlife permit for the accidental loss of long-tailed bats, lizards and birds was required during construction of the Waikato Expressway (Cambridge and Huntly sections). The permit was obtained in recognition of the fact that while efforts were made to minimise the potential for loss of individuals during the construction works the risk could not be completely excluded, and for example, individuals may have required capture in order to rehabilitate them.

Permit applications must include information on the proposal and consideration of all actual and potential adverse (or positive) effects of the proposed activity at the site, including effects on the target species, other indigenous species and ecosystems. For negative effects the application requests that methods to manage the effects are identified.

Conditions may be imposed directly from DOC via the wildlife permit. As such a different and possibly more stringent set of conditions may result than those determined during the statutory consenting process (ie resource consent or designation conditions) for that project. This highlights the potential for different conditions to arise from the RMA statutory planning process and the wildlife permit authorisation.

There is no provision for emergency works in the Wildlife Act. As such, theoretically a wildlife permit is required when emergency works are undertaken under section 330 of the RMA. Advice should be taken from local DOC offices under such circumstances.

11.1.4 Biosecurity Act 1993

The Biosecurity Act 1993 provides a legal basis for excluding, eradicating and effectively managing pests and unwanted organisms. The Act is administered by the Ministry for Primary Industries but provides functions and powers to regional councils and territorial authorities. The principal means by which councils undertake pest management is via the preparation of a regional pest management plan (formerly strategy). The plan needs to specify whether it includes portions of road adjoining land it covers, as authorised by section 6 of the Biosecurity Act, and, if so, the portions of road proposed to be included (section 84)(3)(l) of the Biosecurity Act). This means, in some cases, land within road designations is not bound by the rules in the regional pest management plan.

However, the Act now requires all Crown agencies to comply with good neighbour rules. A good neighbour rule seeks to manage the spread of a pest that would cause costs to occupiers of adjacent or nearby land. Therefore if a pest is managed by a good neighbour rule, road controlling authorities would need to comply.

The control of mammalian predators has been included as a mitigation activity for managing impacts to bats from roading projects. Predator control of land within a road designation needs to be considered within the wider regional pest management goals and objectives of the relevant regional pest management plan.

11.2 National policy documents

11.2.1 National policy statements

NPSs are one of the central government instruments prepared under the RMA that set objectives and policies for matters of national significance. Regional plans must give effect to NPSs. When making decisions on environmental permits, regional councils, the Environment Court and boards of inquiry are required to have regard to provisions of the NPS in consenting decisions. There are a number of NPSs in place that cover issues such as: coastal resources, freshwater management and electricity transmission.

A proposed NPS on Indigenous Biodiversity has been prepared and was notified in 2011. There is no statutory requirement to have regard to a proposed NPS, therefore the following commentary on the proposed NPS on Indigenous Biodiversity merely indicates where current thinking sits. However, considering the relevance of this NPS to endemic vertebrates, further discussion is provided below.

11.2.1.1 Proposed NPS on Indigenous Biodiversity

The proposed NPS on Indigenous Biodiversity is intended to provide clearer direction to local authorities on their responsibilities for managing indigenous biodiversity. It outlines policies and decision-making frameworks for identifying and managing indigenous biodiversity found outside the public conservation estate.

The objective of the proposed NPS reads as follows:

> *To promote the maintenance of indigenous biological diversity by protecting areas of significant indigenous vegetation and significant habitats of indigenous fauna, and to encourage protection and enhancement of biodiversity values more broadly while:*
>
> - *supporting best practice of local authorities*
> - *recognising the positive contribution of landowners as guardians/kaitiaki of their land*
> - *recognising that the economic, social and cultural well-being of people and communities depends on, amongst other things, making reasonable use of land.*

Policy 2 of the NPS states:

> *In considering the effects of any matter, local authorities shall, in addition to any area of significant indigenous vegetation or a significant habitat of indigenous fauna identified in, or by, provisions of any relevant regional policy statement, or regional or district plan, regard the following as significant indigenous vegetation or significant habitat of indigenous fauna:*
>
> *…. e) habitats of threatened and at risk species.*

The NPS provides a definition of threatened and at risk species which 'means a species facing a very high risk of extinction in the wild and includes nationally critical, nationally endangered and nationally vulnerable species as identified in the New Zealand Threat Classification System lists'.

Policy 4 provides direction to councils to include these areas in their plans.

Policy 5 sets out a hierarchy for addressing effects, as follows:

> *In addition to the inclusion in plans of any other provisions that the plan has or is required to have relating to section 6(c) of the RMA, local authorities must manage the effects of activities through district and relevant regional plans (or be satisfied that the effects are managed by methods outside of district or regional plans) to ensure 'no net loss' of biodiversity of areas of significant indigenous vegetation and significant habitats of indigenous fauna by:*
>
> *a. avoiding adverse effects*
>
> *b. where adverse effects cannot be avoided, ensuring remediation*
>
> *c. where adverse effects cannot be remedied, ensuring mitigation*
>
> *d. where adverse effects cannot be adequately mitigated, ensuring any residual adverse effects that are more than minor, are offset in accordance with the principles set out in Schedule 2.*
>
> *For the avoidance of doubt, in accordance with the principles of Schedule 2, there are limits to what can be offset because some vegetation or habitat and associated ecosystems, is vulnerable or irreplaceable. In such circumstances offsetting will not be possible and local authorities will need to take full account of residual adverse effects in decision-making processes.*

The proposed NPS on Indigenous Biodiversity defines terms not defined in the RMA, including:

Biodiversity offset	Measurable conservation outcomes resulting from actions which are designed to compensate for more than minor residual adverse effects on biodiversity, where those affects (*sic*) arise from an activity after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure and ecosystem function.
Maintenance	'No net loss' as achieved by the protection of existing areas and habitats and/or the restoration and enhancement of areas and habitats as may be required through biodiversity offsets or other initiatives.
No net loss	No overall reduction in: a the diversity of (or within) species b species' population sizes (taking into account natural fluctuation), and long-term viability c area occupied and natural range inhabited by species d range and ecological health and functioning of assemblages of species, community types and ecosystems.
Threatened species	A species facing a very high risk of extinction in the wild and includes nationally critical, nationally endangered and nationally vulnerable species as identified in the New Zealand Threat Classification System lists.

NPS on Indigenous Biodiversity – key points for land transport projects in relation to vertebrate impacts

While the proposed NPS on Indigenous Biodiversity is not yet in force, and as such does not have legal effect, it has in recent years been referenced in questioning of experts by several hearings commissioners for large land transport projects where bats and other vertebrates were considered, eg Waikato Expressway (Hamilton section), Hamilton Southern Links.

In summary:

- There is no statutory requirement to have a NPS.

- The NPS reiterates the RMA hierarchy of avoid, remedy and mitigate, but adds the concept of offset.
- The NPS emphasises 'no net loss' of biodiversity of areas of significant indigenous vegetation and significant habitats of indigenous fauna.
- The NPS provides guidance on what constitutes significant indigenous vegetation or significant habitat of indigenous fauna. This includes habitats of threatened and at risk species.
- The NPS directly references DOC's New Zealand Threat Classification System lists.
- When operative the NPS will require district and regional plans to identify areas of significant biodiversity within five years of the NPS taking effect. Local authorities are already using a variety of criteria which may or may not include habitats of threatened or at risk species (refer sections 11.3 and 11.5 of this review). There is, however, no indication of when the proposed NPS may be made operative.
- Submissions on the NPS have closed. If the NPS is made operative and district and regional plans are progressively updated to take into account the NPS, there will be opportunities to be involved in reviews of the plan.
- As district and regional plans are progressively updated to take into account the NPS, there may be greater consistency in the way plans identify areas to be protected. The intent is for local authorities to manage the effects of activities through district and regional plans and resource consent decisions (or be satisfied that effects are managed by other methods) to achieve no net loss of biodiversity.

While it is difficult to predict whether there will be significant changes to the wording of this NPS, the Vertebrate/Bat Management Framework should recognise the signal to achieve no net loss of significant habitats of indigenous fauna and that offsetting can be recommended as a method of compensating for negative ecological impacts.

11.3 Regional policy documents

11.3.1 Regional policy statements

As discussed above, NPSs provide guidance on matters of national significance and are prepared by central government. Regional policy statements (RPSs) must give effect to NPSs and are prepared by regional councils. RPSs set out the resource management issues of relevance to the region. These documents are prepared under the RMA and although they do not contain rules to regulate activities, regional and district councils are required to give effect to RPSs when preparing or changing regional or district plans, which may contain rules.

All local authorities must prepare a regional policy statement. Section 62 of the RMA states what a RPS must cover. When developing RPSs, regional councils are to have regard to relevant conservation management strategies and plans prepared by DOC.

A selection of RPS' for this regulatory review were chosen due to the known presence of indigenous bat populations in those areas. These included the:

- Waikato Regional Policy Statement (2016)
- Regional Policy Statement for the Bay of Plenty (2014)
- Proposed West Coast Regional Policy Statement (2015)
- Regional Policy Statement for the Wellington Region (2013).

These documents were reviewed for content relating to biodiversity and threatened species. They all contain policies relating to indigenous biodiversity or significant indigenous vegetation and habitats of indigenous fauna and are discussed in more detail below.

11.3.1.1 Waikato Regional Policy Statement (operative 2016)

The Waikato RPS contains policies relating to indigenous biodiversity and includes directives for how regional and district plans shall implement the policy, eg:

- Regional and district plans shall recognise that adverse effects on indigenous biodiversity within terrestrial, freshwater and coastal environments are cumulative and may include:
  - loss of habitat that supports or provides a key life-cycle function for indigenous species listed as 'threatened' or 'at risk' in the New Zealand Threat Classification System lists (11.1.2).
- Local authorities should liaise with DOC and other relevant agencies to ensure location and distribution data for species listed as 'threatened' or 'at risk' in the New Zealand Threat Classification System lists are available when preparing and implementing regional or district plans (11.1.6).
- Regional and district plans shall require that where loss or degradation of indigenous biodiversity is authorised, adverse effects are remedied or mitigated (whether by onsite or offsite methods). Remediation or mitigation must result in no net loss of the region's indigenous biodiversity. Methods include:
  - (a) replacing the indigenous biodiversity that has been lost or degraded
  - (b) replacing like-for-like habitats or ecosystems (including being of at least equivalent size or ecological value)
  - (c) the legal and physical protection of existing habitat
  - (d) the re-creation of habitat
  - (e) replacing habitats or ecosystems with indigenous biodiversity of greater ecological value (11.1.3).

  These sections encourage territorial authorities (ie district and city councils) to consider maintaining indigenous vegetation and habitat considered significant along with other habitat areas.

11.3.1.2 Regional Policy Statement for the Bay of Plenty (operative 2014)

The Bay of Plenty RPS groups policies according to their scope of application. These different types of policies include: 'broad policies that must be given effect by regional or district plans (in accordance with sections 67(3) and 75(3)(c) of the Act)' and 'specific directive policies for resource consents, regional and district plans, and notices of requirement' as well as 'policies that allocate responsibilities for land-use controls for hazardous substances and indigenous biodiversity between the Bay of Plenty Regional Council and the region's city and district councils'.

The RPS contains a section on integrated resource management with a policy which states that local authorities shall specify objectives, policies and methods (including rules), for the control of the use of land to maintain indigenous biodiversity. It also states the roles and responsibilities of the councils, i.e. regional council: 'for the control of the use of land within the coastal marine area and freshwater bodies to maintain indigenous biodiversity and local councils responsible for specifying in their district plans objectives, policies, and methods (including rules) for the control of the use of land, excluding land within the coastal marine area, to maintain indigenous biodiversity'.

The RPS also contains a section on matters of national importance (as defined by the RMA) and includes policy MN 1B which aims to identify which natural and physical resources warrant recognition and provision as matters of national importance under section 6 of the RMA. Assessment criteria are contained within an appendix to the RPS. The RPS recognises and provides for the protection of areas of significant indigenous vegetation and habitats of indigenous fauna identified.

Further to these policies is Policy MN 2B:

> *Giving particular consideration to protecting significant indigenous habitats and ecosystems based on the identification of significant indigenous habitats and ecosystems in accordance with Policy MN 1B:*
>
> *(a) Recognise and promote awareness of the life-supporting capacity and the intrinsic values of ecosystems and the importance of protecting significant indigenous biodiversity;*
>
> *(b) Ensure that intrinsic values of ecosystems are given particular regards to in resource management decisions and operations;*
>
> *(c) Protect the diversity of the region's significant indigenous ecosystems, habitats and species including both representative and unique elements;*
>
> *(d) Manage resources in a manner that will ensure recognition of, and provision for, significant indigenous habitats and ecosystems;*

The RPS appendix F contains criteria for assessing matters of national importance in the Bay of Plenty Region including criteria for identifying indigenous vegetation and habitats of indigenous fauna. Criteria include 'rarity or distinctive features' such as whether 'indigenous vegetation or habitat of indigenous fauna supports indigenous species or associations of indigenous species threatened or rare nationally, regionally or within the relevant ecological district'; and 'indigenous vegetation or habitat of indigenous fauna which can contribute to the maintenance or recovery of a species threatened or rare nationally, regionally or within the relevant ecological district'. A user guide is also provided.

The Bay of Plenty RPS provides direction about what should be considered a significant indigenous habitat or ecosystem and directs local authorities to use methods to maintain indigenous biodiversity.

11.3.1.3 Regional Policy Statement for the Wellington Region (operative 2013)

The Greater Wellington RPS provides two categories of policies – those that must be given effect in regional and district plans (and the regional land transport strategy) and those that must be considered by these documents. Amongst the policies that must be given effect to are:

- Policy 23: Identifying indigenous ecosystems and habitats with significant indigenous biodiversity values – district and regional plans.

  This policy provides direction on the criteria to be used to identify areas or ecosystems with significant indigenous biodiversity values. Included in the criteria is the provision of seasonal or core habitat for protected or threatened indigenous species.

- Policy 24: Protecting indigenous ecosystems and habitats with significant indigenous biodiversity values – district and regional plans. District and regional plans shall include policies, rules and methods to protect indigenous ecosystems and habitats with significant indigenous biodiversity values from inappropriate subdivision, use and development.

  Included in the explanation is a statement indicating that the intention of the policy is not to prevent change, but rather to ensure that change is carefully considered and is appropriate in relation to the biodiversity values.

- Policy 47 provides a list of considerations to give particular regard to when considering an application for a resource consent, notice of requirement, or a change, variation or review of a district or regional plan, but is seen to be an interim measure until Policies 23 and 24 have been given effect to through district and regional plan reviews.

11.3.1.4 Proposed West Coast Regional Policy Statement (2015)

While the proposed West Coast RPS 2015 contains a section on biodiversity and natural landscapes, it only contains the following relevant policy; therefore providing little direction on how to determine areas of significant indigenous vegetation, significant habitat of indigenous fauna and how these should be protected:

> *(1) Adverse effects on significant indigenous vegetation, significant habitat of native fauna, and outstanding natural character arising from the use and development of natural resources will be avoided, remedied or mitigated via Regional and District Plans and resource consent processes.*

However, as noted in the RPS for this region a large proportion of land is DOC managed (84%) and therefore biodiversity is managed by other means.

Regional policy statements – key points for land transport projects in regards to vertebrate impacts

Within the RPSs reviewed, the treatment and emphasis on:

- the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna (section 6c RMA), and/or
- maintaining indigenous biodiversity (sections 30 and 31 of the RMA), which may involve protecting areas outside of areas deemed ‘significant’

varies subtly between councils. However, all RPSs are driven by the language and intent of the RMA.

Ecological assessments associated with transportation projects typically need to include a discussion of regionally specific ecological values and impacts, and consideration of the criteria for determining significance of any vegetation or habitat to be removed. When processing/considering NORs or resource consent applications, RPSs are one of the documents the consent authority must (subject to Part 2 of the RMA) have regard to.

11.4 Conservation management strategies

11.4.1 Conservation management strategies (CMSs)

CMSs are prepared in accordance with Part IIIA of the CA by DOC and are the primary method of implementing general policies produced by the Director-General of Conservation and of establishing objectives for the integrated management of natural and historic resources, including any species managed by DOC.

CMSs are given regard to in NPSs, RPSs and regional and district plans, and in the assessment of resource consents. Road controlling authorities will therefore need to address the relevant CMS for an area in making resource consent applications and designing any proposed conditions and mitigations strategies.

A survey of a selection of relevant CMSs found the following content of relevance to bats.

11.4.1.1 Waikato Conservation Management Strategy (operative 29 September 2014)

- Policy 9.2.2.2. Advocate for, and work with landowners, iwi, local authorities and others to achieve the protection of the following conservation values off public conservation lands and waters: c) migratory habitat and pathways for birds, especially shorebird, seabird, and wetland bird species, and habitat used by bats, including airspace.
- Policy 9.2.2.14. Should consider applications for access arrangements under the Crown Minerals Act 1991 in accordance with policies 16.9.1.1 to 16.9.1.3 in Part three and the following criteria: b) the activity avoids priority ecosystem units and species populations; in particular, habitats important for the persistence of indigenous frogs, Coromandel brown kiwi, indigenous bats, and other threatened and at risk species.
- Policy 9.2.2.15. May allow sporting events provided: d) habitats that are important for the conservation of indigenous frogs, Coromandel brown kiwi, indigenous bats and other threatened and at risk fauna are avoided.
- Policy 13.2.2.1. Advocate for, and work with landowners, iwi, local authorities and others to achieve the protection of the following conservation values off public conservation lands: c) migratory pathways of birds, particularly shorebirds, and the habitats and airspace used by bats.

11.4.1.2 Auckland Conservation Management Strategy 2014- 2024 (operative 17 November 2014)

- The CMS identifies that long-tailed bats are present in the Kawau area, where populations are threatened.
- Long-tailed bats are identified as nationally endangered threatened species in the CMS.
- The strategy contains objectives and policies related to threatened species management. 9.1 DOC's primary objective is to enhance population numbers and distributional ranges of threatened indigenous species and subspecies where recovery action will be effective. An important part of this work is to prioritise threatened species according to their degree of threat and/or significance using DOC's ranking system.

11.4.1.3 West Coast Conservation Management Strategy 2010–2020 volume 1 (operative 2010)

- The CMS identifies that both long-tailed bats and southern short-tailed bats are found in West Coast Te Tai o Poutini forests and bats are identified as threatened species.
- The CMS includes policies to protect indigenous species, eg 'To prevent further extinctions or range contractions of indigenous species found on the West Coast Te Tai o Poutini' and 'to ensure, where practicable, that representative populations of all indigenous species have long-term security in predominantly natural habitats within their natural range'.

11.4.2 Conservation Management Plans (CMPs)

CMPs are prepared by DOC under section 17E of the CA. This section of the CA outlines the purpose of a CMP, which is to implement conservation management strategies and establish detailed objectives for the integrated management of natural and historic resources within any area or areas referred to in subsection (4) of the RMA, and for recreation, tourism and other conservation purposes.

CMPs may contain provisions requiring management of biodiversity in an area including objectives to protect biodiversity (e.g. 'ensure protection of biodiversity through integrated conservation management of ecosystems and species protection' in the Coromandel Peninsula CMP 2002, and 'protect the natural resources of Kaweka Forest Park' in the Kaweka Park CMP 1991) and have specific provisions for managing habitats of indigenous flora and fauna on conservation land.

11.4.2.1 CMSs – key points for land transport projects in relation to vertebrate impacts

CMSs and associated CMPs have a different emphasis than policy documents prepared under the RMA. They have more emphasis on species management and recognition of threatened species status. However, they do not have as much weight when assessing a proposal for a land transport project under the RMA. As discussed in section 11.1.2 of this review, they have greater significance if a project passes through land managed under the CA and a concession is required from DOC.

11.5 Regional and district plans

11.5.1 Regional plans

Regional councils are charged with establishing policies and methods to achieve integrated management of the natural and physical resources of the region. This includes control of land use for the purpose of maintenance, enhancement of ecosystems in water bodies and coastal water, along with the establishment, implementation and review of objectives, policies and methods for maintaining indigenous biological diversity.

Unlike district plans, which territorial authorities are required to have under the RMA, regional plans are not compulsory. Despite the 2003 RMA amendment inserting the maintenance of biodiversity as a regional council responsibility, the regional plans reviewed (Waikato, Bay of Plenty and West Coast) tend to focus on water (including aquatic biodiversity), soil and coastal resource management. For example, the Waikato Regional Plan 2012 has a land and soil section but does not specifically address biodiversity. All three of these plans have vegetation clearance rules.

11.5.2 District plans

Territorial authorities have the function of controlling the effects of the use, development, or protection of land, including for the purpose of maintaining indigenous biological diversity. They are also responsible for objectives, policies and methods for maintaining biological diversity.

A review of a selection of district council plans provides examples of the way district and city councils have policies and rules that apply to land transport projects and the protection of endemic vertebrates. Notwithstanding that roading projects usually propose designations, in making a recommendation on a NOR, the territorial authority must have particular regard to the relevant provisions of a district or regional plan (section 171, RMA).

Relevant sections of the following district plans are outlined below:

- Proposed Hamilton City District Plan (2014)
- Waikato District Plan (2013)
- Proposed Waipa District Plan (2013).

11.5.2.1 Hamilton City Council Proposed District Plan (Appeals Version 2014)

Hamilton City Council Proposed District Plan has a chapter on natural environments including significant natural areas (SNAs), which include areas of significant indigenous vegetation, biodiversity and habitats of indigenous fauna. The sites were assessed using the criteria in the 2000 RPS. The chapter contains a number of policies aimed at protecting the SNAs including:

> *20.2.1n The loss of habitat that supports indigenous species classified as at risk or threatened shall be avoided.*

Activities within these areas are very restricted such that even removal of exotic trees within a SNA requires a resource consent, and a restrictive category of consent is required (non-complying) for earthworks or removal of indigenous vegetation with a SNA.

11.5.2.2 Waikato District Plan – Waikato section (2013)

The Waikato District Plan recognises the importance of indigenous biodiversity and contains a number of objectives related to this including:

> *- Areas of indigenous vegetation and habitats of indigenous fauna, and the life-supporting capacity of indigenous ecosystems should be maintained or enhanced through on-site works, and the creation of ecological buffers and linkages using eco-sourced plants. (2.2.2)*
>
> *- Priority should be given to protecting and restoring threatened habitats and habitats of threatened species such as coastal and lowland forest, riparian areas, wetlands, dunes and peatlands (2.2.3).*
>
> *- Areas of significant indigenous vegetation and significant habitats of indigenous fauna should be managed in a way that protects their long-term ecological functioning and biodiversity through such means as:*
>
> *(b) undertaking plant and animal pest control*
>
> *(c) retaining and enhancing vegetation cover…*
>
> *(e) avoiding physical and legal fragmentation* (2.2.5)*…*
>
> *- Subdivision, use and development should be located and designed to avoid, remedy or mitigate adverse effects on indigenous biodiversity. This will include adverse effects on the ecological functioning and values of significant indigenous vegetation and significant habitats of indigenous fauna, in-stream values, riparian margins and gullies (2.2.6)*
>
> *- When avoiding, remedying or mitigating adverse effects on indigenous biodiversity, regard should be had to:*
>
> *(a) the need for species to continue to have access to their required range of food sources and habitats during their life cycle*
>
> *(b) the need for species to have access to refuges from predators and disturbances*
>
> *(f) the need to replace or restore habitats*
>
> *(g a) maintenance and enhancement of ecological corridors and buffer areas.* (2.2.7)

The Waikato District Plan states that:

> *Areas of significant indigenous vegetation and significant habitats of indigenous fauna will be identified by assessment against the criteria listed in this plan in Appendix O. These criteria are taken from Appendix 3 of the Waikato Regional Policy Statement. An area is significant if it meets one or more of these criteria, as determined by a suitably qualified person.*

Objectives can be met through a number of methods, including rules relating to vegetation clearance. In order for vegetation clearance to be a permitted activity the council must certify that the vegetation to be cleared is not significant indigenous vegetation or significant habitat of indigenous fauna. The criteria set for determining whether the vegetation is 'significant indigenous vegetation' is included in Appendix Oc of the plan and includes vegetation or habitat[10] that is currently habitat for indigenous species or associations of species that are: threatened with extinction or endemic to the Waikato Region. Most vegetation clearance not meeting permitted activity status is a discretionary activity[11] and the council will consider a number of matters when deciding whether to grant approval for the clearance including (among others): effects on ecological values and effects on significant indigenous vegetation and habitat.

11.5.2.3 Waipa District Plan (proposed)

This proposed district plan has a section on management of effects on the areas of indigenous vegetation and wetlands which support indigenous biodiversity values. Policies and rules follow a three-level structure whereby the most restrictive provisions apply to specifically identified and recorded significant natural areas and bush stands referred to as significant natural areas (SNAs). In addition to these areas 'biodiversity corridors' are also identified on planning maps and are considered to have potential significance to indigenous biodiversity values due to the desirability of improving connectivity between wetlands and areas of indigenous vegetation. These areas are given more protection than remaining areas of indigenous vegetation in the district.

24.1.7 of the plan states:

> *To achieve the requirements of Section 6(c) of the Act, and ensure that the overall proportion of remaining indigenous vegetation is maintained and enhanced, this Plan includes consideration of the 'no net loss' principle of the Waikato Regional Policy Statement to ensure that that biodiversity controls at a district level contribute to no net loss at a regional scale. This is achieved through the identification of significant areas of indigenous vegetation and significant habitats of indigenous fauna of national, regional and local significance; as well as rules intended to protect or maintain and enhance significant natural areas and other remnant areas of indigenous vegetation and wetlands*
>
> *Policy – Maintenance and enhancement of indigenous biodiversity*
>
> *24.3.1.1 To achieve the maintenance and enhancement of indigenous biodiversity values in the District by ensuring that removal of indigenous vegetation or disturbance of wetland areas only occurs where:*
>
> *(a) Connectivity to link core habitats along biodiversity corridors is supported; and*
>
> *(b) Sensitive sites remain buffered from intensive land use, development and subdivision; and*
>
> *(c) Habitat is retained for at risk and threatened indigenous species; and*
>
> *(d) Customary activities do not adversely affect at risk or threatened indigenous species; and*
>
> *(e) Consideration has been given to opportunities that contribute to no net loss at a regional scale.*

For the identified areas: [significant areas of indigenous vegetation and significant habitats of indigenous fauna of national, regional and local significance]

> *Policy – Limiting indigenous vegetation removal and other activities within identified significant natural areas and bush stands.*

---

[10] The word indigenous is not used. It is assumed therefore that exotic vegetation can meet the criteria of 'significant indigenous fauna' if it meets these criteria.

[11] The activity status influences the level of detail required in an AEE and can limit what issues the council takes into account when making a decision.

> *24.3.3.1 To protect the ecological sustainability, indigenous biodiversity values and characteristics of significant natural areas including wetlands, and bush stands by ensuring that:*
>
> *(a) The removal of indigenous vegetation or habitat of indigenous species is discouraged and:*
>
> *(i) Only occurs in sustainable quantities in significant natural areas of local significance; and*
>
> *(ii) Only occurs in limited circumstances within internationally, nationally or regionally significant natural areas and bush stands.*
>
> *(b) The health and functioning of significant natural areas including wetlands, and bush stands is maintained through appropriate land use practices.*
>
> *Removal of indigenous vegetation for any other purpose such as reducing risk to existing transmission lines, maintaining fences, within a significant natural area is non-complying or discretionary depending on the category of SNA."*

11.5.3 Regional and district plans – key points for land transport projects in relation to vertebrate impacts

Regional plans are not compulsory and do not always have sections dedicated to biodiversity. However, of the small selection reviewed all had rules pertaining to vegetation clearance.

The selection of district plans illustrates the hierarchy between RPSs and districts plans which must give effect to RPSs. The district plans reviewed all had objectives and policies addressing biodiversity and habitat protection with differing recognition of habitats for threatened species.

11.6 Iwi management plans

Iwi management plans are planning documents recognised by an iwi authority and lodged with the relevant council. Iwi management plans must be taken into account when preparing or changing RPSs and regional and district plans (sections 61(2A)(a), 66(2A)(a), and 74(2A)) as long as they are relevant to the resource management issues of the region/district. In addition, section 104(1) (c) of the RMA means that when considering an application for a resource consent, the consent authority must, subject to Part 2, have regard to: any other matter the consent authority considers relevant and reasonably necessary to determine the application. This could include an iwi management plan. The content of iwi management plans varies, but often contain 'policies' relating to the care and protection of indigenous fauna and habitat.

11.7 Summary

The planning review of key legislation and associated policy documents has identified some areas of relevance to land transport projects with impacts on vertebrates/indigenous bats:

- Proposals need to describe actual and potential adverse effects and how these can be avoided, remedied or mitigated. Inherent in this assessment is the need to have sufficient knowledge and information about the effect being considered.
- There is the potential for variable interpretation and implementation of how local authorities meet the RMA requirement to maintain 'indigenous biological diversity'.
- There is an increasing emphasis from councils on no net loss of biodiversity.

- The proposed NPS on Indigenous Biodiversity encompasses compensation (i.e. offsetting) in addition to the avoid, remedy, and mitigate hierarchy established by the RMA.
- Wildlife permit requirements and processes are not as clearly defined by law as RMA permit requirements.

12 Project reviews

12.1 Introduction

A selection of infrastructure projects is examined in this section that were either land transport projects or included roads, or tracks and associated vegetation clearance. Expert ecological evidence and or ecological assessments on potentially affected vertebrate species, particularly bats, were important considerations in the decision to approve the authorisations required for the projects. Projects reviewed include:

- Waikato Expressway – Cambridge, Huntly and Hamilton sections
- Hamilton Southern Links
- Puhoi to Warkworth
- Tukituki/Ruataniwha Dam and irrigation proposal.

The following sections examine these projects and provide for each project:

- a brief description
- environmental permits required and the process undertaken to gain these
- a summary of vertebrate impacts and issues, particularly relating to bats
- discussion/evidence around interpretation of law, plans or policies in relation to the assessment of and mitigation of impacts on bats.

At the end of this chapter a summary is provided of the consent conditions relating to bats which highlights the differences and similarities in the approaches of the different regulatory bodies.

The success of management controls required by the permits is discussed in chapter 7 in Part 1 of this report.

12.2 Waikato Expressway

The Waikato Expressway (WEX) project aims to improve safety and reliability and reduce travel times and congestion on SH1 by delivering a four-lane highway from the Bombay Hills in Auckland to south of Cambridge, Waikato (NZ Transport Agency 2016).

The WEX project consists of seven separate sections: Longswamp, Rangiriri, Ngaruawahia, Huntly, Te Rapa, Hamilton and Cambridge. These projects have all been through the environmental approvals process with the exception of Longswamp which was going through the approvals process at the time of writing. Impacts on long-tailed bats, which are known to inhabit the Waikato region, are an important consideration of the AEEs and subsequent consent conditions for the Cambridge, Huntly and Hamilton sections. These three sections of the WEX are discussed in further detail below.

12.2.1 Cambridge section

The Cambridge section of the WEX starts south of the existing Tamahere interchange and runs for 16 kilometres, ending around 2.5 kilometres south of Cambridge town where it connects with the existing State Highway 1. Construction work began work in September 2013 and was finished in December 2015.

The project involved the construction of three interchanges and twin viaducts over the Karapiro Stream gully and associated ancillary works, including temporary construction and access, safety and noise barriers, removal of vegetation, restoration landscaping and planting.

The corridor for the expressway involved a number of existing designations that fell under the authority of Waipa District Council (Cambridge section – Designation DN20 and J7)) and Waikato District Council (Tamahere section – Designation J9). NORs to update the designations were made and the new designations approved in 2011. A number of resource consents were also required from the Waikato Regional Council including land use consents, water permits and discharge permits.

Applications for NORs and resource consents were heard jointly by a panel of commissioners.

The hearing report for the NOR and resource consents discussed DOC’s submission and considered ‘there was an absence of information on the effects on native long-tailed bats known to frequent the Karapiro Stream gully, and highlighted that the “at risk” mudfish may also be present in Karapiro Stream and the ephemeral drains affected by the proposal’ (Withy 2011, p11). These concerns were resolved through the conditions to the resource consents so that ‘monitoring effects of the expressway on the bat population could be quantified; requiring replacement of bat roosts; and the application of protocols in respect of disturbance by construction of active roosts and timing to avoid nesting’ (Withy 2011, p11).

The hearing report also found the proposal was consistent with the RPSs and plans in both operative and proposed forms.

In addition, a wildlife permit was obtained for the project in August 2013 relating to the disturbance of long-tailed bats and lizards and their habitat. The conditions contained within this permit were in line with the bat management requirements of the resource consent conditions.

The project conditions are discussed further in section 12.6.

12.2.2 Huntly section

The Huntly section comprises a 15 kilometre length of the WEX commencing at the southern end of the Ohinewai section and finishing at the northern part of the Ngaruawahia section at the Gordonton Road Interchange.

The Huntly section designation was originally secured in 2008 after a notified process. However, following a detailed review of the preliminary design, a review of the alignment was undertaken. A significant alteration to the designation was required and a number of resource consents obtained which related to soil disturbance and vegetation clearance, water permits for working in watercourses, taking water, drilling below the water table and diverting and damming watercourses.

The NORs and resource consent applications were processed separately by independent commissioners and gained in 2013 (designations) and 2014 (resource consents).

The new alignment passes through Taupiri Scientific Reserve and as such mitigation of the impacts on this reserve and the wider ecological impacts were a focus of both the NOR and resource consent processes.

The package of mitigation measures agreed through the consenting process included terrestrial, wetland and stream riparian revegetation, domestic stock exclusion fencing of terrestrial, wetland and stream habitats, ecological weed and pest management and the legal protection of sites designated for mitigation or compensation.

The vehicle for delivery of this mitigation package was the requirement for the consent holder to prepare a landscape, visual and ecological management plan to be certified by Waikato District Council prior to the commencement of construction. This is formalised in the consent and designation conditions.

Resource consents contain a number of specific conditions relating to each permit and a set of general conditions relating to all permits. Included in this set of conditions is the requirement to prepare an ecological management plan to remedy, mitigate and environmentally compensate or offset for all ecological effects of the project with the intent of achieving no net loss. The conditions required a number of subject or species specific ecological management plans to address specific impacts on bats, mudfish, lizards and a revegetation plan.

A wildlife permit was also obtained relating to the disturbance of long-tailed bats and lizards and their habitat. This permit contains a number of conditions in addition to designation and resource consent conditions, including monitoring, reporting and procedures associated with death of animals.

The project conditions are discussed further in section 12.6.

12.2.3 Hamilton section

The Hamilton section of the WEX comprises the 22 kilometres of expressway from Ngaruawahia in the north to Tamahere in the south.

A designation for the corridor for the WEX – Hamilton section was confirmed in 2005 and was included in the district plans of both Waikato District Council and Hamilton City Council. However, following an assessment of the design in 2013, a discrete set of alternations to the existing designations was required. The alterations were gained in 2014.

Statutory organisations involved in the hearing included: Waikato District Council, Hamilton City Council, Waikato Regional Council, and the Waikato River Authority. The environmental permits required for the roading project are summarised as follows:

- a NOR lodged by the Transport Agency for alterations to the expressway with the Waikato District Council
- a NOR lodged by the Transport Agency for alterations to the expressway with the Hamilton City Council
- an application for resource consents made by the Transport Agency to the Waikato Regional Council in respect of the expressway
- a NOR lodged by the Waikato District Council for the link road.

The regional council resource consents included land use consent for disturbance from earthworks and vegetation clearance; water permits for structures; discharge permits for stormwater discharge, and permits for groundwater take/drilling below water table.

A joint hearing was held and a decision made by independent commissioners. According to the hearing report:

> *…there was considerable disagreement between the Requiring Authorities/Applicants, the reporting officers and the Department of Conservation (DOC) regarding ecological matters…. [including] …*
>
> - *Effects on long-tailed bats (Chalinolobus tuberculatus)*
> - *Other effects on terrestrial ecology*

- *Effects on aquatic ecology* (Mitchell et al 2014b)

> *All the expert witnesses acknowledged that the South Hamilton bat population is relatively poorly understood, that predicting, with any certainty, how bats would be affected by the Expressway is extremely difficult, if not impossible, and that after mitigation measures are undertaken there may still be what the ecologists referred to as "residual effects" on bats (Mitchell et al 2014b)*

Specific areas of disagreement relating to long-tailed bats discussed during the hearing included:

- timing of tree felling protocol
- length of baseline studies
- nature of length of pre- and post-construction surveys
- physical boundary of the area covered by the BMP (ie road/designation footprint only vs wider)
- level of proof required for mitigation, eg efficacy of artificial roosts
- conditions (mitigation) outside the scope of the law, ie related to effects that were considered cumulative across projects covered by different consents, eg a regional bat enhancement plan.

Following consideration of the evidence the commissioners made the following conclusions, which are reflected in the final conditions:

- A tree felling protocol to protect long-tailed bats should be developed prior to removing vegetation during 'enabling works'.
- Baseline surveys for two years are sufficient, but the scope and extent of baseline and post-construction surveys should be as proposed by Dr Borkin on behalf of the Waikato Regional Council.
- The proposed BMP should be confined to an area 'within and near the road footprint', as proposed by the applicant, but be prepared in accordance with Dr Borkin's recommendations.
- As advised by DOC, monitoring techniques should not 'as a minimum' utilise 'acoustic surveys'.
- The baseline surveys should address 'distribution and behaviour'.
- There is no need for the degree of certainty regarding the efficacy of artificial bat roosts DOC has proposed.
- All bat-related monitoring and assessment is to be undertaken by appropriately qualified and experienced ecologists.
- Fifteen years post-construction monitoring will suffice, noting that additional monitoring can, if necessary, be addressed under the imposed review condition.

Project conditions are discussed further in section 12.6.

12.3 Hamilton southern links

Southern Links is a Transport Agency initiative in partnership with the Hamilton City Council which involves 21 kilometres of state highway, three new river crossings – including two over the Waikato River – and 11 kilometres of urban arterial network inside Hamilton's Peacocke growth area. The project will link SH1 from Greenwood Street in Hamilton City (to the west), to Tamahere and the Waikato Expressway (in the east) and SH3 from the intersection of SH3/SH21 (in the south). The Hamilton City Council urban arterial roads will establish the key transport network within the Peacocke area and become the basis for future urban development there. This process was to enable the planning of growth in the area. No plans to construct the project in next 10 years have been made.

The statutory process included:

- a NOR for the land (four where the Transport Agency was the requiring authority and one where Hamilton City Council was the requiring authority)
- resource consents for the new bridges.

The receiving councils were: Waipa and Waikato District Councils and Hamilton City Council for the roading network designations and Waikato Regional Council for the bridge consents. A joint hearing was held and a decision made by independent commissioners.

According to the hearings report of the hearings commissioners, dated 24 October 2014, a number of issues relating to long-tailed bats were discussed. These can be summarised as:

- whether significant background research had been undertaken to identify significant bat sites/more could be done to identify and protect bat roosts
- magnitude of impacts on long-tailed bats
- effectiveness of mitigation – effectiveness of artificial bat roosts, replacement of feeding habitat
- habitat restoration areas and the appropriate ratio and compensation multipliers
- advanced restoration
- extent of bat monitoring required and the importance of this
- role of pest control
- protection of bat species requires a 'whole of region approach'.

