Considering bird-vehicle collision risks, effects, evidence and mitigation in New Zealand

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Abbreviations and acronyms

AI	artificial intelligence
BACI	Before–After, Control–Impact
DOC	Department of Conservation
EcIA	ecological impact assessment
GIS	geographic information system
GPS	Global Positioning System
KDE	kernel density estimation
LiDAR	light detection and ranging
NZTA	NZ Transport Agency Waka Kotahi
UAVs	unmanned aerial vehicles

Contents

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Executive summary

Roads are a dominant feature of contemporary landscapes. While essential for human transport and connectivity, they can also present serious risks to wildlife. In New Zealand, where many bird species are flightless, ground-dwelling, or constrained to fragmented habitats, vehicle collisions could represent an under-recognised source of mortality. This report is a detailed synthesis of current knowledge on the impacts of road-kill on New Zealand's avifauna, integrating findings from structured surveys, opportunistic observations, and expert accounts. It identifies the bird species most at risk, provides information on key locations and time periods where mortality can occur, and outlines methodological and strategic priorities for improving national monitoring and mitigation.

Rationale and scope

The scale and implications of bird road-kill in New Zealand are poorly documented despite widespread concerns and anecdotal reports of bird deaths. A gap analysis conducted by the Ministry of Transport's Biodiversity and Transport Knowledge Hub highlighted road mortality as a key knowledge gap with potential consequences for threatened species. This report fills that gap by examining available data, evaluating international and local best practice for road-kill monitoring and mitigation, and recommending feasible approaches tailored to the New Zealand context.

The report is structured into four main parts: (1) a literature review on road-kill ecology, mitigation, and monitoring methods; (2) a synthesis of New Zealand-specific data; (3) guidance for developing standardised monitoring protocols; and (4) recommendations for research, policy integration, and ecological impact assessments (EcIAs).

Bird road-kill patterns in New Zealand

Data collated in this report confirm that birds constitute a significant portion of road-kill across New Zealand. Although mammals dominate many road-kill datasets, birds consistently represent between 6% and 26% of observed vertebrate carcasses, depending on survey location, method, and species composition. Recent structured surveys found birds accounted for 62% of newly observed road-kill along a peri-urban road network in Canterbury, with 18.2% of these identified as native species.

Species affected span a wide range of functional types, including:

- flightless or ground-dwelling endemics (eg, kiwi, weka, penguins)
- wetland and coastal birds (eg, pāteke/brown teal (*Anas chlorotis*), pūkeko (*Porphyrio melanotus*))
- scavengers and roadside foragers (eg, Australasian harriers (*Circus approximans*), New Zealand falcons (*Falco novaeseelandiae*))
- common urban and rural species (eg, Eurasian blackbirds (*Turdus merula*), Australian magpies (*Gymnorhina tibicen*)).

Road-kill risk is often elevated near habitat edges, wetlands, and coastal nesting zones. Seasonal peaks in mortality coincide with breeding and fledging periods, with juveniles particularly vulnerable due to inexperience or dispersal movements. Some seabird fledglings, such as Hutton's shearwaters (*Puffinus huttoni*) and Westland petrels (*Procellaria westlandica*), are also susceptible to light-induced disorientation during fledging, increasing the risk of crash-landing on roads near urbanised coastal areas.

Carcass persistence also affects observed vulnerability. Small-bodied, cryptic, or nocturnal birds are under-represented in most datasets due to rapid removal or low detectability, though their actual mortality may be substantial. A recent study showed carcass longevity varied widely by species and condition, with some taxa (eg, hedgehogs) persisting for weeks, while others (eg, small passerines) disappeared within 1–2 days.

Structured vs opportunistic monitoring

We distinguish between structured surveys, which follow repeatable designs, and opportunistic data collection (eg, citizen science, wildlife hospital records). Both approaches have value, but also limitations. Structured surveys yield consistent data but are resource-intensive. Opportunistic observations offer broader geographic and temporal coverage but lack standardisation, which limits comparability and interpretation.

The combined dataset reveals consistent themes:

- Some species, particularly kererū (*Hemiphaga novaeseelandiae*) and harrier, are frequently reported across multiple regions.
- Road-kill events can cluster temporally (eg, at fledging time) or spatially (eg, near colonies or wetland crossings).
- Scattered incidents, particularly involving cryptic species, may reflect real but difficult-to-monitor risks for species that are often of conservation concern.

Ecological impacts and knowledge gaps

While the demographic impacts of road-kill remain difficult to quantify at national scale, effects on localised populations could be significant. For species having low reproductive rates, high adult survival dependence, or restricted ranges, even modest vehicle-related mortality may contribute to population declines, and could exacerbate existing pressures from predation, habitat loss, or climate change. Current monitoring efforts are often one-off, spatially limited, and inconsistent in method, limiting our understanding of the magnitude or importance of ecological impacts or suitability of mitigation design.

Principles of effective monitoring

Drawing on international best practice, the report outlines five key principles for effective road-kill monitoring:

1. **Species-focused design:** Tailor surveys to the size, activity patterns, and detectability of target taxa.
2. **Spatial standardisation:** Use fixed transects and repeatable routes, allowing comparisons over time and across locations.
3. **Temporal coverage:** Monitor across seasons and years to ensure sampling reflects variability in road-kill patterns and captures both seasonal and interannual trends.
4. **Bias management:** Account for variation in carcass detectability, persistence, and search effort.
5. **Technology integration:** Adopt tools such as Global Positioning System (GPS) enabled apps, dashboard cameras, and automated detection systems where feasible.

These principles form the basis for the monitoring protocol templates presented later in the report, which offer practical templates for structured surveys targeting high-risk species and locations.

Recommendations for management and research

The report concludes with detailed recommendations across four areas:

1. **Monitoring and data collection**
    a. Establish long-term monitoring at selected sites representing different habitats and species.
    b. Encourage dual-observer systems combining frequent, widespread but lower-resolution data (eg, from road crews) with slower, more localised but high-sensitivity surveys by ecologists.
    c. Expand citizen science engagement via apps and platforms like iNaturalist NZ.

   d. Adopt or develop mobile tools for standardised data entry (eg, voice-driven apps for hands-free recording).
   e. Trial remote sensing tools such as vehicle-mounted cameras with artificial intelligence (AI) for species identification in suitable contexts.

2. **Mitigation and planning**
   a. Use data to identify high-casualty hotspots and implement site-specific mitigation (eg, speed limits, warning signage, barrier for wildlife).
   b. Prioritise known crossing points, such as penguin colonies or wetland-road intersections, for infrastructure adaptation.
   c. Incorporate bird road-kill explicitly into environmental management plans and EcIAs.
   d. Coordinate mitigation with seasonal activity patterns (eg, avoid works near known breeding zones in spring).

3. **Policy integration**
   a. Include bird road-kill as a distinct source of avian mortality in EcIA templates and assessment matrices.
   b. Encourage early engagement with wildlife specialists during road design and consenting.

4. **Research priorities**
   a. **Long-term monitoring:** Standardised, long-term road-kill monitoring programmes are needed across New Zealand to track trends, assess cumulative impacts, and support robust EcIAs. Where possible, monitoring should be stratified by functional bird groups (eg, ground-dwelling, wetland species, nocturnal flyers) to better understand patterns of vulnerability and inform targeted mitigation.
   b. **Species-specific vulnerability:** Research into species traits, movement patterns, and road-crossing behaviours, especially for vulnerable ground-dwelling or wetland birds, will inform more effective mitigation.
   c. **Detection and bias:** Improving our understanding of carcass persistence and detectability through experimental trials and emerging technologies is essential to reduce sampling bias in road-kill studies.
   d. **Mitigation evaluation:** Systematic assessment of mitigation measures such as fencing, signage, and lighting is needed to determine their effectiveness in reducing bird mortality.
   e. **Public engagement:** Further work should explore how citizen science and public attitudes can enhance data collection and inform the design and acceptability of road-kill mitigation strategies.