The hearings report stated:

> *While observations of long-tailed bats close to existing roads to the south of Hamilton suggest a degree of tolerance to disturbances associated with roads (light, noise and vehicle movements), the potential for significant adverse effects remains. With uncertainties concerning the nature and significance of effects of roads on bats, it follows that the methods of avoidance, remediation, mitigation and offset recommended carry with them significant uncertainty in terms of their necessity, suitability and likely effectiveness. (Mitchell et al 2014a)*

Notwithstanding the above excerpt from the hearing report, the commissioners found the ecological effects of the proposal could be appropriately managed by the imposition of conditions. These project conditions are summarised in section 12.6.

12.4 Puhoi to Warkworth

The Puhoi to Warkworth Roading Project comprises the construction, operation and maintenance of an 18.5 kilometre section of four-lane, dual carriageway motorway consisting of:

- seven major viaducts, including a viaduct across the Okahu Estuary (in the coastal marine area) and an 'ecoviaduct' over a stand of mature kauri to the west of Perry Road
- five bridges where the motorway crosses local roads and a floodway

- two major stream diversions along with the culverting of a number of streams
- extensive earthworks.

Detailed design was due to start in early 2016, with construction works also beginning in 2016.

Environmental permits required for this project included an alteration to designation and new requirement to designate the remainder of the route; 15 resource consents, including coastal permits, discharge permits, water permits and land use consents. The project was considered to be a project of national significance and so was processed by a board of inquiry.

No draft management plans were provided with the application based on detailed design being undertaken at a future date including specific methods for managing construction and operational effects. The Terrestrial Ecology Assessment Report submitted with the NOR/resource consent application recommended a BMP should be prepared prior to construction. However, the final conditions did not include the requirement for a BMP.

Key terrestrial vertebrate ecology impacts of the project discussed during the board of inquiry hearing included:

- habitat loss and direct mortality of bats as a result of vegetation clearance
- direct loss of indigenous forest vegetation and creation of edge effects due to vegetation loss
- direct loss or mortality of birds, lizards and snails during construction of the proposal
- effects of dust deposition on vegetation. (URS 2014, p6.11.1)

Witness conferencing, where expert witnesses have the opportunity to discuss evidence, occurred on a number of topics including terrestrial and freshwater ecology. Proposed conditions were progressively updated and refined as a result of expert conferencing and cross-examination. Following expert conferencing on terrestrial ecology, a number of meetings took place between the Transport Agency, the Director General of Conservation and Auckland Council resulting in an agreed set of conditions to address terrestrial ecology. They agreed with the conditions proposed during the board of inquiry hearing aimed at enhancing bat roosting and suggested one of the conditions be amended to require that the structures underneath viaducts include places for bats to roost, as they were considered by the assembled experts to be ideal for protecting bats from predators (Priestley et al 2014)

The resultant project conditions are discussed further in section 12.6.

12.5 Tukituki/Ruataniwha dam and irrigation proposal

The Ruataniwha project is located in Hawkes Bay and comprises a dam and irrigation system, including significant tracking and a linear canal system. It was approved in 2015 and construction has not yet begun.

The Hawke’s Bay Regional Council Investment Company Limited applied for 17 resource consents and a NOR for the construction of a water storage dam and associated structures in the upper reaches of the Tukituki River catchment, relating to the Ruataniwha Water Storage Scheme. Significant linear earthworks similar to that required for transportation projects were needed to construct the headrace canal and pipeline network. The matters applied for in the construction of the proposed dam and headrace canal distribution network included significant associated infrastructure, such as small quarries to supply raw material, a concrete batching plant, workshops, access roads and worker habitation.

At the same time as this project was proposed, the Hawke's Bay Regional Council proposed a plan change (PC6), which covered a suite of changes to rules for land and water management in the Tukituki River catchment.

Together these proposals were considered to be of national significance and were considered jointly by an independent board of inquiry (Chisholm et al 2014). The proposal was approved in 2015.

Key terrestrial vertebrate ecology impacts of the project discussed during the board of inquiry hearing included:

- permanent loss of a variety of indigenous vegetation communities and braided river within the reservoir, dam and spillway footprint area
- permanent loss of a variety of feeding, roosting and breeding habitats (both exotic and indigenous) for birds, lizards, bats and invertebrates
- alteration of habitats for indigenous flora and fauna within and adjacent to braided river ecosystems downstream of the dam and upstream water intake structure associated with changes in sediment deposition rates, river flow patterns and changes in land use
- disturbance of remaining indigenous flora and fauna adjacent to the reservoir due to potential increases in the recreational use of the reservoir and its margin.

Ecological evidence and resulting conditions around vertebrate mitigation and management included:

- protocols to minimise the impacts on bats, indigenous birds and lizards during vegetation removal or construction
- provision for capture and translocation of at risk and threatened fauna
- procedures for the identification, protection, management and replacement of bat roosts found during the pre-construction surveys, and how bat maternity roosts would be avoided
- the importance of monitoring and reporting of key indicator fauna including bats for 10 years following commencement of filling of the reservoir
- pest animal control as a mitigation method for terrestrial vertebrates.

It is not known whether a wildlife permit was obtained for these works.

Resultant project conditions are discussed further in section 12.6.

12.6 Comparison of conditions

All authorisations gained for the projects reviewed had conditions attached to them relating to the monitoring and management of long-tailed bats. This section discusses and compares the conditions placed on the reviewed projects.

Under the RMA, councils are allowed to include conditions on resource consents (section 108 of the RMA). The conditions may require the consent holder to make and record measurements; to take and supply samples; to carry out analyses, surveys, investigations, inspections or other specified tests, to provide information to the consent authority at a specified time and or a specified manner: The purpose of the conditions must be to achieve a resource management purpose and must be within a council's powers under the RMA. Section 171 of the RMA states that when making a recommendation on a NOR the territorial authority may recommend to the requiring authority that it impose conditions.

In the projects reviewed, during consideration of the applications, the type, content and nature of conditions and whether the imposition of the conditions could effectively mitigate the potential adverse effects on bats, was considered at length.

Types of conditions used to mitigate the impacts on bats in the projects generally fell under the following categories:

- development and implementation of a management plan or plans to manage mitigation and monitoring activities
- baseline monitoring including pre-construction surveying
- protection when felling trees and removing vegetation including the development of performance standards, eg tree felling protocols
- habitat enhancements through vegetation to improve habitat and maintain population linkages/reduce fragmentation of populations, prevent collisions
- habitat enhancements by providing artificial roosts
- habitat enhancement by controlling introduced mammalian predators
- managing impacts from light
- monitoring requirements.

These types of conditions are discussed below in relation to the projects reviewed. Tables containing the conditions are provided in appendix A. The effectiveness of these conditions as management controls is discussed in chapter 7.

12.6.1 Development and implementation of a management plan or plans to manage mitigation and monitoring activities (appendix A, table A.1)

All projects were required to prepare and submit for RMA approval either an ecological management plan or a BMP (except Puhoi – Warkworth), or both. The specific objectives of these plans are similar in their intent. Common expressions used in the conditions stating the objectives include ‘remedy, mitigate ecological effects’ with a number of the plan objectives, in more recent decisions, referring to achieving ‘no net loss’ of biodiversity (eg Hamilton Southern Links, Huntly section of WEX resource consents). The designation decision for the Huntly section of the WEX emphasises compensation and offsetting of the ecological effects.

Wildlife permits did not specify a requirement for BMPs. However, for both the Cambridge and Huntly projects BMPs were already required through RMA approvals.

12.6.2 Baseline monitoring (appendix A, table A.2)

Conditions (except Ruataniwha) require that baseline surveys (nocturnal) are undertaken to confirm occupancy (by bats) of areas affected by the projects. In some cases the months are specified (ie November to April) and in the case of the Hamilton section of the WEX, the condition specifies the temperature threshold. This condition also specifies the baseline survey is conducted for a minimum of two seasons and incorporates bat distribution and behaviour (as opposed to just occupancy). The Cambridge section WEX conditions also states the survey should include all potential roosting and foraging habitats.

Several of the permits have conditions which relate to ongoing monitoring of bat activity and behaviour.

12.6.3 Roost removal and disturbance (appendix A, table A.3)

A number of conditions relate to minimising disturbance of roosts during construction. Conditions require that measures be developed to avoid, minimise and monitor roost removal and habitat loss during construction by identifying and monitoring roost trees. Consequently these trees (if they are required to be removed) can be confirmed vacant prior to being felled to prevent injury or mortality. The conditions require the development of specific minimum standards (eg tree removal protocols) by an appropriately qualified ecologist (or words to that effect, often referring also to 'best practice'). The Huntly Wildlife Permit conditions associated with tree removals also specify requirements for tree felling records.

Effectiveness of the tree removal protocols is discussed in section 7.3.

12.6.4 Habitat enhancements through vegetation to improve habitat and maintain population linkages/reduce fragmentation of populations and prevent collisions (appendix A, table A.4)

All projects except the Ruataniwha dam and irrigation proposal included conditions requiring the BMP to include details of measures to minimise habitat fragmentation and alteration to bat movement. The conditions do not prescribe what the measures should be but use words such as 'details of habitat enhancement and replacement' (Cambridge, Huntly, and Hamilton section of WEX) or 'provision of replacement foraging habitat including planting' (Huntly section of WEX). The majority of the projects also had conditions which referred to habitat enhancement by creating bat crossing points across the project, eg hop overs, bridges tunnels. This is often accompanied by the phrase 'if such measures are deemed appropriate by a suitably qualified and experienced bat ecologist'.

The Hamilton Southern Links condition requires habitat restoration/offset mitigation for bat habitat, at a ratio of 1:1.

Planting of vegetation to mitigate habitat loss and planting of vegetation to provide traffic 'hopovers' is discussed in sections 7.4 and 7.5.

12.6.5 Habitat enhancements by providing artificial roosts (appendix A, table A.5)

All RMA approvals for the projects reviewed contained conditions requiring details of replacement/alternative roosting sites. Conditions mention planting trees (suitable indigenous or exotic and artificial roosts) and the use of artificial roosts.

The success of artificial roost boxes as a management control is discussed in section 7.6.

12.6.6 Habitat enhancement by controlling introduced mammalian predators (appendix A, table A.6)

Of the projects reviewed the following had conditions relating to predator control: WEX – Huntly section, Hamilton Southern Links, and for species other than bats, Puhoi to Warkworth. Predator control for these projects was considered to mitigate impacts on a number of species, not just bats.

The success of predator control as a management technique is discussed in section 7.2.

12.6.7 Managing impacts from light (appendix A, table A.5)

In order to mitigate the effects that infrastructure lighting could have in forming a barrier to the use of habitat (refer to section 7.7), many of the conditions dealing with habitat enhancements (such as hopovers), also refer to providing dark zones, reducing 'spill' and justifying the choice of lights. These are given as examples of how the BMP should provide 'details of measures to minimise habitat fragmentation and other barriers'.

12.6.8 Monitoring (appendix A, table A.7)

All projects reviewed, except Puhoi to Warkworth, required the BMP or equivalent to include details of monitoring and reporting of bat activity to identify and assess changes in bat activity and behavioural patterns. These monitoring conditions generally require monitoring during construction, post construction/during operation as well as baseline monitoring. The exception is Puhoi to Warkworth, which only requires pre-construction monitoring, and Ruataniwha, which only requires monitoring upon commencement of reservoir filling.

In addition, monitoring to assess mitigation options was included in a number of the conditions, for example 'details of monitoring measures required to ensure the mitigation, restoration and environmental compensation or offset measures are met' (WEX – Huntly) and 'assess and report on the effectiveness of measures to avoid, remedy and mitigate effects' (WEX – Hamilton).

The Hamilton Southern Links conditions very specifically require monitoring of the effectiveness of mitigation:

> *The specific priority objectives of monitoring shall include:*
>
> *i) Determining the effects of lighting and roads on the movement of bats and what other key potential barriers (e.g. bridges, embankments) are to movement; i*
>
> *ii) Monitoring to gauge the effectiveness of the Animal Pest Control required by condition 17.3(c) (iv); and iii)*
>
> *iii) Identification, protection and ongoing monitoring of key habitats (e.g. maternal roosting sites and foraging sites)".*

However, most of the conditions refer to more general monitoring 'to identify and assess changes in bat activity and behavioural patterns that may occur'. A number of the conditions also specified the length for which the monitoring should be carried out and range from five to 15 years post-construction.

The success of monitoring management actions is discussed in section 5.

12.7 Summary

Overall, in the projects reviewed there was little or no contention of the projects meeting the requirements of national, regional or local planning documents. Conclusions made by the hearings commissioners generally concluded the projects would not compromise these documents provided appropriate conditions were imposed to avoid, remedy or mitigate.

For all the projects reviewed, considerable deliberation was undertaken on ecological evidence and whether the potential impacts on ecological diversity would be mitigated or in some cases offset. The results of this deliberation are expressed in the conditions associated with the project approvals.

Based on the lengthy examination of ecological information during the approvals process for the reviewed projects, a vertebrate/bat management framework including standard conditions for designations, consents and wildlife permits, endorsed by the ecological community, would likely help streamline future approvals processes for similar projects.

Key points identified during the comparison of conditions were:

- The level of baseline surveying required has not been consistently addressed by the conditions, ie what is the level of proof that bats are there or not and when is the best time (in the context of project development) to undertake this baseline surveying.
- Conditions are written in a way that recognises the lack of data on the effectiveness of mitigation methods and gives the consent holder flexibility in deciding which methods to use as guided by appropriately qualified professionals.
- Variation exists between conditions in monitoring requirements, including timing of monitoring (before, during, after), along with the length of monitoring.
- A BMP is required for all projects other than Puhoi-Warkworth.
- Predator control has been applied as a condition for only a few projects.
- While there were some differences in the conditions there are many similarities. A set of model consent conditions for managing indigenous bat/vertebrate impacts, with sufficient flexibility to reflect location and unique project characteristics, would be useful in addressing many of the issues raised. Having a comprehensive and tested starting point for conditions, endorsed by DOC and local authorities, could help to streamline the approvals process.

13 Conclusions

In New Zealand, regulatory approvals of land transport projects and their associated environmental impact assessments are largely approved at the local government level. Even when decisions are made at the national level, regional and local planning instruments play an important role in decisions on whether to approve projects and the level of environmental mitigation required. This leads to both regulators and land transport operators assessing and managing impacts on a case by case basis resulting in a range of outcomes and costs.

Consequently, the Transport Agency has identified a need to develop a nationally accepted framework for studying and developing management strategies for reducing or mitigating the impact of road construction on endemic vertebrates, in particular bats.

This statutory and project review has identified a number of matters that should be considered during the development of a nationally accepted vertebrate/bat management framework, including:

- Level of knowledge/proof required to determine whether the actual and potentially adverse effects of proposals are avoided, remedied or mitigated and to what level. Inherent in this assessment is the need to have sufficient knowledge and information about the effect being considered.
- Need to provide consistency, while still allowing for the potential for variable interpretation and implementation of how local authorities meet the requirement to maintain ‘significant biological diversity’.
- Increasing emphasis from councils on no net loss of biodiversity and what this means in the context of impacts on vertebrate/bat species.
- Role of offsetting as an effective management control.
- Role of the Wildlife Act permit requirements, with the aim of clarifying when they are required for potential accidental loss (ie what is the threshold), what the information requirements are and a process to ensure DOC’s conditions are aligned with designation/resource consent conditions.
- Methodology to establish whether bats or other vertebrates are present in a project area and when is the best time (in the context of project development) to undertake this surveying. Projects to date have relied on a combination of anecdotal evidence, past investigations, and field work. Pre-lodgement discussions and agreements with regulatory bodies as to the need, or otherwise, for such assessments are accepted practice; however, it would be advantageous for a more robust and reliable set of ‘presence’ parameters to be established.
- Comprehensive guidance on monitoring recommendations for vertebrates/bats affected by land transport projects – before, during and after.
- Identify methods for the impacts of land transport projects on indigenous bats/vertebrates to be assessed and managed at a regional/national level. Consent conditions in project approvals are limited by their ability to manage at a local project level only.
- Provide guidance on consent conditions. The framework should develop a set of model consent conditions for managing indigenous bat impacts. A comprehensive and tested starting point for conditions could help streamline the approvals process. Conditions should be developed in conjunction with DOC and local authorities. Conditions for designations consents and wildlife permits should reflect the regulatory role of the consent/permit granting authority, and avoid duplication.

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Appendix A: Condition summary tables

Table A.1 Management plan objectives

Project	Project type	Consent/permit type	Year of approval	Management plan title	Condition
WEX Cambridge	Roading – expressway	Designation and resource consents	2011	Ecological Management and Restoration Plan (incorporating Bat Management Plan (BMP))	Provide for the management of long-tailed bats, black mudfish, and the ecological enhancement of instream and riparian habitats associated with the project.
WEX Tamahere	Roading – expressway	Designation and resource consents	2011	BMP	N/A
WEX Cambridge	Roading – expressway	Wildlife permit	2013	No plan requirement	N/A
WEX Huntly	Roading – expressway	Resource consents	2014	Ecological Management Plan with BMP as sub-plan	Remedy, mitigate and environmentally compensate or offset for all ecological effects of the project with the intent of achieving no net loss. The objectives are among other matters to: Minimise wildlife disturbance and stormwater contamination arising from construction and operation of the expressway; provide for the restoration, revegetation, enhancement and/or protection of indigenous forest, wetlands and stream habitat to remedy, mitigate or environmentally compensate or offset for the habitat removed or adversely affected within the designation corridor or otherwise resulting from the project.
WEX Huntly	Roading – expressway	Designations	2013	Landscape, Visual and Ecological Management Plan	Prior to the commencement of construction, the requiring authority shall prepare a landscape, visual and ecological management plan consisting of the following two parts to meet the landscape, visual and ecological objectives below: b) Ecological mitigation measures to be implemented to remedy, mitigate and environmentally compensate or offset the ecological effects of the project (6.1). Landscape, Visual and Ecological Management Plan objectives: … d) To provide for the restoration, revegetation, enhancement and/or protection of forest, wetland and stream habitat to remedy, mitigate and environmentally compensate or offset for the habitat removed or adversely affected within the designation corridor.
WEX Huntly	Roading – expressway	Wildlife permit	2015	No plan requirement	N/A

Project	Project type	Consent/permit type	Year of approval	Management plan title	Condition
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	2015	Reservoir Filling and Edge Rehabilitation Plan	To manage clearance of vegetation within the reservoir footprint to minimise adverse effects on indigenous fauna, particularly bats, and to provide an opportunity for mana whenua to access suitable indigenous timber for traditional cultural uses.
WEX Hamilton section	Roading – expressway	Designation and resource consents	30 June 2014	Ecological Management and Restoration Plan including BMP	Avoid, remedy, or mitigate adverse ecological effects associated with the project on terrestrial, wetland and perennial stream habitats and nationally 'threatened' or 'at risk' species associated with these habitat types, including long-tailed bats, black mudfish, other indigenous fish, other indigenous lizards, little shag and any rare or uncommon plants (Resource consent 48). BMP shall address mitigation to be undertaken within, and near, the road footprint to avoid, remedy or mitigate any adverse effects from the construction and operation of the road on long-tailed bats (Resource consent 48d).
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	No plan requirement	N/A
Hamilton southern links	Roading	Designation and resource consents	2014	Ecological Management and Monitoring Plan	Objectives of the Ecological Management and Monitoring Plan shall be to demonstrate how the NZ Transport Agency intends to achieve no net loss of terrestrial, wetland and stream biodiversity values. It shall provide details on how monitoring, management and mitigation of the significant adverse effects of construction activities and project operation is to be undertaken, including but not limited to effects on long-tailed bats, with the aim of enhancing long-tailed bat habitat.

Table A.2 Baseline/pre- construction survey conditions

Project	Project type	Consent/permit type	Year	Approval body	Condition
WEX Cambridge	Roading – expressway	Designation and resource consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	Details of a comprehensive nocturnal surveys/long-tailed bat monitoring programme to confirm occupancy at both the Karapiro Gully and other potential (including non-indigenous) habitats along the expressway route. Monitoring shall be carried out over the breeding season and peak activity period (beginning of November to the end of April) and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats.

Project	Project type	Consent/permit type	Year	Approval body	Condition
WEX Cambridge	Roading – expressway	Wildlife permit	2013	DOC approval	Prior to and during any habitat clearance or construction works which may cause the incidental loss of absolutely protected wildlife all agreed measures to remove or minimise impacts to absolutely protected wildlife must be completed in accordance with the approved tree removal protocols for bat protection (version 4.1), contained within the draft HEB Waikato Expressway: Tamahere – Cambridge Section BMP (stage one: enabling works), the lizard survey, capture and transfer wildlife permit (36943-FAU), and any subsequent wildlife management plans developed and agreed to by the Waikato Regional Council in consultation with DOC .
WEX Huntly	Roading – expressway	Resource consents	2014	Waikato Regional Council	Details of a comprehensive nocturnal survey/long-tailed bat monitoring programme to confirm occupancy at potential (including non-indigenous) habitats along the expressway route. Monitoring shall be carried out between the beginning of November and the end of April and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats.
WEX Huntly	Roading – expressway	Designations	2013	Waikato District Council	Details of a comprehensive nocturnal surveys/long-tailed bat monitoring programme to confirm occupancy at potential (including non-indigenous) habitats along the expressway route. Monitoring shall be carried out over the breeding season and peak activity period (beginning of November to the end of April) and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats
WEX Huntly	Roading – expressway	Wildlife permit	2015	DOC approval	N/A
Ruataniwha	Water storage & irrigation scheme	Designation and resource consents	2015	Hawke's Bay Regional Council, Central Hawke's Bay District Council, Hastings District Council	N/A
WEX Hamilton section	Roading – expressway	Designation and resource consents	30 June 2014	Waikato Regional Council, Waikato District Council, Hamilton City Council	Pre-construction baseline distribution surveys shall include surveys using appropriate techniques to assess bat distribution and behaviour within areas of potential bat habitat along the entire Hamilton Section of the Waikato Expressway alignment. A minimum of two surveys shall be undertaken during the months of November to April inclusive for a minimum of two monitoring seasons, immediately prior to construction commencing. Monitoring for the surveys should take place on nights when the temperature remains above 10 degrees for the first two hours after sunset and little precipitation occurs.

Project	Project type	Consent/permit type	Year	Approval body	Condition
					Temperature and precipitation must be recorded.
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	Auckland Council	The requiring authority shall engage a suitably qualified expert to conduct bat habitat identification and surveys within the designation between New Zealand Transverse Mercator coordinates (1747939, 5960828) and (1746707, 5965552) in the summer months immediately before construction in that area of the project.
Hamilton Southern Links	Roading	Designation and resource consents	2014	Waikato District Council, Waikato Regional Council, Waipa District Council and Hamilton City Council	Details of ongoing monitoring and reporting of bat activity, including the establishment of adequate baseline survey. Monitoring shall be carried out over the long-tailed bat breeding season and peak activity period (beginning of November to the end of April), first commencing two years prior to construction works starting, and continuing during construction and five years post construction for the first stage of the project, and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats as well as suitable control sites. The timeframes for the monitoring in accordance with this condition shall only be triggered with respect to the first stage of construction works for any part of the project. The pre-construction monitoring can be carried out without a certified Ecological Management and Monitoring Plan being in place.

Table A3 **Roost removal and disturbance.**

Project	Project type	Consent type	Year of approval	Condition			
				Roost removal	Specific tree felling protocol condition?	Construction disturbance of roosts	Minimising disturbance to roosts
WEX Cambridge	Roading – expressway	Designation and resource consents	2011	Minimum standards for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations.	No	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered until such roosts are confirmed to be vacant of bats, as determined by a recognised bat ecologist using current best practice.	Specific minimum standards as determined by a recognised bat ecologist for minimising disturbance associated with construction activities around active roosts within the footprint of the project or its vicinity that do not require removal.

Project	Project type	Consent type	Year of approval	Condition			
				Roost removal	**Specific tree felling protocol condition?**	**Construction disturbance of roosts**	**Minimising disturbance to roosts**
WEX Tamahere	Roading – expressway	Designation and resource consents	2011	Minimum standards for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations).	No	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered until such roosts are confirmed to be vacant of bats, as determined by a recognised bat ecologist using current best practice.	Specific minimum standards as determined by a recognised bat ecologist for minimising disturbance associated with construction activities around active roosts within the footprint of the project or its vicinity that do not require removal.
WEX Cambridge	Roading – expressway	Wildlife permit	2013	Prior to and during any habitat clearance or construction works which may cause the incidental loss of absolutely protected wildlife, all agreed measures to remove or minimise impacts to absolutely protected wildlife must be completed in accordance with the approved tree removal protocols for bat protection (version 4.1), contained within [BMP]. below and any subsequent wildlife management plans developed and agreed to by the Waikato Regional Council in consultation with DOC	Yes. Condition refers to already prepared protocol. Must also provide results of bat monitoring and pre felling checks to DOC within 24 hours after the end of pre-felling surveys . Hold a complete electronic record of all trees felled with information including species of tree, DBH (diameter at basal height) and GPS positions and provide to DOC upon completion of felling. Appropriately qualified and experienced ecologist shall undertake all measurements of tree DBH, and the ecologist shall also clearly	N/A	N/A

Project	**Project type**	**Consent type**	**Year of approval**	**Condition**			
				Roost removal	**Specific tree felling protocol condition?**	**Construction disturbance of roosts**	**Minimising disturbance to roosts**
					label each tree as high risk or low risk through agreed robust methodology.		
WEX Huntly	Roading – expressway	Resource consents	2014	Details of measures to avoid, minimise, and monitor tree and other vegetation removal and potential roost and other habitat loss including an agreed vegetation removal protocol detailing specific minimum standards for roost tree identification and monitoring prior to tree and vegetation removal. This protocol must be approved by Waikato Regional Council in a technical capacity prior to any works taking place that involve the removal of vegetation.	No	N/A	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered until such roosts are confirmed to be vacant of bats, as determined by a suitably experienced and qualified bat ecologist using current best practice.
WEX Huntly	Roading – expressway	Designations	2013	Details of measures to avoid, minimise and monitor roost removal and habitat loss (including specific minimum standards determined by a recognised bat ecologist for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree	No	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered until such roosts are confirmed to be vacant of bats, as determined by a recognised bat ecologist using current best practice.	Specific minimum standards as determined by a recognised bat ecologist for minimising disturbance from construction activities around active roosts within the footprint of the project or its vicinity that require removal.

Project	Project type	Consent type	Year of approval	Condition			
				Roost removal	**Specific tree felling protocol condition?**	**Construction disturbance of roosts**	**Minimising disturbance to roosts**
				occupancy in some situations), as well as habitat replacement and enhancement.			
WEX Huntly	Roading – expressway	Wildlife permit	2015	No tree may be felled if bats are detected on the last two out of three valid monitoring nights immediately prior to the planned felling of the tree, in accordance with the tree felling protocol. If the authority holder cannot comply with the tree felling protocol or conditions in this authority, then the authority holder shall obtain a management plan approved by the grantor for the felling of the tree.	The authority holder shall ensure that all tree felling is carried out in accordance with the BMP part 1 – tree removal protocol, revision 3, dated 16 September 2015.		
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	2015	Procedures for the identification, protection, management and replacement of bat roosts found during the pre-construction surveys, and requiring avoidance of disturbance of all bat maternity roosts while they are in use.	No	N/A	N/A

Project	**Project type**	**Consent type**	**Year of approval**	**Condition**			
				Roost removal	**Specific tree felling protocol condition?**	**Construction disturbance of roosts**	**Minimising disturbance to roosts**
WEX Hamilton section	Roading – expressway	Designation and resource consents	30 June 2014	Details of measures to avoid, minimise and monitor roost removal and habitat loss (including specific minimum standards developed by an appropriately qualified and experienced bat ecologist for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations), as well as habitat replacement and enhancement.	Details of…. specific minimum standards developed by an appropriately qualified and experienced bat ecologist for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations.	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered, or already known, until such roosts are confirmed to be vacant of bats, as determined by an appropriately qualified and experienced bat ecologist using current best practice.	N/A
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	N/A	No	Upon identification of any roosting sites, the requiring authority shall ensure clearance of these sites shall only occur from 14 February to 1 May . On the night prior to clearance of any potential roosting sites, a suitably qualified ecologist shall survey the relevant area for any active roosting sites. The requiring authority shall leave standing any tree identified as an active roosting site, until the	N/A

Project	Project type	Consent type	Year of approval	Condition			
				Roost removal	Specific tree felling protocol condition?	Construction disturbance of roosts	Minimising disturbance to roosts
						roosting site is confirmed to be vacant by the suitably qualified expert.	
Hamilton Southern Links	Roading	Designation and resource consents	2014	The EMMP provisions for long-tailed bat management shall include, but not be limited to, the following: a) details of measures to avoid, minimise and monitor roost removal and habitat loss (including specific minimum standards determined by a recognised bat ecologist for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations), as well as habitat replacement and enhancement.	Specific minimum standards as determined by a suitably qualified bat ecologist for minimising disturbance associated with construction activities around active roosts within the footprint of the project or its vicinity that do not require removal. This includes the preparation of a pre-tree-felling protocol following consultation with DOC. The purpose of the pre-tree felling protocol shall be to avoid the injury or mortality of roosting long-tailed bats.	Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are discovered until such roosts are confirmed to be vacant of bats, as determined by a recognised bat ecologist using current best practice.	N/A

Table A.4 **Habitat enhancements – vegetation**

Project	Project type	Consent type	Year of approval	Statutory bodies	Conditions	
					Mitigating reduced bat movement/ habitat fragmentation	**Mitigation measures (general) or habitat enhancement**
WEX Cambridge	Roading – expressway	Designation and resource consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as a bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road).	Details of measures to avoid, minimise and monitor roost removal and habitat loss as well as habitat replacement and enhancement.
WEX Tamahere	Roading – expressway	Designation and resource consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as a bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road).	Details of measures to avoid, minimise and monitor roost removal and habitat loss as well as habitat replacement and enhancement.
WEX Cambridge	Roading – expressway	Wildlife permit	2013	DOC approval	N/A	N/A
WEX Huntly	Roading – expressway	Resource consents	2014	Waikato Regional Council	Details of measures to minimise habitat fragmentation and alteration to bat movement including creating possible bat crossing points such as bridge/tunnels/ culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or	Details of provision of replacement foraging habitat including planting that is specifically designed to link potential roosting and foraging habitat.

Project	Project type	Consent type	Year of approval	Statutory bodies	Conditions	
					Mitigating reduced bat movement/ habitat fragmentation	Mitigation measures (general) or habitat enhancement
					installing baffles on lighting columns to reduce the 'spill' of light away from the road; and justifying the type of lights that will be used to minimise disturbance of bats' if such measures are deemed appropriate by a suitably qualified and experienced bat ecologist.	
WEX Huntly	Roading – expressway	Designations	2013	Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road).	Methods to mitigate or environmentally compensate or offset for adverse effects that cannot be avoided or remedied. In recognition that surveying and monitoring may not have been completed prior to commencement of works, a range of scenarios is to be presented that identifies what mitigation and/or environmental compensation or offsetting shall apply for each potential scenario. DOC shall be consulted at least three months prior to submission
WEX Huntly	Roading – expressway	Wildlife permit	2015	DOC	N/A	N/A
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	2015	Hawkes Bay Regional Council, Central Hawkes Bay District Council, Hastings district council	N/A	Plan to include protocols to minimise the impacts on bats, indigenous birds and lizards during vegetation removal or construction.
WEX Hamilton Section	Roading – expressway	Designation and resource consents	30 June 2014	Waikato Regional Council, Waikato District Council, Hamilton City Council	Details of measures to minimise habitat fragmentation and other barriers to bat movement. Possible mitigation methods include the creation of bat crossing points	Details of habitat replacement and enhancement.

Project	**Project type**	**Consent type**	**Year of approval**	**Statutory bodies**	**Conditions**	
					Mitigating reduced bat movement/ habitat fragmentation	**Mitigation measures (general) or habitat enhancement**
					such as 'hop-overs' for bats to be formed with planting and/or earthworks, installation of bridge/tunnels/culverts, reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in particular ways or the installation of baffles on lighting columns to reduce the 'spill' of light away from the road, accepting that lighting design for the benefit of bat movement must not conflict with the primary function of lighting for safety reasons along the expressway.	
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	Auckland Council	The requiring authority shall, where practicable, enhance bat habitat by retaining large edge pine trees and enhance roosting and foraging opportunities in the long-term, including the provision of artificial bat habitat (ie bat roost boxes) in vegetation to be retained or under viaducts or bridges, as recommended by a suitably qualified ecologist .	The requiring authority shall, where practicable, enhance bat habitat by retaining large edge pine trees and enhance roosting and foraging opportunities in the long-term, including the provision of artificial bat habitat (ie bat roost boxes) in vegetation to be retained or under viaducts or bridges, as recommended by a suitably qualified ecologist .
Hamilton Southern Links	Roading	Designation and resource consents	2014	Waikato District Council, Waikato Regional Council, Waipa District Council and Hamilton City Council	Habitat restoration/offset mitigation on the following basis: i) A minimum 1:1 restoration ratio for areas of gully, bat habitat and river margin affected by the designation (including habitat dominated by exotic vegetation). ii) a minimum 3:1 restoration ratio for significant indigenous habitats (including indigenous forests, wetlands, seeps and springs) affected by the	The EMMP shall set out the methodologies and processes that will be used to achieve these objectives and shall include, but will not be limited to: a) ecological management; i) vegetation and habitat management; ii) management of effects on long-tailed bats, avifauna, and lizards.

Project	Project type	Consent type	Year of approval	Statutory bodies	Conditions	
					Mitigating reduced bat movement/ habitat fragmentation	Mitigation measures (general) or habitat enhancement
					designation. The total area to be restored based on the ratio in i) and ii) above shall be a minimum of 2.19 hectares. iii) gully habitat restoration proposed by the EMMP shall generally align with Wall and Clarkson (2006) *Gully restoration guide: a guide to assist in the ecological restoration of Hamilton's gully system*. 3rd revised edition. Hamilton City Council (or an updated version).	

Table A.5 Habitat enhancements – artificial roosts

Project	Project type	Consent type	Year of approval	Statutory bodies	Condition	
					Bat movement/habitat fragmentation	Alternative roost provision
WEX Cambridge	Roading-Expressway	Designation and Resource Consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as a bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road).	Details of the provision of alternative roosting sites (including suitable indigenous or exotic trees for roost habitat and artificial bat houses), with artificial roosts installed as far in advance of construction as possible where bat roosts have been shown to have a reasonable likelihood of occurring along the alignment.
WEX Tamahere	Roading – expressway	Designation and resource consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as a bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark	Details of the provision of alternative roosting sites (including suitable indigenous or exotic trees for roost habitat and artificial bat houses), with artificial roosts installed as far in advance

Project	Project type	Consent type	Year of approval	Statutory bodies	Condition	
					Bat movement/habitat fragmentation	Alternative roost provision
					zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road).	of construction as possible where bat roosts have been shown to have a reasonable likelihood of occurring along the alignment.
WEX Cambridge	Roading – expressway	Wildlife permit	2013	DOC approval	N/A	N/A
WEX Huntly	Roading – expressway	Resource consents	2014	Waikato Regional Council	Details of measures to minimise habitat fragmentation and alteration to bat movement including creating possible bat crossing points such as bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road; and justifying the type of lights that will be used to minimise disturbance of bats' if such measures are deemed appropriate by a suitably qualified and experienced bat ecologist.	Details of the provision of replacement roosting sites in both the short-term and the long term (including suitable indigenous or exotic trees that are to be planted for roost habitat, and the specific design or artificial bat houses to be installed at least six months in advance or vegetation removal .
WEX Huntly	Roading – expressway	Designations	2013	Waikato District Council	Details of measures to minimise habitat fragmentation and alteration to bat movement (eg creating possible bat crossing points such as bridge/tunnels/culverts; reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in certain ways or installing baffles on lighting columns to reduce the 'spill' of light away from the road)	Details of the provision of replacement roosting sites (including suitable indigenous or exotic trees for roost habitat and artificial bat houses), with artificial roosts, if shown to be a working option, installed as far in advance of construction as possible where bat roosts have been shown to have a reasonable likelihood of occurring along the alignment.
WEX Huntly	Roading – expressway	Wildlife permit	2015	DOC	N/A	N/A

Project	**Project type**	**Consent type**	**Year of approval**	**Statutory bodies**	**Condition**	
					Bat movement/habitat fragmentation	**Alternative roost provision**
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	2015	Hawkes Bay Regional Council, Central Hawkes Bay District Council, Hastings district council	N/A	N/A
WEX Hamilton section	Roading – expressway	Designation and resource consents	30 June 2014	Waikato Regional Council, Waikato District Council, Hamilton City Council	Details of measures to minimise habitat fragmentation and other barriers to bat movement. Possible mitigation methods include the creation of bat crossing points such as 'hop-overs' for bats to be formed with planting and/or earthworks, installation of bridge/tunnels/culverts, reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in particular ways or the installation of baffles on lighting columns to reduce the 'spill' of light away from the road, accepting that lighting design for the benefit of bat movement must not conflict with the primary function of lighting for safety reasons along the expressway.	Details of the provision of alternative roosting sites (including where possible advanced planting of indigenous or exotic trees for roost habitat) and artificial bat roosts, that are considered suitable for that purpose by an appropriately qualified and experienced bat ecologist, installed at least six months prior to the removal of trees where bat roosts are likely to occur along the alignment.
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	Auckland Council	The requiring authority shall, where practicable, enhance bat habitat by retaining large edge pine trees and enhance roosting and foraging opportunities in the long-term, including the provision of artificial bat habitat (i.e. bat roost boxes) in vegetation to be retained or under viaducts or bridges, as recommended by a suitably qualified ecologist.	Yes

Project	**Project type**	**Consent type**	**Year of approval**	**Statutory bodies**	**Condition**	
					Bat movement/habitat fragmentation	**Alternative roost provision**
Hamilton Southern Links	Roading	Designation and resource consents	2014	Waikato District Council, Waikato Regional Council, Waipa District Council and Hamilton City Council	Habitat restoration/offset mitigation on the following basis: i) a minimum 1:1 restoration ratio for areas of gully, bat habitat and river margin affected by the designation (including habitat dominated by exotic vegetation). ii) a minimum 3:1 restoration ratio for significant indigenous habitats (including indigenous forests, wetlands, seeps and springs) affected by the designation. The total area to be restored based on the ratio in i) and ii) above shall be a minimum of 2.19 hectares. iii) gully habitat restoration proposed by the EMMP shall generally align with Wall and Clarkson (2006) *Gully restoration guide: a guide to assist in the ecological restoration of Hamilton's gully system*. 3rd revised edition. Hamilton City Council (or an updated version).	Details of the provision of alternative roosting sites (including suitable indigenous or exotic trees for roost habitat, their ongoing management to enhance their roosting potential (for example, encouraging cavity formation or providing artificial bat houses), with artificial roosts installed as far in advance of construction as possible.