Concluding remarks

The findings in this report confirm that bird mortality from vehicle collisions in New Zealand is a widespread, complex issue with ecological and planning implications. While data gaps remain, the evidence clearly demonstrates that road-kill affects a wide range of native birds, including species of conservation concern. Addressing this issue will require a coordinated national approach that combines improved monitoring, targeted mitigation, policy integration, and public engagement. Robust and ongoing monitoring will be essential to generate the data and evidence needed to guide decision making and support meaningful engagement.

Birds occupy a unique place in New Zealand's biodiversity and cultural identity. Ensuring their protection in a landscape increasingly shaped by infrastructure is both a critical conservation goal and a matter of national responsibility. With better tools, stronger coordination, and sustained investment, New Zealand can lead by example in tackling a problem common to road networks worldwide.

Abstract

Vehicle collisions represent an under-recognised source of avian mortality in New Zealand, with potential consequences for native bird populations and conservation efforts. This report synthesises available data on bird road-kill across the country, drawing from structured surveys, opportunistic observations, and expert accounts. It documents a broad range of species from affected bird species functional types, including flightless endemics, wetland and coastal species, scavengers, and common generalists. Road-kill events are commonly associated with areas near native bird habitat, including wetlands, forest edges, and coastal nesting sites, and tend to peak during breeding, fledging, and dispersal periods. Species vulnerability reflects a combination of ecological traits, seasonal movements, and landscape features, and may be compounded by other conservation pressures. While long-term population impacts remain difficult to quantify, road mortality could pose a significant local threat to slow-reproducing or range-restricted birds. Current monitoring efforts are fragmented and inconsistent, limiting their value for impact assessment or mitigation planning. The report identifies priorities for future research, including standardised long-term monitoring, species-specific movement studies, evaluation of mitigation measures, and expanded citizen science engagement. Improved data and coordinated management responses will be essential to better understand, mitigate, and reduce the impacts of vehicle collisions on New Zealand’s bird species.

1 Introduction

1.1 Project approach

This research project aimed to provide a foundation for developing and implementing effective methods to monitor bird road-kill, specifically addressing the significant mortality caused by vehicle collisions. The findings represent a first step towards addressing the knowledge gap regarding the impact of direct road-related mortality on native bird populations.

The project includes:

- a literature review to detail methods and best practice regarding road-kill survey design and mitigation techniques from overseas and New Zealand
- a desktop investigation to identify bird species and road locations in New Zealand where vehicle collisions are likely to cause significant mortality, and to characterise the associated species traits and site attributes
- principles guiding sampling design and the development of road-kill monitoring methods
- examples of road-kill monitoring protocols that could be applied in New Zealand.

The project was supported by a steering group appointed by NZTA, and also included input from independent peer reviewers. The steering group provided input through meetings at various stages of the project, including the beginning of the project and at multiple stages of the draft process. Peer reviewers provided detailed comments on drafts of the report.

1.2 Project rationale

This research topic was identified by the Ministry of Transport's Biodiversity and Transport Knowledge Hub while undertaking research gap analysis and prioritisation. Since current knowledge of the impacts of road-kill on New Zealand's native birds is poor (Simcock et al., 2022), it is not known whether significant population-level consequences from collisions with vehicles exist for some species. There is little understanding as to what site attributes may create a road-kill 'hot spot', what native bird species are most vulnerable, and how significant road-kill is to native bird populations. Such information, likely obtained through the collection and analysis of long-term and taxa-specific data, would also help support ecological impact assessments and provide a stronger foundation for evidence-based decision-making in New Zealand.

To address the knowledge gap regarding how roads impact native bird populations, the following questions must first be answered:

1. Which native bird species in New Zealand are most susceptible to vehicle collisions, and which road locations are associated with the highest rates of mortality?
2. What species traits and site attributes characterise the above examples?
3. What are the current rates of road-kill of these species at these sites, and how do they vary by season and year?

Developing and implementing road-kill monitoring methods that can generate robust, comparable data within New Zealand is essential to fully answer these questions. We have aimed to address them as thoroughly as possible in this study using the information currently available.

2 Literature review

2.1 Approach

We gathered published information on bird mortality from vehicle collisions (ie, road-kill) in New Zealand and internationally using Google Scholar. Our approach began with a review of international literature to outline key ecological concepts, patterns, and monitoring principles relevant to bird road-kill. This is reflected in sections 2.2 to 2.6. We then focused specifically on New Zealand, drawing from peer-reviewed and grey literature to synthesise available data on bird road-kill within a local context, as covered in section 2.7. A broad range of search terms was used to capture relevant literature, and sources were selected based on relevance to bird road-kill, monitoring methods, and mitigation. While we do not provide a full systematic review here, the material reflects a targeted effort to summarise key findings from both New Zealand and international studies. Additional information was obtained from unpublished datasets and discussions with conservation personnel.

Finding information on this topic proved challenging, partly due to the limited number of New Zealand-specific examples and the inconsistent spelling and use of alternate terms for ‘road-kill’. For example, we found all of the following to be used in the literature: *road-kill, road kill, roadkill, road mortality, vehicle collision, collision with vehicle, animal–vehicle accident, bird–vehicle collision, road deaths, road collisions, run over by cars, hit by car, hit by vehicle, vehicle strike, vehicle accident*. In this report, we use ‘road-kill’ wherever possible for consistency, although other terms were sometime unavoidable.

Table A.1 in Appendix A lists scientific and common names of birds in New Zealand discussed in this report, along with the New Zealand Threat Classification status of native species (Robertson et al., 2021).

2.2 Introduction to road ecology

The construction and expansion of transportation networks have transformed landscapes around the world, enabling the movement of people and goods, sometimes at considerable ecological cost. Road ecology is the interdisciplinary field that examines the interactions between roads, their use, and the environment, including their effects on wildlife populations, ecological processes, and landscape connectivity (Forman et al., 2003; van der Ree, Smith, & Grilo, 2015). The discipline has emerged over the past three decades as an essential component of conservation biology and transportation planning.

Roads can fragment habitats, restrict animal movement, alter microclimates, impact surface and groundwater flow, and facilitate the spread of invasive species (Benítez-López et al., 2010; Trombulak & Frissell, 2000). These impacts are not uniform, but vary according to species traits, landscape configuration, traffic volume, and road design (Coffin, 2007). In many terrestrial ecosystems, roads have been shown to function as both physical and behavioural barriers, reducing genetic exchange between populations and potentially lowering long-term species viability (Holderegger & Di Giulio, 2010; Jaeger et al., 2005).

One of the most visible and quantifiable effects of roads on wildlife is road-kill. Road-kill refers to wildlife deaths caused by vehicle collisions, including birds struck while on the road or hit in flight. Road-kill has increasingly been recognised as a major source of anthropogenic mortality for many species, including birds, mammals, amphibians, and reptiles (Erritzoe et al., 2003; Loss et al., 2015; Rytwinski et al., 2016). However, road ecology encompasses a broader suite of questions beyond wildlife mortality. These include how roads influence species distribution, movement, reproductive success, foraging behaviour, and predator–prey interactions (Fahrig & Rytwinski, 2009; van der Ree, Smith, & Grilo, 2015).

In response to these complex challenges, road ecology has evolved into a multidisciplinary domain that integrates spatial ecology, behavioural science, landscape architecture, engineering, and policy analysis

(Forman et al., 2003; van der Ree, Smith, & Grilo, 2015). Tools such as ecological modelling, remote sensing, Global Positioning System (GPS) tracking, and citizen science platforms are now regularly employed to better understand and mitigate road-related impacts.

For transport authorities, applying road ecology principles offers a framework to minimise environmental harm while maintaining road safety and functionality. Ecological considerations are becoming more prominent in New Zealand road planning, particularly in relation to high-profile taxa such as kiwi (*Apteryx* spp.) and seabirds, though implementation remains uneven. For instance, NZTA has previously undertaken research to identify, assess, and manage road edge effects on biodiversity, highlighting a growing awareness of ecological impacts in transportation projects (Simcock et al., 2022).