Table A.6 Habitat enhancements – predator control

Project	Project type	Consent type	Year of approval	Statutory bodies	Condition
WEX Cambridge	Roading – expressway	Designation and resource consents	2011	Waikato Regional Council, Waipa District Council, Waikato District Council	N/A
WEX Cambridge	Roading – expressway	Wildlife permit	2013	DOC approval	N/A
WEX Huntly	Roading – expressway	Resource consents	2014	Waikato Regional Council	Details of extent of planned predator control that targets rats and possums (28e (vi)))) [of the consent document].
WEX Huntly	Roading – expressway	Designations	2013	Waikato District Council	Details of mammalian predator control and restoration and enhancement package is detailed in 6.6 (a) through (c).
WEX Huntly	Roading – expressway	Wildlife permit	2015	DOC	N/A
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	2015	Hawke's Bay Regional Council, Central Hawkes Bay District Council, Hastings district council	N/A
WEX Hamilton section	Roading – expressway	Designation and resource consents	30 June 2014	Waikato Regional Council, Waikato District Council, Hamilton City Council	N/A

Project	Project type	Consent type	Year of approval	Statutory bodies	Condition
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	2014	Auckland Council	Any land snails (*Amborhytida dunniae*), copper skinks, forest geckos, or Hochstetter's frogs (*Leiopelma* aff. *hochstetteri*) found during the checks required by condition D47 shall be captured and relocated to a site: a) that has been subject to predator control measures for at least six (6) months prior to the first transfer and will receive ongoing predator control for three years after the last transfer b) deemed appropriate by a suitably qualified ecologist (ie in fauna relocation) c) approved by the manager. Unless deemed unnecessary by a suitably qualified ecologist, any fernbird found during the pre-construction check required by condition D49 shall be captured and transferred to a site: a) that has been subject to predator control measures for at least six (6) months prior to the first transfer and will receive ongoing predator control for three years after the last transfer b) deemed appropriate by a suitably qualified ecologist (ie in fauna relocation) c) approved by the manager.
Hamilton Southern Links	Roading	Designation and resource consents	2014	Waikato District Council, Waikato Regional Council, Waipa District Council and Hamilton City Council	Pest animal control, undertaken for a period of 20 years, at known significant roost sites (significant roost sites being maternity roost sites or others roost sites used by multiple bats on a regular basis). Any measures implemented must be determined by a pest animal control specialist as having a reasonable prospect of being effective. The duration or nature of pest animal control in accordance with this condition can be altered should monitoring of the pest animal control demonstrate that it is ineffective, or to allow alternative pest animal control approaches to be trialled. Any alteration to the duration or nature of pest animal control shall necessitate a review of the EMMP in accordance with condition 17.7.

Table A.7 Monitoring

Project	Project type	Consent type	Conditions		
			Monitoring and reporting of bat activity including baseline and post- construction (scope and length)	**Post- construction specific**	**Specific requirement to monitor the effectiveness of mitigation measures**
WEX Cambridge	Roading – expressway	Designation and resource consents	Details of ongoing monitoring and reporting of bat activity, including the establishment of adequate baseline survey and post-construction monitoring to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Cambridge section of the Waikato Expressway at all locations where bats are detected.	N/A	Monitoring of behavioural pattern changes.
WEX Tamahere	Roading – expressway	Designation and resource consent	Details of ongoing monitoring and reporting of bat activity, including the establishment of adequate baseline survey and post construction monitoring to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Cambridge section of the Waikato Expressway at all locations where bats are detected.	N/A	Monitoring of behavioural pattern changes
WEX Cambridge	Roading – expressway	Resource consents	Details of ongoing monitoring and reporting of bat activity, including the establishment of adequate baseline survey and post construction monitoring to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Cambridge section of the Waikato Expressway at all locations where bats are detected.	N/A	Monitoring of behavioural pattern changes
WEX Huntly	Roading – expressway	Designations	Details of baseline monitoring and monitoring during and after construction and reporting of bat activity to be able to identify changes and	Baseline monitoring shall include annual monitoring prior to construction – annual monitoring	Monitoring of behavioural pattern changes

Project	Project type	Consent type	Conditions		
			Monitoring and reporting of bat activity including baseline and post- construction (scope and length)	**Post- construction specific**	**Specific requirement to monitor the effectiveness of mitigation measures**
			assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Huntly section of the Waikato Expressway.	during construction – annual monitoring for 15 years from beginning of operation – monitoring shall be undertaken between months of November and April.	
WEX Huntly	Roading – expressway	Designation and resource consents	Details of baseline monitoring and monitoring during and after construction and reporting of bat activity to be able to identify changes and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Huntly section of the Waikato Expressway at all locations where bats are detected.	Details of monitoring measures required to ensure the mitigation, restoration and environmental compensation or offset measures are met, including but not limited to: ii) any monitoring requirements identified in the BMP (6.6(e).	Monitoring of behavioural pattern changes
WEX Huntly	Roading – expressway	Wildlife permit	The authority holder shall within one week of completing construction of the Huntly Bypass project, obtain an approved 'post construction long-tailed bat monitoring plan' from the Grantor. The plan shall include, but not be limited to: • practices such as banding or transmitters for monitoring survival of bats • timeframes for monitoring • extent and location of monitoring stations • contingencies.		
Ruataniwha	Water storage and irrigation scheme	Designation and resource consents	Annual monitoring reports regarding key indicator indigenous fauna and flora species (including bats) and their habitats for every year for the first 10 years following the commencement of the first filling of the reservoir as set in the schedule ten.	N/A	N/A

Project	Project type	Consent type	Conditions		
			Monitoring and reporting of bat activity including baseline and post- construction (scope and length)	**Post- construction specific**	**Specific requirement to monitor the effectiveness of mitigation measures**
WEX Hamilton section	Roading – expressway	Designation and resource consents	Details of a monitoring programme to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Hamilton Section of the Waikato Expressway at all locations where bats are detected during comprehensive pre-construction baseline distribution surveys required by section 48(f)(vii) [of the consent document]. The monitoring programme should be sufficiently robust to inform the mitigation design and subsequent assessment of the effectiveness of mitigation	Assess and report on the effectiveness of measures to avoid, remedy and mitigate effects. Such monitoring shall occur annually during the months of November to April inclusive, as a minimum, and the monitoring data shall initially be assessed and reported on annually for the first five years from the commencement of works authorised by this resource consent, and thereafter at five-yearly intervals for a period of 15 years from the commencement of works authorised by this consent.	Where measures are found to be ineffective, the ecologist(s) shall make recommendations for additional measures to avoid, remedy and mitigate effects resulting from the establishment of the Hamilton section of the Waikato Expressway. Reports shall be provided to Waikato Regional Council and DOC within two months of the completion of each assessment, and the matters contained within these reports shall be considered in accordance with the procedures for review of the EMRP required by condition 48e.(48(f)(vii)) [of the consent document].
Puhoi to Wellsford	Roading – motorway	Designation and resource consents	N/A	N/A	N/A
Hamilton Southern Links	Roading	Designation and resource consents	EMMP shall set out the methodologies and processes that will be used to achieve these objectives and shall include, but will not be limited to, ecological monitoring. Details of ongoing monitoring and reporting of bat activity, including the establishment of adequate baseline survey and post construction monitoring to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the project network at all 3804669 23 locations where bats are detected. The specific priority objectives of monitoring shall include: i) Determining the effects of lighting and roads	Monitoring shall be carried out over the long-tailed bat breeding season and peak activity period (beginning of November to the end of April), first commencing two years prior to construction works starting, and continuing during construction and five years post construction for the first stage of the project, and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats as well as suitable control sites. The timeframes for the monitoring in accordance with this condition shall	Determining the effects of lighting and roads on the movement of bats and what other key potential barriers (eg bridges, embankments) are to movement. ii) Monitoring to gauge the effectiveness of the pest animal control required by condition 17.3(c) (iv) [of the consent document].

Project	Project type	Consent type	Conditions		
			Monitoring and reporting of bat activity including baseline and post- construction (scope and length)	**Post- construction specific**	**Specific requirement to monitor the effectiveness of mitigation measures**
			on the movement of bats and what other key potential barriers (eg bridges, embankments) are to movement; ii) Monitoring to gauge the effectiveness of the pest animal control required by condition 17.3(c) (iv); and iii) iii) Identification, protection and ongoing monitoring of key habitats (eg maternal roosting sites and foraging sites). Monitoring shall be carried out over the long-tailed bat breeding season and peak activity period (beginning of November to the end of April), first commencing two years prior to construction works starting, and continuing during construction and five years post-construction for the first stage of the project, and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats as well as suitable control sites. The timeframes for the monitoring in accordance with this condition shall only be triggered with respect to the first stage of construction works for any part of the project. The pre-construction monitoring can be carried out without a certified EMMP being in place.	only be triggered with respect to the first stage of construction works for any part of the project. The pre-construction monitoring can be carried out without a certified EMMP being in place.	

Appendix B: Influence of climate variables on long-tailed bat activity in an exotic conifer plantation forest in the central North Island

B1 Introduction

In recent years the effect of roading projects on long-tailed bats (*Chalinolobus tuberculatus*) has become a topical issue. In particular, implementation of the Waikato Expressway roading projects and investigations for the Hamilton Southern Links notices of requirement have become the first roading projects in New Zealand to deal with the need to mitigate and manage the adverse effects of roading projects on long-tailed bats. Consequently, the NZ Transport Agency has become interested in the development of improved monitoring methods for long-tailed bats.

To mitigate or manage potential adverse effects of roading projects on long-tailed bats it is essential to have survey and monitoring methods that are effective at monitoring bat activity, presence and abundance. However, there is considerable debate over when and how long-tailed bat monitoring should be undertaken. In particular, the effects of temperature, humidity and precipitation on long-tailed bat activity has been debated at various stages of resource consent evaluations and implementation for various road development projects. Both O'Donnell (2000a) and Griffiths (2007) have identified relationships between temperature and long-tailed bat activity, but it is not clear whether this relationship is consistent across all regions of New Zealand or whether other climatic variables may also be important.

B2 Objectives

The objective of this research was to use an existing data set to determine whether climatic variables, such as temperature, humidity, wind speed, and rain, predict long-tailed bat activity. If some of the variables measured, do predict bat activity then the analysis may be able to identify conditions that are more favourable for the monitoring of long-tailed bats.

The data used for this analysis is from Borkin (2010). This dataset includes records of long-tailed bat activity across all months throughout a year. In addition, climatic variables – temperature, relative humidity, rainfall, wind speed – recorded in the study location were available for correlation with bat activity. The data provides a useful opportunity to investigate the above objective, but was not collected for this specific purpose. Field design and data collection was aimed at meeting the specific research objectives of Borkin (2010).

B3 Methods

B3.1 Study site

Long-tailed bat activity was recorded monthly over a year in three main habitat types – *Pinus radiata* stands, pasture and native regenerating areas – within or adjacent to Kinleith Forest (37° 47' S, 175° 53' E). Kinleith Forest is an exotic plantation forest comprising mainly *Pinus radiata* logged using clearfell harvest on a 26–32 year cycle (Ministry of Agriculture and Fisheries 2007). Long-tailed bats roost and forage within this forest (Borkin and Ludlow 2009; Moore 2001). The area studied was defined by the boundaries of the Kopakorahi Stream, Waikato River, State Highway 1 and Jack Henry Road.

B3.2 Data collection

Acoustic monitoring of long-tailed bats was undertaken using automated bat monitoring units (ABMs); (constructed by DOC's Electronics Unit, Wellington, New Zealand 2005) between December 2006 and November 2007. These units contain a heterodyne bat detector and are described in O'Donnell and Sedgeley (1994).

ABM monitoring took place on the first five fine nights of each month that were available for monitoring. Monitoring began at sunset and ended at sunrise. Times of sunrise and sunset were based on the closest main centre (Tauranga) published in the *New Zealand nautical almanac* (Land Information New Zealand 2006; 2007). Monitoring did not occur on nights when rain was recorded in the first two hours after sunset. If the weather deteriorated sufficiently to disturb data collection, monitoring was abandoned and repeated on the next available fine night. One ABM was placed at five different sites each night, so 25 sites were monitored each month. ABMs were allocated randomly to sites.

Roads and edges were chosen as monitoring sites as long-tailed bats are known to use them more often than forest interiors (Borkin and Parsons 2009; Griffiths 2007; Moore 2001; O'Donnell 2000b). The microphone of each ABM was oriented parallel to the edge. The direction along the road or edge where the microphone was oriented was determined by the throw of a coin. ABMs of the design used in this study can detect long-tailed bats that pass within 50m of any unit (Parsons 1996).

ABMs were set to 40kHz, which corresponds with the peak energy of long-tailed bats' echolocation calls (Parsons 2001). Calls of the other extant New Zealand bat species, *Mystacina tuberculata*, peak in energy at 28kHz, and so echolocation calls are easily differentiated (Parsons 2001). Bat activity was quantified as number of bat passes recorded. One bat pass was defined as a sequence of two or more echolocation calls separated from other calls by a period of silence of at least one second (Thomas 1988).

Weather data was supplied by the Rural Fire Protection Authority from a permanent weather station (Athol Base) situated within the area being studied. Data provided for analyses included rainfall (mm), air temperature (^{0}C), relative humidity (%) and wind speed (km/h^{-1}) by the hour. Maximum overnight temperature, relative humidity and wind speed, as well as the total overnight rainfall was calculated, in addition to that of the night previous. Differences between the maximum overnight weather variables and the same variables for the previous night were also calculated.

B3.3 Data analysis

Bat passes were analysed using generalised linear mixed effects models in R (Ihaka and Gentleman 1996). Initially a Poisson distribution was used, but the models were over-dispersed. A negative-binomial distribution (log-link) was therefore used, as negative-binomial models have their own over-dispersion parameter (Bolker 2008; Sileshi 2008). Negative binomial models are also more robust when data is zero-inflated (Sileshi 2008). The models were ranked using Akaike information criterion (AIC) and Akaike eights (Burnham and Anderson 2002). Models with the smallest AIC value are considered to be more parsimonious, given the data, than models with higher AIC. Akaike weights are interpreted as the probability that a given model is the best model in that model set. Initially attempts were made to run models using the full dataset, but models with random effects failed to converge and models with only fixed effects had poor model fit. Consequently, to minimise zero inflation and allow modelling of sites as a random effect a reduced dataset was created by removing all sites where bats were never observed, and all sites that were monitored less than four times. This reduced the dataset from 56 sites

(n=300 observations) to 22 sites (n=168 observations), but allowed site to be modelled as a random effect. In addition, one extremely high bat count of 305 was removed because it produced an unacceptably high amount of leverage.

All models had site as a random effect. Our approach to modelling fixed effects was as follows. First, we ran an intercept only model, ie a model that had an intercept term but no other covariates. We used this model as a null model to reference our other models against. Models that AIC ranks below the 'intercept' model are not considered informative. We then modelled the following predictors separately: temperature, humidity, wind speed, rain and season. For temperature, humidity, and wind speed we had the following variations: the maximum daily value, the value at sunset, the value 0–1 hours after sunset, the value 1–2 hours after sunset, the value 2–3 hours after sunset, through until 14–15 hours after sunset. For all three climate variables we ran the maximum daily value and the value at sunset, after that we only ran models using the values recorded later at night if the climate variable had models ranked above the intercept model. However, we stopped, ie did not continue through until 14–15 hours after sunset, if the consecutive models for that climate variable had started to fall below the top model (ie we found a peak). We justify this because long-tailed bat activity is known to peak during the first 2–3 hours following sunset (O'Donnell 2000a; Borkin 2010). Season was modelled as a categorical covariate. In addition to these predictors we also included the difference between the value of each climate variable on the night of the survey, to that of the previous night, to assess whether there might be a potential lag effect. No models with interaction effects were included in this analysis because small sample sizes meant they were unable to converge properly (see section B4).

B4 Results

The top model in our analysis was 'temperature 3–4 hours after sunset'. The second and third top models were 'temperature 2–3 hours after sunset' and 'temperature 1-2 hours after sunset' and both are within 2 Delta AIC of the top model. Collectively these models have 66% of the Akaike weight. These results suggest that temperature 1-4 hours after sunset is an important predictor of bat activity. Figures B.1–B.3 indicate that bat activity increases if the temperature 1–4 hours after sunset is greater than 5ºC with particularly high activity in the 10–17ºC range. Figures B.1(b)–B.3(b) also indicate strong site-specific variation in the response of bat activity to temperature, ie the layered effect you can see in these graphs results from the mixed-effects models fitting different intercepts to different sites.

The only other climatic variable which had models above the 'intercept' model in table B.1 was relative humidity ('relative humidity at sunset' and 'maximum daily humidity'). Relative humidity at sunset was the seventh top model with 4% of the Akaike weight (table B.1). Figure B.4 suggests bat activity increases when relative humidity at sunset is ≥70% with very high bat activity when relative humidity at sunset is in the 80–95% range. Again there appears to be strong site-specific variation in this response. Maximum daily wind speed and total daily rain fell below the intercept. Due to problems with model convergence we were unable to test for any interactions between relative humidity and temperature.

An attempt to model season as a categorical covariate failed to converge leading to its exclusion from the model set presented in table B.1. However, figure B.5 shows the highest bat count frequencies were recorded in autumn and spring.

Table B.1 Models of climate variables as predictors of nightly total bat passes. Models are ranked using AIC. 1, 2, 3–6 indicate hours after sunset, eg '4 hours' translates to temperature or humidity 3–4 hours after sunset.

Model	AIC	Delta AIC	Akaike weight
Temp 4 hours after sunset	702.69	0	0.304618485
Temp 3 hours after sunset	703.3	0.61	0.224541405
Temp 2 hours after sunset	704.4	1.71	0.129549121
Temp 6 hours after sunset	705.25	2.56	0.084695301
Temp 5 hours after sunset	705.96	3.27	0.059386096
Temp 1 hour after sunset	706.4	3.71	0.047658458
Relative humidity at sunset	706.9	4.21	0.037116445
Temperature at sunset	707.8	5.11	0.02366649
Maximum daily humidity	707.8	5.11	0.02366649
Daily temp difference	710	7.31	0.00787789
Intercept	710.1	7.41	0.007493681
Rain at sunset	710.3	7.61	0.006780563
Humid 2 hours after sunset	710.6	7.91	0.005836085
Maximum daily wind speed	710.6	7.91	0.005836085
Humid 1 hour after sunset	710.9	8.21	0.005023165
Humid 3 hours after sunset	711.3	8.61	0.004112619
Humid 4 hours after sunset	711.53	8.84	0.00366585
Humid 5 hours after sunset	711.8	9.11	0.003202911
Humid 6 hours after sunset	711.91	9.22	0.003031508
Maximum daily temperature	711.6	8.91	0.003539764
Total daily rain	711.9	9.21	0.003046703
Wind speed at sunset	712	9.31	0.002898114
Daily humid difference	712.1	9.41	0.002756771

Note: Temp=temperature, Humid=relative humidity. Intercept = a model with only an intercept (ie no predictor variable).

Figure B.1 **Total bat passes plotted against the temperature 3–4 hours after sunset (a) and predicted bat passes given the temperature 3–4 hours after sunset (b). The predictions were from the top model in table B.1.**

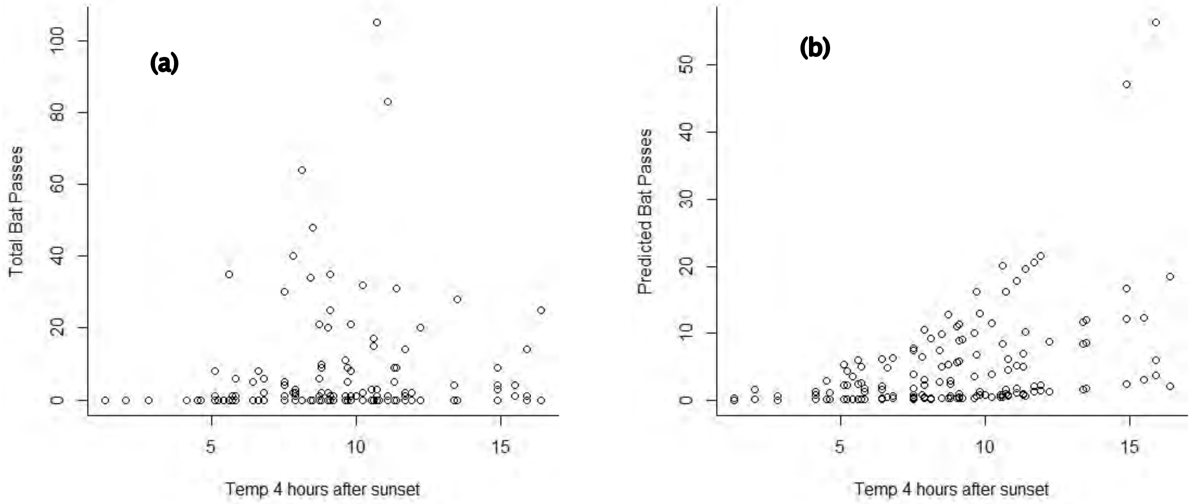


Figure B.2 **Total bat passes plotted against the temperature 2- 3 hours after sunset (a) and predicted bat passes given the temperature 2- 3 hours after sunset (b). The predictions were from the second top model in table B.1.**

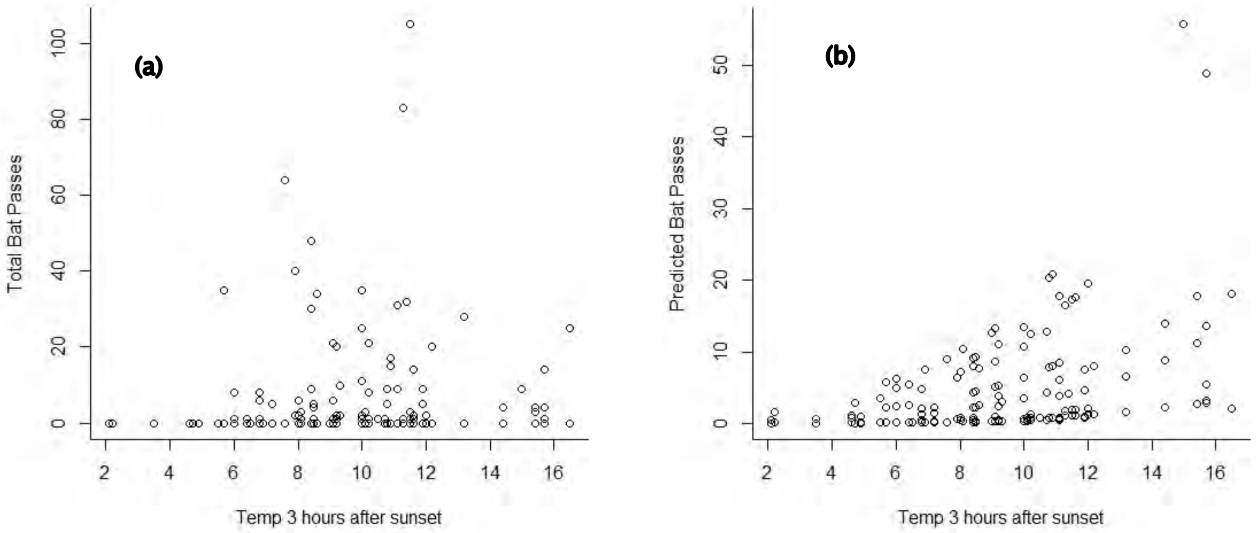


Figure B.3 **Total bat passes plotted against the temperature 1-2 hours after sunset (a) and predicted bat passes given the temperature 1-2 hours after sunset (b). The predictions were from the third top model in table B.1.**

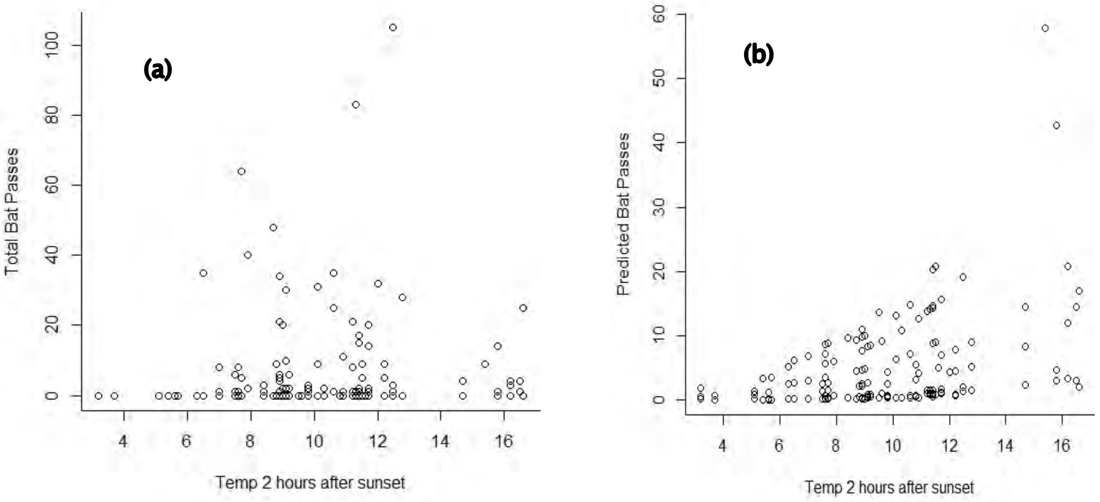


Figure B.4 **Total bat passes plotted against relative humidity (%) at sunset (a) and predicted bat passes given the relative humidity at sunset (b). The predictions were from the seventh top model in table B.1.**

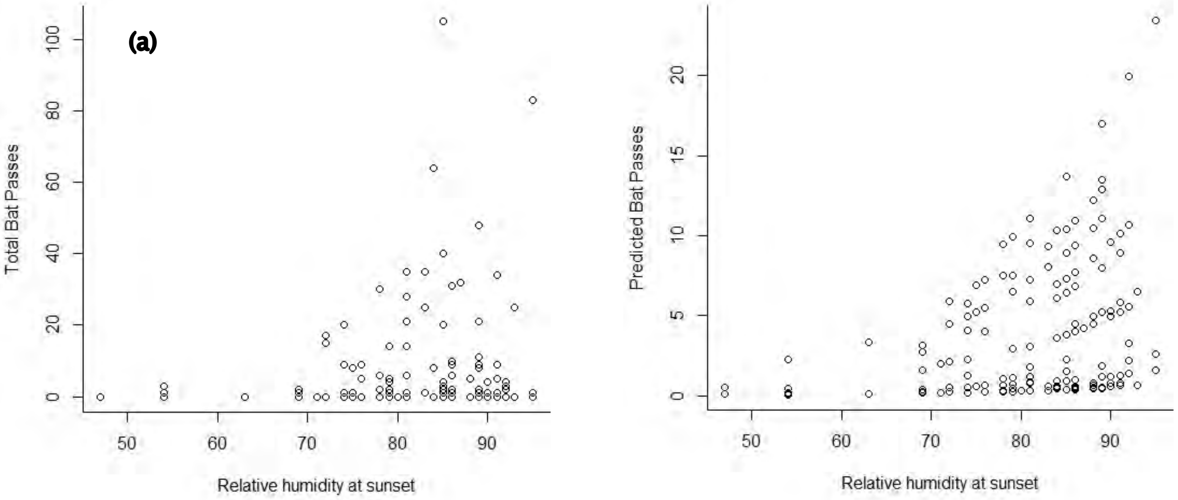
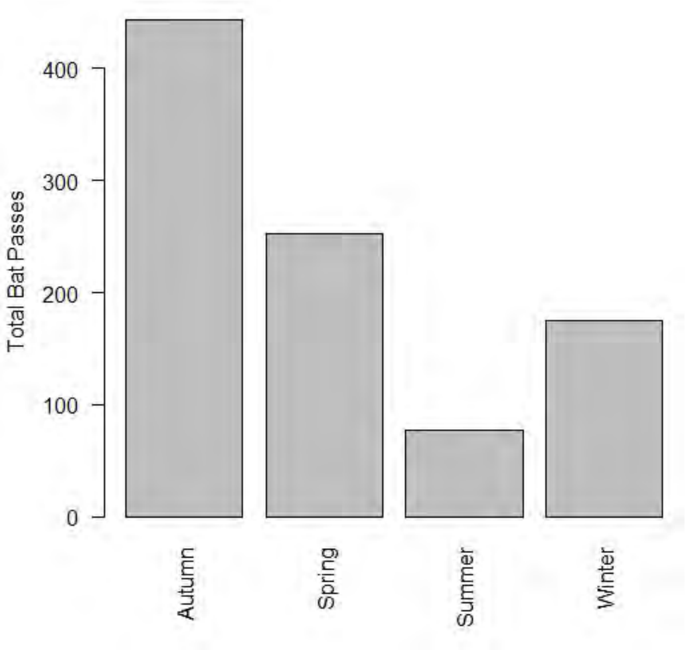


Figure B.5 Histogram of bat counts summed per season



B5 Discussion

Little is known about what drives long-tailed bats to become active at certain sites on certain nights. O'Donnell (2000a) and Griffiths (2007) observed long-tailed bat emergence and activity was related to temperature, with the latter study observing a 5ºC threshold below which long-tailed bats would not emerge. Our research supports this and suggests the critical period over which the temperature needs to be above 5ºC is 1–4 hours after sunset and bat activity is likely to be highest for temperatures in the 10–17ºC range. Bat activity was also correlated with relative humidity, with high bat activity occurring above 70% relative humidity. It is not clear whether there is any interaction between temperature and humidity that may further explain peaks in bat activity. Although there was no model support for the impact of rain and wind on bat activity, the data used in this analysis were collected using a protocol that involved specifically avoiding inclement weather, therefore it would be worthwhile exploring the impacts of rain and wind on bat activity more thoroughly. It must be stressed, however, that despite these results, undertaking monitoring at high temperature and humidity over one night does not guarantee detection of long-tailed bats if they are present. Our analysis included all sites where bats were detected at least once, and zeroes were recorded across the full range of temperatures and humidity levels observed. In addition we observed strong site-specific variation in the relationship between bat activity and temperature and humidity. This may result from variation in population size, but it may also result from other factors such as habitat and food availability.

An important issue is, why does long-tailed bat activity data contain so many zeroes, even during seemingly favourable conditions? Although, seasonal changes in behaviour account for some of this, it does not account for all of it. Borkin and Parsons (2009) suggested it was necessary to monitor sites with ABMs for two nights to enable a reasonable chance of detecting long-tailed bats at a given site. This could be because long-tailed bats use different parts of their range on different nights. If this is the case, then long-tailed bat monitoring should deploy arrays of ABMs over much larger areas than presently occurs. The spatial extent of the ABM array should reflect the extent of possible movements of long-tailed bat social groups. Research would be required to determine the size and density of the ABM array, but once it was determined, detection of long-tailed bats on any one of the ABMs within the array would count as a detection for the whole array. This would reduce the likelihood of non-detection of bats at sites where they are both present and active. For example, in Fiordland *Nothofagus* forest, 50 long-tailed bats from three social groups, with overlapping collective foraging areas, ranged over 11,700 hectares in total (O'Donnell 2001). In Kinleith Forest, individual long-tailed bat home range spans were as large as 16 kilometres (K Borkin, pers comm). Clearly, arrays of ABMs (collectively viewed as one monitoring unit) should reflect these scales of movements, otherwise monitoring lacks independence and is therefore pseudo-replicative.

Although the correlations between climate variables and long-tailed bat activity described here will be of value to monitoring strategies, a more robust approach to designing a good monitoring strategy would be the use of occupancy modelling (MacKenzie et al 2006). Occupancy modelling uses data from repeat surveys of sites to account for probability of detection (p) which is of fundamental interest for developing a robust survey methodology. Occupancy modelling does not estimate the abundance of a species; instead it estimates the proportion of an area occupied by the species (occupancy). Normally the repeat surveys of a site are undertaken over a short timeframe, eg every day for four days, during which time the population is assumed to be closed to significant births, deaths, immigration and emigration (MacKenzie et al 2002; MacKenzie et al 2006). The key advantages of occupancy models are: 1) covariates (eg temperature and humidity) can be modelled as predictors of both p and occupancy; and 2) they can be used to estimate the proportion of sites where a species was not detected during a survey, that were in fact likely to have been occupied by that species.

It was not possible to use the data from Kinleith Forest in an occupancy analysis because data was collected once per month, violating the assumption of a closed population and preventing per season estimation of p but, as mentioned previously, the data was not collected for this purpose. To undertake an occupancy analysis on long-tailed bats it would be necessary to select a sample of suitable sites and to use ABMs to monitor them repeatedly over 4–5 nights within each season. If repeated seasonally, this would result in 16–20 surveys for each site per year, eg 4-5 surveys in each of winter, autumn, spring and summer. This would be sufficient to get seasonal estimates of p and determine how covariates (such as climate variables) interact with them. It would also allow use of the following equation to estimate the survey effort required to provide a given level of confidence that a survey is robust (Tyre et al 2003):

$$(1-p)^n \qquad \text{(Equation B.1)}$$

Where p is probability of detection and n is the number of surveys. To give an example, Smith et al (2014) used occupancy modelling to estimate that summer was the best time to survey for northern leopard frogs (*Lithobates pipiens*) and that two consecutive days of surveying in summer would give a probability of 0.9 of detecting northern leopard frogs if they were present.

B6 Conclusion

We analysed data on long-tailed bat activity collected over one year within Kinleith Forest and found bat activity increased with increasing temperature 1–4 hours after sunset. This supports earlier analyses by O'Donnell (2000) and Griffiths (2007) which also found temperature to be important. In addition we found there to be a correlation between relative humidity at sunset and bat activity. We suggest bat monitoring is undertaken when temperatures 1–4 hours after sunset are above 5ºC, and preferably in the 10–17ºC range. Humidity above 70% at sunset may also be a desirable condition for monitoring. However, we stress caution that these results are from one location during one year, and encourage replication of this research in other regions of New Zealand. Also, long-tailed bat activity was highly variable even at high temperature and humidity levels and we express caution in assuming bats are not present because they were not detected by ABMs during a high temperature or high humidity night. Finally, we suggest collection of data appropriate for a site occupancy analysis would be very useful for undertaking an analysis that could be used to design a strong monitoring protocol for long-tailed bats.

B7 References

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Appendix C: The relationship between traffic intensity and long- tailed bat activity along New Zealand highways

C1 Introduction

There is a considerable uncertainty in relation to the effects of roads on New Zealand's endemic bat species, and this has led to much debate during the planning and consent phases of recent major road development projects in New Zealand. The NZ Transport Agency (the Transport Agency) commissioned Wildland Consultants, in collaboration with Landcare Research and AECOM, to undertake research and develop a national framework which will guide the Transport Agency and other agencies through the necessary statutory process for land transport projects that occur within bat habitats. A literature review undertaken as the first step in this process found that information on the relationship between bats and roads in New Zealand was largely anecdotal (see Part 1 of this report).

The long-tailed bat is an edge-adapted species (Borkin and Parsons 2009; O'Donnell et al 2006; O'Donnell 2000) considered vulnerable to extinction by DOC, the government agency responsible for the conservation and management of New Zealand's biodiversity. The threat classifications for long-tailed bats are 'nationally vulnerable' in the North Island and 'nationally critical' in the South Island (O'Donnell et al 2013). Long-tailed bats are central place foragers, and as such their distribution is limited by the need to return to a roost each day (Borkin and Parsons 2011a; Sedgeley and O'Donnell 1999; Borkin and Parsons 2011b; Daniel and Williams 1984; Sedgeley and O'Donnell 2004). Although primarily found in New Zealand's indigenous forests, there is a population in parts of Hamilton City where there are low levels of housing, street lighting (Dekrout et al 2014) and road density (Le Roux and Le Roux 2012). Long-tailed bats are known to commute and forage along remote forestry roads and roads that bisect national parks (Borkin and Parsons 2009; O'Donnell 2000). Le Roux (2012) provided some evidence that long-tailed bat activity lowers with proximity to roads, and this is supported by overseas research which has found that activity of other bat species declines closer to roads (Berthinussen and Altringham 2012; Kitzes and Merenlender 2014). If roads are acting as barriers to bat movement, they could be resulting in the fragmentation of bat populations. Despite these initial findings, the impact of traffic volumes on bat activity remains unclear.

In this report we present research aimed at addressing the current lack of robust information by exploring the relationships between long-tailed bat (*Chalinolobus tuberculatus*) populations and highways in New Zealand.

C2 Study objectives

The aim of this study was to investigate the relationship between long-tailed bat activity and traffic intensity (volume) along roads and highways in New Zealand. Given that long-tailed bats are known to forage along forest edges, including quiet sections of forested or private roads (Borkin and Parsons 2009, O'Donnell et al 2006; O'Donnell 2000), road impacts may be related to traffic intensity rather than the presence of a road. If traffic levels are affecting bat behaviour, then observations of bat activity will decline with increasing traffic intensity. This research objective is particularly relevant given that traffic volumes in New Zealand have increased by 75% since records began in 1989 (Wen 2015).

A further objective of the research was to compare the effectiveness at detecting bats of Song Meter zero crossing (SMZC) bat recorders and frequency compression (FC) automated bat monitoring (ABM) units developed by DOC. In New Zealand the use of FC ABM units is more common than the use of SMZC units. FC uses a linear frequency transformation, eliminating artificial harmonics to create a more acoustically accurate result.

C3 Methods

C3.1 Comparison of bat monitoring devices

Omni-directional bat detectors based on the FC of ultrasound have been estimated to detect bats over a distance of 30–50 metres (S Cockburn, DOC, Wellington, New Zealand, pers comm, 29 October 2015). The SMZC bat recorders also used in this study have been estimated to detect bats, at 40kHz, the peak amplitude of long-tailed bat calls, 38 metres from units (Agranat 2014). Variation in detection distances is likely to occur even between bat detectors of the same model because of variation in microphone sensitivity, orientation of bats, bat detectors and surrounding vegetation, and the distances between these; as well as the strength of bat calls (Agranat 2014). It was therefore considered important to compare detection rates between FC and ZC bat detectors.

We paired FC and ZC units at nine locations along road edges in exotic plantation forests that were known to have resident long-tailed bat populations foraging along forest edges (Borkin and Parsons 2009). Each pair of FC and ZC units was set up within 10 metres of each other. Bat detectors were set to begin recording at sunset and conclude recording at sunrise, from 30 December 2015 to 7 January 2016. All bat detectors were placed within two metres of the ground.

A long-tailed bat pass was defined as a series of two or more calls each with peak amplitude at or around 40kHz separated from other calls by a period of silence lasting at least one second (Thomas 1988). Short-tailed bat passes can be distinguished from long-tailed bat passes because they utilise two alternative parts of the spectrum (a fundamental frequency of 25–30kHz and a harmonic frequency at 50–60kHz), as well as a having shorter pulse duration and a higher pulse rate (Parsons 1997). Calls of New Zealand bats are readily distinguishable from other nocturnal sounds, including insects, birds, wind, and rain, which are also recorded on bat recorders.

For ZC units, bat calls were identified using Wildlife Acoustics (2015) Kaleidoscope version 3.1.5. Recordings were processed and converted from ZC file format to an audible.wav file format. Identification of bat calls was undertaken manually by viewing a spectrogram and/or listening to the .wav file of each recording. Call shapes (or wave forms) were defined as pulses on the spectrogram, or clicks on the corresponding audible .wav file, each with peak amplitude at or around 40kHz.

For FC units, bat calls were identified using BatSearch 3.05 (DOC proprietary software, 2014). Identification of bat calls was undertaken manually by viewing a frequency compressed image of a spectrogram (ie the frequency axis is compressed but the time axis is not) of each recording and comparing these with images of known long-tailed bat calls (eg Cockburn 2014).