This report focuses on one of the core areas of road ecology – road-kill impacts on birds – as a starting point for building broader, evidence-based approaches to mitigate transport–wildlife conflicts.

2.3 Road-kill impacts on birds

Collisions with vehicles are an increasingly recognised source of anthropogenic mortality for birds worldwide. Globally, estimates suggest that vehicle collisions cause several hundred million bird deaths annually. In North America, between 80 and 340 million birds per year are estimated to die on roads in the United States (Loss et al., 2014) and 14 million in Canada (Calvert et al., 2013). Estimates for Europe are 194 million (Grilo et al., 2020), with 27 million in the United Kingdom alone (Erritzoe et al., 2003). These figures place road-kill among the most significant human-related causes of bird mortality worldwide, following predation (particularly by feral and domestic cats) and impacts with buildings, windows, and power lines (Calvert et al., 2013; Erickson et al., 2005; Loss et al., 2015).

Estimates of mortality are also sometimes underestimated, as it has been shown that many bird carcasses go undetected due to rapid removal by scavengers, decomposition, or being struck in ways that leave no obvious visible remains (Antworth et al., 2005; Guinard et al., 2012; Santos et al., 2011). One road-kill study reported that fewer than 50% of small bird carcasses remained on the road after 24 hours (Santos et al., 2011). Mortality figures reported also do not capture the number of birds that are injured but not immediately killed, rescued individuals that never return to the wild, or indirect losses such as the starvation of nestlings after a parent is killed (Holm & Laursen, 2011; Mumme et al., 2000).

The impacts of road-kill extend beyond individual fatalities to affect population viability, reproductive success, and species distribution. For species with small or declining populations, even relatively low numbers of vehicle-related deaths can influence population trends. For instance, in the United States, the Florida scrub-jay (*Aphelocoma coerulescens*), a threatened species, suffers substantial mortality on roads, and road-adjacent populations act as demographic sinks (areas where deaths exceed births and immigration is needed to sustain numbers) (Mumme et al., 2000).

Reproductive consequences have also been demonstrated in European passerines. Kuitunen et al. (2003) reported that pied flycatcher (*Ficedula hypoleuca*) nestlings in Finland had significantly lower fledging success when one of the parent birds was lost to road-kill. A similar effect was observed in great tits (*Parus major*) in Denmark, where the loss of a parent bird due to vehicle collision led to measurable declines in chick survival (Holm & Laursen, 2011).

The risk of road-kill is especially high for species that are low-flying, ground-dwelling, or that forage near or on roads. Corvids (eg, magpies, rooks, crows) and some raptors (ie, birds of prey) are frequently reported as victims, often due to their attraction to carrion or road-side prey (Erritzoe et al., 2003; Morelli et al., 2014). Scavenging behaviour can increase exposure to risk, as birds feeding on previous road-kill may be struck themselves, potentially creating a cascading mortality effect. In North America, vehicle collisions have been identified as a leading cause of death for many urban raptors, especially diurnal species that hunt near roadsides. Vehicle collisions were reported for 12 of 19 owl species (63%) in a review of raptor mortality in North America, and were identified as the leading cause of death for 6 species (32%) (Hager, 2009).

Seabirds and nocturnally active species are also highly vulnerable. In coastal and island settings, fledgling seabirds can become grounded by disorientation from artificial lighting near roads, after which they are struck by vehicles. Podolsky et al. (1998) recorded large numbers of wedge-tailed shearwaters (*Ardenna pacifica*) killed in Hawai‘i, while Le Corre et al. (2002) reported similar events for Barau’s petrels (*Pterodroma baraui*) on Réunion Island. Both situations showed clear increases in road mortality linked to light pollution, nearby roads, and the timing of fledging.

The design and location of roads can compound the problem. High-speed roads, multi-lane highways, and roads passing through ecologically sensitive or high-use bird habitat tend to have the highest mortality rates (Clevenger et al., 2003; Coffin, 2007). Roads that bisect migratory corridors or sit between nesting and foraging areas present particular hazards. For example, nesting success in cliff swallows (*Petrochelidon pyrrhonota*) declined along high-traffic routes due to frequent vehicle collisions (Brown & Bomberger Brown, 2013).

Although some species may exhibit behavioural avoidance of traffic, others may habituate to roads or be slow to respond to oncoming vehicles. Studies suggest that even where road-kill accounts for a modest percentage of annual adult mortality, the cumulative effects, especially in long-lived or slow-breeding species, can be considerable (Benítez-López et al., 2010).

In summary, road-kill is now recognised as a widespread and biologically significant source of avian mortality. The ecological effects are especially concerning for rare, endemic, or long-lived species with low reproductive output, as well as for localised populations already under pressure from habitat loss or other anthropogenic threats. Understanding which species are most at risk, and under what conditions, is an essential next step and forms the focus of the sections that follow.

2.4 Factors influencing road-kill numbers

Bird mortality from vehicle collisions is driven by a complex interaction of factors related to bird traits, road characteristics, and the broader landscape or environment. While some aspects of these dynamics are shared with other taxa, there are bird-specific behaviours and vulnerabilities that shape road-kill risk, including flight patterns, ground use, and attraction to certain roadside features. Understanding these factors is important for identifying high-risk species and sites, and for developing effective mitigation strategies.

2.4.1 Bird-related factors

Species identity plays a central role in determining road-kill risk, as behavioural and morphological traits influence how and when birds interact with roads. Several studies show that road-kill frequency differs markedly between species, even within the same habitat (Erritzoe et al., 2003; Kociolek et al., 2011).

Birds that forage, roost, or nest near roads (eg, corvids and raptors) are especially at risk due to the extended time they may spend on or near road surfaces, increasing their exposure to traffic (Erritzoe et al., 2003; Hager, 2009; Morelli et al., 2014). Flightless periods, such as during moult or when escorting goslings between roosting and feeding areas, further elevate collision risk in species like geese (Huijser et al., 2008).

Flight behaviour and height are also key contributors. Low-flying species face a heightened risk of vehicle collisions, as seen in barn owls that hunt just 1–3 m above the ground and Eurasian blackbirds (*Turdus merula*) that commonly cross roads at similarly low altitudes. Australasian bitterns (*Botaurus poiciloptilus*) generally have slow and heavy flight, which could make them susceptible to injury or death from collisions

(Williams, 2024). Similarly, birds that flush late (ie, delay take-off until a vehicle is very close) are also at higher risk (Erritzoe et al., 2003; Grilo et al., 2012).

Body size may influence both detectability and likelihood of survival post-collision. Larger birds are more likely to be noticed and reported, but they are also less agile and less likely to avoid an oncoming vehicle once airborne. On the other hand, small-bodied species may be under-represented in surveys due to rapid scavenger removal or observer error (Santos et al., 2011; Slater, 2002).

Age is another important factor. Juvenile birds are particularly susceptible, as they are less experienced with navigating human-altered environments, less likely to respond appropriately to threats, and more prone to foraging in risky areas. Fledglings, such as from nocturnal seabird species, are vulnerable to light disorientation and may become grounded in large numbers during their first flights, as reported for Hutton's shearwaters (*Puffinus huttoni*) in New Zealand (Deppe et al., 2017).

Adaptive behaviour may offer some species protection. Birds that can quickly adapt to traffic patterns or learn to avoid vehicles may have lower mortality rates. However, in species with rigid behavioural responses or strong site fidelity (eg, returning repeatedly to nest or forage at the same roadside site), risk can persist over time (Kociolek et al., 2011).