For each of the nine sites, the number of bat passes per night was tallied for each detector type, and the number of nights when bats were detected was calculated.

C3.1.1 Data analyses

Data on the difference in the number of bat passes between bat detectors were analysed using a Welch's two sample t-test. Welch's t-test was chosen because it allows for unequal variances (Welch 1947).

C4 Traffic intensity and bat activity

This research was undertaken between December 2015 and April 2016, within the austral summer and autumn.

C4.1 Site selection

We chose sites by identifying locations along New Zealand's state highways that are:

- within known or potential long-tailed bat habitat
- sites where traffic volume is monitored by the Transport Agency (Wen 2015).

At each monitoring site ZC units were put out in pairs, with the first ZC unit placed at the edge of the 'highway' along a forest edge, treeline, or other linear landscape feature, while its partner was placed alongside another piece of forest edge or linear landscape feature that was ≥200 metres 'distant' from the road. We chose this distance because Berthinussen and Altringham (2012) found noise pollution due to roads appeared to reduce to near ambient levels at around 200 metres, and Altringham and Kerth's (2016) review of the effects of roads on bats considered the effects of light pollution from roads and vehicle lights would only operate over relatively short distances. Side roads were not used for the partner ZC unit unless it was a forestry road. This is because forestry roads are usually closed to vehicles at night and bat activity along this edge should therefore not be affected by traffic. At some traffic monitoring sites only one pair of ZC units was deployed, while at other sites, where habitat extent allowed, more than one pair of ZC units were deployed. Where two or more pairs of ZC units were deployed along the same section of road, pairs were placed ≥250 metres apart (figure C.1).

ZC units were set to 'record at night' mode – from sunset to sunrise – for two entire nights. Metservice weather forecasts were used to ensure ZC units were not used during periods of rain. Sunset and sunrise times were recorded automatically by the ZC units. ZC unit location, distance to the road edge and to the pair partner were recorded using a hand-held GPS unit.

Bat passes were identified using the methods described for ZC units in section C3.1. The number of bat passes per night was tallied for each ZC unit at each site.

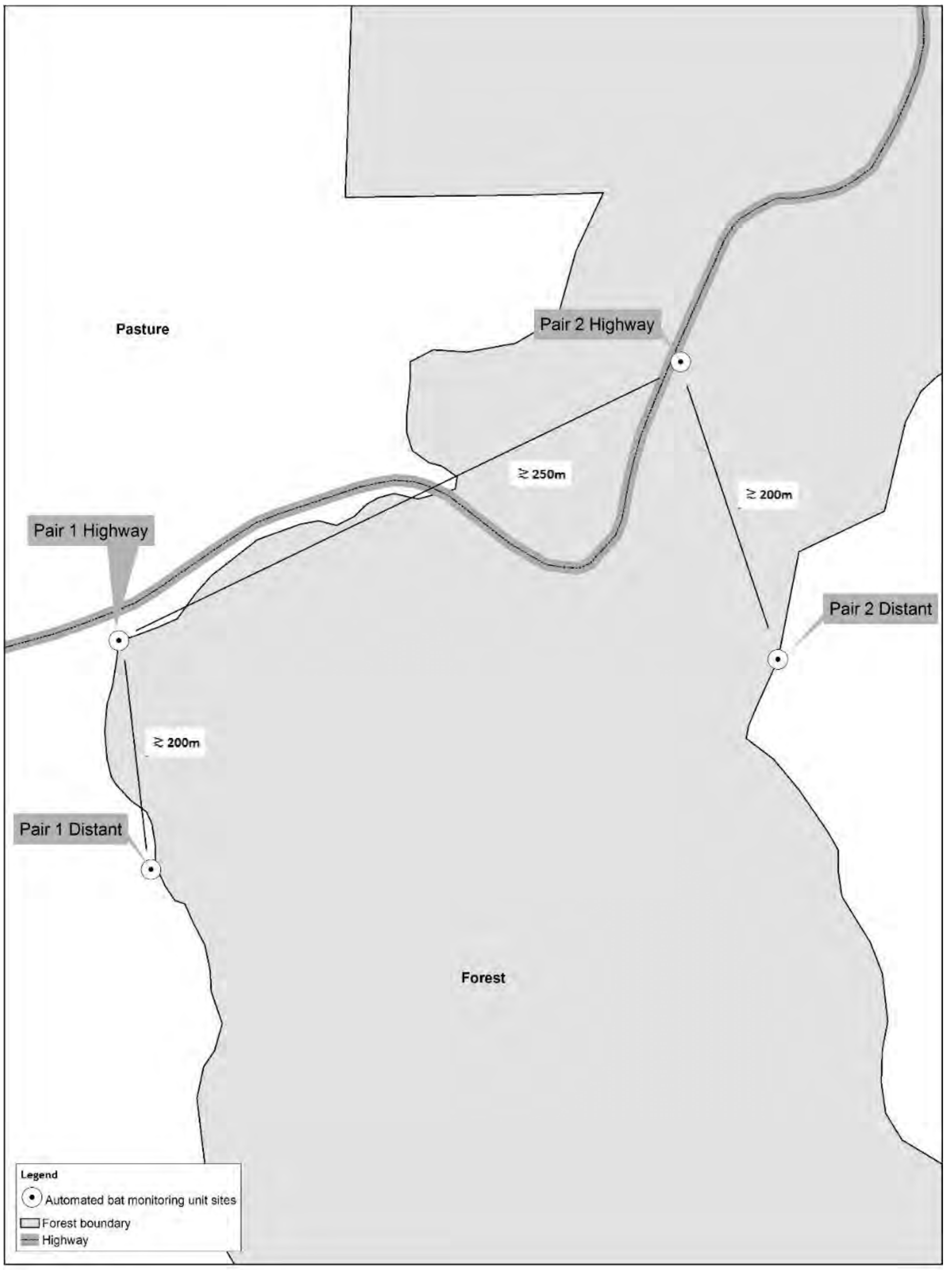
C4.2 Traffic intensity data

Data on traffic intensity were provided by the Transport Agency. From this data we used or established three bat activity covariates:

- Day-time traffic intensity:
  - For day-time traffic intensity we used a metric called annual average daily traffic (AADT) volume (Wen 2015). The most recent year this was available for was 2014.
- Percentage heavy traffic volume:
  - Percentage of heavy traffic is an estimate of the proportion of the AADT which is deemed to comprise a heavy vehicle, ie greater than 3.5 tonnes for the current year (Wen 2015). This was also available for the 2014 calendar year.
- Night-time traffic intensity
  - A standard 'average overnight traffic per night' was determined by summing traffic that passed the count site location between 8pm and 6am over seven nights during the traffic monitoring period and then calculating its mean. The seven-day traffic monitoring period utilised was closest

by date to the period over which bat monitoring took place, unless traffic monitoring was continuous and the first seven days of the same month were then used. The period from 8pm to 6am was chosen because this encompassed sunset times for most of the locations sampled over the summer and autumn monitoring period. These data were available for 2015–2016.

Figure C.1 Schematic diagram of bat monitoring sites along highways. All bat monitoring sites were established at locations where traffic volumes are being monitored by the NZ Transport Agency. At some traffic monitoring sites only one pair of bat detectors was established but, at other sites, when habitat extent allowed, more than one pair was established.



C4.2.1 Data analyses

Bat detection data were analysed using generalised linear mixed-effects models using the package lme4 (Bates et al 2015) in R (Ihaka and Gentleman 1996). Models included two nested random effects: 1) transport monitoring site, and 2) bat monitoring site, ie each ZC pair. Initial modelling attempts assumed a negative-binomial distribution, but several models failed to converge, so a binomial distribution was used, ie the data were constrained to be either 0 no bats were detected or 1 bat was detected. The use of a binomial distribution was supported by the median counts for 'highway' and 'distant' sites (see section C5). With the exception of % heavy traffic, data on traffic intensity was log transformed. Only sites where bats were detected at least once were modelled. This was done because we were not confident that sites where bats were not detected were occupied by bats. Adding sites where bats were not detected, and might not have been present, would lead to zero inflation in the data, and provide no additional information on the specific hypotheses that we were trying to address. We also removed one further bat monitoring site because the paired ZC units were 1.5 kilometres apart and this was not consistent with our data or study design.

We ran the following models, all of which had the presence and absence of bats (BP) as the dependent variable: BP~Intercept (intercept only, no predictor), BP~Position (highway versus distant – categorical covariate), BP~Day traffic (day-time traffic intensity), BP~Night traffic (night-time traffic intensity), BP~Heavy (% heavy traffic), BP~Position*Day traffic (interaction), BP~Position*Night traffic (interaction), BP~Position*Heavy (interaction). The models were ranked using AIC and Akaike weights (Burnham and Anderson 2002). The model with the smallest AIC value is considered the most parsimonious in the model set given the data and the number of parameters. Akaike weights are the probability that a model is the best model in that model set (Burnham and Anderson 2002). The intercept model is a 'null model', essentially modelling nothing, if it is the top model, or near the top, the rest of the models are considered uninformative.

C5 Comparison of bat monitoring devices

The trial comparing FC and ZC bat detectors was undertaken during a period when overnight minimum temperatures ranged from 7.5 to 16.1°C, while temperatures at sunset ranged from 10.5 to 19.9°C. Overnight precipitation occurred on 1 January, 2 January, and 4 January: 4.2mm; 5.8mm; and 1.2mm respectively (CliFlo Station 41077: Rotorua EWS; http://cliflo.niwa.co.nz/, accessed 16 May 2016).

Only long-tailed bats were detected. The median number of detections per site for FC units was 20 (range=1-228), while for ZC units it was three (range=0-112). Figure C.2 shows both types of detectors have outlying values that make the graph difficult to interpret, and these values have been removed in a second boxplot (figure C.3). FC bat detectors have a much greater variance in bat detections (variance=52612) than the ZC bat detectors (variance=1309). A Welch's t-test did not detect a significant difference in bat detections between the two types of detectors (t=1.01, d.f.=11.478, $p=0.3333$). However, table C.1 shows that, overall, FC units detected bats over more nights than ZC units.

Table C.1 Number of nights when paired frequency compression (FC) and zero crossing (ZC) bat detectors did not detect bats

	FC non- detections	ZC non- detections	Total nights
Pair 1	3	5	10
Pair 2	3	5	10
Pair 3	5	7	9
Pair 4	8	8	10
Pair 5	8	8	9
Pair 6	8	9	10
Pair 7	1	3	10
Pair 8	8	9	9
Pair 9	3	4	10

Figure C.2 **Boxplot comparing the number of bat detections between zero crossing (ZC) and frequency compression (FC) bat detectors.**

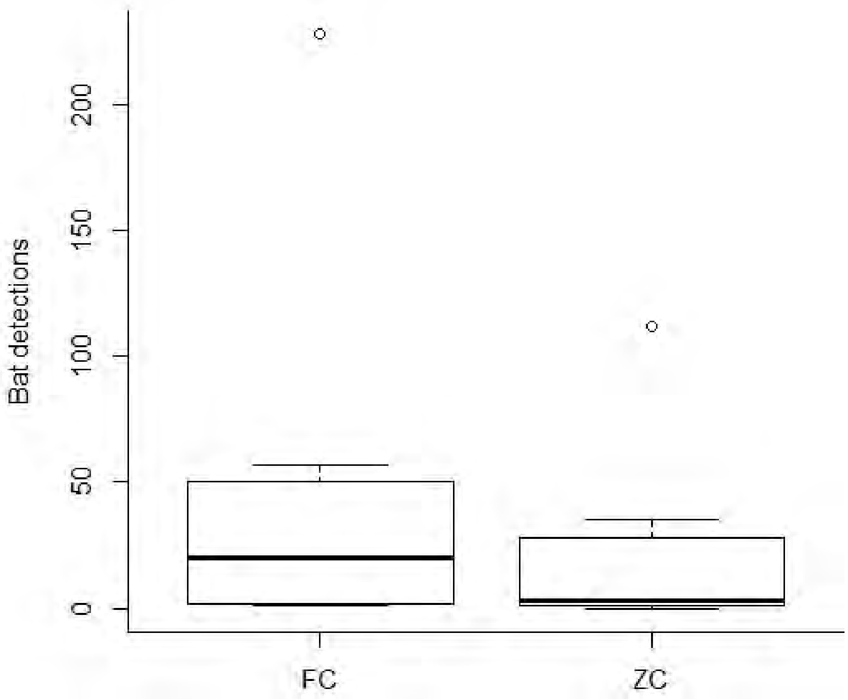
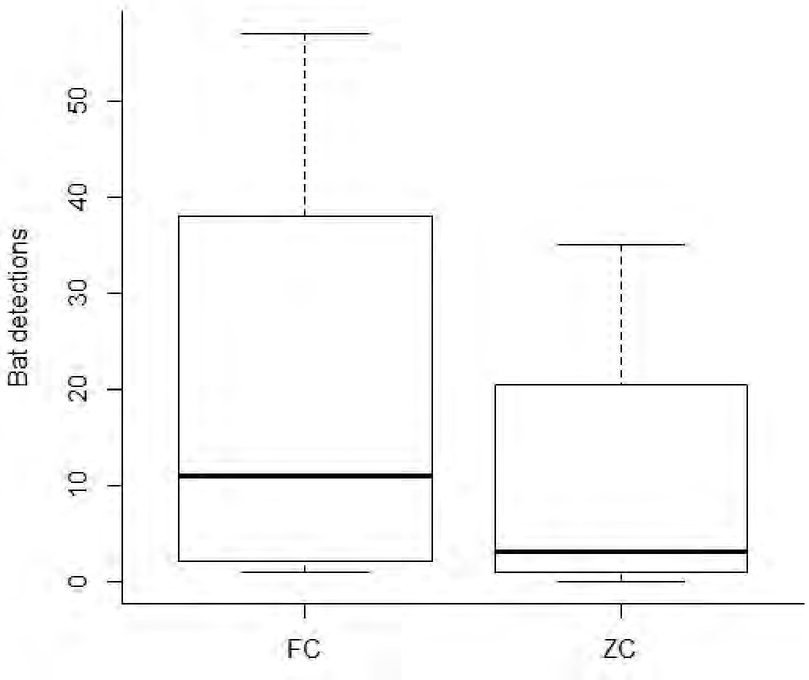


Figure C.3 **Boxplot comparing the number of bat detections between frequency compression (FC) and zero crossing (ZC) bat detectors with the two outliers in figure C.2 removed.**



C6 Traffic intensity and bat activity

Between December 2015 and April 2016, 57 traffic monitoring sites were sampled across the following regions of New Zealand: Waikato and Bay of Plenty in the North Island, and West Coast and Canterbury in the South Island (figure C.4). Within these traffic monitoring sites, a total of 108 bat monitoring sites (ZC pairs) were deployed.

When bat monitoring sites that never detected bats were removed[12], data remained for 39 traffic monitoring sites and 56 bat monitoring sites. Distant ZC units averaged 291 metres from the road (±10.75 SE), while the average highway ZC unit was 18 metres from the road (±1.95 SE). The sum of bat detections was 760 for distant ZC units (mean 6.6, range=0-90) and 518 for highway ZC units (mean 4.5, range=0-64). The median number of bat passes for distant ZC units was 1 and for highway ZC units it was 0.

For the generalised linear mixed effects models, the top model in the model set was the interaction effect between position (highway ZC, distant ZC) and night-time traffic intensity, with an Akaike weight of 0.95 (table C.2). The interaction effect in this model was statistically significant (z=-2.89, p=0.00374). The second and third ranked models, both with Akaike weights of 0.02, were the interaction between position and % heavy traffic, and position. Position was the highest ranked individual covariate model (ie model without an interaction effect). This model predicts bats are more likely to be detected at distant ZC units compared with highway ZC units (odds ratio for the highway=0.49, odds ratio for distant=1.76). The interaction effect between position and day time traffic intensity failed to converge.

Table C.2 Models of bat activity and traffic intensity ranked using AIC. The model position*day traffic failed to converge, so no AIC value is given in this table.

Model	*k* (fixed effects)	AIC	Delta AIC	Akaike weight
Position*night traffic	4	297.30	0.00	0.95
Position*heavy	4	304.69	7.39	0.02
Position	2	305.44	8.14	0.02
Day traffic	2	307.76	10.46	0.01
Heavy	2	307.95	10.65	0.00
Night traffic	2	308.37	11.07	0.00
Intercept	1	309.63	12.33	0.00

For the top model the coefficient describing the relationship between distant sites and night-time traffic intensity was 0.05 with a SE of 0.21, indicating there was not a strong relationship between distant ZC units and night-time traffic intensity. However, the coefficient describing the relationship between highway ZC units and night-time traffic intensity was -0.73 with a SE of 0.25 (CV=34%) indicating a negative relationship between bat detections and night-time traffic intensity. We used the 'predict' function in R to get the predicted probabilities for each site and plotted them against night-time traffic intensity (figure C.5).

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[12] No detections were identified as short-tailed bat passes.

Figure C.4 Locations of bat monitoring sites used for this study

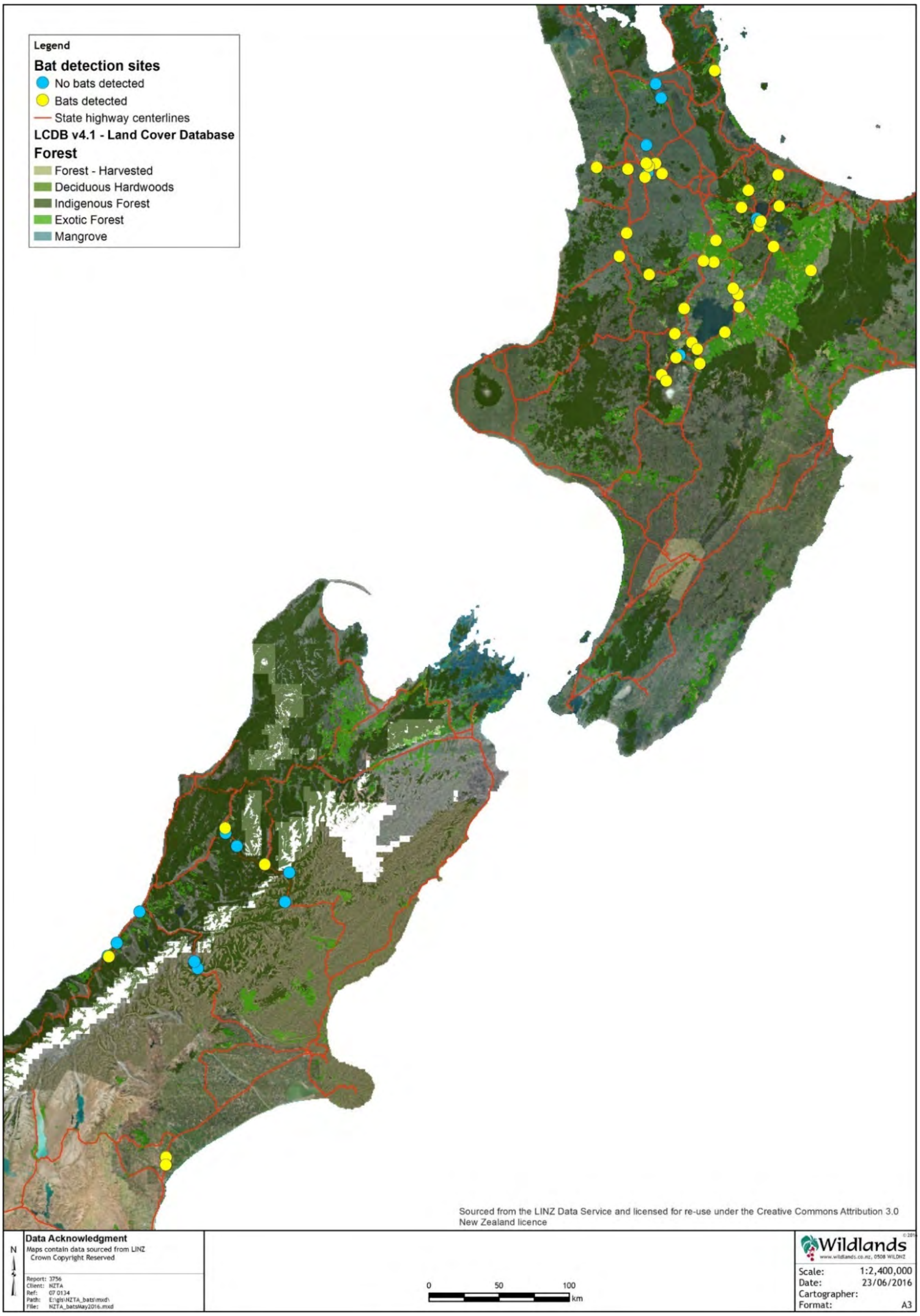
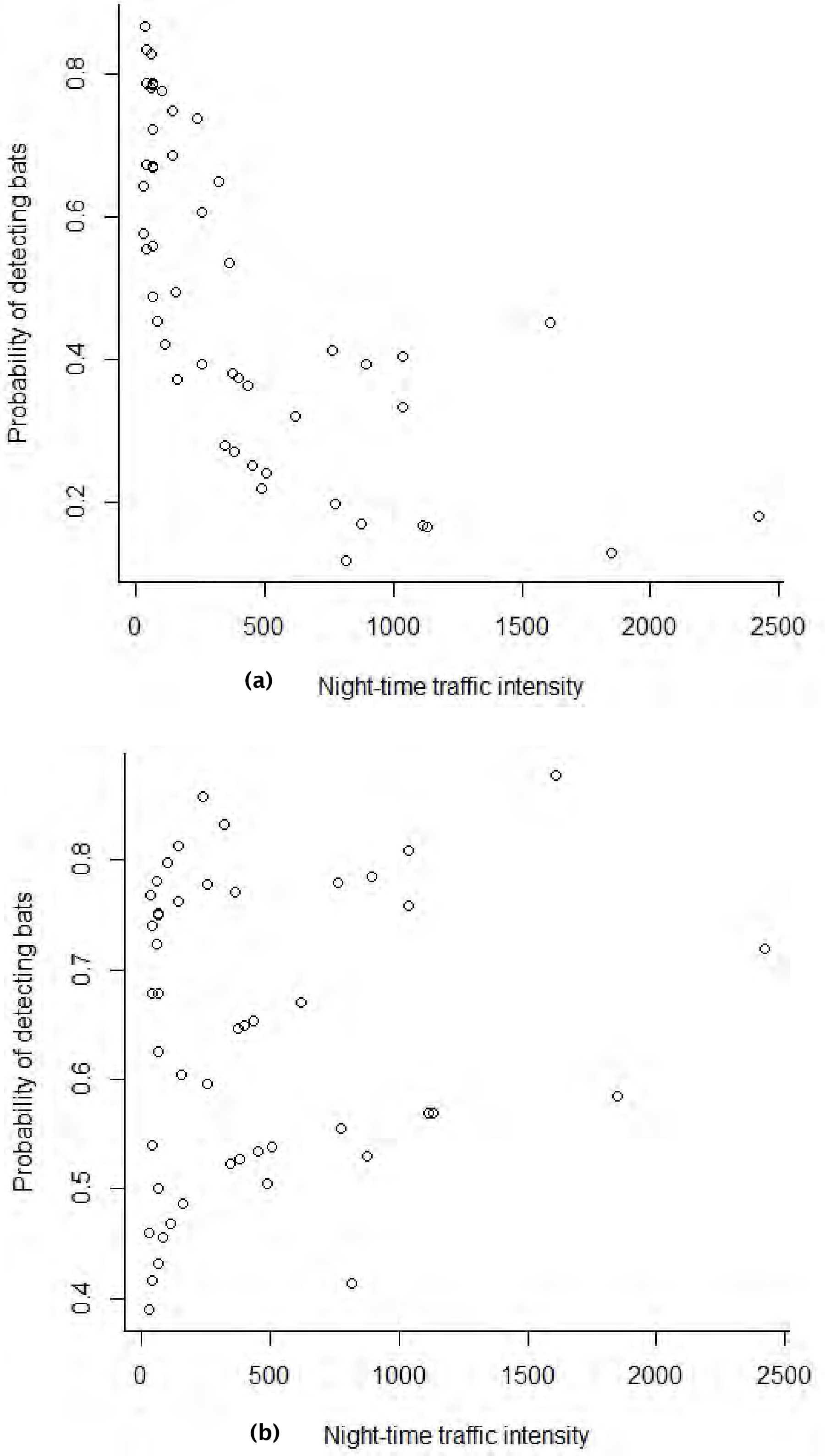


Figure C.5 **Predicted probabilities from the top model plotted against night- time traffic intensity for a) bat detectors on highways, b) bat detectors 200 metres or more from highways (distant). Night- time traffic intensity is the number of vehicles using a highway between 8pm and 6am.**



C7 Discussion

C7.1 Comparison of bat monitoring devices

Our comparison of ZC and FC bat detectors suggests FC units are more sensitive for long-tailed bat detection, having detected long-tailed bats over more nights than ZC units and recorded higher frequencies of passes. However, it also demonstrated ZC units do detect long-tailed bats, and consequently their use has not jeopardised this study. In general, we recommend using FC bat detectors to monitor long-tailed bats in New Zealand, particularly in situations where it is critically important to reliably determine presence/absence.

Caution should be taken when using these results to decide which type of bat detector to use for a task. This research focused solely on the detection of long-tailed bats' echolocation calls; social calls may be important in identifying active roosts. The FC bat detectors used in this research may detect long-tailed bats' social calls made in roosts when these overlap with the frequencies at which they record data, but at least some social calls could be missed with this equipment as it only records data that coincides with 28kHz and 40kHz (Ian Davidson-Watts, Davidson-Watts Ecology Ltd, 2 November 2016, pers comm).

C7.2 Traffic intensity and bat activity

C7.2.1 Bat responses to traffic intensity

The top model from our analysis of bat activity and traffic intensity predicts that, for paired monitoring devices, with one near the edge of the highway and one 200 metres or more from the highway, the distant monitoring device is more likely to detect long-tailed bats than the monitoring device near the highway. It also predicts that bat activity along highways will be negatively correlated with night-time traffic intensity, while bat activity at distant locations will be comparatively unaffected.

Our study aimed to monitor as many sites as possible with varying traffic intensity. Consequently, we did not investigate how varying distance from the highway correlates with bat activity, but instead used distance as a categorical covariate (beside highway; c.200 metres distant from the highway). Figure C.5(a) shows that bat activity along highways can be high when traffic rates are low (close to zero), but this activity declines rapidly as traffic rates reach ≥1,000 vehicles per night.

Establishing whether, or to what extent, this observed decline in bat activity is related to impacts on bat survival and population viability was beyond the scope of this study, but is an important next step. Forman et al (2013) showed collisions between many wildlife species and vehicles increase with increased traffic volume, vehicle speed, and proximity to wildlife corridors and habitat. However, to date, no research has investigated the relationship between bat mortality rates due to roadkill and traffic volume (Altringham and Kerth 2016). However, if long-tailed bats response to a threat is to move away from it at speed, then roads with high traffic volumes may be acting as substantial barriers to them (Jacobson 2016).

C7.2.2 Possible ecological reasons for the negative relationship between bat activity and traffic intensity

While traffic intensity may have direct impacts on long-tailed bat survival, it may also affect their behaviour, which may result in indirect effects on their survival. The following paragraphs consider possible mechanisms for this effect that have been identified in the international literature. Determination of the causal mechanisms that explains the reduction in long-tailed bat activity along New Zealand highways is an important research priority.

Overseas studies suggest the magnitude of the effects of roads on bats may depend on the habitat preferences of the individual species (Kerth and Melber 2009) and their tolerance of light (Lacoeuilhe et al

2014) and noise (Schaub et al 2008; Bennett and Zurcher 2013). It appears that, in general, roads may be more of a barrier to bats which forage close to taller vegetation, such as the short-tailed bat, than those species which forage in open areas such as long-tailed bats (Kerth and Melber 2009). However, roads with low traffic density can act as positive filters to bat movement while high traffic roads are barriers to their movement (Abbott et al 2012, Bennett et al 2013). Zurcher et al (2010) suggested that bats perceive vehicles as a threat and may exhibit predator avoidance behaviour in response to their presence e.g. changing direction quickly in response to a vehicle's approach. The only study of long-tailed bats that has investigated their relationship with noise suggests that they can become habituated to it, but this study specifically addressed aircraft noise (Le Roux and Waas 2012).

Edges are profitable foraging areas for bats due to the relatively high abundance of invertebrates (Pawson et al 2008), protection from wind (Davies-Colley et al 2000), and ease of navigation (Kalcounis-Rueppell et al 2013). However, it is possible roadside sites may become relatively unprofitable foraging areas, because foraging may need to be interrupted by the need to avoid vehicles (Zurcher et al 2010; Bennett and Zurcher 2013), and invertebrates may be affected by anthropogenic noise and light (Morley et al 2014). In Europe, Daubenton's bat (*Myotis daubentonii*) is thought to reduce their foraging activity due to the need to avoid traffic (Luo et al 2015).

The impact of increased light associated with increased traffic rates on long-tailed bats is difficult to predict without further research. This is because overseas research has shown bats can be grouped into two groups: those that avoid artificial light and those that may be attracted to light for foraging opportunities (Lacoeuilhe et al 2014). In the UK, Stone et al (2009) found lesser horseshoe bats (*Rhinolophus hipposideros*) avoided light, while in Canada Furlonger et al (1987) observed other species foraged around street lights.

Lack of response of long-tailed bats at distant sites to traffic intensity could be related to a reduction in traffic noise and light. The rate at which bats turn away from vehicles is thought to be related to both the noise at the location where they encounter the vehicle and the noise of the vehicle itself (Bennett and Zurcher 2013). Bennett and Zurcher (2013) attributed increases in avoidance behaviour by bats to the disturbance threshold (a noise threshold above which bats would be more likely to reverse their route and avoid vehicles) for each species. They found the Indiana bat (*Myotis sodalis*) had a threshold of approximately 88 dBA, although this could vary between species. Research in New Zealand has found noise produced by heavy traffic is regularly equivalent to or in excess of this threshold, although it can vary dependent on both road surface and location (Divett and Cenek 2008). Consequently, it is possible increased traffic volume results in higher road noise, causing bat activity near to a road to decrease. Importantly for this research, Bonsen et al (2015) found all traffic noise above 5kHz was lost within the first 150 metres from a road. This frequency does not overlap with the peak amplitude of long-tailed bats echolocation calls, so traffic noise at distant sites may not affect echolocation. The effects of light are also likely to be reduced at short distances from roads (Altringham and Kerth 2016).

C8 Conclusion

We found long-tailed bat activity on New Zealand's highways to be negatively correlated with night-time traffic intensity. The extent to which this is driven by behaviour versus mortality is unknown, but bat activity at adjacent paired sites, ≥200 metres from highways, showed no relationship with night-time traffic intensity. Whether, or to what extent, reductions in bat activity along highways affects the long-term viability of long-tailed bat populations needs to be assessed urgently. If busy highways are acting as barriers to long-tailed bat populations then they may be fragmenting landscapes and resulting in bat populations becoming isolated from each other. A further important priority is to establish why bat activity is lower in high traffic areas and understanding this will allow effective mitigation methods to be developed.

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Appendix D: Bat management framework for linear transport infrastructure projects

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Contents

D1 Introduction

D1.1 Background

New Zealand has two species of indigenous bat: the long-tailed (*Chalinolobus tuberculatus*) and lesser short-tailed bat (*Mystacina tuberculata*), both of which are of serious conservation concern and are listed as threatened (O'Donnell et al 2013) under the NZ Threat Classification System. A recent study in New Zealand (Borkin et al 2016), along with overseas evidence (see Part 1 of this report, chapter 3), suggest linear infrastructure presents significant risks to bat populations. These potential risks/impacts include the alteration of quantity and quality of available habitat and roost sites, noise and light pollution (from construction and operation), mortality through vehicle collisions, and the fragmentation of local populations through the interruption of flight paths and creation of barriers to feeding and dispersal.

The NZ Transport Agency (the Transport Agency) through their sector research programme has identified the need to develop a national framework that considers and guides management and monitoring of the impacts of linear transport projects on bats. The framework presented here ('this framework') will allow potentially adverse effects of linear transport to be addressed more consistently across New Zealand, following the mitigation hierarchy (avoid-minimise-mitigate) stipulated in the *Proposed national policy statement for indigenous biodiversity* (Ministry for the Environment 2011). This means in the first instance, the effective planning of a linear transport project to avoid disturbing, injuring or killing bats. If alternatives to avoiding options or routes are not possible, then bat populations must be sustained through the project development process via a comprehensive mitigation and/or compensation package.

A precursor to this framework has involved a review of the various approaches used in New Zealand and overseas to locate bats and assess their behaviour around roads, along with a review of the effectiveness of mitigation techniques. This information has been presented in a literature review (see Part 1 of this report, chapters 6 and 7) that provides more specific and detailed supporting information. The literature review also sought to understand the statutory planning processes relevant to the management of impacts on bats from linear transport projects. The information in the literature review underpins the framework, which aims to guide best practice for those dealing with the potential impacts of linear transport projects on bats in New Zealand.

Although this framework focuses on bats, there are common themes, particularly in the statutory processes, that can be applied to interactions between linear transport projects and other indigenous terrestrial vertebrate species. The applicability of the framework to other indigenous vertebrates is considered in section D1.

D1.1.1 Key challenges

The literature review phase of this framework highlighted significant knowledge gaps around the extent to which linear transport infrastructure affects New Zealand bats and the effectiveness of potential methods for managing those impacts. Recent fieldwork undertaken by Wildlands Consultants (Borkin et al 2016) is a first step in addressing these gaps and provides evidence that bats are in fact impacted by roads in New Zealand. However, to what extent and why is still unknown. Where information is lacking on certain topics (ie where there is no supporting scientific evidence) this framework establishes basic principles, drawing on currently available information, recommends processes and outlines priorities for further research.

D1.2 Purpose

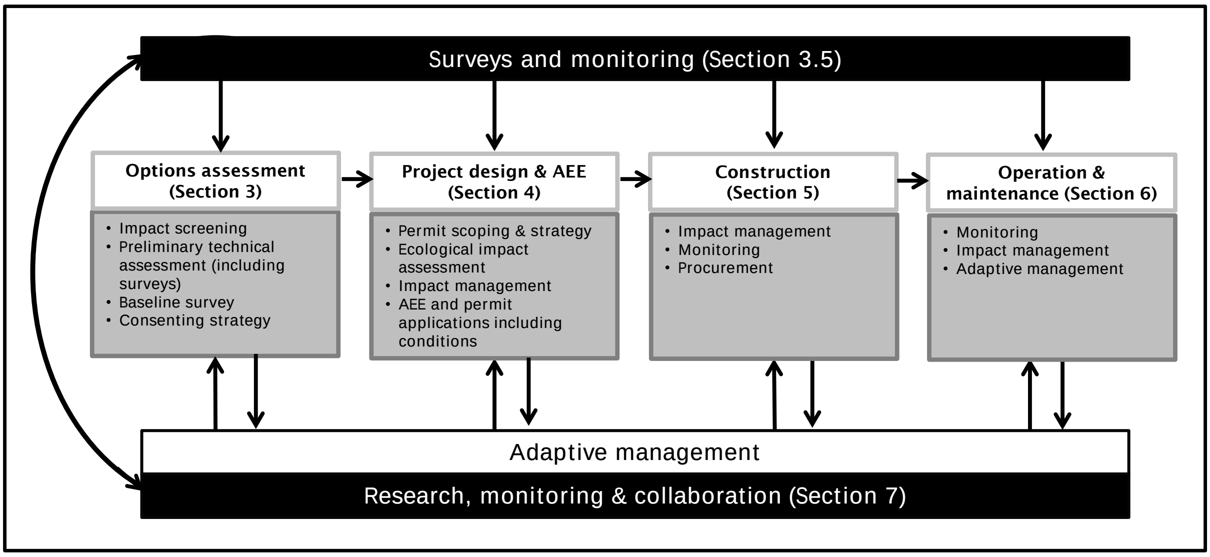
Linear transport projects that potentially affect bats must navigate an impact assessment and environmental permitting process for which there are currently no national standards.

This framework aims to facilitate a consistent and cohesive approach to the planning, designing, constructing and operating of new, linear transport infrastructure projects. It also covers maintenance activities on existing infrastructure in areas inhabited by bats. It brings together current knowledge of bats, including impact assessment, monitoring, mitigation, and management methods and applies the knowledge to the development, delivery and maintenance of linear transport infrastructure. It aims to ensure the effective planning of linear transport projects to avoid/mitigate/minimise and compensate for disturbing, injuring or killing bats.

D1.3 Content overview

The development of new linear infrastructure is carried out in several project phases which involve key decisions that can affect the magnitude of impacts on bats. For this reason, the framework is organised according to the key phases of project development. An overview of the typical project phases relevant to the framework is presented in figure D.1.

Figure D.1 Framework – project phases overview



As shown in figure D.1, some activities such as surveys and monitoring (section D3.5), adaptive management (section D6.4) and research and collaboration (section D7) are applicable across the development of an entire project. Adaptive management is a key component of the framework. Its application will ensure project decisions are based on the best available research and information, backed up by monitoring to measure the effectiveness of any decision that has been made. Adaptive management can be applied both at the project level and across multiple projects.

D1.4 Stakeholders

This framework is a reference document that is accessible to all key stakeholders who are involved in linear transport projects including:

- planners
- project managers
- linear transport infrastructure providers
- engineers
- project ecologists
- environment managers
- contractors responsible for building or modifying linear transport infrastructure
- contractors responsible for ongoing maintenance of linear transport infrastructure
- councils – regional/district/unitary
- DOC staff.

The stakeholders consulted in the development of this framework include: Transport Agency (project managers, planners, environmental specialists); DOC (bat specialists and planners); regional and district council planners and project managers.

D2 How to use this framework

D2.1 Applicability

Although funded by the Transport Agency, this framework can apply to any type of linear transport project/infrastructure that encounters bats. This predominantly means roads (forestry, construction access, state highway and local roads) and rail (passenger and freight). However, due to the current interactions of roading projects and bats, the framework is most closely linked with Transport Agency roading projects. It discusses their well-established project development methods throughout the framework and sets out the applicability of the Transport Agency business case approach (refer table D.1).

This framework is intended to apply to the management and monitoring of long-tailed and lesser short-tailed bats (commonly known as short-tailed bats). In many cases, there may be different requirements for these two species. For instance, O'Donnell et al (2006) found that patterns of habitat use and activity differed between long-tailed bats and short-tailed bats. Most data on New Zealand bats relates to long-tailed bats and for this reason the framework focuses on this species. As such, extra care should be taken when applying this framework to short-tailed bats as even less is known about this species.

D2.2 Framework users

It is recognised this framework will be unable to meet the varied needs of all stakeholders. For this reason, the framework will focus on three key users – project managers, project ecologists/environment managers and project planners (project and statutory). The key actions that should be undertaken at each project phase for each of these users is shown in table D.3.

D2.3 Key references

As shown in table D.1, this framework has (where possible) been aligned with the Transport Agency business case process, the Environment Institute of Australia and New Zealand (EIANZ) ecological impact assessment guide (EIANZ 2015) and the (draft) NZ Transport Agency (2017) ecological impact assessment guide.

DOC has a range of publications available in regards to New Zealand bat inventory and monitoring[13]. These should be consulted in conjunction with this framework.

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[13] www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/bats/

Table D.1 Framework sections and applicability to Transport Agency business case, EIANZ and Transport Agency impact assessments

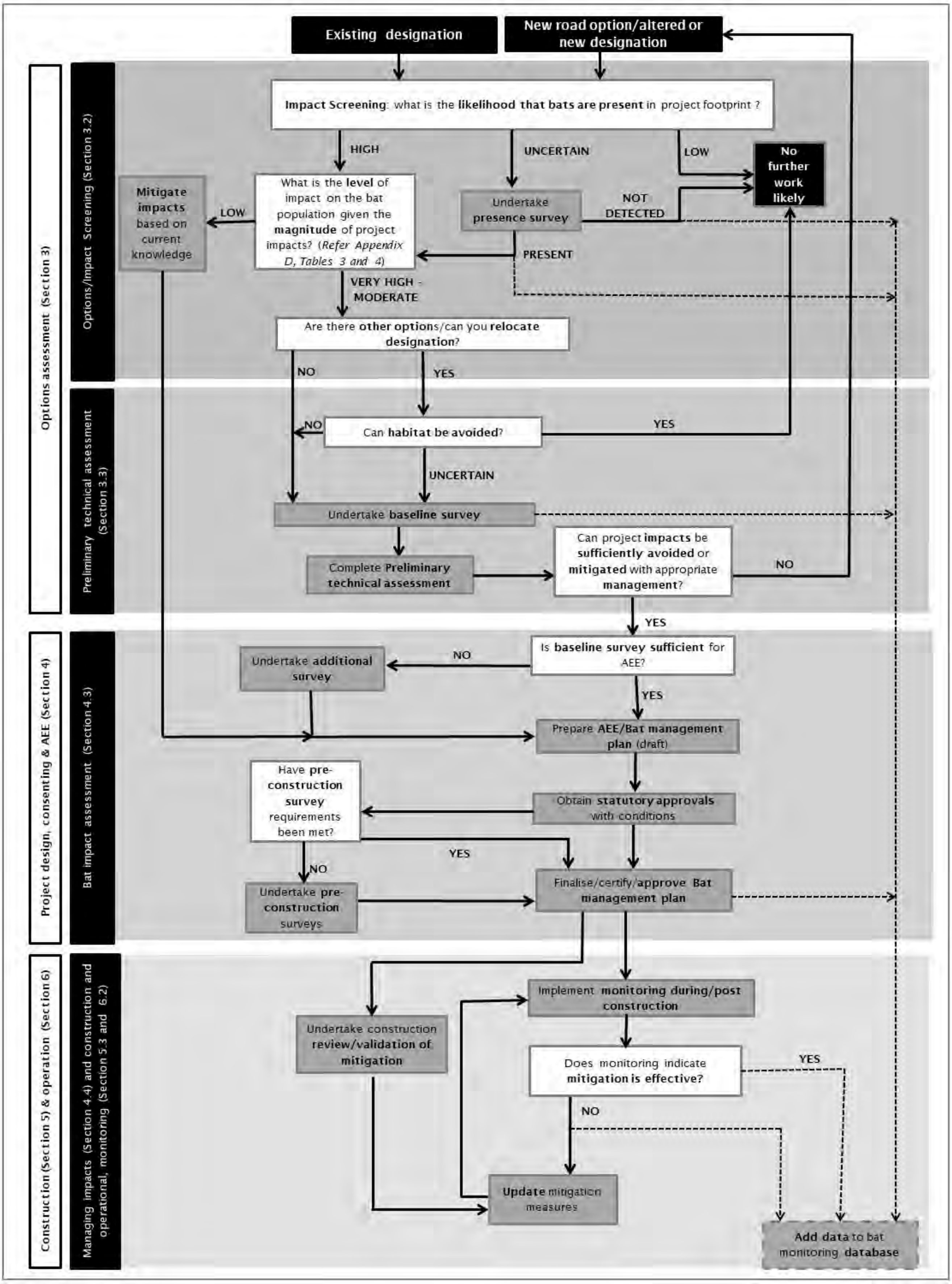
Framework section/project phase	NZ Transport Agency business process	Ecological impact assessment (EIANZ 2015 guidelines)	NZ Transport Agency Ecological impact assessment (2017)
D3: Options assessment	Programme business case development	Screening (for potential ecosystem effects)	Environmental and social responsibility screen
	Indicative business case development	Screening (for potential ecosystem effects)	Environmental and social responsibility screen
	Detailed business case development	Scoping	Preliminary ecological impact assessment
D4: Project design, consenting and assessment of effects	Pre-implementation	Detailed investigations and assessment of actual and potential effects	Detailed ecological impact assessment
D5: Construction	Implementation	Ecological management and monitoring plans (impact management and mitigation)	Ecological impact management Ecological monitoring
D6: Operation and maintenance	Operation and maintenance	Ecological monitoring – operational	Ecological monitoring

D2.4 Framework process

This framework should be utilised and applied throughout the development phases of a project – from options assessment through to project design and assessment of environmental effects (AEE), construction; and finally, operations and ongoing maintenance. It is important that framework activities (ie surveys) are planned far enough in advance for them to be undertaken with sufficient time for completion at the right project phase.

An overview of the framework process is provided in figure D.2. It outlines the key decision points and actions throughout the project phases in order for them to be undertaken in a timely manner and therefore successfully manage impacts on bats. This diagram is a useful reference for all users.

Figure D.2 Framework process



D2.5 Competency guidance

Provision of competent bat ecologists should be considered early in a project and projects need to ensure ecologists are competent for the activity they are undertaking. For larger projects, extensive and complex survey and monitoring operations may be required that need a number of bat ecologists with different skills. As such the services of more than one ecologist may need to be procured to carry out the activities required on a project.

Table D.2 outlines a range of field related competency classes (A, B, C, D and E) in regards to the different bat-related activities required on a linear infrastructure project. Due to the wide range of skill sets of any ecologist, it is possible a range of different classes may be applicable to one ecologist. Guidance is provided on the experience and knowledge required to obtain a specific competency class. DOC is currently developing a certification process for these competency classes.

Class F describes the experience and knowledge required to be competent in a range of office-focused bat-related activities, such as preparing a BMMP or designing a monitoring programme. These activities may be undertaken by an individual or a team of people, who together have the required experience and knowledge specified in the table. DOC is not involved in certification for class F.

When procuring professional ecology services for bat-related work it is important to specify the competency class in procurement documentation. Proof of competencies can be obtained by reviewing curriculum vitae alongside the requirements of table D.2. It is recommended individuals are either certified by DOC for the activity they are carrying out (A–D), or can demonstrate they meet DOC's certification criteria for the relevant class. Contact the DOC's Bat Recovery Group Leader (at the time of writing this is Colin O'Donnell (codonnell@doc.govt.nz)) for further information and/or for a record of individuals currently certified under each class.

Each project procuring ecological services will have unique specialist, planning and legal aspects and these must be considered alongside the competencies described in table D.2. All parties within the project team must ensure their issues or requirements in dealing with bat issues and associated environmental planning and authorisation issues are addressed in the procurement process. It is recommended each organisation dealing with bats has an internal signoff process that ensures this occurs.

Table D.2 Bat competency classes

Class	Key field activity	Competency	Individual experience/knowledge
A	ABMS	• Setting up automatic bat detector monitoring systems (ABMS).	Recent previous experience in installing ABMS in at least 2 comprehensive surveys.
B	Analysing ABMS	• Setting up ABMS, and analysing and interpreting results.	Recent previous experience at analysing and interpreting ABMS results in at least 2 comprehensive surveys.
C1	Identifying bat roosts (short-tailed bats)	• Finding and identifying short-tailed bat roosts that are either occupied or unoccupied. This competency may also include arborists.	Recent extensive experience in searching for and finding active and inactive roosts (by radio tracking, exit observations, and/or visual inspections)
C2	Identifying bat roosts (long-tailed bats)	• Finding and identifying long-tailed bat roosts that are either occupied or unoccupied. This competency may also include arborists.	Recent extensive experience in searching for and finding active and inactive roosts (by radio tracking, exit observations, and/or visual inspections)

Class	Key field activity	Competency	Individual experience/knowledge
D	Handling bats	• Handling bats (in one or more field methods), as outlined in DOC's best practice manual (Sedgeley et al 2012).	Has undertaken field training from a competent trainer demonstrating the required technique to the trainer's satisfaction and meets DOC's best practice manual standards (Sedgeley et al 2012) to carry out *one or more* of the following specialised field methods: • extracting bats from mist nets • using harp traps at roost sites • handling bats • marking bats (eg forearm band, temporary marks) • using wing biopsies for genetic sampling • attaching transmitters • inserting transponder tags • applying release techniques.
E	Trainer for class X	• Competent at the relevant class plus capable of training staff.	• Has a high level of knowledge and experience regarding the competency they are training people in.
F	Bat management	• Survey/monitoring programme design[14] • Survey data analysis and interpretation[13] • Preparation of bat impact assessment reports[13] • Can recommend impact management strategies (eg mitigation) for projects[13] • Prepare, co-author, or certify the appropriateness of BMMPs[13] • Presentation of expert evidence for projects impacting bats.	• Competency in 3 or more of class A/B/C/D activities (field experience relating to competency classes A/B/C/D activities). • Experience writing ecological assessments and/or species restoration or recovery plans. • Thorough knowledge of available bat survey techniques and methodology, and their limitations. • Thorough knowledge of the threats bats face and national recovery actions. • Thorough knowledge of measures to avoid, mitigate or compensate for impacts of infrastructure projects on bat populations. • Understands seasonality and conditions of bat activity, and how these might affect surveys. • Can recognise and articulate how the practical constraints of a survey affect the conclusions in an impact assessment. • Understand the importance of sampling design and sample size (effort) in determining whether monitoring results will have sufficient statistical power to detect changes in the variable of interest.

D2.6 Information gaps

Information gaps identified within the framework will help to guide future research or development of process. These information gaps/priority actions are summarised at the end of each section of the

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[14] May be undertaken by individuals or a team which collectively has these competencies

framework. In some instances information gaps may need further definition or may be partially completed. This information should be used as a starting point to guide framework stakeholders (refer section D1.4) on where to focus their efforts for future research. It is anticipated the framework will be a living document, updated with results obtained from research and project experience.

D2.7 Key actions

Table D.3 provides a useful summary of the framework contents, outlining likely outputs for a linear transport infrastructure/project where bats are likely to be present. The table identifies the key actions (for each user), responsibilities and associated inputs to achieve framework requirements at each project phase.

Table D.3 Framework summary

Output/phase	**FRAMEWORK PURPOSE:** **A consistent approach is used to assess, mitigate and monitor impacts on bats**				
	Key actions	**Key role**			**Inputs**
		PM[1]	**PE[2]**	**PP[3]**	
Section D2: How to use this framework					
Provision of competent ecologists (section D2.5/table D.2)	• Use people with appropriate ecological and statistical skill sets to plan, design and conduct bat surveys or other bat ecological work required for project.	√	√		• Training as required
Section D3: Options assessment					
Impact screening of options (section D3.3)	• Determine presence of bats in option area so habitat can be avoided where possible	√	√		• Desktop review • Presence survey (if required)
Assess/select/discard options (section D.3)	• Consider magnitude and level of potential impacts on bats from options	√	√	√	• Option details • Existing knowledge of bat presence and/or results of presence survey • Existing knowledge of potential impact from project on bats.
Surveys and monitoring (section D3.5)	• Ensure survey and monitoring provides the information needed to assess impacts and the effectiveness of mitigation		√		• Previous survey information • Provision of suitable number of competent ecologists (refer table D.2 of this framework) • Well-designed survey (meets requirements of annex DA: General survey design principals)
	• Ensure data collected complies with data collection standards in annex DA (General survey design principals)	√	√		
Baseline survey (section D3.5.1)	• Establish the pre- or before-implementation conditions of the ecological or species-specific variables of interest. Identifying: • key bat resources, such as roosts, foraging habitats • bat activity patterns in and around those resources		√		• Previous survey information • Provision of suitable number of competent ecologists (refer table D.2) • Well-designed survey (meets requirements of annex DA: General survey design principals) – preferably using before-after-control-impact (BACI) design to assess impacts or mitigation.

Output/phase	**FRAMEWORK PURPOSE:** **A consistent approach is used to assess, mitigate and monitor impacts on bats**				
	Key actions	**Key role**			**Inputs**
		PM[1]	**PE**[2]	**PP**[3]	
Bat preliminary technical assessment (section D3.6)	• Identify potential impacts on bats from different options		√		• Habitat description • Baseline survey methods and results • Potential impacts of the alternative solutions to the transport problem
	• Use bat PTA for decision making about the route choice and design	√			
	• Use bat PTA should to inform procurement and budgeting requirements for the next phases of work	√			
Preliminary planning assessment (section D3.7)	• Identify permits required			√	• Bat preliminary technical assessment (PTA) as part of the preliminary EcIA • RMA requirements • Wildlife Act requirements
	• Identify information required to support each permit application				
	• Identify data gaps and how these will be addressed through procurement of the next phase.	√	√		
Section D4: Project design (preliminary design consenting and assessment of environmental effects)					
Permit review (section D4.2)	• Confirm permit requirements			√	• RMA requirements • Wildlife Act requirements • Bat competency table (refer table D.2 of this framework) • Bat PTA including baseline survey results
	• Scope and procure professional services for bat impact assessment.	√			
Project planning timeline (section D4.2.3)	• Allow time in project timelines for fieldwork	√			• Bat PTA including recommendations for further monitoring • Understanding of bat life history traits
Bat impact assessment (section D4.3)	• Provides the information necessary for environmental permits to be issued without unnecessary delay		√	√	• Bat PTA • Previous surveys (presence, baseline) • Suggested conditions of consent/permit • Guidance from annex DD of this framework
	• Provides information to help detailed design minimise impacts	√			
Managing impacts (planning of mitigation) (section D4.4)	• Use bat life-history to guide selection of mitigation		√		• Bat impact assessment • Understanding of bat life history traits
	• Liaise with wider project team on design and		√		• Other environmental assessments

Output/phase	**FRAMEWORK PURPOSE:** **A consistent approach is used to assess, mitigate and monitor impacts on bats**				
	Key actions	**Key role**			**Inputs**
		PM[1]	**PE**[2]	**PP**[3]	
	mitigation options				
	• Ensure monitoring is in place to measure impacts and effectiveness of mitigation	√	√		• Bat impact assessment • BMMP including monitoring requirements
Environmental permit applications (section D4.5)	• Prepare RMA and Wildlife Act applications including Assessment of Environmental Effects and suggested conditions of consent (annex DH)			√	• Bat impact assessment • Suggested conditions of consent/permit • BMMP
Section D5: Construction (including detailed design)					
Procure construction and detailed design services (section D5.2)	• Incorporate preconstruction monitoring in project scope/timelines • Ensure responsibilities for managing impacts/overseeing mitigation on bats are clear	√ √			• BMMP including monitoring requirements • Conditions of consent/permit • Mitigation designs
Management of construction impacts (section D5.3)	• Manage construction impacts • Ensure mitigation is constructed as designed	√ √	√ √		• BMMP • Advice from bat ecologist • Mitigation designs
Construction monitoring (section D5.4)	• Undertake construction monitoring to measure impacts and determine effectiveness of construction mitigation	√			• BMMP
Section D6: Operation and maintenance					
Operational monitoring (section D6.2)	• Procure and implement post-construction monitoring	√	√		• Permit conditions • BMMP • Previous survey results
Maintenance works (section D6.3)	• If bats are present in the work area prepare a Bat management and monitoring plan				• Carried out desktop review • Presence survey (if required)
Adaptive management (section D6.4)	• Collect and share project data for use by other projects in accordance with data collection standards in annex DA.	√	√		• Monitoring results • Research

Output/phase	**FRAMEWORK PUSPOSE:**				
	A consistent approach is used to assess, mitigate and monitor impacts on bats				
	Key actions	**Key role**			**Inputs**
		PM[1]	**PE**[2]	**PP**[3]	
Section D7: Research and collaboration					
Research and collaboration (sections D7.3 and D7.4)	• Undertake research	N/A	N/A	N/A	• Monitoring results • BMMPs • Working group guidance (refer section D7.3 of this framework)

1= Project manager

2 = Project ecologist

3 = Project planner

D3 Options assessment

D3.1 Introduction

Linear transport projects are initiated usually because of a strategic planning process or the identification of a specific transport problem. This usually starts with a consideration of options. This section of the framework covers the steps that should be followed from project initiation through to selection of the preferred option or route (refer figures D.1 and D.2). The Transport Agency refers to this as 'project development', encompassing the programme, indicative and detailed business case phases (refer table D.1).

Early identification of ecological risks during the planning and options/alternatives assessment phase of project development can help avoid impacts and improve environmental outcomes. As such, a preliminary assessment of impacts (including presence and/or baseline surveys) for bats should be undertaken as early in the project development stage as possible. Additionally, project risk registers should reflect identified ecological risks associated with each project phase. The process for undertaking a preliminary ecological impact assessment along with survey design principals is described in this section.

D3.2 Avoidance

Long-lived, slow-breeding species such as bats tend to be less resilient to environmental changes than short-lived rapid breeders. Avoidance is the only proven method to ensure a project does not impact on bats. It is most straightforward to avoid impacts during the options assessment stage of a project by avoiding bat habitat. Avoidance should continue to be considered throughout the life of a project. If alternatives (options, routes, timings) are not possible, then bat populations must be sustained through the project development process via comprehensive mitigation and/or compensation packages.

D3.3 Impact screening

During the options assessment project phase a high-level screening of potential environmental and social impacts of different options should be undertaken (also referred to as ecological constraints, tier 1 impact assessment, strategic impact assessment). The results of this impact screening will help determine which option or options should be pursued. The Transport Agency has developed a tool to provide a consistent approach to the early identification of environmental and social risks during the development of investment cases for new transport infrastructure[15]). Determining the presence of bats should form part of this screening process.

D3.3.1 Desktop review

The first step for determining whether bats are present within a proposed option is a desktop review. This should include a review of historical records and bat presence databases (refer section D7.2) followed by an assessment of the likelihood that ecological features in the project area, ie habitats may be used by bats (refer figure D.3).

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[15] www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/environment-and-social-responsibility/national-standards-guidelines-and-specifications/esr-screen/

Figure D.3 Likelihood of presence based upon ecological features within an area

Likelihood of presence: Low ↕ High	• A bare field with no features that could be used for roosting, foraging and dispersal such as canopy, gullies or water courses • Habitat containing some features of potential use for bats – trees with hollows, peeling bark, drainage features, but not connected to known occupied habitat or potentially suitable habitat; • Location within the recorded distribution of long-tailed and/or short tailed bats and: • Isolated habitat with specific features that could be used by bats • Habitat adjacent or connected (via linear features such as hedges, watercourses, shelter belts) to potentially suitable habitat • Habitat adjacent or connected (via linear features such as hedges, watercourses, shelter belts) to potentially suitable habitat • Habitat adjacent to habitat where bats have been recorded previously.

Based on the outcome of the historical records and desktop review, recommendations can be made as to whether a bat presence survey is required.

No presence survey recommended

- Where the historical records and desktop review (refer figure D.3) indicate a low likelihood of presence, no further survey is recommended.
- If the likelihood of presence is determined to be sufficiently high from the historical records and desktop review (refer figure D.3), and it can be assumed bats are present, then a presence survey may not be required. Opportunities to avoid habitat should be considered (ie are there other options/can designation be relocated?). If the option is pursued and habitat cannot be avoided, baseline surveys could proceed without a presence survey being undertaken.

Presence survey recommended

- If likelihood of presence is determined to be high from a desktop review (refer figure D.3), and no survey information is available, a presence survey is recommended (refer section D3.3.2).
- Where historical records and the desktop review (refer figure D.3) do not indicate with certainty whether bats are present, further questions need to be asked and may include:
    - Has the habitat changed substantially since the survey was undertaken (ie removal of trees)?
    - Were the original survey methods appropriate and designed robustly (ie valid) (refer annex DA)?
- If the surveys were not recent or did not use appropriate methods, a presence survey should be undertaken of at least high-risk areas (refer figure D.3).

D3.3.2 Undertake survey for bat presence

If the desktop assessment undertaken in section D3.3.1 has highlighted the need for a presence survey, then these would most likely be undertaken using acoustic survey methods with ABMs. Section D4.5 and annex DA should be consulted for more detailed guidance on survey scope and design. It should be noted that recording the number of bat calls using ABMs can only provide an index of activity because the number of bat calls does not necessarily correlate with the number of individual bats encountered. Therefore, relative abundance can only be estimated coarsely if using ABMs for presence surveys; eg commonly detected, uncommonly detected, and rarely detected (Sedgeley 2012b).

D3.3.3 Assess options

If there is any detection during presence surveys, or a record of bats within the vicinity of a project footprint, it is prudent to assume that bats are likely to use the project footprint at least occasionally. During the options impact screening stage of the project it is important to consider the potential magnitude of impacts on bats from the project (refer annex DD, table DD.2). A range of transport options may be available, and an alternative route or transport option should be considered that does not affect an area of known bat inhabitation directly if the level of impacts are considered significant (refer annex DD, table DD.3). Reasons for not avoiding bat habitat should be well documented (ie options assessment report). Transport options with significant effects on the environment or which potentially disturb or kill bats, will be at risk of not obtaining approvals (resource/designation and/or wildlife permit)) from the statutory authorities (refer section D4.2 for further discussion).

In some cases, options impact screening may be based upon a reliable existing knowledge of bat presence and as such no survey work would be required if the area was avoided.

D3.4 Preliminary technical assessment

D3.4.1 Purpose and objectives

During detailed options assessment or early design development of a linear transport project, a preliminary or broad assessment of potential impacts of the project is usually undertaken, depending on the nature and scale of the project, and the ecological risks identified during impact screening (section D4.3). For maintenance works a similar assessment is required (refer section D6). The Transport Agency refers to this as a 'preliminary ecological impact assessment' (preliminary EcIA) which is undertaken during the detailed business case phase, but this is sometimes referred to as scoping. Scoping is defined in Environment Institute of Australia and New Zealand (EIANZ) *Ecological impact assessment (EcIA*) guidelines (EIANZ 2015) as:

> *The process of determining the broad type and nature of biodiversity and ecological features, and the potential effects of a project or development. These guide the appropriate scale and scope of further investigations, project development, impact management, and monitoring which will make up the full ecological impact assessment.*

If bats have already been confirmed in the area or the presence of bats is likely, it is recommended further bat ecological field work is undertaken, described as a bat preliminary technical assessment (bat PTA) and reported as part of a preliminary EcIA. This is most likely to take the form of the baseline survey which is discussed in further detail in section D3.5. As field work can take some time to complete and may only be possible at certain times of year (eg November to April), it is important the bat component of a preliminary EcIA (the bat PTA) and associated field work is planned early in project development. This can help inform a decision to avoid significant ecological features, thereby avoiding impacts and saving money on mitigation/compensation. However, the ability to influence the route (and thereby avoid impacts) may be limited for projects where the scope and location for transport options are narrowed within early project development, eg where all the options being considered traverse bat habitat.

Table D.4 provides examples of the types of questions that may require answering as part of a bat PTA and the complexity of field work required to answer them. It also outlines the types of questions that cannot be answered at this stage of the project.

Table D.4 Example preliminary assessment questions and their relationship to field survey methods

Less complex field methodology required ↕ More complex field methodology required	• What habitat features are present in the study area that may be used by bats and where are they located? • What habitat features are being used by bats? • Do bats use X or Y area for foraging? • Do bats fly through this area? If so, at what exact location and at what height? • Are there bat roosts in the study area? • What are the potential impacts of project x on bat activity? • How is development option x likely to affect bats compared to Y option?
Not likely to be able to be answered at this stage of project development. Inferences based on best available data need to be made[16]	• Are impact management methods available for each option going to be successful?

The exact objective of a bat PTA will depend on the nature of the project, how developed the project is, how much is already known about the local bat population, and whether the project has an overarching ecological strategy[17]. It is essential that the purpose of the bat PTA and ecological objectives of the project are established prior to any field work taking place.

Annex DB contains some examples of bat PTA objectives and their effects on the scope of a bat PTA(including field work). Field work will almost always be required to meet the purpose and objectives of the bat PTA. The field work component of the bat PTA is discussed in section D3.5.

D3.5 Surveys and monitoring

D3.5.1 Baseline survey

Baseline field work surveys or monitoring at the early stages of project development are necessary to:

- gather data on bats, their habitat and behaviour, so that this information can be considered when assessing planning options and the design process
- establish the baseline conditions for future monitoring (including pre-construction if option proceeds). These can be defined as, ‘collecting information and describing the ecological conditions in the absence of the proposed project, to inform the assessment of impacts’ (CIEEM 2016).
- identify frequently used habitat by bats in order to avoid it during route selection.

For the purposes of this framework, field work undertaken at this stage of the project should be based on evidence of whether bats are likely to be present (refer section D3.3), and is referred to as a ‘baseline survey’. Elsewhere this stage of survey may be referred to as baseline ecological surveys/preliminary ecological surveys/phase 1 habitat surveys/ site assessment, or ecological scoping survey, among others

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[16] To build up the body of knowledge we have regarding bats, the effects of roads and effectiveness of mitigation measures must be considered. For knowledge gaps to be filled and questions answered we need to ensure robust efforts are made to measure the changes and impacts that occur within bat populations during construction, and after a project has been implemented. This means ensuring baseline data is collected and that any possible changes within populations are measured through continual monitoring after the project has been implemented. As more hypotheses are tested using robust monitoring, more informed inferences about likely impacts and bat behaviour can be made.

[17] An overarching ecological strategy is one that has aims for the project that encompass a range of ecological features.

(CIEMM 2016). Whatever the term used to describe the field work, the objective(s) of the field work must be clear (annex DA should be consulted for more detailed guidance on baseline survey scope and design).

Along with baseline surveys, there are several reasons that field surveys and monitoring of bats may be required during the life of a linear transport project. It is important to ensure project timelines make allowances for undertaking these surveys.

Surveys should be designed to provide a sufficient baseline and ongoing data for accurate estimation of the effects of development, management activities and mitigation measures. If surveys and monitoring programmes are not designed properly, they impose an additional cost from which little benefit will be derived, and the uncertainty created by weak data may lead to drawn-out resource consent decision-making processes.

This section outlines the basic requirements for all bat field surveys (including baseline) and will cover survey scope (including timings) and general design principles. They are guidelines based upon current best practice in New Zealand and should act as a starting point when planning bat surveys and monitoring methods.

D3.5.2 Baseline field methods

Annex DC presents a range of example questions that can be used to determine which field methods are required and which aspects of bat ecology require surveying. This may include the identification of bat roosts or flight paths. However, depending on the scale and nature of the project, baseline surveys conducted to support options assessments and preliminary impact assessment, should in most cases include at least the following objectives:

- Identify key resources, such as roosts and foraging habitats, so these can be avoided. Survey methods would most likely require radio-tracking or thermal imaging (refer annex DA for further information on survey design).
- Characterise bat activity patterns in and around those resources to predict the likely impacts of the road's development and influence options assessment and early design.
- Collect 'before' baseline data so it can be used in a before-after-control-impact (BACI) design to assess impacts or mitigation.

D3.5.3 Survey scope

A well-planned survey will benefit a project by reducing potential costs, delays and overall uncertainty. Additionally, this will ensure the resource consent decision-making process is more streamlined.

The scope of field work should consider the following factors:

- intended timing for project implementation
- likelihood of project location and/or option and/or designs changing
- availability of resources
- scale and budget of project
- seasonality for species surveyed.

Surveys will be required at different stages of the development of a linear transport project, including during project development, route location and pre-, during and post-construction, when infrastructure is in use. Field work surveys and monitoring timeframes must be aligned with both the seasonal behaviour of bats along with project development. Surveys are only recommended when bats are active (ie November – April) and so surveys must be planned well in advance. Table D.5 outlines the possible different bat field work requirements that will need to be planned for at different stages of a linear transport project.

BACI design provides the most robust results when undertaking monitoring that aims to answer specific questions (Roedenbeck et al 2007).The 'before' (pre-construction baseline) and 'during/after' (construction or post-construction) states of a variable are compared, both at an 'impact' site (where an intervention is to take place) and at a 'control' (reference site). It is recommended the extent of any monitoring programme should be planned using power analysis (in consultation with a bio-statistician). This is a statistical method that addresses the question of how much monitoring effort is required to be reasonably sure that a real effect or difference can be detected over and above normal 'background' variability in the measure of interest.

Table D.5 Field work scope requirements at different project phases

Framework section/ project phase	Framework survey type[18]	Field work purpose	Transport Agency phase
Options assessment (section D3)	Presence survey	• Determine likelihood of bat presence in area • Input into NZ Transport Agency environmental screen/options shortlisting (risk management) • Add to body of knowledge of species' distribution/ habitat preferences • Enable bat habitat to be avoided	Indicative business case development
	Baseline survey	• Establish baseline conditions: describe important ecological features; distribution and habitat use by bats so impacts on these can be avoided or minimised. • Help identify important locations for bats, eg flight paths • Gather information to undertake a preliminary ecological impact assessment. • Minimise impacts on bats.	Detailed business case development
Project design, consenting and assessment of effects (section D4)	Detailed survey	• Update baseline survey information if required. • Collect 'before' data to compare with 'after' to allow assessment of impacts and/or mitigation. • Identification and evaluation of ecological resources and features likely to be affected by project. • Determine location and outline design of mitigation measures, eg to maintain flight paths • Predict and characterise impacts of project, eg lighting and noise • Recommend consent conditions	Pre-Implementation
Construction (section D5)	Monitoring	• Collect pre-construction baseline data (utilising baseline survey data where available and applicable) • Measure construction impacts • Determine effectiveness of construction mitigation • Compliance with consent requirements	Implementation

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[18] Surveys should utilise data from previous survey phases where available and build upon information gained.

Framework section/ project phase	Framework survey type[18]	Field work purpose	Transport Agency phase
Operation and maintenance (section D6)	Monitoring	• Measure impacts of project • Determine effectiveness of operational mitigation • Post-construction monitoring	Operation and maintenance
Research (section D7)	Research	• Refer section D7	All phases

D3.5.4 General survey design principles

The Australian government’s guidelines for surveys of indigenous bats (Department of the Environment, Water, Heritage and the Arts 2010) provide some useful general advice on survey design and implementation. These should be considered when planning all bat surveys and can be summarised as:

1 Confirm survey area and identify likely target species

2 Determine optimal timing for surveys

3 Establish survey design, methods and effort

4 Select appropriate personnel to conduct survey

5 Document survey results

6 Make survey data available for future reference.

Further detail on these survey design principals for New Zealand bats is provided in annex DA.

D3.6 Bat PTA and baseline survey reporting

Once all field surveys are complete, the findings should be provided in a report.

The draft Transport Agency (2017) ecological assessment guidelines provide an overview of what should be covered in preliminary EcIA reports. Reporting will reflect the objectives and scope of the overarching preliminary EcIA, specific details for a bat PTA are detailed in annex DB.

The bat PTA should be utilised for further decision making about the route choice and design and if it is likely that project impacts on bat populations can be mitigated. Ultimately, impacts should be avoided in the first instance. The bat PTA should also be used to inform procurement and budgeting requirements for the next phases of work.

D3.7 Determine what permits may be required

A preliminary planning assessment (ie consenting strategy) of the relevant environmental statutory framework will help identify what permits may be required and the information required to support each permit application. This assessment may be updated during preparation of the project AEE (refer section D4), once a route option is confirmed.

The Transport Agency requires that a ‘consenting strategy’ is prepared during project development (detailed business case and pre-implementation phases). The purpose of the consenting strategy is to identify the project's permitting and consenting requirements under key legislation and to evaluate the consenting package options and different decision pathways[19].

Key legislation governing the protection and conservation of wildlife in New Zealand (including bats) are the:

- Resource Management Act (RMA) 1991
- Wildlife Act 1953
- Conservation Act 1987 (NZ Government 1987).

These are discussed in the further detail in Part 1 of this report.

Where bats are known to be present, or are likely to be present in the project area, and potential impacts on them have been identified through the preliminary EcIA and supporting bat PTA, approvals will be required under the RMA 1991 and the Wildlife Act 1953. Concessions under the Conservation Act 1987 are only required if the project is located on land which passes through, or is adjacent to, conservation land and are not discussed further in the framework. Concession applications would require similar levels of detail and the process described in this framework would still apply.

D3.8 Information gaps/priority activities

Information gaps and related priority activities relevant to this phase of the project are described below (table D.6). In some instances information gaps may need further definition or may be partially completed. This information should be used as a starting point to guide framework stakeholders (refer section D1.4).

Table D.6 Information gaps and priority activities relevant to the options assessment phase of a project

Information gaps	Priority activity	Time frame
Transport Agency business case ecological risk assessments not clear during each phase.	Provision of tools and a process for assessing bat risk and route avoidance at Transport Agency business case phases (particularly the programme phase).	Short
No established or accepted bat presence survey protocol for New Zealand on infrastructure projects.	Develop standardised survey protocols for New Zealand that have the ability to reliably determine bat presence or investigate the use of the DOC inventory and monitoring toolbox for guidance (Greene and McNutt 2012)	Short
No established or accepted bat survey protocols[20] (including agreed climatic survey conditions) for New Zealand that have the ability to monitor bat species' distribution, activity and abundance around linear infrastructure, before, during and after development.	Develop standardised survey protocols for New Zealand that have the ability to monitor bat species' distribution, activity and abundance around linear infrastructure, before, during and after development. These should include specific guidelines, based on research into the interaction between bat activity and localised weather and other environmental conditions, to determine whether surveys have taken place under suitable conditions.	Short
No established, accepted or scientifically tested roost	Undertake research into the ability of current roost-identification protocols to detect roost presence reliably.	Short

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[19] www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/consenting-and-consent-compliance/

[20] DOC has a number of inventory and monitoring toolboxes but these are not specifically designed for measuring the impacts of linear transport projects.

Information gaps	Priority activity	Time frame
identification protocol, apart from capture and radio-tracking.	Develop and test a scientific and standardised method to identify roosts that is an alternative to radio-tracking.	
Information on bat data is not collated and available for use in future projects or research by a sole agency. Comprehensive bat distribution data for all regions is unavailable.	Development of a national system or database that allows for the collection and storage of data that can be used to add to body of knowledge of species distribution/habitat preferences. Work with DOC to bring bat data together and be accessible.	Short
Inability to rely upon bat 'absence' data.	Research into the probability of inferring absence given a certain level of survey effort.	Medium
Lack of New Zealand wide data on habitat variables that predict bat presence/activity.	Undertake research and produce New Zealand wide model to infer the likelihood of presence (foraging and roosting) to local habitat types/characteristics. This may involve the use of previously collected data from throughout New Zealand. Models may need a regional component.	Medium

D4 Project design, consenting and assessment of environmental effects

D4.1 Introduction

This section discusses the steps to be taken once a preferred option has been selected and a project has received funding (for at least preliminary design and statutory approvals). During this phase, the transport solution is designed and environmental permits[21] sought. To support permit applications, a project AEE will be prepared based on the results of a number of specialist impact assessment reports, including a bat or ecological impact assessment report.

For the Transport Agency, a project will move from the 'detailed business case', when a consenting strategy is prepared, through to the 'pre-implementation phase', where permits are applied for.

Further changes to the project route or significant changes to alignment to avoid impacts are unlikely as these would have been considered during the options assessment phase. During this phase specialist impact assessments must identify opportunities to manage effects (which may include minor adjustments to the alignment) and which should be reflected in the proposal and/or proposed conditions, eg construction methodologies and timing.

D4.2 Environmental permit requirements

An updated consenting strategy (refer section D3.7) should be produced that includes a statutory planning assessment to identify potential environmental permit requirements and the likely supporting technical assessments. The strategy will consider the project statutory approval options and risks to determine the recommended project approval pathway (refer to the Transport Agency Consenting Strategy Approvals and Pathways Guide, 2013 for further information). Where bats are confirmed to be present in the project area, the consenting strategy should highlight (among other things) the uncertainties associated with mitigating impacts on bats.

Conditions of RMA or Wildlife Act approvals are legally binding, and through stipulation within contract documents, become part of detailed design and construction contracts. Where possible it is recommended to apply for all statutory applications (including wildlife permits or DOC concessions) simultaneously (or in close succession) to minimise the prospects of unreasonable and conflicting conditions and compliance obligations (a set of model consent conditions is provided in annex DG). Where this is not possible, it is important to have oversight to ensure consistent and complementary outcomes. Depending on the status of the activity for which approval is being sought, if actual or potential impacts on bats are determined to be too high, then permits may not be granted by the approving authorities (regional/territorial councils and DOC).

D4.2.1 Specify the scope of supporting documentation

Following the identification of the necessary project authorisations, the scope and detail of the supporting technical assessments are developed. At this time pre-application meetings with the regulatory authorities (including separate consultation with DOC) are likely to be beneficial in agreeing the approach and/or detail of supporting technical assessments.

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[21] For the purposes of the framework, environmental permits include statutory approvals required under the Resource Management Act 1991 and the Wildlife Act

The timing of field work (season and duration) needed to meet the impact assessment requirements should be considered and included in the environmental permit scoping document. A competent bat ecologist (refer table D.2) should assist with this task.

The following sections describe particular scoping requirements for RMA permits and Wildlife Act permits relating to bats.

D4.2.2 RMA resource consent and designation application requirements

Parts 6 and 8 and schedule 4 of the RMA state the information requirements for a resource application and designation process, respectively. Collectively these stipulate the content of the project AEE required to support any RMA approvals sought.

A key component of the consideration of consents and designations applied for under the RMA is whether the actual and potential adverse effects of the proposal on bats are avoided, remedied or mitigated and to what level. Inherent in this assessment is the need to have sufficient reliable knowledge and information about the effects being considered and the likely effectiveness of any mitigation methods.

The scope of the bat assessment completed to support the project AEE scope should take into account:

- wider project ecological objectives[22]
- the field work required to assess the actual and potential effects on the environment and how long this will take in relation to desired permitting milestones
- the competencies and skills of the ecologist undertaking the bat impact assessment and supporting field work
- how the bat ecologist should interact with other specialists, particularly landscape architects and other ecologists. This is particularly important when impact management is being considered.

Relevant parts of regional and local planning documents that should be considered by the bat ecologist may include:

- maps and/or schedules of areas of ecological value, and the rules associated with these; particularly vegetation rules
- biodiversity offsetting policy(ies)
- interpretation and application of section 6(c) of the RMA and whether specific assessment or criteria are given that will be used to assess an application
- vegetation removal planning rules and how these will have to be addressed through permit application.

To provide the appropriate level of detail for supporting AEEs, field work will be required.

D4.2.3 Wildlife Act permit requirements

The Wildlife Act is administered by DOC and deals with the protection and control of wild animals and the management of game. Bats are absolutely protected under the Wildlife Act. Permits are required for a number of activities including:

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[22] The NZ Transport Agency requires projects to consider and develop strategic objectives in respect to environmental issues (assessment and management) responding the local situation and requirements. This will provide direction for projects to undertake work in a targeted way towards identified outcomes.