2.4.2 Road-related factors

The physical and operational characteristics of roads themselves greatly influence bird mortality risk. Traffic volume and speed are among the most consistent predictors of road-kill. High-speed roads offer less time for birds to react, and studies have shown a strong positive correlation between traffic speed and bird mortality rates (Kociolek et al., 2011; Malo et al., 2004). However, it has also been shown that higher traffic volumes can create a 'barrier effect' that can deter wildlife, while moderate traffic levels may lead to more frequent collisions (Brockie et al., 2009). For example, Grilo et al. (2012) showed that barn owls are more likely to cross roads when light-vehicle traffic was low (continuous but less noisy).

However, some studies suggest that barrier effects are not solely determined by average traffic volume, but also by temporal mismatches between wildlife activity and traffic intensity. For example, Bíl, Kubeček, & Andrášik (2020) found that roe deer (*Capreolus capreolus*) predominantly crossed roads at night during low-traffic periods, while collisions occurred more frequently during the day when traffic was heavier. This highlights the importance of considering daily traffic patterns when assessing road permeability and wildlife risk, as misalignment between peak animal activity and peak traffic load may either reduce or amplify collision rates depending on timing.

Road width and the number of lanes also matter. Wider roads may act as stronger barriers to movement and increase the likelihood of mid-road stops or hesitation, particularly for species reluctant to cross open spaces. Birds using roads for warmth, grit, or foraging may linger longer in the centre of wide roads, increasing exposure. Certain road types also contribute to increased bird mortality. Rural roads often traverse ecologically valuable habitats and may lack mitigation structures, while urban roads may expose birds to additional threats like reflective surfaces, light pollution, and noise. Bridges and causeways across wetland areas or estuaries can also create pinch points where birds are funnelled into narrow flight paths intersecting with roads (van der Ree, Smith, & Grilo, 2015).

Roadside vegetation plays a dual role. On one hand, it can attract birds by offering food (eg, berries, insects), cover, or perching opportunities. On the other hand, dense vegetation close to the road edge can reduce visibility, creating sudden take-off events when birds are startled by approaching vehicles. Tree lines and hedgerows running parallel to roads have been associated with higher bird mortality due to habitat proximity, although some vegetation types (eg, tall thorny hedges) may encourage birds to fly higher over traffic, potentially reducing risk (Erritzoe et al., 2003; Orłowski, 2008).

Lighting is another important consideration. Artificial light, especially high-intensity streetlight, has been implicated in disorienting nocturnally active species. This is a known problem in seabirds such as shearwaters, which can be drawn towards lights, become grounded on roadways, and subsequently be hit by vehicles (Le Corre et al., 2002; Rodríguez et al., 2017).

2.4.3 Landscape and environmental factors

The risk of road-kill also varies depending on landscape configuration, land use, and environmental conditions. Birds are more likely to cross roads when roads bisect preferred habitat or lie between essential resources, such as nesting and foraging areas. This is especially important for species that depend on wetland or forest patches scattered across a modified landscape. Landscape permeability and the spatial arrangement of habitat corridors can influence crossing frequency and the density of road-kill hotspots (Clevenger et al., 2003).

Urbanisation can influence bird road-kill in different ways. While it often reduces overall species richness, it can lead to higher road-kill rates for generalist or human-associated species (such as pigeons, starlings, and gulls) that are common in cities and frequently interact with roads. In contrast, some bird species avoid heavily urbanised areas altogether, which may lower their risk of vehicle collisions (Donnelly & Marzluff, 2006).

Seasonal variation also strongly influences road-kill rates. During breeding seasons, adults travel frequently between nests and food sources, increasing the chance of crossing roads. Dispersal of juveniles in late summer and early autumn, as well as post-breeding movements, are associated with seasonal peaks in road-kill (Erritzoe et al., 2003). Migration periods are another high-risk time, particularly in regions with migratory flyways intersecting road networks.

Lunar cycles can also influence the frequency of road-kill events. For example, in Japan, the frequency of Amami woodcock (*Scolopax mira*) road-kill increased the closer the moon was to full (ie, greater moonlight), when the birds were more active on the roads (Mizuta, 2014). Conversely, in New Zealand, a greater number of streetlight-caused groundings of Hutton’s shearwaters occurred during new moons (ie, less moon light) ultimately increasing their risk of vehicle collisions. This may be due to artificial light having a greater effect at times when there is less natural light (Deppe et al., 2017).

Finally, ‘ecological traps’ may occur where roads mimic attractive habitat features (eg, open ground for dust-bathing or warmth, linear clearings resembling flyways), drawing birds into high-risk areas. These traps may become ongoing sources of mortality if they are not identified and addressed (Battin, 2004).

2.5 Road-kill mitigation

Effective mitigation of road-kill events requires an understanding of both the ecological drivers of risk and the technological or infrastructural options available to reduce them. Globally, many mitigation tools have been developed and trialled, often driven by the need to reduce human fatalities and injuries resulting from wildlife–vehicle collisions. In countries such as the United States, where collisions with large mammals such as deer, elk, and moose are common, these crashes cause over 200 human deaths and 26,000 injuries annually, with associated costs exceeding US$8 billion (Huijser et al., 2008). In Europe, estimates suggest that up to one million ungulates may be killed on roads annually, with tens of thousands of vehicle accidents involving deer, moose, and wild boar recorded in countries such as Sweden and Germany (Langbein et al., 2011). These substantial human safety risks have justified major investments in mitigation infrastructure such as wildlife overpasses, underpasses, and extensive fencing. While these measures also reduce wildlife mortality, their primary justification has often been based on human safety and economic impact.

In many countries, particularly in Europe, wildlife–vehicle collisions also carry legal and financial implications, with compensation frameworks in place for both property damage and human injury (Bíl et al., 2025). While such liability structures are not currently a major factor in New Zealand, they may shape future policy responses if public concern or wildlife-related crashes increase.

In contrast, New Zealand's unique fauna, characterised by the absence of native large terrestrial mammals, presents a very different context. Road-kill incidents involving large, introduced mammals are relatively uncommon, making the associated risk to human life lower compared to countries with larger wildlife species. However, international studies suggest that even small animals can lead to injury-causing accidents, particularly for motorcyclists (Bíl, Andrášik, & Bílová, 2024), highlighting a potential but poorly understood human safety dimension in New Zealand. Nevertheless, large-scale investment in wildlife road-kill mitigation is less easily justified in New Zealand on human safety grounds alone.

In addition, many international mitigation strategies were designed primarily for large mammals and are often poorly suited to New Zealand's ecological conditions. Mitigation approaches must therefore be tailored to the specific species traits, landscapes, and traffic patterns found in New Zealand.

This section reviews some of the more common and newly emerging mitigation strategies relevant to road-kill, with a focus on their applicability to New Zealand's distinctive ecological landscape.

2.5.1 Signage and driver warning systems

Wildlife warning signage, particularly static roadside signage, is one of the most widespread mitigation tools used globally. However, for static signs in particular, their effectiveness remains variable and they are not recommended as a stand-alone solution (Townsend et al., 2024). Static signs tend to produce minimal and short-lived changes in driver behaviour. It is reported that most motorists fail to respond to them, particularly when signs remain unchanged, or because they rarely detect animals, leading to distrust in the sign itself (Huijser et al., 2015). For bird species, which often have low visibility and unpredictable flight or foraging behaviour, static signs are even less likely to aid drivers in reducing collisions with birds.

Enhanced signage, including signs with flashing lights, seasonal activation, or species-specific messaging, is often proposed to improve driver awareness and reduce wildlife collisions. For example, such signage is deployed annually on Phillip Island, Victoria, Australia, during the short-tailed shearwater fledging period to raise driver awareness during this high-risk time (Townsend et al., 2024). While evidence of effectiveness is still limited, surveys of Australian drivers suggest that including road-kill statistics or recent casualty updates may improve sign credibility and responsiveness (Bond & Jones, 2013). Similar approaches could be explored in New Zealand during seasonal movement periods for vulnerable species, such as seabird fledging events near coastal roads.

Intelligent signage, activated in real time by animal detection systems, may offer an increasingly viable strategy to reduce road-kill at known hotspots. These systems are designed to trigger only when animals are present, which may help reduce driver habituation – a common limitation of static or seasonal signage. They work by sending a signal to activate signage that alerts drivers to nearby wildlife, prompting them to reduce speed, and remain inactive when no animals are detected. While these systems have largely been trialled with large animals, including birds such as the southern cassowary (*Casuarius casuarius*), their potential application to smaller species has yet to be fully explored (Nandutu & Okouma, 2022; Townsend et al., 2024). Although more costly, this approach may be especially valuable on small road sections with high-risk road-kill hotspots, such as where birds congregate in large numbers (eg, wetland foraging areas or communal roosts). Developing intelligent detection systems for bird-specific applications in New Zealand represents a promising research opportunity.

2.5.2 Detection systems and in-vehicle alerts

A growing frontier in road-kill mitigation involves detection systems capable of identifying wildlife and transmitting warnings either to roadside signage (ie, intelligent signage) or directly into vehicles. These technologies do not directly reduce road-kill, but are instead used alongside other tools and systems that are specifically designed for road-kill mitigation. Technologies under development include thermal and optical cameras, machine-learning-assisted recognition, light detection and ranging (LiDAR), infrared motion sensors, and acoustic detection systems (Townsend et al., 2024). While many of these systems are not yet fully validated for small, fast-moving species like birds, they are rapidly evolving.

Bird-specific applications face unique challenges. Birds may be difficult to detect with current roadside systems due to small size, or rapid, unpredictable movement, or varying flight heights. Moreover, many existing detection platforms are designed around large mammal movement patterns (Townsend et al., 2024, Section 7.2). However, targeted trials are beginning to emerge for small-bodied species. For instance, recent proof-of-concept trials using artificial intelligence (AI) to detect turtles via car dashboard cameras showed 90% accuracy at highway speeds (Townsend et al., 2024).

In-vehicle alerts generated from detection systems, either onboard or via roadside communications, may eventually enable real-time driver warnings for bird concentrations or individuals detected ahead. This approach may hold promise for detecting road-roaming or roadside birds like pūkeko (*Porphyrio melanotus*), penguins, or weka (*Gallirallus* spp.).

2.5.3 Fencing and barrier infrastructure

Physical fencing is a widely used mitigation strategy to reduce road-kill, particularly by preventing animals from accessing roads and funnelling them towards safer crossing points (van der Ree, Smith, & Grilo, 2015). Fences can be constructed from a variety of materials, including mesh, plastic, concrete, electric wires, or noise walls (Townsend et al., 2024). They can also differ in height and incorporate design features such as overhanging lips or buried bases, depending on the target species and local context. Originally developed for large ungulates, fencing has since been adapted for other taxa, including reptiles and amphibians (eg, Helldin & Petrovan, 2019; Macpherson et al., 2021).

However, several limitations constrain the utility of fencing, especially in contexts relevant to bird conservation in New Zealand. The obvious first would be that many bird species are capable of flight and can easily bypass physical barriers. Fences themselves may also introduce new risks to some birds. For example, fences designed to exclude large mammals can unintentionally act as collision hazards for large, less manoeuvrable birds such as grouse and quail (Phasianidae) (van der Ree, Smith, & Grilo, 2015), and may pose similar risks for species like kererū (*Hemiphaga novaeseelandiae*) in New Zealand. While flagging fences to increase visibility may reduce such collisions, the effectiveness of this approach remains untested. Furthermore, no mitigation measures currently exist for species with erratic or low flight patterns, such as swallows, which are frequent road-kill casualties (Erritzoe et al., 2003).

Even for flightless birds (eg, kiwi and weka) or birds that often cross roads on foot (eg, pūkeko), fencing may not offer full protection due to gaps or breakages as a result of vandalism, fallen trees, or human access (van der Ree, Gagnon, & Smith, 2015). Additionally, effective fencing and other measures that limit animal movement across roads disrupt ecological connectivity by restricting movement within populations (Clevenger, 2003).

In general, short sections of fencing seem to be less effective at guiding wildlife to safe crossings compared with longer, more continuous fences (Huijser et al., 2016). However, recent research highlights that long, uninterrupted fencing (eg, >5 km) is often not feasible in many regions due to landscape constraints, costs, or land ownership patterns. In Central Europe, for example, only a small proportion of road sections meet this threshold, and shorter fencing solutions are more typical (MacDougall et al., 2024; Sedoník et al., 2023). These shorter sections require careful attention to fence endpoints, where wildlife may concentrate and road-kill rates increase ('end-of-fence effect'), necessitating targeted monitoring and mitigation.

In parts of Europe, protective netting screens approximately 4 m high are being tested as a lower-cost alternative to traditional barriers. These lightweight mesh screens aim to guide the flight paths of birds and bats over busy roads, offering a potential mitigation tool for species vulnerable to low-altitude collisions. While still under evaluation, they may represent a more affordable and species-specific option than the noise walls historically used for this purpose (see Centrum dopravního výzkumu [Transport Research Centre], 2024).

In the New Zealand context, if long stretches of fencing were to be implemented, various factors would need to be considered, such as cost, topography, and the ecological impact of vegetation clearance, particularly in native forests or sensitive wetland habitats. Given these trade-offs, fencing alone is unlikely to serve as a viable mitigation tool for birds in most New Zealand road environments. However, purpose-built fencing for certain species at specific sites could prove a viable option, if not for its absolute exclusion, but for its role in directing movement towards safer crossing zones. Future efforts should prioritise integrative approaches that balance effectiveness, cost, and habitat connectivity; potentially combining fencing with other mitigation approaches, such as species-specific deterrents, signage, or habitat modifications.

2.5.4 Wildlife crossing structures

Wildlife crossing structures are widely used to increase the permeability of roads by allowing animals to safely cross under or over, thereby reducing the risk of road-kill and restoring connectivity across fragmented landscapes (Smith et al., 2015). The location of crossing structures is important and should align with the movement behaviours, home ranges, seasonal habitats, and/or foraging routes of target species. Additionally, infrastructure originally built for other purposes, such as drainage culverts or stock underpasses, can often be modified to support wildlife movement. Crossing structures have been installed across a wide range of environments globally, with species from salamanders to elephants documented using them effectively. Wildlife crossing structures traditionally fall into two main categories: overpasses and underpasses. A third, more recent approach involves at-grade crossings, which are still emerging and have been trialled in limited contexts.

2.5.4.1 Wildlife overpasses

Wildlife overpasses are elevated structures that enable animals to cross above roads, helping to reduce road-kill while maintaining ecological connectivity. These structures come in several forms, including wildlife overpasses, ecoducts (or 'green bridges'), and canopy bridges (Smith et al., 2015). Ecoducts are typically broad structures, allowing for the inclusion of multiple vegetation zones and soil types that support a wider diversity of species. In contrast, wildlife overpasses are generally narrower, limiting the range of habitat features that can be incorporated.

While many birds are capable of flying over roads, certain species, particularly those that are forest-dependent or reluctant to cross open landscapes, may benefit from well-vegetated overpasses that reconnect fragmented habitats. The inclusion of appropriate vegetation, substrate, and screening can encourage usage by species sensitive to light or noise disturbance (van der Ree, Smith, & Grilo, 2015). Specialised structures such as canopy bridges and glider poles are primarily intended for arboreal mammals and gliders, but similar features have been trialled as 'hop-overs' for bats, with limited evidence of success (Smith et al., 2015). Wildlife overpasses have not been implemented in New Zealand to our knowledge.