- catching, handling and releasing wildlife at one site
- disturbing, injuring or killing wildlife or their eggs
- catching wildlife in the wild and moving them to another wild location into which they are released.

Therefore, to undertake field work using methods that include catching, handling and releasing bats, a wildlife permit must be authorised by DOC. In some cases, a research or collection authorisation may also be required. Surveys that involve the use of ABMs, hand-held bat detectors or count surveys away from the roost site will not require a wildlife permit.

It should also be noted an animal ethics approval may be required for any project involving the manipulation of animals that does not constitute routine species management. This may include banding bats or inserting passive integrated transponder (PIT) tags. If applicants are uncertain whether they need to apply they should contact the current chair of the Animal Ethics Committee via DOC's National Office. Reporting of accidental or incidental death or injury is also required under the Wildlife Act.

Disturbance is not defined in the Wildlife Act. However, the following interpretation is applied by this framework as it relates to the construction of linear infrastructure projects passing through bat habitat:

> *New linear infrastructure projects that may knowingly or unknowingly disturb habitat in a way which disturbs one or more individuals, or have the potential for accidental killing because of habitat destruction.*

In practice, this means projects that are likely to disturb or remove active roosts will require a permit. The permits may have conditions that relate to the operational phase of the project up to a specified time limit. The Wildlife Act does not prescribe the details required in an application in the same detail as the RMA, although DOC (who approves permit applications) has developed some permit application guidance[23]. Permit applications should include the identification of which, if any, roosts are going to be disturbed during the project (ie as part of baseline surveys) or include a methodology for identifying roosts prior to vegetation clearance activities. In addition, DOC requests that applications include:

- the activity being carried out and its purpose
- threat classification of the species (if relevant)
- activity timeframes
- land access
- effects of the proposed activity at the site, including effects on the target species, other indigenous species and the ecosystems at the site
- where adverse effects are identified, what methods will be used to manage those effects?

In order to facilitate the wildlife permit process, it is recommended competency classes (refer table D.2) for bat ecologists are confirmed prior to any bat-related work. These should be discussed with DOC as part of the wildlife permit application process (if not previously done).

There are similarities between the RMA and wildlife permit application information. As such, the permits should be prepared together using the same information sources.

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[23] www.doc.govt.nz/get-involved/apply-for-permits/application-forms/

D4.2.4 Timeline

The final output of the consenting strategy should include a timeline indicating the likely time required for gathering data to support the AEE/wildlife permit and any other preconstruction monitoring that may need to occur prior to procurement and/or construction. This information should have been included in the bat PTA. If not, an ecologist should be consulted to help estimate the timeline.

D4.3 Bat impact assessment

> *Ecological Impact Assessment (EcIA) is an independent, stand-alone, and specific scientific process for identifying, quantifying and evaluating the potential impacts of defined actions on ecosystems or their components; and provides a scientifically defensible approach to ecosystem management in the context of development* (EIANZ 2015, p10).

This section provides guidance on how bat impact assessments (bat EcIA) should be carried out to support the environmental and planning permits required. This section draws on the principals in the *Ecological impact assessment* guidelines (EIANZ 2015) and in NZ Transport Agency (2016) and applies these to bats. It is understood these guidelines will be revised and finalised (respectively) in 2017, so should be rechecked for consistency.

D4.3.1 Potential impacts on bats

If avoidance of an impact is not possible, impacts must be described and assessed to predict the likely severity of effects on bats. Subsequently, the types of mitigation and remediation actions that will be required to reduce these effects will need to be defined. Both direct and indirect impacts and their spatial and temporal distributions should be considered. Potential mechanisms through which roads may affect bat populations may include the following direct impacts:

- roost loss through clearance of roost trees
- loss of foraging habitat
- mortality due to collisions with vehicles, particularly where bats cross roads. Also, increased collision with vehicles due to creation of increased habitat edge. Some species of bat, particularly long-tailed bats in New Zealand, utilise habitat edges for foraging. Increased foraging activity along road verges may increase their risk of mortality through vehicle collisions
- behavioural avoidance of roads that may lead to long-term isolation of individual bat populations and subsequent increased risk of extinction through stochastic (chance) events
- habitat loss, fragmentation or alteration through removal of vegetation, increased light and noise, and physical severance of flight paths.

This may in turn lead to the following indirect impacts:

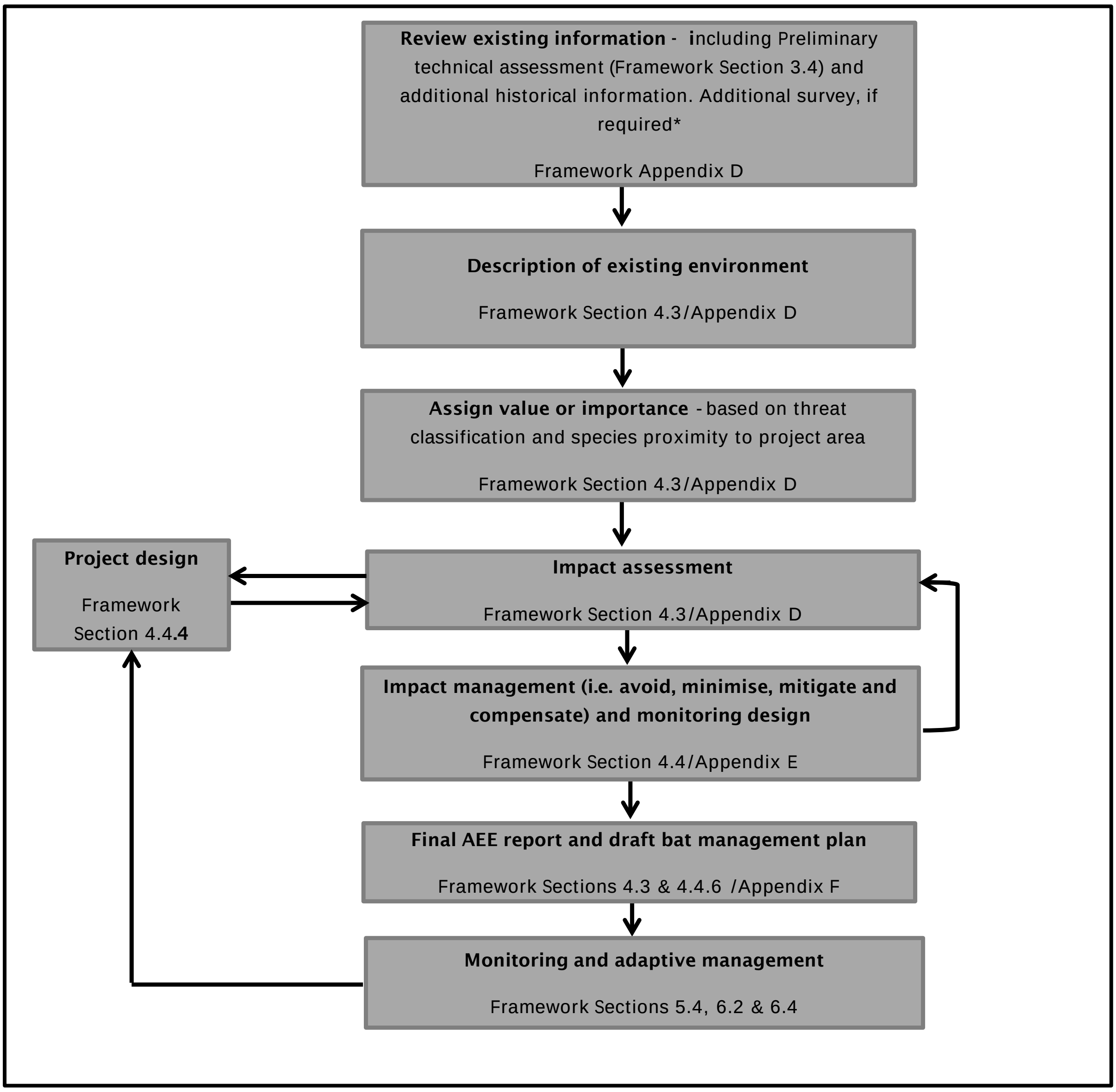
- roost loss through roost abandonment, eg because of noise levels, introduction of artificial lighting or reduction in the availability of potential roosts
- reduction in gene pool due to increased mortality rates caused by direct factors
- reductions in population size and range.

A study undertaken in New Zealand by Borkin et al (2016) in relation to this framework found in areas where roads bisect habitat used by bats, bat activity was higher at sites ≥200 metres away from the roads compared with sites adjacent to roads, and that bat activity declined with increasing overnight traffic volumes. This suggests an effect of road operation on bats, although determining exactly what causes these declines requires further research.

D4.3.2 Ecological impact assessment (EcIA) process overview

A detailed EcIA is produced subsequent to a preliminary EcIA and supporting bat PTA (refer to section D3.3) and contains the following steps as outlined in figure D.4. A more detailed outline of the detailed EcIA process is contained in annex DD.

Figure D.4 EcIA process as it relates to bats following EIANZ (2015) and NZ Transport Agency (2017)



* In some cases, the preliminary EcIA may be sufficient to support the preparation of an AEE.

D4.4 Managing impacts

Managing the impacts on bat populations should be based on a series of essential, sequential steps taken throughout a project's life-cycle in order to eliminate or limit any residual negative impacts on bats and other biodiversity values. This consists of:

1 Avoid: measures taken to avoid creating impacts from the outset. This is often the easiest and most effective way of reducing potential negative impacts, but it requires biodiversity to be considered in the early stages of a project. It places large emphasis on pre-construction bat surveys to locate potential roosts (particularly maternity roosts), feeding sites and flight paths, with particular focus on avoidance of roost destruction and disturbance, and avoidance of flight paths. This may necessitate changing the location/route/alignment or selecting a different option.

2 Minimise: measures taken to reduce the duration, intensity and/or extent of the direct, indirect or cumulative impacts that cannot be avoided completely. Effective minimisation, eg strategies that maintain landscape connectivity can eliminate or reduce some negative impacts on a population.

3 Mitigate: measures taken to alleviate degradation or damage following exposure to project impacts that cannot be completely avoided and/or reduced. It is noted, however, that the success of bat mitigation measures in New Zealand is currently unknown. On-going testing and adaptive management are a key component to any mitigation strategy.

4 Off-set: like-for-like measures undertaken elsewhere to compensate for any significant residual, adverse impacts following full implementation of the previous steps.

5 Environmental compensation: any action (work, services or restrictive covenants) to avoid, remedy or mitigate adverse effects of activities on a relevant area, landscape or environment, as compensation for unavoidable and unmitigated adverse effects of the activity for which consent is being sought (eg JF Investments Limited v Queenstown Lakes District Council, Environment Court C48/2006 cited in EIANZ 2015).

Given the lack of research that attempts to understand the impacts of linear transport infrastructure on bats and the most effective methods to minimise or mitigate these impacts, the step with the most certainty is likely to be avoidance. However, at this stage of the project (ie project development), avoidance may not be possible, and the most realistic approach will typically be a combination of minimisation and mitigation.

D4.4.1 Using life history to prioritise mitigation

Bat life history should be used to guide assumptions about how methods may assist in maintaining population size. Based on population model outputs taken from the literature review (Part 1 of this report) (Wildlands 2016) and on fundamental population ecology principles, the following assumptions can be made in regards to a bat population under threat from several potential impacts:

- If a population is small, it is likely to be very vulnerable to chance catastrophic impacts and other small-population effects.
- Growth of all populations will be most sensitive to reduced adult survival; given that even a healthy bat population is likely to grow slowly, any impact on adult survival should be regarded as a threat to population viability. As such, maintaining survival rates of adult female bats is likely to have the greatest effect on sustaining population growth.
- Because adult survival is the most important contributing parameter to population growth, larger populations are likely to be less vulnerable to short-term reductions in the productivity of young, but longer-term impacts will restrict their population growth. Small populations may be vulnerable to short-term reductions in productivity.

D4.4.2 Mitigation

There is currently a lack of evidence for the effectiveness of strategies to mitigate potential adverse effects of linear transport infrastructure on bat populations in New Zealand.

Until further research is undertaken, it is recommended a competent bat ecologist (Class F – refer to table D.2) works closely with engineers to ensure any proposed mitigation is feasible, and its likely effectiveness defensible, given the best scientific evidence currently available. Demographic modelling of long-tailed bats undertaken as part of the ecological literature review in Part 1 of this report (Wildlands 2016), estimated an annual population growth rate of just below 1%. The model showed that maintaining survival rates of adult female bats would have the greatest effect on sustaining population growth. This data should assist bat ecologists with the prioritisation of interventions (ie protection of maternity roosts), particularly where resources (eg costs) are limited on a project.

Mitigation incorporated into any linear transport project will be a financial cost to the project. The implementation of mitigation must have appropriate monitoring of its effectiveness and an associated commitment to modify management if monitoring data indicates mitigation is ineffective. Therefore, when selecting mitigation methods, the measurement of their success, ie how their success will be monitored, should be considered concurrently. This information will then enable money spent on mitigation to be justified/validated and lessons learned captured/added to growing knowledge around bats and development.

D4.4.3 Mitigation options

Based on the life history characteristics of bats (refer to section D4.4.1), mitigation needs to be planned and implemented early to be effective immediately. Annex DE presents a range of mitigation options that have been used to mitigate the impacts of roading projects both in New Zealand and internationally, and their applicability to bat species in New Zealand. Annex DE should be consulted when considering use of mitigation strategies in New Zealand. Most of the mitigation identified has been applied in Europe and some strategies have been implemented in New Zealand (although their effectiveness in New Zealand is yet to be proven). Other mitigation strategies may exist that have not been included in this table. As with any proposed mitigation, monitoring will be required to determine whether the predicted efficacy of the mitigation meets expectations.

D4.4.4 Mitigation through design

By the preliminary design stage of a project there are often very limited opportunities to completely avoid environmental impacts (if not considered prior). The plans for a project become more detailed as it progresses, and the alignment more fixed. As such, mitigation measures should be identified during the early design stages to prevent unnecessary costs. There is rarely one ideal solution and trade-offs among environmental impacts are usually required because the ecological relationships within an ecosystem are diverse and complex.

To achieve a linear transport infrastructure design that accounts for bats and the best project outcomes, it is important that:

- Accurate ecological knowledge is available early.
- Infrastructure design is an iterative process between designers, engineers, planners, regulators, ecologists and the community.
- Ecological requirements are stated and understood so that technical inputs from design engineers, planners and environmental managers are undertaken in a coordinated way.

- Mitigation goals and objectives are clearly defined and SMART (specific, measurable, achievable, relevant and time-bound).
- Maintenance requirements of mitigation measures are considered in the design.

During preliminary design stages, consideration should be given to minimising the environmental impact of linear infrastructure on bats by minor alterations to the location of the infrastructure (ie to avoid a localised habitat or potential roosts), or through design changes. In particular, the following elements should be designed in consultation with the bat ecologist:

- water crossings due to their potential to impact flight paths and foraging habitat
- landscape and urban design. These elements may encourage or discourage bat movement/affect collision rates, or provide alternative habitat
- acoustics, eg road surfaces and noise walls
- lighting, eg exclusion of lights (dark areas), selection of lighting type and placement
- other environmental mitigation. Coordinated habitat restoration and pest management will likely achieve better outcomes in the long term.

Potential mitigation measures are discussed in more detail in annex DE.

A pre-construction review of infrastructure and mitigation design to assess constructability and identify opportunities for improvement should be undertaken by a team with experience in construction and who also understands the intent of the design, such as the construction environmental manager, or bat ecologist.

It is important a bat ecologist is involved throughout the design and construction stage of a project to ensure mitigation measures are correctly incorporated into the design and implemented. The construction phase is discussed in further detail in section D5.

D4.4.5 Measuring the effectiveness of mitigation

The effectiveness of mitigation in sustaining population viability can only be assessed by monitoring characteristics of the population (size, density, growth rate) or demographic vital rates (annual survival, reproductive output), that can reasonably be assumed to be surrogates for population viability or that can then be used in population models to estimate growth.

Measuring the effectiveness of mitigation should ideally commence during the base line survey (refer to section D3.5). Evaluation of a mitigation approach should include the following components (van der Grift et al 2013):

- a clearly-defined SMART (specific, measurable, achievable, relevant, time-bound) goal against which project results can be evaluated
- selection of appropriate measurement endpoints (eg % utilisation of mitigation compared with pre-construction) that will inform managers of the project's effectiveness
- a survey design that can detect real effects where they exist. This will, ideally, include an assessment of statistical power and subsequent identification of sampling requirements (number of surveys and their duration)
- identification of appropriate survey/monitoring methods
- robust analysis of data and feedback of monitoring results in an appropriate format for managers to make decisions with confidence (adaptive management).

Adaptive management uses monitoring data to both evaluate the effectiveness of a project in achieving its outcomes and compare observed data with predicted effects. This allows managers to evaluate their management interventions and to modify future actions based on robust evidence (refer to section D6.3). Thresholds should be defined ahead of time, which trigger modifications of management, or at least its review.

Clearly, some mitigation approaches, such as bat crossing structures, may be difficult to modify to improve their effectiveness on a single project following construction. To overcome this, a centrally coordinated adaptive management process can be used to inform the design of structures on proposed projects based on the evidence of effectiveness of others. Aggregated information from more than one project will be much more powerful and useful than that from a single project. Information collection and dissemination and adaptive management are discussed in further detail in section D7.2 and section D6.4 respectively.

D4.4.6 Bat Management and Monitoring plan (BMMP)

Environmental and Social Management Plans (ESMPs) are one mechanism that can be used to manage and monitor environmental effects and the effectiveness of mitigation strategies. The ESMPs of large land transport projects will consist of several sub-plans which typically include an ecological management plan and/or a BMMP.

It is recommended a preliminary BMMP is prepared to accompany the permit applications (AEE and wildlife permit). A BMMP should be prepared (preliminary and final) with input from a Class F (refer table D.2) bat ecologist or team. A final updated BMMP will require independent certification after permits have been approved, as required by conditions of consent. For Transport Agency projects the Transport Agency's Environment and Urban Design team will review the BMMP prior to certification.

An example template of a BMMP is provided in annex DF.

D4.5 Environmental permit applications

D4.5.1 Timing and integration of applications

Project planners will generally have the responsibility for preparing and submitting RMA applications. Wildlife permit applications are usually prepared and submitted by the project ecologist with advice from a competent bat ecologist (refer table D.2). Where possible, it is recommended that designations (notice of requirement), resource consent applications and wildlife permits are applied for at the same time. However, this may not be possible in the case of designations being established to allow future development of routes or corridors, with no imminent commitment to initiate these changes.

D4.5.2 Conditions

When RMA or Wildlife Act approvals are granted, they are issued with a set of conditions[24]. Where possible, RMA and Wildlife Act conditions should be aligned and avoid duplication or different requirements (e.g. different set of monitoring requirements). One way to achieve this is to prepare draft conditions to submit with the AEE and permit applications. Early engagement with stakeholders in devolving conditions acceptable to all parties may alleviate the need for adversarial hearings later in the process. Statutory authorities will review consent applications against plan requirements and prepare consents.

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[24] In the case of a notice of requirement application, the conditions may be accepted or rejected by the applicant (requiring authority).

A set of guiding conditions is included in annex DG and covers the following topics:

- design development
- baseline monitoring requirements (ie pre-construction)
- BMMPs
- mitigation, ie conditions requiring specific mitigation methods
- ongoing monitoring requirements and triggers for adaptive management.

The conditions included in annex DG are a useful starting point for resource consent and wildlife permits and have been based on consultation with DOC, councils and consultants.

Annex DH includes a vegetation removal protocol which is designed to be included as a schedule to the conditions.

D4.6 Information gaps/priority activities

Information gaps and related priority activities relevant to this phase of the project are described below (table D.7). In some instances information gaps may need further definition or may be partially completed. This information should be used as a starting point to guide framework stakeholders (refer section D1.4).

Table D.7 Information gaps and priority activities relevant to the planning phase of a project

Information gaps	Priority activity (PA)	Time frame
Lack of an alternative method for capture and radio-tracking of bats to find roosts.	Develop and test cost-effective, scientific and standardised method to identify roosts (including maternity) that may be an alternative to capture and radio-tracking. Ensure the preservation and avoidance of female-dominated colonial or maternity roosts for linear transport projects	Short
Poor understanding of effectiveness of mitigation of linear transport impacts on bats.	Establishment of a collaborative funding model for supporting the research and development of mitigation methods.	Short
Lack of knowledge of how linear infrastructure affects bat activity/behaviour.	Ensure all linear transport projects collect standardised data before, during and after construction monitoring. This should be included as a condition of consent for all projects. The data should be collected in and collated so that it is available for future use.	Medium
Poor understanding of flight path behaviour\methods of mitigating flight path severance	Gather knowledge on flight behaviours, such as where, when and at what height they occur, to maintain existing flight paths.	Medium

D5 Construction

D5.1 Introduction

This section of the framework covers information that should be considered as part of the procurement process, and provides methods for managing impacts during construction along with construction monitoring (refer figure D.2).

From a Transport Agency perspective, this phase includes all the steps required to facilitate completion of the project, from initiating the project through pre-implementation (preliminary design development, procurement, consenting and property) through to implementation (final design and construction) and handover of the asset for operation. Different transport providers will have their own specific procurement requirements. Further information on the Transport Agency's requirements can be found here: www.nzta.govt.nz/roads-and-rail/highways-information-portal/.

D5.2 Procurement for construction

The more clarity provided about the scope of works being procured, the better the environmental and cost-efficiency outcomes of the project are likely to be.

Contract documentation will contain project specifications, principal requirements or minimum requirements. These requirements ensure best practice is implemented, resource consent and wildlife permit conditions are met, and reporting is undertaken and communicated successfully through the appropriate channels.

Where a linear transport project may potentially have impacts on bats the following should be addressed in contract specifications or requirements:

- environmental permit conditions, including any pre-construction requirements (eg monitoring and reporting, adherence to BMMP, impact management)
- training and education
- roles and responsibilities.

It is recommended the contract documentation is prepared in conjunction with a bat ecologist so specific bat permit requirements are understood in relation to the scope of the contract to ensure all legal requirements are met.

D5.2.1 Environmental permit requirements

Contract requirements must, as a minimum, ensure the legal requirements of the relevant environmental permits are incorporated into contract documentation. For bat-associated linear transport infrastructure this will mean including requirements for adherence to monitoring, a BMMP and vegetation removal protocol.

The details of these will likely have been specified in permit conditions; however, the following should be considered when setting up contracts to help ensure permit requirements are met:

- To draw conclusions about project impacts and the effectiveness of any mitigation used, bat monitoring is required at an appropriate frequency prior to the commencement of works (baseline monitoring), during construction and subsequent (eg annually) for several years after construction.

- In some circumstances the baseline surveys conducted during the assessment and permitting phase will meet pre-construction monitoring requirements, for other projects this monitoring will form part of construction procurement.
- There needs to be a mechanism to transfer responsibility for implementing conditions beyond the construction phase into the operational phase.
- Reporting should be undertaken in accordance with the requirements of the resource consent and wildlife permit conditions as well as recommendations in the BMMP.
- The format of monitoring results and associated reports has a bearing on whether information collected for a project can be applied in a wider setting. Having information readily accessible, in a commonly used, standardised format that will contribute to adaptive management of mitigation measures and continually evolving management plans (both for the current project as well as parallel and future projects) is essential. This can help ensure maximum value is gained from the effort spent. Therefore, the format of data and reporting requirements should be clearly specified in contract documents (refer to annex DA, section DA5).
- It may be in the best interest of project timelines for the client (eg Transport Agency) to procure ecological services separately, to the construction contractor to ensure monitoring is undertaken when it needs to be, ie assigning an ecologist to the project to undertake some or all of the tasks associated with meeting environmental permit requirements.

D5.3 Management of construction impacts

D5.3.1 Environmental and Social Management Plans and Bat Management and Monitoring Plans

The BMMP forms part of a suite of sub-plans that are included as part of an Environmental and Social Management Plan (ESMP) (for Transport Agency projects). The ESMP is required to meet a specific set of Transport Agency (2014) guidelines, and should include detail of roles and responsibilities, training, impact identification, inspections and auditing.

Based on overseas evidence, activities that may cause a detrimental effect during construction include noise, lighting and vehicle/machinery movement, human voices, as well as specific tasks undertaken such as vegetation clearance. Impacts on bats associated with construction are not yet confirmed in New Zealand; however, they may be similar to those observed overseas. The full effects of construction activities on bats may not be fully known until a construction methodology is confirmed (including the placement and use of site offices and storage areas). It is important the environmental manager and bat ecologist stay involved during the construction planning to ensure impacts can be minimised if possible, eg locating of site offices/laydown areas away from areas where bats are present, restricting construction to daytime only, noise management and directing lights.

Prior to construction, the contractor's bat ecologist should update the BMMP with a confirmed construction methodology and all known information about possible construction effects. Usually at this stage the final BMMP should be updated and submitted to the statutory authority as required by consent conditions. As detailed in the model consent conditions (annex DG) the BMMP should be finalised by a bat ecologist with the appropriate competencies (table D.2).

D5.3.2 Training

Education and engagement of construction teams are critical to the success of a project. Information and site controls related to bats should be included as part of any site induction (where relevant). This should be supplemented by targeted information sessions or 'toolbox' talks for specific groups of personnel.

D5.3.3 Roles and responsibilities

All projects where bats are present should employ dedicated ecological staff to be involved in all relevant aspects of the project. Staff may be employed directly by the contractor or seconded from elsewhere.

Table D.8 provides an example of the key responsibilities of those involved in assessing and managing impacts on bats during construction of a linear infrastructure project.

Table D.8 Positions of those involved in bat mitigation, including key relationships

Position	Key responsibilities	Key relationships
Environmental manager/project ecologist	• Ensure adherence to resource/designation consent bat conditions • Ensure adherence to wildlife permit conditions • Provide reports to appropriate people • Communication with stakeholders and client	• Department of Conservation (DOC) • Regional/District councils • Transport Agency environmental specialists
Site manager	• Facilitate adherence to all bat conditions	• Environmental Manager
Bat ecologist (Class A-F)	• Ensure adherence to resource/designation consent bat conditions • Ensure adherence to wildlife permit conditions • Implement bat surveys in accordance with requirements • Preparing and implementing a suitable bat management and monitoring plan (BMMP) • Undertaking post-construction monitoring and reporting	• Environmental manager • Site manager • DOC • Regional/District Councils • Transport Agency environmental specialists
Other contractors	• Adhere to instructions from bat ecologist in relation to bat surveys, monitoring and mitigation • Facilitate adherence to all conditions	• Environmental manager • Site manager • Bat ecologist
DOC staff	• Approve bat survey methodology and BMMP (if required by conditions) • Receive and review reports • Support and maintenance of a National bat database.	N/A
Council	• Monitor compliance with consent conditions • Receive and review reports • Approve BMMP and survey methodology	N/A

Note: the contract will need to specify whether the role of the bat ecologist is undertaken by the contractor or whether this role is to be undertaken separately.

D5.3.4 Communication

It is imperative good lines of communication are kept both within the project team (environmental manager/project ecologist/project manager) and between the project team and the Transport Agency Environment and Urban Design team. Additionally, responsibilities for engagement with DOC should be specified between project teams and the Transport Agency during procurement. Regular and timely communication ensures any activities potentially impacting bats can be identified early and appropriate management methods implemented.

D5.4 Construction monitoring

Monitoring of bats during construction should form part of any well-planned monitoring programme. It is also likely to be a condition of environmental permits obtained for the project. Monitoring is recommended to ensure construction mitigation is successful and to test whether the effects of the construction works are having the impacts predicted or an impact on bat populations that was not predicted. The most robust monitoring design is the BACI (refer section D3.5).

By monitoring construction mitigation activities and determining their effectiveness, possible changes to mitigation can be implemented if they are not working adequately. This information can also be used to inform subsequent construction projects and their chosen mitigation. Monitoring design and techniques are described in further detail in section D3.5 and annex DA.

D5.5 Information gaps/priority activities

Information gaps and related priority activities relevant to this phase of the project are described below (table D.9). In some instances information gaps may need further definition or may be partially completed. This information should be used as a starting point to guide framework stakeholders (refer section D1.4).

Table D.9 Information gaps and priority activities relevant to the construction phase of a project

Information gap	Priority activity (PA)	Time frame
No established accepted or scientifically tested Vegetation Removal Protocol	Undertake research into the ability of current vegetation removal protocols to detect roost presence reliably. A cost-effective method to identify roosts is developed and tested scientifically. Subsequently, a standardised methodology could be developed to identify actual roosts prior to vegetation removal.	Short
Lack of knowledge of how construction activities affect bat activity/behaviour	Establishment of a cross-agency collaborative funding model for supporting research into the impacts of linear infrastructure projects.	Medium
	Ensure all linear transport projects undertake standardised before, during and after construction monitoring. This should be included as a condition of consent for all projects. The data should be collected in a standardised way and that it is collated and available for future analysis.	Medium

D6 Operation and maintenance

D6.1 Introduction

The operation of linear transport infrastructure can have ongoing direct and indirect impacts on bat survival rates and, in turn, population sustainability. This section discusses the steps following the construction phase of a project that are required to understand any impacts on bats and the effectiveness of any implemented mitigation (refer figures D.1 and D.2).

Maintenance activities are also a key consideration for this phase of works and can often have similar types of impacts as construction works, eg tree felling, noise, lighting.

D6.2 Operational monitoring

During operation of a linear transport project, ongoing monitoring (for newly constructed roads) is crucial for determining any long-term direct or indirect impacts on bat populations and the effectiveness of mitigation measures. This type of monitoring is usually specified in resource/designation/wildlife consents/permits and associated BMMPs. Permit conditions and BMMPs are discussed in section D4. Ideally, the resulting data will form part of collaborative approach including data from: earlier phases of the project, other similar projects and research to inform whether mitigation and management is effective (refer to section D4.4). Post-construction monitoring must be of sufficient duration, and robust enough, to be able detect an effect in the ecological feature of interest where that effect exists, eg bat demography, behaviour and habitat utilisation.

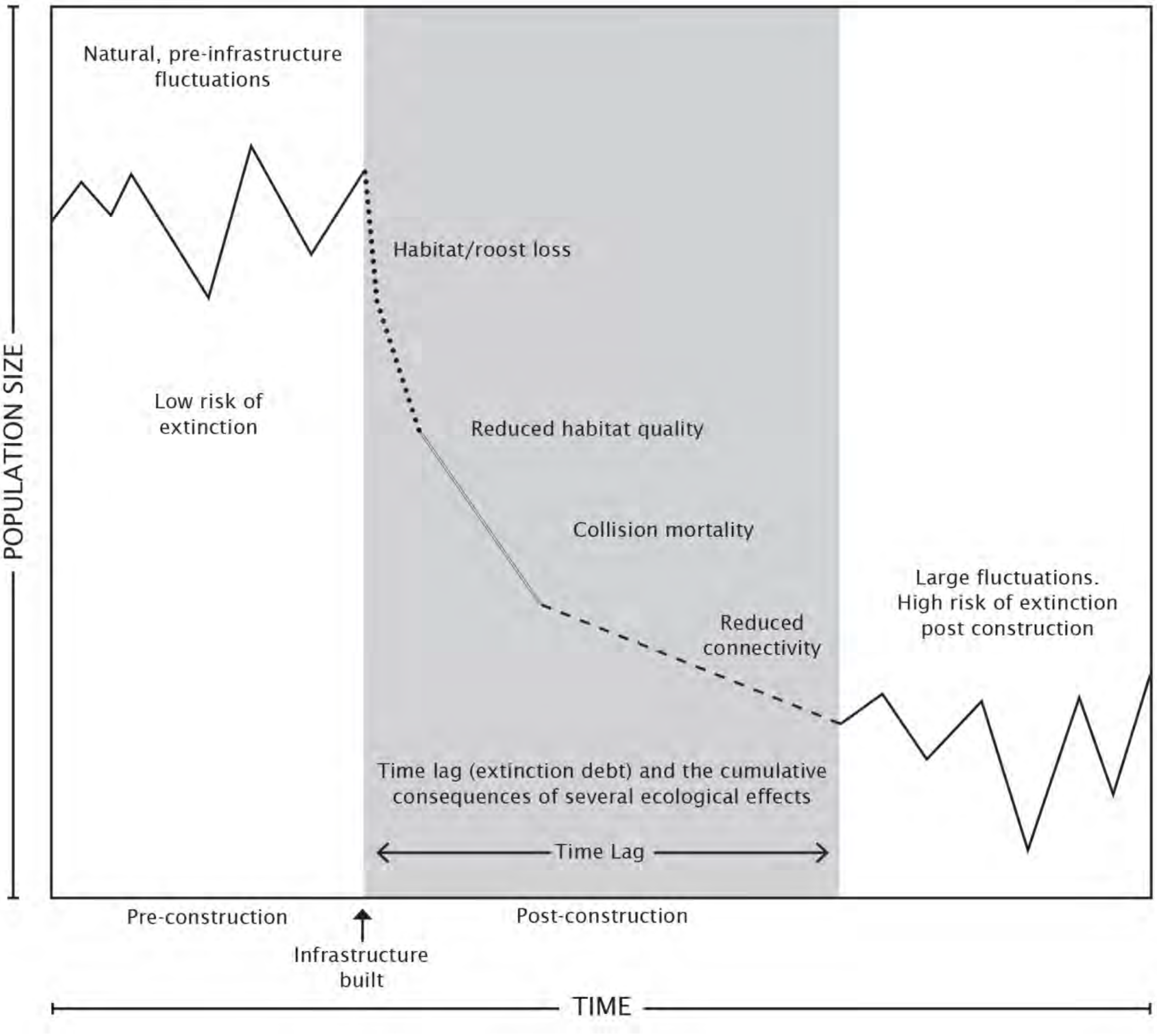
Figure D.5 illustrates the potential time lag that exists between project implementation and population impacts.

In conjunction with pre-construction monitoring and non-treatment monitoring, post construction/operational monitoring can be used to:

- assess whether operation and maintenance of the linear transport infrastructure is affecting the bat population
- establish if mitigation measures are effective
- determine if mitigation provides long-term benefits for bats and their habitats.

Post-construction monitoring requirements (including methods) are outlined in section D3.5.

Figure D.5 Time lag of project effects (adapted from Forman et al 2002)



D6.3 Maintenance works

Maintenance works of existing roads such as tree felling/trimming, removal of hazardous trees, changes to light regimes, night works and bridge works have the potential to disturb bats. When these activities are planned, the first step is to consider whether bats are present or could be present (refer to section D3.3).

If bats are present in the work area and there are no alternatives an impact assessment should be carried out and a BMMP prepared to manage the identified actual and potential impacts. The BMMP should follow the template in annex DF. It is likely a wildlife permit will be required (refer section D4.2). The same impact assessment process described in section D4.3 applies.

For a NZ Transport Agency Network Outcome Maintenance Contract (NOC), the risk of bats being present in the network area should be identified and addressed within the NOC ESMP. If required, a BMMP should be prepared as a sub-plan.

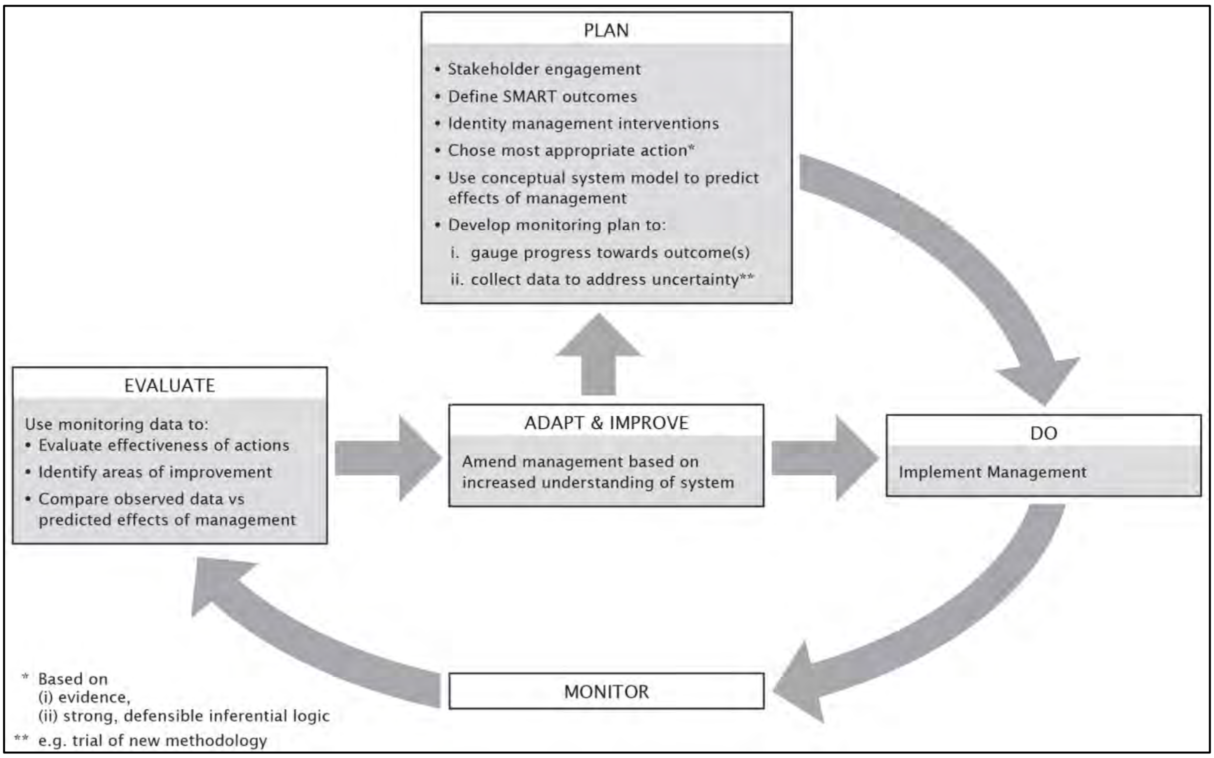
D6.4 Adaptive management

Adaptive management involves the collection and analysis of monitoring data as well as additional related research, to evaluate the effectiveness of mitigation measures by comparing the observed data with predicted effects. This allows project managers to evaluate their management measures and modify future actions based on robust evidence (figure D.6). Adaptive management can be integrated as part of resource/designation consent conditions (refer section D4.5). The challenges and questions that must be considered during this stage of the project include:

- Is the data collected providing enough information about population-level impacts of the project?
- Is mitigation effective?
- Should mitigation be altered based on evidence of the effectiveness of the mitigation method?

As shown in figure D.6, clear outcomes need to be developed for all monitoring ('PLAN'), identifying the actions considered most likely to achieve them ('DO') and deciding on what to monitor to best inform on the project's performance ('MONITOR'). Monitoring data can then be used to evaluate the effectiveness of the project ('EVALUATE') and to allow evidenced-based adjustments of actions to improve performance '(ADAPT AND IMPROVE'/'DO').

Figure D.6 Simplified adaptive management cycle



D6.5 Information gaps/priority activities

Information gaps and related priority activities relevant to this phase of the project are described below (table D.10). In some instances information gaps may need further definition or may be partially completed. This information should be used as a starting point to guide framework stakeholders (refer section D1.4).

Table D.10 Information gaps and priority activities relevant to the operation and maintenance phase of a project

Information gap	Priority activity (PA)	Time frame
Lack of knowledge of how linear infrastructure affects bat activity/behaviour	Based on the results of the field work undertaken in association with this framework (Borkin et al 2016), undertake further research into understanding why bat activity declines with increasing traffic intensity.	Medium

D7 Research and collaboration

D7.1 Introduction

Research into roading impacts on bats (and other native vertebrates), and the methods of mitigating and monitoring available to manage these impacts on them is necessary to improve knowledge. By collecting and disseminating data from both research and individual infrastructure projects knowledge can be better utilised. This research and data sharing will help both individual projects and the wider industry better understand, avoid or manage their impacts on bat populations.

D7.2 Information collection and dissemination

If information is collected, stored, and shared appropriately it can:

- provide greater understanding of how and to what extent roads affect bats and other endemic vertebrates
- provide information for improving the design and implementation of mitigation approaches
- inform design of monitoring techniques
- reduce the likelihood of mistakes being repeated
- stop projects ‘re-inventing the wheel’
- identify the most effective methods for species management
- identify cost-effective approaches
- provide data that subsequent projects can use in power analyses
- save money for future projects.

A range of bat-focused reports will be produced over the lifetime of a linear transport project. The data contained in these reports includes records of survey methodology, and monitoring results providing important data that could be applied beyond the life span of just one project. This information needs to be collated and made available by a sole agency in collaboration with all stakeholders (refer to section D1.4). Further work is required for this to occur. The current status of bat data collection in New Zealand is described below.

D7.2.1 National bat database

DOC maintains a national bat database that collates the results of bat presence surveys from a range of sources (a distribution map of these locations collated by DOC) individuals, usually DOC staff, who are looking for bats, ie for research, survey or teaching purposes. Casual reports of bats are obtained from incidental ad hoc sightings made by the public, observer groups such as caving groups and tramping clubs that may encounter bats, and opportunistic records from other survey work (eg kiwi surveys) (Sedgeley 2012a)

It is desirable for bat data collected as part of linear transport infrastructure projects to be included in the national bat database. A process for submitting and retrieving information from the national bat database is currently being worked on by DOC. In the meantime, information submissions and requests for regional data (including the bat distribution map) should be sent to each DOC region's technical advisor (fauna) (see 'bat recovery group contacts' in Sedgeley 2012a).

D7.2.2 Project Echo – Hamilton

Project Echo aims to gather information about bat distribution throughout Hamilton City. Bat sightings can be submitted electronically to Project Echo via the Waikato Regional Council website.

D7.2.3 Auckland Council

Auckland Council maintains a Biodiversity-Bat website page that encourages region-wide surveys to help study the impact of urban pressures on native bats. Bat sightings are to be reported via the Auckland Council online contact form or by phoning (09) 301 0101. Bat presence data in Auckland has been collated and is available upon request via the same contact details.

D7.3 Working group

It is recommended a collaborative working group should be established to progress and support research efforts to address the information gaps/prioritised actions identified at the end of each section within this framework.

A range of stakeholders (refer to section D1.3 – including others such as universities and Landcare Research) should work collaboratively to achieve commonly agreed research priorities. This may be achieved through the initiation of a bat working group that includes bat professionals and stakeholders giving their time to work towards a common goal. The working group would help to organise funding for priority activities and research.

D8 Other vertebrates

This framework has been developed to facilitate the management and mitigation of road and road construction impacts on New Zealand's endemic bat populations, and therefore discusses bat specific issues in considerable detail. Linear transport infrastructure projects will also impact on other native vertebrate taxonomic groups such as birds, lizards and freshwater fish. Understanding the extent to which roading projects impact on these taxonomic groups, and how these impacts should be best managed and mitigated, requires a separate series of investigations and the development of separate frameworks.

However, this framework provides a precedent and outline that will be useful for developing these other frameworks. In particular:

- The statutory process will be similar with consents required under the RMA, and permits needed under the Wildlife Act, although freshwater species may require consents under the Conservation Act regardless of land tenure.
- It would be advantageous to identify the need for these consents and the management actions associated with them early in the development of a project's business case.
- Attempts to identify realignments that completely avoid wildlife habitat should be initially considered, but if this is not possible surveys should be undertaken to establish species' abundance, distribution and the extent of their habitat in the proposed project area.
- A detailed options assessment will need to be undertaken, coupled with an AEE.
- Specific management plans will need to be developed to define methods for monitoring the species before, during and after road construction, and identify methods for avoiding, mitigating or offsetting adverse effects on the species.
- Specialised ecologists with recognised competency with the species will need to be employed to provide advice, write the management plan, implement monitoring, and implement mitigation, and write progress reports for the consenting authority.
- A model set of consent conditions, endorsed by DOC, should be developed.

Beyond this, the ecology of the species will largely dictate specific recommendations in the framework. For example, there may be specific hydrological considerations for freshwater fish to prevent wetland loss or allow fish passage, or salvage and translocation requirements for lizards.

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Annex DA: General survey design principles

The Australian government's guidelines for surveys of indigenous bats (Department of the Environment, Water, Heritage and the Arts 2010) provide some useful general advice on survey design and implementation. These can be summarised as:

1. Confirm survey area and identify likely target species
2. Determine optimal timing for surveys
3. Establish survey design, methods and effort
4. Select appropriate personnel to conduct survey
5. Document survey results
6. Make survey data available for future reference.

Further detail on these survey design principals is provided below for bats in the New Zealand context.

DA.1 Target species and location

When establishing if a survey should account for long-tailed and/or short-tailed bats, consideration should be given to known distributions and habitat use. Long-tailed bats are distributed widely across the North Island, on the west coast of the South Island with small, isolated populations on the east coast of the South Island. They are found in, or use, indigenous forest and exotic plantations and there are also known populations in urban or semi-urban areas including Hamilton, Temuka and Auckland (O'Donnell 2005; Lloyd 2005). In comparison, short-tailed bats have 13 known populations, 11 in the North Island, in the Eglinton Valley of the South Island and on Whenua Hou (Codfish Island). The largest populations of short-tailed bats are found in mature, unmodified, lowland indigenous forest, although they can commute over 10 kilometres between day roosts and foraging areas, which can be found in different locations (O'Donnell 2001). Due to the elusive nature of bats, neither species should be readily excluded from bat surveying efforts.

DA.2 Optimal timing

Bat activity is generally considered to increase with increasing overnight temperature (Kuenzi and Morrison 2003; O'Donnell 2000; Scanlon and Petit 2008; Smith and Borkin 2016). Therefore, in order to have a higher probability of detecting bat presence, monitoring sessions should be planned for warm periods with little or no rain. Monitoring is recommended to take place between November and April, the period over which peak activity occurs (Borkin 2010).

Long-tailed bats usually emerge from day roosts from up to an hour before sunset until 30 minutes after, although they may emerge later when roosting alone or during winter months (O'Donnell 2001). Short-tailed bats usually only emerge when it is fully dark and return before dawn (O'Donnell et al 1999). Emergence (ie activity at dusk and dawn) may give an indication of bat roosting in the area. There is currently no official standard for the detection of bat roosts. However current practice in New Zealand is often to monitor vegetation for signs of emergence in order to determine the location of bat roosts, although the effectiveness of this has not been confirmed. Potential roost sites can also be confirmed via other survey methods such as field observations and radio tracking.

Bat activity, emergence times and whether bats emerge from their roosts at all, can be influenced by temperature, humidity, invertebrate activity and light levels (Smith and Borkin 2016; O'Donnell 2005). Consequently, bat survey protocols should consider these factors. Recent research into long-tailed bat activity by Wildland Consultants (Smith and Borkin 2016) suggests bat monitoring will be most successful when:

- temperature one to four hours after sunset is greater than 6°C (but preferably in the range of 10–17°C)
- humidity is ≥70%.

However even if these conditions are achieved monitoring should be repeated if bats are not detected, as data suggests bats sometimes do not emerge, or use particular sites, even when conditions are favourable.

When undertaking field surveys, overnight temperatures will need to be predicted using weather forecasts then measured in the field. If temperatures drop below the desired range and no bats are detected, a decision will need to be made on whether or not to repeat the monitoring. Guidance on survey duration/effort is provided in section DA.3.

DA.3 Establish survey design and survey effort

Bat surveys are required to:

- determine the presence of bat colonies, roosts, flight paths and other habitat features necessary for their survival
- ascertain the likely impact of a proposed linear transport projects
- evaluate the success of a mitigation approach.

Survey design should be considered early in project development to facilitate the avoidance of impacts or to allow impacts to be assessed at a later date and quantify the effectiveness of mitigation. The steps below should be followed to ensure the establishment of a scientifically robust survey design.

Step 1: Questions

Project-specific questions should be posed that will guide the survey design. The type of questions will direct the selection of the appropriate field method(s) (refer annex DC for example questions). For each stage of project development decisions will need to be made about the appropriate levels of effort expended to answer these questions.

Step 2: Methodology

A range of different field methods for surveying bats are available in New Zealand. These include [25]:

- acoustic monitoring using automated bat monitoring units (ABMs)
- direct observation
- mark-recapture
- radio telemetry
- thermal imaging (infrared) cameras (limited use in New Zealand to date)
- radar (to date not used in New Zealand)
- 3D microphone network (to date not used in New Zealand).

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[25] www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/bats/

The main part of the report, together with the Department of Conservation (DOC) bat inventory and monitoring module (Sedgeley 2012a, 2012b), provide information about the range of bat monitoring methods and guidance on choosing the most appropriate survey method. If survey methods will disturb bats in any way, or involve catching bats, then a wildlife permit will be required under the Wildlife Act 1953 (refer section D5.5 of this framework for further discussion).

Annex DC of this framework illustrates the range of potential survey questions relevant to different project phases, the different field methods available and their constraints.

Step 3: Survey length and effort

There is currently no official standard or best practice for the recommended level of effort required to detect New Zealand bats. However, the following are important considerations which may influence bat activity and therefore their ability to be detected (in addition to general good practice survey methodology):

- timing (month and time of day or night)
- climate (temperature and humidity)
- duration
- extent of area surveyed.

For guidance on timing and climate refer to section D1.2.

Guidance regarding ABM survey duration is provided by (Sedgeley 2012b). DOC recommends varying the number of sampling nights for ABM surveys according to the number of ABMs available, resources, terrain, habitat type and area requiring coverage. Species of bat is also relevant. Surveys designed to detect the presence of long-tailed bats are not effective at detecting short-tailed bats due to their difference in habitat use, and repeated surveys are required before they are detected (Borkin and Parsons 2010). Detection rates can also be very low if bats are in low numbers. If the objective is simply to determine the presence of bats, and calls are recorded the first night, units may be moved onto a new site. However, because bat activity is strongly influenced by weather conditions and other factors, it is often necessary to leave the units for several nights to ensure the sampling period includes nights of fine weather. Case studies provided in the DOC guidance notes (Sedgeley 2012b; 2012c) may provide some guidance for planning a survey using ABMs.

DA.4 Select appropriate personnel to undertake survey

Projects need to ensure ecologists are competent for the bat-related activity they are undertaking. For larger projects, extensive and complex survey and monitoring operations may be required that need a number of bat ecologists with different skills. Table D.2 of the framework outlines a range of recommended competency classes (A, B, C, D, E and F) for the different bat-related activities required on a linear infrastructure project. Guidance is provided on the experience and knowledge required to reach a specific competency class. Due to the wide range of skill sets of any particular ecologist, it is possible that a range of different classes may be applicable to one ecologist. Alternatively, the services of more than one ecologist may need to be procured to carry out the activities required on a project.

When procuring professional ecology services for bat-related work it is important to specify the competency class in procurement documentation. Proof of competencies can be obtained by reviewing CVs alongside the requirements of table D.2 of the framework. Further clarification may be sought from DOC if required.

DA.5 Documenting survey methods and results

Data should be collected and described in such a way that the exact methodology can be replicated in the future by someone foreign to the project. This means that in addition to using a standardised method of data collection, the manner in which data is collected needs to be described in full.

Collecting and storing data in a standardised way will allow for further analysis of the data in the future, for example in a meta-analysis. Meta-analyses are a way of using data from several studies to answer a particular question that cannot be answered with a single dataset. For example, meta-analyses have previously been used in the past to estimate collision rates with bats (Fensome and Mathews 2016); the effect of urbanisation on bats (Jung and Threlfall 2016); and their lunar activity patterns (Saldaña-Vázquez and Munguía-Rosas 2013).

To allow for future meta-analyses that will facilitate the development of more robust strategies for managing and mitigating roading impacts on bats, it is recommended data is collected, recorded and reported in a standardised manner. If data are recorded in an imprecise and un-standardised manner then these meta-analyses will not be possible.

The following are recommended as minimum data collection standards for projects that monitor bats in association with roads and road developments:

DA.5.1 Location and date

- Location where the monitoring took place, ie place name, eg Leitch's Hut.
- Description of habitat type, ie dominant vegetation type; was it along an edge, eg forest-pasture edge)/within forest/along a road, eg tawa forest-pasture edge.
- GPS location of monitoring devices, eg E1755149 N5744943.
- Date monitoring took place, eg night beginning 18 December 2015.

DA.5.2 Person(s) undertaking monitoring

- Name of person who installed monitoring equipment or undertook monitoring and analysed data and current contact details, eg Josephine Bloggs, ACE Consulting, 021123456, jo.bloggs@ACE.com

DA.5.3 Specific information about monitoring

- Method used, eg handheld detector or ABM devices. Make and model of the device. This is important to record because different monitoring devices have different detection probabilities and therefore different models are frequently unable to be compared with another. It is important to keep the model type consistent throughout monitoring programmes so comparisons can be made. If the model used in monitoring changes, then calibration between models needs to occur and correction factors created to allow comparisons.
- Target activity being monitored, eg roost emergence or road verge activity
- Reason for undertaking monitoring including any questions that the monitoring was designed to answer, eg' monitoring was designed to determine if current predator control regime was associated with changes in long-tailed bat activity. This ABM monitoring is associated with a simultaneous programme of mark-recapture to investigate the relationship between activity and population size'.
- Details of associated monitoring, eg 'this monitoring forms part of a long-term research project which began in 2000 and will be completed in 2016. Monitoring takes place each summer during this period'.

- Overall effort applied during the monitoring session, eg ‘10 ABMs over 10 nights over 1 kilometre stretch of tawa forest-pasture edge (spaced x m apart) from sunset beginning 16 December 2015’.
- Time over which data was recorded, eg ‘ABMs were set up to begin recording half an hour before sunset at 8.08pm and finish recording half an hour after sunrise at 6 23am’.
- Sunset and sunrise times at the location, eg ‘8.38pm, 5.53am’.
- Weather conditions for each night that monitoring takes place. These can often be collected from CliFlo, New Zealand’s National Climate database, https://cliflo.niwa.co.nz/ but if weather stations are not located near the monitoring location then site-specific weather data should be collected. Ideally, the weather data would be collected for each hour of the night and should include temperature, relative humidity, rainfall, and wind speed.
- Moon phase, eg ‘three nights after full moon’.

DA.5.4 Response data

- Tally of the total bat passes per night per site and which species of bat was detected, eg ‘112 long-tailed bat passes at E1755149 N5744943’.

The following data is also beneficial to data interpretation, but can add substantial time and effort to data collection:

- Bat passes per hour, eg ‘2 long-tailed bat passes between 0–1 hours after sunset; 65 passes between 1–2 hours after sunset’.
- The timing of bat passes, eg ‘1 long-tailed bat pass at 03.25am NZDT’.
- Identification of the types of passes, eg ‘the proportion of social calls; foraging passes; or feeding buzzes’.

DA.5.5 For roading projects, recording the following variables would be important:

- the distance between the monitoring devices and the road edge
- the distance between monitoring devices and the nearest habitat edge (including the type of habitat), eg ‘15m from tawa forest edge, ABM is located within forest’.
- traffic volume, including overnight traffic volume
- project phase or time lapsed since road construction
- data on traffic noise levels and light levels (from headlights and/or road lighting).

Annex DB: Bat preliminary technical assessment requirements

DB.1 Objectives of a bat preliminary technical assessment

Table DB.1 Example objectives and relevant scope of bat preliminary technical assessment (PTA)

Example bat PTA objectives (adapted from NZ Transport Agency (2017) Ecological Impact Assessment guidelines	**Relevant scope of bat PTA and field work**
Describe the zone of influence	The 'zone of influence' for a project is the area over which ecological features may be subject to significant effects as a result of the proposed project and associated activities (CIEEM 2016). For bat populations, this needs to take into account their home range and home range span.
The identification of key ecological features	Key ecological features relevant to bats include: • potential tree roosts (including maternity) • habitat suitable for foraging • location of flight paths/feeding routes • waterways • emergence times.
Identify key impacts, particularly those that could be avoided through changes to project design or selecting a different option	• Road alignment options • Habitat clearance/alteration • Lighting design • Construction timing.
Define what further monitoring needs to be undertaken to provide the necessary data to inform the detailed impact assessment and environmental permitting requirements	The development of a long-term monitoring plan may be part of the scope. Alternatively, as a minimum, determine what further monitoring needs to be undertaken to provide the necessary data to inform the detailed impact assessment and environmental permitting requirements. This should be based on baseline data collected as part of the preliminary assessment.
Identify ecological constraints to the project in order to make recommendations on options assessment or design.	Describe characteristics of local bat population, eg vulnerability; rarity within region; habitat availability

DB.2 Requirements of a bat PTA

A bat PTA should include:

- project description, including any other projects in the vicinity which may contribute towards cumulative impacts
- objective(s) of the baseline survey and bat assessment component of the PTA
- habitat description (based on daytime visit(s)); which includes a description of any roosts/potential roost sites, potential foraging areas and the general surrounding area
- field survey methods, dates, times, personnel (to include experience, DOC permit number if required), equipment used, weather conditions, constraints and limitations (factors influencing survey results) sample size, survey frequency, survey location

- survey data (as described in section D3 of this framework)
- interpretation and evaluation: presence/potential for presence, roost type (eg colonial or solitary), population size assessment where relevant, site status assessment
- map(s) of survey area (with habitat description, marking structures or features examined; summary of survey results marked on map if appropriate)
- foraging areas and dispersal/commuting routes of the local bat population (where surveyed)
- the potential impacts of the alternative solutions to the transport problem
- the identification of impacts on the local bat population that could be addressed through changes to project design
- discussion of appropriate ways to avoid, minimise or mitigate impacts, including the timing of these
- details of consultation undertaken
- identification of existing data and data gaps, and how these will be addressed including recommendations of further field work required, methods to be used and timescales required including timings for seasonally-dependent surveys to be undertaken to provide the necessary data to inform further assessments.

Annex DC: Survey questions

Table DC.1 Survey questions at different project phases and associated methodologies and constraints

Framework section	Example survey question	What do you need to measure/ identify?	Field method	Constraints	Reliability/likely ability to answer question	Effort required (resources, skill, cost)
Project initiation and options assessment (section D3)	Are bats present in the study area?	Presence	Automated bat monitoring units (ABMs) Review of existing databases and casual records (eg from DOC database)	Weather, time available, availability of staff to interpret outputs.	High/reasonable likelihood of detection if survey is undertaken over long period and/or repeated.	Low
Project initiation and options assessment (section D3) Preliminary technical assessment (section D3.3) Project design, consenting and assessment (section D4)	Which parts of the study area are used for foraging?	Behaviour	Capture and radio-tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	Medium; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High
			ABMs along transects	Weather, time and equipment available; availability of skilled staff to identify foraging.	Medium; ABMs may not be able to define flight location with sufficient precision.	Medium
	Where and how high are bats flying through the study area? (so that flyways can be avoided/ protected).	Flight paths/flyways	Capture and radio-tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	Medium; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High
			ABMs along transects	Weather, time and equipment available; skilled staff to identify foraging. Cannot identify height accurately without an intense array.	ABMs may not be able to define flight location with sufficient precision.	
	Where are roosts located? (so can be avoided/protected)	Roost identification	Visual signs Manual search by skilled, experienced, bat ecologist Capture and radio-tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	Low-medium if based on visual signs and/or manual search; high if radio-tracked; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High

Framework section	Example survey question	What do you need to measure/ identify?	Field method	Constraints	Reliability/likely ability to answer question	Effort required (resources, skill, cost)
	Does the construction of a road through a certain area reduce population size?	Population estimated before during and after construction	Capture-mark-recapture (capture and mark with passive integrated transponder (PIT) tags or wing bands)	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be recaptured or re-sighted.	High
Managing impacts (section D4.4) Operations and maintenance (section 7)	Does activity index change before and after implementation of mitigation?	Changes in relative activity	ABM records	Availability of skilled staff, cost, equipment availability.	High if robustly designed	High
	Does bat abundance change before and after implementation of mitigation?	Changes in bat abundance in proximity to road project or at monitored roosts.	Capture-mark-recapture prior to and post-implementation	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be recaptured/resighted Risk that monitored roosts may be abandoned permanently or temporarily between survey periods.	High
	Are bats still present in the area after project implementation?	Presence	ABMs	Weather, time and equipment available; availability of staff to interpret outputs.	High/reasonable likelihood of detection if survey is undertaken over long period and/or repeated.	Low
	Does the removal of bat habitat result in behavioural changes?	Behaviour	Eg compare the use of a roost before and after removal of XX habitat? By roost counts Capture and radio tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High
Project initiation and options assessment (section D3)	Are bats present in the study area?	Presence	ABMs	Weather, time available, availability of staff to interpret outputs.	High/reasonable likelihood of detection if survey is undertaken over long period and/or repeated.	Low

Framework section	Example survey question	What do you need to measure/ identify?	Field method	Constraints	Reliability/likely ability to answer question	Effort required (resources, skill, cost)
Project initiation and options assessment (section D3) Preliminary technical assessment (section D3.3) Managing impacts (section D4.4)	Which parts of the study area are used for foraging?	Behaviour	Capture and radio-tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	Medium; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High
			ABMs	Weather, time and equipment available; availability of skilled staff to identify foraging.	Medium	Medium
	Where are bats flying through the study area?	Flight paths/flyways	Capture and radio-tracking ABMs along transects	Availability of skilled staff, cost, equipment availability, permit being granted, availability.	Medium; risk that capture rates are low and bats leave study area or are unable to be radio-tracked; ABMs may not be able to identify flight location with sufficient precision.	High
	Where are roosts located?	Roost identification	Visual sign Manual search by skilled, experienced, bat ecologist Capture and radio-tracking	Availability of skilled staff, cost, equipment availability, permit being granted.	Low-medium if based on visual signs and/or manual search; high if radio-tracked; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High
	Does the construction of a road through a certain area reduce population size?	Population estimated before during and after X	Capture-mark-recapture	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be recaptured/resighted.	High
	Does population index change before and after implementation of X?	Changes in relative abundance	ABM records or sightings per unit time or roost emergence counts	Availability of skilled staff, cost, equipment availability.	Low; generally little evidence to show any direct correlation of activity indices with abundance; are frequently confounded with activity; ie unable to determine whether one individual is flying by or many individuals; roost	High

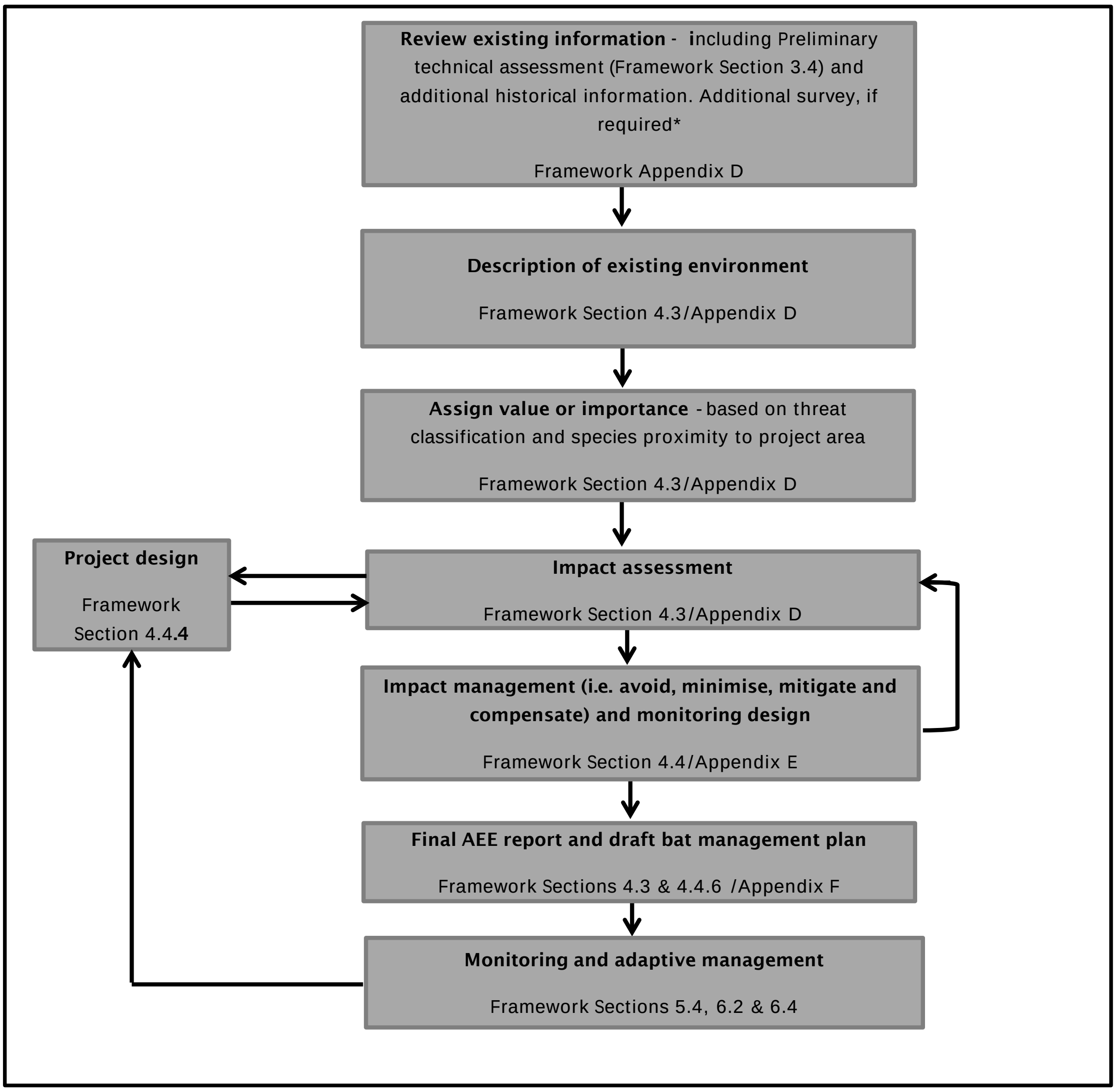
Framework section	**Example survey question**	**What do you need to measure/ identify?**	**Field method**	**Constraints**	**Reliability/likely ability to answer question**	**Effort required (resources, skill, cost)**
					emergence counts may not include all roost sites within area and may not reflect population size	
	Does bat abundance change before and after implementation of X?	Changes in bat abundance in proximity to road project.	Capture-mark-recapture prior to and post-implementation	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be recaptured/resighted.	High
	Does population index change before and after project implementation?	Number of bats observed using specific roosts	Counting at roosts using exit counts (cameras, visual counts, infrared) Infrared away from roosts is not recommended for estimating population size or monitoring population over time.	Availability of skilled staff, cost, equipment availability, permit being granted.	Low; potential to double count individuals generally little evidence to show any direct correlation of indices with abundance; are frequently confounded with activity. Risk that monitored roosts may be abandoned permanently or temporarily between survey periods.	High
	Are bats still present in the area after project implementation?	Presence	ABMs	Weather, time and equipment available; availability of staff to interpret outputs.	High/reasonable likelihood of detection if survey is undertaken over long period and/or repeated.	Low
	Does the removal of XX habitat result in behavioural changes?	Behaviour	Eg compare the use of a roost before and after removal of X habitat by roost counts Capture-mark-recapture and radio tracking.	Availability of skilled staff, cost, equipment availability, permit being granted.	High; risk that capture rates are low and bats leave study area or are unable to be radio-tracked.	High

Annex DD: Bat detailed ecological impact assessment process (EcIA)

The detailed ecological impact assessment (EcIA) process described here draws on the guidelines of the Environment Institute of Australia and New Zealand 2015 (EIANZ 2015). While the EIANZ guidelines reflect the relationship between the processes of ecological science and New Zealand's planning and regulatory framework, the detailed scope of any Bat EcIA should be discussed with an RMA planner to ensure the bat assessment addresses the biodiversity rules and assessment criteria in the relevant district and Regional rplans and policies.

Figure DD.1 describes the EcIA process as it relates to bats following the EIANZ (2015) and the draft NZ Transport Agency (2017) *Ecological impact assessment for state highway projects*. It is understood these guidelines will be revised and finalised (respectively) in later in 2017, so should be rechecked for consistency.

Figure DD.1 Guidelines for assessing the impact of linear transport infrastructure on bat populations



* In some cases, the preliminary EcIA may be sufficient to support the preparation of an AEE.

DD.1 Review existing information

A bat preliminary technical assessment (PTA) should have been undertaken during the initial options assessment or early in the design development process. This provides a preliminary assessment of the ecological features on site and the potential impacts on bats of the project. The bat PTA will usually include a baseline survey and/or review of previous surveys used to guide the appropriate scale and scope of further investigations. Information obtained during these early stages should be used to inform the bat EcIA and in some cases may be sufficient to support permit AEEs.

If the baseline survey results are not sufficient to identify with a high degree of confidence whether bat populations are present or predict project impacts and appropriate mitigation, or are not still relevant or acceptably recent, additional surveys should be undertaken (refer section D3.4).

DD.2 Additional survey and description of the environment

Additional surveys should only be undertaken if the information obtained from the bat PTA (and baseline survey) is not considered sufficient to inform the AEE. This may happen if there is a significant time lag between options assessment and recommendation of a particular option and detailed design. In this case, changes to the route may occur through further development of the design concept. At this point in the process, specific consideration should be given to the zone of influence (ZOI)[26] on bats and the impact of the proposed works. When undertaking additional detailed surveys, objectives formed at the start of the process should be reconsidered and updated where necessary. Where possible, survey work should aim to meet anticipated pre-construction monitoring requirements.

If previous surveys have suggested bats are absent, an additional site-based review should be undertaken. This would only occur where a previous desk top review indicated bats were likely to be present in the project area.

DD.3 Assigning value

When producing a bat EcIA, ecological value must first be assigned to species, sites and ecosystems. Level of effect is then determined by considering both the magnitude of effect and the value of the affected biodiversity or ecological feature (EIANZ 2015). Ecological value at a species level can be assigned according to the species' threat classification following the New Zealand Threat Classification System (table D.1) and on the species' proximity to the project area. Under the system, both New Zealand bat species are listed as threatened (O'Donnell et al 2013). The threat classification is then converted into an expression of ecological value in accordance with the EIANZ (2015) guidelines, which propose a conversion for species based on the national threat classification and extended for cases of local rarity or threat. Where species, such as bats, are listed as nationally threatened and are found within the project ZOI or are likely to occur within the ZOI either permanently or occasionally, their ecological value in relation to the site is 'very high'.

Table DD.1 Threat status of New Zealand bats under DOC's Threat Classification System (O'Donnell et al 2013)

Long- tailed bat (*Chalinolobus tuberculatus*)	Lesser short- tailed bat (*Mystacina tuberculate*)
Threatened – nationally vulnerable (North Island form) Threatened – nationally critical (South Island form)	Threatened – nationally endangered (Northern and South Island forms) Threatened – nationally vulnerable (central form)

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[26] The areas/resources that may be affected by the biophysical changes caused by the proposed project and associate activities (EIANZ 2015).

DD.4 Impact assessment methodology

Further research is required to provide certainty about the impacts of linear transport infrastructure on bats. Currently, the following approach is suggested to assess project impacts on bats:

- Describe the proposal and the potential impact this will have on ecological features. For example, the construction of a roading project may result in long-term increase in traffic intensity which may reduce bats’ use of the area (either direct mortality or behavioural avoidance).
- Consideration should be given to whether the impact is temporary or permanent, ie will there only be a temporary impact on bats, eg noise caused during construction or will the impact be permanent due the removal of roost habitat, foraging habitat, the interruption of flight paths, operational traffic noise?
- Measures should be taken to avoid impacts in the first instance after which methods to minimise or remedy mitigate impacts should be considered. Communication with the engineering design team is critical.
- Use table DD.2 to assess the magnitude of impact (adapted from the EIANZ (2015) guidelines, table 9.
- Combine the magnitude with the ecological value (threat status) to provide a measure/estimation of the level of impact (refer table DD.3.
- Consider impacts over a wider scale than just the project. Are there cumulative impacts between projects or within geographic areas, or over time?

Table DD.2 Criteria for describing the magnitude of impact (adapted from the EIANZ (2015) guidelines – examples are given for potential impacts incurred on bats during roading projects.

Magnitude	Description
Very high/severe	Total loss or significant change to bat habitat identified on site which will result in a change in comparison with the baseline survey results, habitat utilisation and flyways; and/or will result in the loss of a very high proportion of the local population and range. This may be a result of direct mortality through roost removal and vehicle collisions or indirectly through the loss of habitat, or impact on their behaviour.
High	Major loss or alteration of bat habitat, ie removal of most roost sites which may result in a change to the baseline survey results, or changing the character and composition of the site for bat utilisation ; and/or fragmenting bat populations by creating roads that lead to barriers to their movement across the landscape. Loss of a high portion of the known population or range.
Moderate/medium	Partial loss or alteration of habitat, ie composition of bat habitat on the site will be partially changed Loss of a moderate portion of the known population or range.
Low/minor	Minor shift from baseline survey condition – sites Having a minor effect on known population or range.
Negligible	Very slight shift from baseline conditions, no noticeable effect between surveys is likely to be observed There is a negligible effect on known population or range.

The ecological value determined by a bat’s threat status (‘very high’) is combined with the magnitude of the impact score (table DD.3) and can be used to provide an overall level of the impact.

Table DD.3 Level of impact matrix (modified from table 12, EIANZ (2015) guidelines)

Ecological value (very high for Bats) →	**Very high**
Magnitude ↓	
Very high	Very high
High	Very high
Moderate	Very high
Low	Moderate
Negligible	Low

The different levels of impact are defined below (very high, moderate and low) and should be used to guide the extent and type of the ecological response required (EIANZ 2015). The methodology for mitigating different impacts (based on current knowledge) is discussed in section D4.4.

- **Very high** indicates a high level of impact on New Zealand bats and warrants complete avoidance of bat habitat, ie fly ways/flight paths and roosts and/or a level of mitigation that aligns with the high level of impact. Currently in New Zealand the success of mitigation measures is unknown/untested and as such, avoidance is the only guaranteed option to prevent such impacts.
- **Moderate** indicates a level of impact that requires careful assessment and analysis of the individual case. Such an effect could be mitigated through avoidance, design or extensive appropriate mitigation actions (which includes testing of success and adaptive management).
- **Low** – it should be noted that due to the large home ranges of native bats (up to 1,589 hectares for male long-tailed bats (O'Donnell 2005) and 6,220 hectares for short-tailed bats (Lloyd 2005), detection of bats some distance away from a project site may still mean they have been affected by features of the linear infrastructure project. As such, a ‘low’ level of ecological impact is not likely to be applicable when bats are present.

Annex DE: Impact management strategies

Table DE.1 Summary of the potential strategies that could be used to manage the effects of linear infrastructure projects on bat populations, internationally and in New Zealand, and factors that may influence their successful application in the New Zealand context (strategies are ordered by timing in relation to construction, ie before, during and after)

Strategy – avoidance	Potential impact measure seeks to address	Desired outcome	Applicability to New Zealand bats and overseas evidence	Critical success factors	Limitations	Scale of costs	Timing (in relation to construction)	Data requirements
Identification and protection of maternity roosts during the route selection/detailed design phase	• Roost destruction during habitat clearance. • Direct and indirect impacts on pregnant mothers/ young • Decline in population growth as recruitment rate (pups) reduced	Complete avoidance of maternity roosts	Recommended management strategy as avoidance of impacts considered to be the only effective method of managing impacts. Additionally, life history analysis of New Zealand bats indicates that breeding females are key to population growth	Identifying maternity roosts reliably during baseline surveys.	• Difficulties in reliably identifying maternity roosts with acoustic surveys • Bats may move to other roosts.	• Low (provided design is based on baseline surveys or roosts are already known) • High (if capture and radio tracking is method used).	Before (pre-construction)	Location of maternity roosts.
Avoidance of key habitat during the route selection/detailed design phase	• Direct and indirect mortality of bats. • Roost destruction during habitat clearance.	Complete avoidance of key habitat.	Recommended management strategy as avoidance of impacts considered to be the only effective method of managing impacts.	Identifying key habitat during baseline surveys.	Availability of suitable area for linear infrastructure that is not bat habitat.	Low (provided design is based on baseline surveys).	Before (pre-construction)	• Vegetation preference • Roost sites • Foraging habits

Strategy – mitigation	**Potential impact measure seeks to address**	**Desired outcome**	**Applicability to New Zealand bats and overseas evidence**	**Critical success factors**	**Limitations**	**Scale of costs**	**Timing (in relation to construction)**	**Data requirements**
Artificial roost provision	Loss or disturbance of roost sites.	Replacement and compensation for loss of natural roosts from road construction.	• Applied in NZ however effectiveness has not been tested, ie uptake by the effected bat population. • Some evidence of limited use by long-tailed bats in New Zealand. • Variable results from overseas studies (3–100% occupancy rates from 15 different studies).	• Placement of roosts where natural roosts were located or where natural roosts are limited. • Orientation to sunlight. • Provision of appropriate design and in location that provides a variety of temperatures of roosts.	Lack of knowledge of effectiveness	Low	• Before • After	• Roost locations • Roost use preference.
Vegetation removal protocols	• Direct mortality of bats. • Roost destruction during habitat clearance.	Prevention of mortality of roosting bats during habitat clearance.	Applied in New Zealand; however, to date there has been only a very low number of roosts discovered using the current protocol, ie one found by DOC staff in Fiordland.	• Ensuring reliable data on climatic conditions for bat emergence. • Ability to identify a roost from ABM data (bats do not always echolocate when emerging). • Protocols must include all vegetation to be removed, (ie	Effectiveness relies upon accuracy of roost identification, which is untested.	Medium	During	• Roost locations • Climatic effects on emergence.