2.5.4.2 Wildlife underpasses

Wildlife underpasses are structures built beneath roads and are the most commonly used type of crossing (Smith et al., 2015). These range from open-span bridges, which preserve broad habitat continuity (eg, across river valleys), to small or medium-sized culverts or tunnels. Their utility depends on factors such as dimensions, internal microclimate, construction material, and the presence of vegetation or natural substrate. Larger underpasses tend to serve a wider variety of species, while smaller structures, sometimes by design, may restrict use by larger-bodied species. Existing drainage culverts and stock underpasses can offer opportunities for low-cost adaptation. Modifications such as the installation of dry ledges, elevated walkways, or the removal of large rocks at entrances can make these structures more suitable for wildlife passage (Veenbaas & Brandjes, 1999; Villalva et al., 2013). Adding a second culvert with a raised floor adjacent to one with permanent water flow can also be a simple but effective approach for certain species. Wildlife underpasses are not commonly used in New Zealand. A notable example is in Oamaru, where an underpass was installed to reduce kororā/little penguin (*Eudyptula minor*) road crossings near the nesting site, especially during periods of high visitor traffic (see section B.2.3.3 in Appendix B). While some penguins still cross nearby, the success of the underpass is currently assessed based on penguin usage rather than changes in reported road-kill numbers, which remain low.

2.5.4.3 At-grade wildlife crossings

A newer class of crossing structures, known as ‘at-grade fauna passages’, has recently been developed and trialled in Europe, particularly for ungulate species (Elfström & Olsson, 2025). These designs maintain the road surface at grade but include embedded wildlife-friendly features such as fencing-guided entry points, textured substrates, and signage to alert drivers. Unlike traditional underpasses or overpasses, these crossings aim to reduce road-kill by guiding animals across the road safely at ground level rather than separating them vertically from traffic. While data on their long-term effectiveness remain limited, such structures may offer potential for use in contexts where grade separation is not feasible and where species of concern (such as flightless birds) are known to cross at specific, predictable locations.

2.6 Road-kill monitoring

A critical first step in understanding how vehicle collisions affect biodiversity is to quantify mortality on roads. This includes identifying which species are most at risk and locating areas of higher risk (Grilo et al., 2020). While this report focuses on quantifying road-kill, the second step – evaluating how this mortality influences population trends, distribution patterns, and long-term species persistence – is also essential and warrants further study.

Effective road-kill mitigation not only depends on implementing scenario-appropriate strategies but also on the ability to evaluate their effectiveness through rigorous monitoring (Rytwinski et al., 2016; van der Ree, Smith, & Grilo, 2015). Obtaining reliable road-kill data, before and after mitigation, is critical for assessing outcomes and guiding future actions. Meaningful evaluation requires monitoring methods that are not only repeatable and systematic but also tailored to minimise detection bias and reflect the ecological characteristics of the target species. Monitoring is therefore not a supplementary activity but a core component of any science-based mitigation framework.

Road-kill data can be collected using a range of approaches, which broadly fall into two categories: structured monitoring and opportunistic reporting. Structured methods involve repeated surveys of defined routes using standardised protocols that allow for accurate estimates of search effort, presence or absence, and carcass detection rates over time. These data are essential for calculating rates (eg, mortality per kilometre), comparing trends across seasons or locations, and evaluating the efficacy of mitigation actions. Opportunistic approaches, on the other hand, rely on incidental observations, such as those made by members of the public, conservation groups, or road workers. These observations are typically unstandardised, but can be valuable for capturing rare events, expanding geographic reach, and sustaining long-term community engagement. As demonstrated in previous studies, combining opportunistic records with species distribution models and structured transect data can provide a more comprehensive understanding of road-kill patterns (Roger et al., 2012). This blended strategy, also endorsed by Snäll et al. (2011), strengthens the ability of researchers and policymakers to assess impacts and tailor responses. It is especially valuable when applied across diverse ecological conditions and road network types.

Bird-focused road-kill monitoring efforts vary considerably across the literature, with differences in survey frequency, spatial scale, and data resolution reflecting differing research aims and constraints. Technological tools and citizen science platforms are increasingly being used to enhance traditional monitoring, although limitations exist, such as in detection accuracy and spatial coverage. While this diversity of methods underscores the flexibility of monitoring approaches, it also highlights a lack of standardisation. Most studies tailor their methods to specific local or taxonomic contexts, reinforcing the idea that no single monitoring method is universally applicable. In the context of New Zealand, these international examples provide a valuable starting point but will require local adaptation to account for unique avifauna, road types, and logistical constraints. Sampling design principles and considerations, including correction for bias, are explored in more detail in chapter 3 of this report.

2.6.1 Structured road-kill monitoring

Structured monitoring involves the repeated survey of designated transects or road segments using defined protocols. These surveys may be conducted by researchers, professionals, or trained volunteers and typically include records of search effort, timing, and environmental variables. Monitoring fixed transects allows researchers to track long-term trends, assess mitigation effectiveness, and detect spatial patterns with greater statistical confidence.

In contrast to opportunistically collected data, structured data can isolate the effects of road features (eg, speed zones or verge width) from confounding variables such as observer density or search bias (Vercayie & Herremans, 2015). When properly designed, structured monitoring offers the ability to calculate absolute mortality rates, such as the number of carcasses per kilometre per year, enabling direct assessments of population-level impacts. Additionally, with known effort and standardised repetition, structured protocols make it possible to correct for detection and scavenging biases, and to conduct robust comparisons across road types, seasons, and regions. While more demanding in terms of surveyor time and logistical planning, structured monitoring is indispensable for high-quality road-kill data that can inform policy decisions.

Vehicle-based surveys are the most commonly used method for monitoring road-kill, and occur on various types of roads, from highways to rarely used dirt tracks (Erritzoe et al., 2003; van der Ree, Smith, & Grilo, 2015). Observers typically drive a vehicle along a predefined route, scanning the road and sometimes road verges for carcasses. The number of observers, whether the observer is the driver or passenger, or the level of training for each observer, varies between studies. The speed driven also varies by study, which can affect the number of carcasses seen by observers. From a review of driving surveys for bird road-kill in Europe, Erritzoe et al. (2003) noted a general lack of mean vehicle speeds provided by studies. In a review of vertebrate road-kill surveys, Collinson et al. (2014) reported a mean vehicle speed of 53 km/h, with a range of 15–100 km, along with other summarised findings (Table 2.1).

Table 2.1 A summary of 61 peer-reviewed studies showing the mean and median speeds driven, the number of observers used, the sampling frequency, the mean sampling distance, and the number of transects driven (reprinted from Collinson et al., 2014, p. 3061)

Technique	*n* of 61 studies	Mean/ median	Range
Mean speed ($km \cdot h^{-1}$)	28	53	15–100
Median speed ($km \cdot h^{-1}$)	28	51	–
Mean/median observers	21	2	1–2
Mean sampling frequency (months)	47	29	4 days–168 months
Median sampling frequency (months)	47	24	–
Mean sampling distance (km)	40	185.2	1.6–732
Median sampling distance (km)	40	41.8	–
Mean number of transects	42	4	1–15
Median number of transects	42	2	–

The frequency of road-kill surveys varies considerably in the literature, even among bird-focused studies (Erritzoe et al., 2003). Some studies conducted daily or multi-daily surveys over short periods to capture fine-scale mortality patterns while others surveyed weekly, monthly, or seasonally to monitor long-term trends. Others even adjusted survey frequency according to the time of year. Mumme et al. (2000) monitored Florida scrub-jays over multiple breeding seasons to assess the demographic consequences of road mortality. Repeated surveys of the same route, particularly those aligned with known biological cycles such as breeding or migration, are common.

Carcasses were usually visually identified to species level, although if the observer was unable to (eg, carcass was too small, too far away, or the survey was conducted at high speed), identification was limited to higher taxonomic levels (eg, passerine, corvid, waterfowl) (Erritzoe et al., 2003; van der Ree, Smith, & Grilo, 2015). Sometimes carcasses were retained for closer inspection or genetic analysis. Across studies, carcass data were typically recorded either as numbers per kilometre of road or by precise location (eg, GPS coordinate). Sometimes data were collected en route, while other times the observer stopped. In some studies, carcasses were left in place for secondary purposes such as carcass persistence trials, while in others they were removed or marked to avoid double counting (Guinard et al., 2012). Sometimes other data were recorded, such as road position (eg, road, shoulder, verge), time, date, and signs of trauma.