Strategy – mitigation	**Potential impact measure seeks to address**	**Desired outcome**	**Applicability to New Zealand bats and overseas evidence**	**Critical success factors**	**Limitations**	**Scale of costs**	**Timing (in relation to construction)**	**Data requirements**
				dead ponga trunks), not just trees.				
Underpass/ culvert	• Mortality through vehicle collisions. • Interruption to flight paths and barriers to dispersal.	• Reduced risk of vehicle collisions by guiding bat movements under road. • Maintenance of pre-development flight paths. • Increased road permeability leading to reduced barrier effect.	• Potential to use underpasses built for minor roads, paths or water in New Zealand to guide bats under roads. • Four studies in Europe found varying proportions of bats to be using existing underpasses below roads and crossing over the road above.	• Knowledge and maintenance of bat flight path and height data • Larger cross-sectional area and greater height of underpass may increase use. • Reduce use of artificial lighting in surrounding area. • Incorporation of a waterway may increase use.	Lack of knowledge of effectiveness	Low (provided underpass is built for other purposes and design is based on pre-construction surveys)	After (operational)	• Flight height • Flyway/flight paths
Road/foot-bridge – unvegetated	• Mortality through vehicle collisions. • Interruption to flight paths and barriers to dispersal.	• Reduced risk of vehicle collisions by guiding bat movements above traffic height. • Maintenance of pre-development flight paths. • Increased road permeability	• Potential to use road or foot bridges built in NZ to also guide bats over roads. • No overseas evidence to show that overpasses assist a significant proportion of bats to cross roads safely.	• Bridge height and location follows alignment/height of pre-development flight paths. • Reduce use of artificial lighting in surrounding area.	- Lack of knowledge of effectiveness	Low (provided bridge is built for other purposes and design is based on pre-construction surveys)	After	• Flight height • Flyway paths

Strategy – mitigation	Potential impact measure seeks to address	Desired outcome	Applicability to New Zealand bats and overseas evidence	Critical success factors	Limitations	Scale of costs	Timing (in relation to construction)	Data requirements
		leading to reduced barrier effect.						
Vegetated 'green' bridge	• Incidental mortality through vehicle collisions. • Interruption to flight paths and barriers to dispersal.	• Use of bridges for foraging by bats. • Reduced risk of vehicle collisions by guiding bat movements above traffic height. • Maintenance of pre-development flight paths. • Increased road permeability leading to reduced barrier effect.	• Potential to enhance road or foot bridges built in NZ to also guide bats over roads. • Use of green bridges demonstrated for one European study (90% of bat crossing at that location used it). Although this does not show its effectiveness at maintaining bat populations.	• Increased bridge width important. • Well vegetated with dense and continuous trees/shrubs. • Good continuity with roadside bat habitats • Follows alignment/height of pre-development flight paths.	• Lack of knowledge of effectiveness. • Depending on planting time and type, a significant time-lag between planting and trees/ vegetation reaching sufficient effective height.	Medium (provided bridge is built for other purposes and design is based on pre-construction surveys)	After	• Flight height • Flyway/flight paths • Vegetation preference • Foraging habits
Bat-bridge/gantry	• Incidental mortality through vehicle collisions. • Interruption to flight paths and barriers to dispersal.	• Reduced risk of vehicle collisions by guiding bat movements above traffic height. • Maintenance of pre-development flight paths.	• No known benefits to bats. **Use in New Zealand not recommended**. • One UK study found fewer bats using bat gantries to safely cross roads than numbers that were crossing at traffic height.	Bridge/gantry height and location must follow alignment/height of pre-development flight paths.	• High cost. • No known benefits to bats.	High	After	• Flight height • Flyway/flight paths

Strategy – mitigation	Potential impact measure seeks to address	Desired outcome	Applicability to New Zealand bats and overseas evidence	Critical success factors	Limitations	Scale of costs	Timing (in relation to construction)	Data requirements
		• Increased road permeability leading to reduced barrier effect.						
Vegetated 'Hop-over'	Mortality through vehicle collisions.	• Reduced risk of vehicle collisions by guiding bat movements above traffic height. • Maintenance of pre-development flight paths. • Increased road permeability leading to reduced barrier effect.	• Applied in New Zealand; however, effectiveness has not been tested. • While there is evidence that bats will cross roads at greater heights in the presence of high canopy cover or roadside embankments (Russell et al 2009; Berthinussen and Altringham 2012), there is no overseas evidence for the effectiveness of hop-overs in guiding bats safely over roads and maintaining local bat populations.	Tree height must follow alignment/height of pre-development flight paths.	Depending on type and timing of planting, a significant time-lag between planting and trees/vegetation reaching sufficient effective height.	Medium	After	• Flight height • Flyway paths • Vegetation preference • Foraging habits
Lighting management	Incidental mortality through vehicle collisions.	Deterrence of photo-phobic species away from roads to reduce collision risk.	• Applied in NZ however effectiveness has not been tested. • NZ survey results indicate long-tailed bat activity is	• Height of light posts should consider alignment/height of pre-development flight paths.	• Use of deterrence effect must be balanced carefully against concurrent increase in a	Low	After	• Flight height • Flyway paths

Strategy – mitigation	Potential impact measure seeks to address	Desired outcome	Applicability to New Zealand bats and overseas evidence	Critical success factors	Limitations	Scale of costs	Timing (in relation to construction)	Data requirements
			reduced in areas of Hamilton where lighting is more intense (Le Roux & Le Roux 2012). Further research required. • No overseas evidence for the effects of deterring bats from roads with lighting.	• Type of light should be considered.	‘barrier’ effect. • Lights may attract bats to roads due to increases in insect food source.			
	Interruption to flight paths and roosts, and barriers to dispersal.	Avoidance of illumination of flight paths and roosts.	• Applied in New Zealand; however, effectiveness has not been tested. Two UK studies found bats more likely to emerge from roosts and fly along hedgerows when left unlit than illuminated.	• Type of light should be considered • Avoid use of short-wavelength light.	Removal of possible food source.	Low	After	• Flight height • Flyway paths
Replanting	• Interruption to flight paths and roosts, and barriers to dispersal. • Loss of habitat and roost sites.	• Maintenance of functional connectivity of habitats. • Mitigation for roost loss during road construction; provision of foraging habitat.	• Applied in New Zealand; however, effectiveness has not been tested • Use based on limited observational studies from overseas.	• Maintenance of connectivity for foraging and roosting between remaining habitat patches. • Like-for-like replacement.	Dependent on plant type and timing, and likely large time lag between planting and any accrual of benefits to population (may take 60-80 years).	Medium	After	• Vegetation preference • Roost sites • Foraging habits

Strategy – mitigation	**Potential impact measure seeks to address**	**Desired outcome**	**Applicability to New Zealand bats and overseas evidence**	**Critical success factors**	**Limitations**	**Scale of costs**	**Timing (in relation to construction)**	**Data requirements**
Road margin/verge design	Mortality through vehicle collisions.	• Reduced risk of vehicle collisions by discouraging bats' use of areas close to roadside. • Reduce habitat fragmentation.	• Applied in New Zealand; however, effectiveness has not been tested. • Some evidence of modified behaviour from Europe.	Height of barrier or design alignment/height must follow pre-development flight paths.	Depending on planting type and timing, there will be a significant time-lag relative to time-scale of impacts before any benefits may accrue.	Low	After	• Flight path height • Flyway/flight paths
Introduced predator control (in order to increase population recruitment rates as an offset to the impacts of road induced mortality)	Bat mortality due to pest predation.	Increase bat survival rates (particularly adult female bats).	• Previously applied in New Zealand. • New Zealand studies suggest increase in survival and population persistence.	Only effective over large areas.	Limited spatial and temporal scale of control may limit effectiveness. More likely to be effective if predator control is focused on areas where maternity roosts are likely to be located. Could be considered as off-site compensation	Low	• Before • During • After	Location of maternity roosts or the extent of the bat population's roosting range.

Annex DF: Bat Management and Monitoring Plan – template

Quality information

Document	Bat Management Plan for XXXXXX
Ref	
Date	
Prepared by	
Reviewed by	

Revision history

Revision	Revision date	Details	Authorised	
			Name/position	Signature

This template is used to prepare a BMMP for roading capital or maintenance works. The template is anticipated as a starting point and will need to be adapted to address local issues and the scope of the project, which may include deletion of content that is not relevant to the project.

Where a permit, consent or designation condition or conditions require the preparation of a BMMP or an ecological management plan including bats, the conditions have precedence over this template.

The structure of the template has been designed so the BMMP can be easily updated and amended as new information becomes available or project details change.

All notes in *italics* should be deleted or edited and should not form part of the plan without modification.

1 Introduction

1.1 Purpose and objectives

State BMMP purpose eg ‘The purpose of the Bat Management and Monitoring Plan is to identify management and operational procedures to avoid, remedy or mitigate adverse impacts on bats from the [insert relevant activities/project]’

1.2 Regional and local context

This section should cover:

- *Bat species affected*
- *Knowledge of local and regional bat populations*
- *Other projects in the area that may also have an impact on bat population– now and in the known future*

1.3 Project description

Provide project description, with particular focus on impacts to bats. Should cover all stages of a project including enabling works, tree felling, construction and post-construction.

Figure 1: Site location and proposed activity

1.4 Relationship to other management plans

Describe relationship to other management plans (including landscape plans) eg is the bat management plan a sub plan of an ecological management plan or environmental and social management plan.

Figure 2: Management plan structure

2 Responsibilities and competencies

Identify all those with responsibilities in implementing the BMP, including Principal contractor if known. Include c*ontact details of people with responsibilities in an appendix.*

Table 1 BMP responsibilities

BMP section	Person responsible	Competency levels
BMP – overall responsibility and implementation		
BMP – author		
Mitigation strategies		
Pre-construction monitoring		
Vegetation removal protocol implementation (including pre-felling monitoring)		
Mitigation implementation		
Post-construction monitoring		

3 Regulatory framework

3.1 Relevant consents and permits

Provide an outline of the resource consents, wildlife permits, concessions or other relevant legal agreements and conditions that are associated with bats. Include a table showing how relevant sections of the BMMP demonstrate compliance with conditions as well as the status of the compliance. (Use suggested consent/permit conditions when preparing a draft management plan).

Table 2 Consents and permits - BMMP compliance

Consent/ permit	Condition #	Condition	Relevant section of BMP demonstrating compliance	Status

4 Baseline survey

Describe current understanding of bat populations affected by project, important ecological features; distribution and habitat use by bats. Include maps and diagrams where relevant. Include survey summary and results, identifying where further work is required.

5 Impact identification

5.1 Summary

Summarise potential impacts of project on bats, their scale, magnitude and timescale for preconstruction, construction and operational phases.

5.2 Procedure to review and update impacts

Explain how the impact identification section will be updated as monitoring results become available and if project details change.

6 Impact management

6.1 Approach

Describe the impact management approach (ie measures to avoid, remedy or mitigate effects on bats). Mitigation and other impact management should be linked in the first instance to project impacts identified in the impact assessment (section 5.1) and with bat behaviour and life history. The impact management should be updated as impacts are monitored and the effectiveness of management methods assessed.

Reference specific management procedures, eg roost identification, tree felling, predator control, design specifications for bat passes/ roadside planting/lighting

6.2 Environmental thresholds/performance criteria

For each impact or management method, determine measurable criteria against which to assess its effectiveness and the threshold trigger. For example:

Table 3 Environmental thresholds

Potential impact	Management method	Desired outcome	Threshold	Time frame
Loss of roost trees	*Vegetation removal protocol*	*No occupied roosts felled (based on post felling inspection)*	*0 occupied roosts felled (based on post felling inspection)*	*Construction period*

Refer section 8 for procedures to reviewing and updating impact management methods if thresholds are not being met.

6.3 Impact management procedures

In this section include any specific procedures that must be followed such as: procedures for identifying roosts, procedures for minimising disturbance from construction activities or vegetation removal protocol.

7 Monitoring programme

7.1 Objectives

Monitoring objectives should be prepared and include objectives which:

1. *Measure the impacts of construction activities, roads, noise and lighting and other potential barriers (eg bridges, embankments) on the movement of bats*
2. *Identify and measure use of key habitats (eg maternal roosting sites, flight paths and foraging sites).*
3. *Measure the effectiveness of the impact management detailed in table 3 of this BMP.*

Permit/consent conditions may stipulate the objectives of monitoring (refer section X) in which case these should be included.

Objective X:

Objective X:

Objective X:

Objective X:

7.2 Monitoring requirements

Divide up the monitoring requirements needed to meet monitoring objectives by phases. [Note if survey methods will disturb bats in any way, or involve catching bats, then a wildlife permit will be required under the Wildlife Act 1953, refer to section D4.2.3 of the Bat Framework].

7.2.1 Pre- construction monitoring

[Outline additional monitoring surveys that will be required (or have previously been undertaken) to provide sufficient baseline information to inform impacts, vegetation removal protocols, mitigation and during and post-construction monitoring]

7.2.2 Construction monitoring

7.2.3 Post- construction monitoring

7.3 Monitoring methodologies

For each phase of monitoring specify the monitoring survey design, timing, method, effort and expertise required for the different project phases. Permit/consent conditions may stipulate details of monitoring. Methods may include: acoustic monitoring, thermal Imaging, direct observation, mark-recapture, radio telemetry, radar (to date not used in New Zealand); and 3D microphone network (to date not used in New Zealand).

The Department of Conservation has produced a bat inventory and monitoring module which provides information about the different types of bat monitoring methodologies (www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/bats/).

Also specify report format and frequency.

7.3.1 Pre- construction

7.3.2 During construction

7.3.3 Post- construction

7.3.4 Reporting

8 Procedures for review and updating impact management

Describe procedures for evaluating impact management methods and updating if the thresholds stipulated in table 3 are not being met, or research questioning the effectiveness of the mitigation measures becomes available or an unexpected adverse impact associated with the [project] is identified through monitoring.

Appendices:

1. Key contacts and responsibilities
2. Relevant resource consent conditions
3. Vegetation removal protocol
4. Bat surveys/ecological reports

Appendix X Key contacts and responsibilities

Role	**Contact details**
Consent holder	
Engineer to the contract/provision of ongoing bat monitoring	
Contractor/BMP implementation	
Designer/BMP author	
Regulatory authorities/approvals of BMP	
Nominated lead ecologist and approved bat specialist	
Other nominated ecologists with bat experience	
Nominated arborist	

Annex DG: Suggested conditions of notice of requirements, resource consents and wildlife permits

The following conditions establish the basic framework of conditions covering avoidance, mitigation and ongoing management of impacts for a linear transport project, primarily through the use of a BMMP, which may be part of a project/contract ecological management plan and/or ESMP. Where areas of uncertainty exist, the conditions have been written so details can be inserted as more information about bats (eg their behaviour, impacts from linear transport and the effectiveness of mitigation) becomes available.

When applying these conditions to specific projects the following should be noted:

- Conditions need to reflect the nature, scale and significance of the effects.
- Conditions will need to reflect the extent of baseline monitoring completed, road design progress and amount of detail presented in the preliminary BMMP.
- Where the exact location of the route is unknown (eg for non-transport projects that require construction of an access way) the 'design' conditions (refer section DG.6) should be used.
- The competency table D.2 can be found in section D2.5.
- If a notice of requirement (NOR) or resource consent application already incorporates a preliminary BMMP, consent conditions can include more detail including the performance criteria that must be achieved as specified in the BMMP and mitigation methods that must be carried out.
- The BMMP will most likely form part of a management plan framework and should be consistent with other management plans where possible. Hence timeframes for monitoring, reporting and review have been left blank, except for when they have specific relevance to bats. The certification procedure will be similar to other sub-plans, so a specific condition has not been included.
- The intention of the conditions is to encourage monitoring and to allow for evaluation and alteration of mitigation and management to meet pre-set criteria regarding mitigation of impacts through reviewing and updating the Bat Management Plan.
- A vegetation removal protocol is contained in annex DH and is designed to be included in these consent conditions as schedule A.
- Post-construction monitoring conditions should specify who is responsible for ensuring the conditions are met. Where possible the conditions should reflect the procurement model and ownership structure of the transport infrastructure project.
- The conditions listed below should provide the starting point for developing conditions relating to bat impact management, however the relevance and applicability of each condition will depend on the individual project conditions and what permits are being applied for.

DG.1 Using the conditions:

- Suggested condition text is in *italics* with relevant information requiring insertion between [XX]
- Technical terms should be included in the definitions section of the conditions, eg construction footprint, commencement of works, site coverage, key habitats.

- The conditions should detail the process for certification and re-certification of the BMMP and the process to resolve disputes should the approving authority chose not to certify the plan or requires amendments. This is not addressed in the following suggested condition text.

DG.2 Competency of bat ecologists

Any reference to a Class A, B, C, D, E or F bat ecologist in these conditions shall mean a person who fulfils the experience and knowledge requirements stipulated in the following table:

Table X: [Insert competency table D.2].

DG.3 Baseline monitoring requirements

This section of conditions outlines baseline monitoring requirements that would likely need to be undertaken prior to and during the detailed design and development stages of a proposal. However, if adequate baseline monitoring (refer section D3.5) has been undertaken prior to the preparation of a consent or wildlife permit application, these conditions (i) will not be required.

i. *Pre-construction baseline distribution surveys shall include surveys using techniques approved by a Class F bat ecologist to assess bat distribution, activity, and behaviour within areas of potential bat habitat at the proposed site (s);*

ii. *Monitoring sites outside the project area within areas of bat habitat shall be included to provide control sites for comparison;*

iii. *A minimum of [x number] surveys at each monitoring site shall be undertaken during each of [X number] different summers (November to April inclusive), prior to construction commencing;*

iv. *All survey and monitoring activities must be undertaken by people who meet the experience and knowledge stipulated in table X for the type of survey work they are undertaking. and must be undertaken in accordance with the Department of Conservation's 'Best practice manual of conservation techniques for bats' (Sedgeley et al 2012);*

v. *Identification of occupied roosts and potential roost habitat shall be undertaken by a Class C [insert 1 or 2 for short or long tailed bats or both] Bat Ecologist and must follow procedures outlined in the Vegetation Removal Protocol in Schedule A; and*

vi. *The Class C Bat Ecologist (1 or 2) must provide reports [insert frequency] to [approving authority] detailing any bats observed/heard and trees or vegetation that may contain bat roosts detailing the size, location and type of tree/vegetation. Data collection requirements must comply with the standards specified in the Bat Management Framework – Linear Transport Infrastructure, November 2016, (Appendix A, Section D3.6 documenting survey methods and results). The methodology used to identify roosts shall be detailed in the reports provided.*

DG.4 Bat Management and Monitoring Plan (BMMP)

It is recommended a draft BMMP is submitted with the consent/permit application and is based on the template BMMP (refer annex DF). The BMMP should detail specific methodologies and processes that provide measures to avoid, minimise, mitigate, manage and review potentially adverse effects on bats during construction and provide methodologies to monitor and mitigate the effects after the completion of works (during operation). The preliminary BMMP prepared as part of the approvals applications may require updating during the approvals process or subsequent to gaining RMA and Wildlife Act approvals.

Certification: The certification of the BMMP must be carried out by a Class F bat ecologist. The conditions should detail the process for certification and re-certification and the process to resolve disputes should the approving authority choose not to certify the plan or should it require amendments.

vii. *Bat Management and Monitoring Plan*

The consent holder shall develop and implement a Bat Management and Monitoring Plan (BMMP) which meets the requirements set out in the [reference framework plan template]. The purpose of the BMMP is to provide a management and operational framework to avoid, remedy or mitigate and monitor adverse impacts on bats from the [insert relevant activities/project]. The BMMP shall be prepared or co-authored by a Class F bat ecologist or ecologists The BMMP shall include, but not be limited to, the following:

1) *Measures to avoid, remedy or mitigate effects/impacts on bats [insert relevant activities/project]*
2) *Measurable criteria against which to assess the effectiveness of the measures (herein referred to as "environmental thresholds").*
3) *A list of key personnel and points of contact, including but not limited to bat ecologists and personnel with specific management responsibilities under the conditions of the consent and the BMMP;*
4) *Procedures for:*
    i) *Identification of roosts in accordance with schedule A*
    ii) *Minimising disturbance from construction activities within the vicinity of discovered roosts until such roosts are confirmed to be vacant of bats, as determined by a Bat Ecologist using current best practice*
    iii) *Vegetation removal in accordance with schedule A. The purpose of the vegetation removal protocol shall be to avoid the injury or mortality of roosting bats.*
5) *Bat monitoring programme (refer Conditions xi-xii)*
6) *Process for BMMP review including details of how ongoing monitoring and evaluation of the effectiveness of the BMP against the determined environmental thresholds will be used to review and update the content of the BMP in accordance with conditions [xv to xvi] described in this consent.*

viii. *Any subsequent changes proposed to the BMMP shall be confirmed in writing by the consent holder and certified in writing by [XX consent/permit authority] prior to the implementation of any proposed changes.*

ix. *No physical works can commence until the BMMP has been certified by [XX consent/permit authority] for implementation.*

x. Consultation on BMMP

The consent holder shall provide a draft of the BMMP to the [XXX relevant consenting/permitting authority(s) X] for comment at least XX working days prior to it being submitted to [XXXX] for certification. The consent holder shall consider for incorporation into the final version of the BMP any comments/suggested amendments provided by the [XXXX]. If those comments/amendments are not incorporated into the final BMMP, the consent holder shall forward copies of the comments/amendments to [approving authority for certification] stating the reasons.

DG.5 Bat monitoring programme

xi. *The consent holder shall prepare a monitoring programme to be included in the BMMP. The objectives of monitoring shall be stated in the BMMP [X reference BMMP condition] and should cover:*

a) Measuring the impacts of construction activities, roads, noise and lighting and other potential barriers (eg bridges, embankments) on the movement of bats;

b) Identifying and measuring use of key habitats (eg maternal roosting sites, flight paths, and foraging sites); and

c) Measuring the effectiveness of the impact management detailed in the BMMP in accordance with [Conditions X to X]).

xii. *The monitoring programme must detail pre-construction, construction and post construction monitoring to be carried out including but not limited to:*

a. Location of monitoring;

b. Timing of surveys, eg season, temperature, humidity and light levels; and

c. Reporting format and frequency.

d) Pre-construction monitoring must be carried out for a minimum of [X] years.

e) Monitoring of roost removal and habitat loss (including specific minimum standards determined by a level 3 or 4 Bat Ecologist) for roost tree identification and monitoring of roost trees before their removal (recognising the limitations for determining roost tree occupancy in some situations),

f) Post-construction monitoring shall be carried out for a minimum of [XX] years post construction, and shall ensure adequate site coverage incorporating all potential roosting and foraging habitats as well as suitable control sites, ie areas where the bats are not likely to be affected by the road being constructed or in operation.

g) The results of the monitoring must be forwarded to the [insert relevant consent/permit authority] in a report on an [annual basis/or specify frequency]. Data shall be presented in accordance with the Bat Management Framework – Linear Transport Infrastructure, November 2016, (Annex DA, Section D3.6 documenting survey methods and results).

h) If monitoring shows that the previously agreed/stipulated project environmental thresholds (refer Condition [XX]) are not met, then the BMMP must be reviewed, updated, and implemented, in accordance with condition xiv below.

DG.6 BMMP reporting and review

xiii. *The Consent Holder must review the BMMP and the associated monitoring and forward to [XX] for recertification:*

a. Following completion of construction and prior to the commencement of post-construction monitoring;

b. If an environmental threshold identified in the BMMP is not met, or research questioning the effectiveness of the mitigation measures becomes available or an unexpected adverse impact associated with the [project] is identified by the consent holder or the consent authority: and

c. *If the scope of the project has altered in location, nature or scale.*

xiv. *In circumstances where an environmental threshold identified in the BMMP has not been met or an unexpected adverse impact associated with the project is identified by the [Consent Holder] and / or another party as a result of activities authorised by this consent, the Consent Holder must:*

a. *Complete an assessment of management approaches in order to avoid, remedy or minimise the impacts of the environmental threshold non-compliance identified in the BMMP or the unexpected adverse impact. The assessment must include consideration of relevant environmental monitoring data. The assessment must identify the timeframe for implementation of the solution. This assessment must be provided to [insert relevant position at consenting authority] for certification within 1 month of advising the [insert relevant position at consenting authority] unless a timeframe extension is requested by the Consent Holder and approved by [insert relevant position at consenting authority].*

DG.7 Design development

This condition applies to projects where little or no route design has been carried out such as access roads being constructed on private property.

xv. *The consent holder, based on the advice of the* Class F *Bat Ecologist, must take all practicable efforts to ensure that* <u>*no*</u> *trees or vegetation containing bats are felled and all practicable efforts are made to avoid felling unoccupied or occupied roosts and potential roosting habitat during design.*

xvi. *An alternative route/ construction footprint should be used if potential bat roosts or flight paths are present in the preferred route/ construction footprint.*

xvii. *If no practicable alternative route/clearance that avoids bat roosts or frequently used flight paths can be identified, the route which will have the least impact on bats shall be proposed subject to the opinion of a Class F Bat Ecologist. If, despite best endeavours, a bat roost tree is planned to be, or is unexpectedly, removed then a currently 'unprotected' roost or area with equivalent habitat must be protected.*

Annex DH: Vegetation removal protocol (VRP)

DH.1 Definitions

- **Dawn** and **dusk** are defined as starting and ending 0.5 hours either side of the closest sunrise and sunset times provided by LINZ[27].
- **Visual surveys** include a visual inspection of potential roost sites to confirm the presence of bats and/or bat signs, ie guano.
- **Supervising bat ecologist (SBE)** is defined as Class C bat ecologist competency level (refer table D.2, appendix D), dependent on project size and complexity. Class A and B bat ecologists may form part of their team and undertake tasks outlined within this VRP (as defined by table D.2) under supervision from the SBE. The SBE is not required to be present at the site all the time but must retain sufficient oversight of their team to be confident good decisions are being made regarding presence/absence of bats and potential roost sites. However, the SBE is expected to be available to oversee vegetation removal.

DH.2 Introduction

Bat activity, emergence times and whether bats emerge from their roosts at all, can be influenced by temperature, humidity, invertebrate activity and light levels (O'Donnell 2005). Consequently bat survey protocols should consider these factors. Recent research into long-tailed bats activity suggests long-tailed bats are more likely to be detected when the temperature 1–4 hours after sunset is greater than 6°C and particularly when temperatures are in the range of 10 to 17°C, with humidity ≥70%. Long-tailed bats did not emerge from roosts in a study based near Geraldine, South Canterbury, when temperatures were less than 5°C (Griffith 2007). However further work is required to understand how these factors should be accounted for in this protocol.

Application of this protocol will require refinement to reflect current knowledge and project characteristics, particularly with respect to the size and type of tree the protocol applies to, precipitation conditions for surveys and contact details in annex DH.

DH.3 Quality assurance and communication procedures

1. The relevant provisions of DOC's *Best practice manual of conservation techniques for bats* (Sedgeley et al 2012) should be adhered to for all aspects of bat work.
2. The vegetation removal protocol (VRP) will apply to all trees > X dbh (diameter at breast height), tree ferns and other vegetation that meet the criteria for a potential bat roost as defined in annex DH[28]
3. All practicable effects must be undertaken to ensure that **no** trees or vegetation containing bats are removed.
4. Prior to the commencement of surveys, automated bat monitoring devices or units (ABMs) shall be checked for correct operation at a site where bat activity is known to be high. Faulty or suspect ABMs are not to be deployed.

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[27] See www.linz.govt.nz/sea/nautical-information/astronomical-information

[28] Previous protocols have required vegetation over 15cm dbh in the Central North Island and Waikato, and 25cm dbh in Fiordland, to be checked for the presence of bats.

5 ABM data from each pre-felling survey shall be reviewed without unnecessary delay. If no bat activity at potential roost trees is identified and the SBE determines the vegetation can be removed, this information should be relayed to the contractors in sufficient time to allow contractors to clear vegetation prior to dusk the same day.

6 No trees or associated vegetation identified as potential roosts (see annex DH) can be felled or cleared without the approval of the SBE.

7 Once the results of the visual surveys and ABM data have been reviewed by the SBE the following communication procedures shall be implemented.

a If no bats are sighted or detected, the SBE shall call the vegetation clearance supervisor to give permission for the affected tree(s) and/or vegetation to be removed. In addition, at the completion of felling works, an email report shall be sent to the site manager and a representative of both the local council and DOC.

Table DH.1 Details for key project contacts

	Name	Contact details
Site manager	[Insert]	[Insert]
DOC representative	[Insert]	[Insert]
[XX] Council representative	[Insert]	[Insert]

b If bats are sighted or detected the SBE shall call the vegetation clearance supervisor to inform them that the affected vegetation cannot be cleared. In addition, an email shall be sent to the site manager, and a representative of both the local council and DOC detailing the results of the survey and outlining measures for on-going visual surveys as detailed in annex DH.

c Additionally, the results of the roost surveys and ABM data shall either be reported or reviewed by the SBE. The report should include the presence and/or absence of bat roosts within the proposed clearance areas including the size, location and type of trees or vegetation. The report shall be forwarded to the above representatives: within xx days following completion of the survey or if appropriate, or required by consent conditions within an annual monitoring report.

DH.4 Roost identification

DH.4.1 Potential roost identification – habitat assessment

a) All locations where vegetation may be disturbed must be surveyed by the SBE for ‘potential bat roost trees’.

b) All potential roost trees in the site must be clearly marked.

[Note: Roosts tend to be observed in mature trees that are >15 dbh (Borkin 2010); *however, native bats have also been observed in tree ferns and cabbage trees* (Borkin 2010; Sedgeley and O'Donnell 1999; 2004)*. Therefore habitat assessment should be broad, encompassing mature trees and other vegetation types and should consider the following criteria.*

a) Bat roosts are likely to have one or more of the following attributes:

- *Cracks, crevices, cavities, fractured limbs, or other deformities, large enough to support roosting bat(s).*
- *Sections of loose flaking bark large enough to support roosting bats.*
- *A hollow trunk, stem or branches.*
- *Deadwood in canopy or stem of sufficient size to support roost cavities or hollows.*

b) <u>Trees or vegetation with minimal potential as roosts will have:</u>

- *No cracks, crevices cavities, fractured limbs, or other deformities, large enough to support roosting bat(s).*
- *No substantial section of deadwood in the canopy or stem of sufficient size to support roost cavities or hollows.*
- *No sections of loose flaking bark large enough to support roosting bat(s).*]

DH.4.2 Roost confirmation

Once potential roosts have been identified, the use of a tree as a roost can be confirmed by visual confirmation alone or by using a combination of ABMs and visual confirmation.

DH.4.2.1 ABMs

This section discusses the use of ABMs to confirm roost occupancy.

1 To determine if trees or other types of vegetation are roosts they should be monitored overnight (including sampling dusk + 3.5 hours and dawn) between September and April using an ABM or several ABMs for a minimum of [3] days.

2 The ideal time to undertake surveys is when temperature ranges between 10 and 17°C.

3 Surveys are optimal when relative humidity is c.>70%.

4 Little precipitation should occur within the first two hours after dusk. The amount of precipitation allowed during this period is [XXXXX}.

5 Monitoring during a full moon should be avoided.

6 The ABM(s) should be placed so that detection of bats is likely if they are using the potential roosts.

7 ABM data should be analysed to indicate the potential for roosts. It should be noted that based on the current understanding of bat calls near roosts, it is possible that roosts will not be detected. In these cases, the criteria outlined in DH.4.2.2 should be followed.

8 In the event ABM data and/or observations indicate bat roosting before the two-night monitoring duration has been completed no further monitoring is necessary and the vegetation used for roosting may not be removed.

DH.4.2.2 Visual

Each tree or vegetation with features that make it a potential roost may be inspected to confirm the site as a roost. This may be subsequent or prior to ABM monitoring depending on the method of roost confirmation chosen.

1 Potential roost locations can either be visually inspected from the ground by using, for example, roost emergence watches, or trees must be climbed and inspected by an arborist or trained climber.

2 To undertake an inspection while climbing, the arborist or trained climber will relay any potential evidence of bats (eg staining, cavities, guano) by way of live audio-visual equipment and/or photographs for review by a SBE prior to removal. The arborist or trained climber will also check for signs of bats using a bat detector (to detect social and echolocation calls from roosting bats, under supervision of the SBE).

3 If potential roost locations are within tree ferns or other 'delicate' vegetation, climbing should only be undertaken if it is safe to do so for the climber and if this will not reduce the likelihood of the roost being used in the future. All climbing must take place under the careful supervision of the SBE to prevent roost damage.

DH.4.2.3 Exit observation at roosts

In some instances bats do not always call when emerging from their roost (Borkin pers comm). If a potential roost site has been identified in habitat using DH.4.2.1 criteria and it is considered highly likely to contain a roost, but could not be confirmed using ABMs or external visualisation of the roost, observations of bats leaving their roosts provides an alternative roost confirmation methodology. In this instance, the following methodology should be implemented:

1. Bats begin to leave roosts while there is still light outside therefore there is potential to observe bats without the aid of cameras of video equipment.
2. Observations should begin before sunset. Ambient temperature should be >10°C and there should be no precipitation (otherwise bats may not emerge).
3. Observations shall be carried out close to potential roost sites where flying bats are back-lit against the sky. It may be useful to have more than one person observing potential roost sites from different angles to determine precise trees or vegetation and exit holes.
4. Hand-held bat detectors may also be useful to alert the ecologist(s) to the presence of bats nearby, narrowing down the potential roost site locations and allowing roosts to be confirmed.
5. Infrared cameras and video recorders may also be used to confirm the presence of bats leaving potential roost sites.

DH.5 Vegetation removal

1. Trees ideally should not be removed from May – September when bats could be hibernating or torpid.
2. If bats are confirmed in a tree, then that tree should not be felled.
3. All potential roost trees and vegetation to be removed within the calendar year must be clearly marked by the SBE and distinguished from trees to be retained. To determine roosting, all potential bat roost trees and vegetation must be inspected for the presence of bats immediately prior to any proposed felling using DH.4.
4. If trees are surveyed in appropriate conditions and no bat activity is recorded, or the level and activity patterns do not indicate roosting according to the interpretation of the SBE, the tree or vegetation may be removed – removal must occur on the same day the survey ends. The SBE should be available for the duration of all vegetation clearance operations to advise staff should bats be detected (leaving trees or injured) and to inspect each felled tree or vegetation for signs of bat roosts.
5. If no bat activity is recorded and a roost has not been found visually (refer DH.4.2.1 or by observation (refer DH.4.2.2 then the tree or vegetation can be cleared. Removal must occur on the same day as the visual inspection.
6. If bat activity is observed during vegetation clearance, then clearance should stop immediately and should not commence until further monitoring confirms that the bats have abandoned the roost. Trees and vegetation should be marked and site staff briefed immediately to indicate a roost is present. If bats are found injured or dead DH4 should be implemented.
7. If bats are detected while felling is in progress, felling must stop long enough to allow any uninjured bats to escape (if it is safe to do so). Every effort should be made to relocate the section of trunk/branch where the bats are roosting before felling may commence (if it is safe to do so).
8. If bats are confirmed to still be roosting by following DH4 after seven days then an agreed team of the SBE and contractor representatives will be contacted to re-assess and consider alternative methods to

progress vegetation removal. This will be a risk assessment-based approach dependent on the type of roost identified. The team shall include a council ecologist or their nominated representative, a DOC nominee, a contractor nominee and the SBE. If the team cannot make a decision within 48 hours of the meeting taking place then the [xx] council shall be advised and a final decision made by the certifying officer/DOC.

DH.6 Bat injury or mortality

In the event of finding a dead or injured bat(s) the following procedures should be implemented:

1 Injured bats should be taken immediately to the following location, approved by DOC for assessment:

Table DH.2 Contact information for approved contact in the event bat injury occurs

Vet clinic/zoo or other specialist	
Name	
Contact details	
Address	

2 Bats should be placed in a cool dark material-lined box/bag by or under the direction of the SBE to ensure the animal is handled appropriately.

3 The local DOC office or DOC hotline (if after hours) should be contacted no longer than two hours after the injured or dead bat is found.

Table DH.3 Contact information for DOC contacts

Local DOC office	
After hours	0800 DOCHOTline 0800 362 486

4 DOC and veterinary advice shall be sought in conjunction with the SBE when considering the rehabilitation requirements of any injured bats (for example legislative requirements will need to be considered). Once the vet has made an assessment the SBE and vet will determine any rehabilitation action required and the longer-term future for the bat/s.

5 Bats confirmed as injured should be sent to the Massey University Wildbase hospital for rehabilitation. It should be noted that release after rehabilitation is unlikely due to the risk of disease being transferred back into the local bat population.

6 If the animal is dead or euthanised by the vet, it must be taken to the local DOC office as soon as practicable. The bat/s must be stored in a fridge at less than 4°C

Appendix E: Glossary

AADT	annual average daily traffic (volume)
ABM	automated bat monitor (unit/device)
AEE	assessment of environmental effects
AIC	Akaike information criterion
Allee effects	a phenomenon in biology characterised by a correlation between population size or density and the mean individual fitness (often measured as per capita population growth rate) of a population or species.
BACI	before-after-control-impact (study design)
Bat crossing structures	vegetated bridges, gantries, hop-overs, underpasses
BMI	Bite Mark Index
BMMP	Bat Management and Monitoring Plan
BMP	Bat Management Plan
BP	presence or absence of bats
CA	Conservation Act 1987
CIEEM	Chartered Institute of Ecology and Environmental Management
CMP	Conservation Management Plan
CMS	Conservation Management Strategy
DEFRA	Department for Environment Food & Rural Affairs, United Kingdom
Detailed EcIA	Detailed ecological impact assessment to support the AEE
DOC	Department of Conservation, New Zealand
EcIA	ecology impact assessment
EIANZ	Environment Institute of Australia and New Zealand
EMaR	environmental monitoring and reporting
EPA	Environmental Protection Authority
ESMP	Environmental and Social Management Plan
FC	frequency compression
FCABM	frequency compression automated bat monitoring units produced by the New Zealand Department of Conservation
GIS	geographic information system
GPS	global positioning system
HBRC	Hawke’s Bay Regional Council

HBRCIC Ltd	Hawke’s Bay Regional Council Investment Company Ltd
Impact management	avoidance/mitigation/compensation/offsetting
LED	light-emitting diode
LGNZ	Local Government New Zealand
MCP	minimum convex polygon measure of home range size
MfE	Ministry for the Environment
MNA	minimum number alive technique; used to measure population size
Monitoring	Replicated surveys using standard methods over an extended period of time (van der Ree et al 2015).
NOR	Notice of Requirement
NPCA	National Possum Control Authority
NPS	National Policy Statement
PA	priority activity
PE	project ecologist
PIT	passive integrated transponder (tag)
PM	project manager
PP	project planner
Project phases	Stages of linear transport infrastructure project relating to this framework – options assessment, project design, consenting and AEE, construction, operation and maintenance
PTA	preliminary technical assessment (specialist report supporting the preliminary and/or detailed EcIA
Preliminary EcIA	preliminary ecological impact assessment
R	programme used to analyse and model data
RC	resource consent
RMA	Resource Management Act 1991
RPS	regional policy statement
RTC	residual trap catch
RWSS	Ruataniwha Water Storage Scheme
SBE	supervising bat ecologist
SMART	specific, measurable, achievable, relevant and time-bound goal
SMZC	Song Meter zero crossing
SNA	significant natural area
SPCA	Society for the Prevention of Cruelty to Animals

Surveys	The collection of spatial and/or temporal data about a species, a community or a habitat. The information can provide a snapshot of presence/absence, abundance, spatial distribution, habitat use, flyways. This information is used in impact assessment (either preliminary or ecological impact) which is used to evaluate the ecological resource on a site. This information can then be assessed or evaluated against set agreed criteria. Impacts are considered in respect of this information and assessed for significance.
Transport Agency	New Zealand Transport Agency
TRP	tree removal protocol
UK	United Kingdom
VPR	vegetation removal protocol
WEX	Waikato Expressway
WDC	Waikato District Council
WRC	Waikato Regional Council
ZC	Wildlife Acoustics SMZC Zero Crossing Bat Recorders
ZOI	zone of influence