Walking or bicycle surveys have also been used to detect road-kill, although they are less common. These methods were often used to estimate carcass persistence and scavenger removal rates, often as part of efforts to account for sampling bias (Erritzoe et al., 2003; Langen et al., 2007; Slater, 2002; Teixeira et al., 2013).

2.6.2 Opportunistic road-kill reporting

Opportunistic monitoring includes both incidental observations made during unrelated activities and informal reporting (eg, by the public, government workers, conservation groups), typically without a standardised protocol or predefined effort. These methods typically do not record search effort or absence data and may be subject to observer and reporting bias (Vercayie & Herremans, 2015). However, they offer a practical way to capture large volumes of data with minimal resource input. These submissions may come from citizen scientists, council staff, contractors, or researchers conducting unrelated fieldwork. For example, Waugh et al. (2013) describe how reports of petrel and shearwater collisions near coastal towns in New Zealand emerged through informal sightings, providing early insight into species-specific risks.

Though less precise, opportunistic data can reveal road-kill hotspots, seasonal mortality peaks, or emerging conservation threats. Several studies have shown that roving records help detect rare species or shifts in species abundance, sometimes identifying taxa missed entirely in structured surveys (George et al., 2011; Sardà-Palomera et al., 2012; Snäll et al., 2011). For example, in Belgium, rising numbers of red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) road-kill reports coincided with their population recovery and range expansion, illustrating the usefulness of long-term, wide-scale public monitoring efforts (Vercayie & Herremans, 2015).

These data can also inform species distribution models and, when coupled with a geographic information system (GIS), can help forecast road-kill risk zones (Snäll et al., 2011). In Sweden and Norway, smartphone apps were developed to deliver real-time warnings of road-kill hotspots to drivers, drawing on both official wildlife collision databases and public-reported sightings to populate their alerts (Greenwood, 2007).

2.6.3 Citizen science

Citizen science has become an increasingly important tool in the collection of road-kill data, particularly for species and regions where professional monitoring is infrequent or spatially limited. By enabling members of the public to report observations of road-kill, citizen science expands both the geographic and temporal coverage of data collection, often at low cost. For monitoring bird species, some of which are small, quick to disappear from the roadway, or infrequently struck, crowdsourced data can provide early warning of emerging hotspots or supplement structured surveys. These programmes may take the form of ‘opportunistic reporting’, where participants log sightings encountered during their usual travel, or ‘structured participation’, where volunteers monitor a specific route at regular intervals. Both approaches are valuable in extending surveillance capacity.

Several successful international projects demonstrate the value of citizen science in road-kill monitoring. For example:

- The Road Lab (formerly Project Splatter) in the United Kingdom has gathered tens of thousands of road-kill records since its launch in 2013, using online reporting forms and social media outreach to engage volunteers (Shilling et al., 2015).
- Projekt Roadkill in Austria operates via the SPOTTERON mobile app platform, enabling users to submit records with GPS coordinates and photographs. The project has contributed over 15,000 records across 44 countries (mostly in Austria), and users are encouraged to validate each other’s data, strengthening quality control.
- The Animals under Wheels project in Belgium, the world’s longest-running road-kill citizen science programme, uses the ObsMapp mobile app with voice-command functionality, ideal for hands-free reporting during driving or cycling. Volunteers submitted more than 48,000 vertebrate road-kill records over six years, supporting analyses of species-specific risk and spatial hotspots (Swinnen et al., 2022).

Other initiatives, such as the Taiwan Roadkill Observation Network (TaiRON), RoadWatchBC in British Columbia, and iNaturalist-linked road-kill projects, further demonstrate the adaptability of citizen science in different ecological and regulatory contexts. Many of these tools include features such as automatic GPS tagging, photo uploads, and species selection from dropdown lists, which improve data consistency and enable expert review or machine-learning-assisted verification.

Despite these advantages, citizen science approaches also have limitations. Records are often presence-only and may be biased towards accessible locations, larger-bodied species, or animals considered charismatic. Observations may cluster near urban areas, and not all carcasses are identified to species level. However, reliability can be improved through methods such as 'adopt-a-road' structured transects, promotion of negative data (ie, recording when no road-kill is observed), and feedback mechanisms that maintain volunteer engagement. Structured training materials, automated validation tools, and photo requirements also improve species-level resolution.

Although citizen science offers a powerful means of gathering large-scale road-kill data, its success depends on addressing several challenges that are unique to volunteer-based monitoring. Principal among these is the need to ensure data quality and maintain long-term volunteer engagement (Conrad & Hilchey, 2011; Dickinson et al., 2010; Gura, 2013). From a data quality perspective, common issues include species misidentification, inaccurate geolocation, repeated observations of the same carcass, and uneven spatial coverage. While spatial bias is often unavoidable, its relevance will vary depending on the research objectives. Many of these issues can be mitigated through careful project design, training, and validation, or through post-hoc data screening when analysts are aware of the dataset's limitations.

Sustaining volunteer interest and participation over time is also a core concern. Recruiting contributors is relatively easy, but ensuring continued engagement and consistent data submission requires thoughtful coordination and communication. This 'people management' aspect is often the most difficult part of citizen science initiatives (Conrad & Hilchey, 2011; Gura, 2013). However, with sufficient support, clear instructions, and consistent feedback, it is possible to address and overcome these challenges. Well-managed citizen science programmes have the potential to yield large volumes of valuable data that would otherwise be difficult or impossible to collect through professional efforts alone.

Importantly, volunteers often contribute records of species that are not typically represented in formal datasets, such as smaller species or rare events, making citizen data an essential complement to professional surveys (Bíl, Heigl, et al., 2020). To ensure the long-term success of citizen science projects, three factors have been identified by Bíl, Heigl, et al. (2020): (i) sustained volunteer motivation through outreach and feedback, (ii) support in identifying road-kill species where needed, and (iii) regular feedback about how the collected data are used to generate scientific insights. In addition to these, it is also important that volunteers are guided and encouraged to target their efforts in ways that align with monitoring priorities, helping to maximise the scientific value of the data they collect.

In the New Zealand context, citizen science may be especially valuable given the low frequency but high conservation significance of many bird road-kill events. A dedicated national reporting platform, potentially linked to iNaturalist NZ or built as a stand-alone app, could enable rapid, distributed data collection across remote areas, coastal roads, or conservation zones. Strategic engagement with local councils, schools, road contractors, iwi, and community conservation groups would help document incidents involving native species such as weka, kiwi, or penguins, for which even a small number of fatalities may be meaningful. Paired with structured monitoring programmes, citizen science data could provide a strong foundation for detecting spatial and seasonal trends, prioritising mitigation actions, and guiding further research on avian road mortality.

Importantly, any citizen science initiative must prioritise participant safety. Contributors should be clearly instructed not to stop on high-speed roads or attempt carcass inspections in unsafe conditions. Instead, tools such as voice-activated mobile apps, in-vehicle recording devices, or structured surveys on low-speed routes can minimise risks.

In addition to its data collection value, involving citizens in road-kill reporting offers clear outreach benefits. As Devictor et al. (2010) note, citizen science helps people reconnect with nature and can generate public support for conservation interventions. When data are made available through online maps or dashboards, this creates a feedback loop between the public, researchers, and decision-makers, strengthening both awareness and mitigation potential.

Some examples of road-kill focused citizen science projects are listed below.

- The Road Lab (UK): https://www.theroadlab.co.uk/
- Projekt Roadkill (Austria): https://roadkill.at/en/
- Taiwan Roadkill Observation Network, TaiRON, (Tawain): https://roadkill.tw/eng/about
- California Roadkill Observation System, CROS, (California, USA): https://www.wildlifecrossing.net/california/
- RoadWatchBC (British Columbia, Canada): https://www.roadwatchbc.ca/
- Animal-Vehicle Collisions (Czech Republic): http://srazenazver.cz/en/

2.6.4 Tools and technologies for road-kill monitoring

Technologies used to detect and monitor road-kill carcasses are increasingly important for addressing knowledge gaps in road ecology. Traditional driving or walking road-kill surveys remain widely used but are limited by factors such as observer visibility, speed, terrain, and safety. In response, a range of tools has emerged to improve detection accuracy, reduce bias, and enable more reliable data collection across broader geographic areas and over longer timeframes.

Although many of these technologies were initially developed for broader wildlife monitoring or traffic management, some show strong potential for adaptation to direct carcass detection. While several tools were designed with mammals or amphibians in mind, many can be effectively modified for monitoring birds, particularly when accounting for challenges such as smaller body size, limited carcass visibility, and nocturnal behaviour.

Many of these technologies have strong potential in New Zealand, where road-kill involving native birds, even when infrequent, may sometimes still be ecologically significant. Tools that expand coverage, automate detection, or support post-survey image review can help quantify road-kill rates, identify hotspots, and inform mitigation strategies. Technological advancements also complement citizen science approaches (discussed above) and together have the potential to form a flexible toolkit for future road-kill monitoring and research.

2.6.4.1 Dashcams and vehicle-mounted cameras

Dashcams and vehicle-mounted cameras provide continuous visual data that can later be reviewed for carcass detection. This method increases observer safety, improves detection consistency, and can reduce bias against small or cryptic species. Guedes et al. (2019) developed a vehicle-mounted mobile mapping system with stereo vision and GPS that detected approximately 78% of small vertebrate carcasses (including birds) on roads. The setup allowed surveys to be conducted at regular driving speeds, and post-processing of imagery enabled carcass identification and geolocation. This survey method can be carried out by anyone using their system, regardless of prior sampling experience.

Dashcams have also been used in combination with machine learning to test automated carcass detection. Sillero et al. (2018) used dashcam video paired with object detection algorithms to distinguish amphibian carcasses from background features over road surfaces when travelling at up to 30 km/h. These systems are well suited for structured transects, long-distance roads, or volunteer-based monitoring where reviewing recorded footage can increase survey efficiency and accuracy.

In New Zealand, dashcams could support monitoring in low-traffic areas where road-kill events may be less common but still impactful, such as kiwi habitats. Their use at night or in low light may further benefit monitoring of nocturnal species.

2.6.4.2 Fixed roadside cameras

Fixed cameras installed along roadsides have been used to monitor specific high-risk areas continuously. These might include motion-triggered wildlife cameras, adapted security cameras, and thermal imaging systems. While often deployed for live animal detection, they can also capture the appearance and persistence of carcasses over time.

San Diego Zoo Wildlife Alliance demonstrated the applicability of game cameras placed at road verges, which recorded both wildlife crossings and carcasses missed during human surveys (Gray, 2018). Though coverage is limited to a small field of view, such systems can document time-stamped appearances of carcasses and help assess scavenging rates or collision timing.

These cameras could be deployed in New Zealand at known road-kill hotspots or at vulnerable crossing locations (eg, penguin pathways or forest roads in kiwi territories). Night-capable or thermal models could further support monitoring where visual confirmation is difficult.

2.6.4.3 Drones and aerial surveys

Unmanned aerial vehicles (UAVs), or ‘drones’, may provide a flexible platform for road surveys, particularly in remote or otherwise inaccessible areas. High-resolution cameras can capture visual imagery of road surfaces and verges, which may be reviewed manually or processed with object detection tools. Although most documented use has focused on locating large mammal carcasses (eg, Gentle et al., 2018), drones become increasingly relevant for smaller species, especially in open environments where roadside vegetation does not obstruct visibility (Corcoran et al., 2021).

Thermal imaging can enhance drone-based detection by identifying the heat signature of freshly killed animals, and drone-based thermal cameras have been used to locate wildlife carcasses (Rietz et al., 2023). In New Zealand, drones could be deployed for post-storm fallout events involving seabirds, or to monitor isolated roads in national parks where human access is limited. Early morning thermal surveys may be particularly effective due to cold road temperatures.

2.6.4.4 AI-enabled detection and image analysis

AI has been applied to automate the detection and classification of road-kill, using object detection models such as ‘YOLO’ to distinguish carcasses from other roadside objects and to identify species or carcass types from images. Ferrante et al. (2024) trained several such models on Brazilian road-kill imagery, achieving reliable detection of small carcasses in dashcam footage. Models varied in accuracy and speed, with some prioritising low false negatives while others optimised for real-time detection.

These tools are increasingly being integrated into mobile and vehicle-based systems, allowing rapid processing of camera footage to detect carcasses that might otherwise go unnoticed. With suitable training data, they can also support species identification and reduce the burden of manual image review.

In a New Zealand context, training AI models on representative species (eg, kiwi, pūkeko, penguin) could improve automated detection from dashcams or roadside cameras. Existing image datasets from conservation work or museum specimens could be repurposed to build training libraries.

2.6.4.5 Mobile apps

Mobile applications have become essential tools in modern road-kill monitoring. While particularly useful in citizen science initiatives where broad geographic coverage and ease of use are critical, mobile apps also support researchers conducting structured, standardised road-kill studies. These platforms streamline data submission, standardise data formats, and often include GPS tagging, photographic uploads, and automated syncing to centralised databases.

Road-kill data can be collected using stand-alone apps specifically developed for road-kill reporting, or through broader biodiversity platforms like iNaturalist NZ[2], which include road-kill as one of several observation categories. Many smartphone apps can capture geo-referenced data, automatically linking GPS coordinates to individual sightings or images, thereby improving spatial precision. Photos taken through these platforms can also carry embedded location data, aiding in carcass verification and mapping. Hands-free functions such as speech-to-text input offer a safer and more efficient alternative during surveys where stopping is not practical, especially for single-observers (Swinnen et al., 2022). For example, Sullivan et al. (2025) demonstrated the utility of speech-to-text paired with geo-referenced inputs for continuous road-kill surveys, although some post-processing was required. A growing number of national and regional programmes now rely on app-based systems to collect wildlife–vehicle collision data efficiently and consistently. The following examples from Europe illustrate a diversity of approaches, engagement strategies, and integration with research and policy (Bíl, Heigl, et al., 2020).

- **Animal–Vehicle Collisions (Czech Republic)**[3]

  This Android-compatible web-map and app platform collects road-kill data from the public and official police databases. Initially launched to improve traffic safety, it expanded into wildlife monitoring, including game species and structured campaigns such as testing wildlife odour repellents. The system includes automatic spatial analysis, online mapping, live hotspot detection using clustering algorithms, and animated visualisations used for education and public outreach.

- **Projekt Roadkill (Austria)**[4]

  Founded in 2013, this initiative uses Android and iOS apps developed by SPOTTERON to collect data on non-game vertebrate road-kill. Citizen scientists upload sightings and help validate each other's entries. The platform has supported academic outputs including theses and peer-reviewed publications (eg, Heigl et al., 2016). It is noted for its strong community moderation and emphasis on data quality.

- **Animals under Wheels (Belgium)** (YouTube demonstration[5], ObsMapp on Google Play[6])

  This is the world's longest-running road-kill citizen science initiative. Linked with the broader biodiversity platform Waarnemingen.be, it enables users to record road-kill via mobile apps ObsMapp (Android) and iObs (iOS). Volunteers can monitor fixed transects or log opportunistic observations during regular travel using a start/stop feature. Notably, a hands-free voice-command function allows users to record road-kill sightings while driving, enhancing safety and reducing friction in data collection.

- **The Road Lab, formerly Project Splatter (United Kingdom)**[7]

  Operated by Cardiff University, The Road Lab encourages volunteers to submit wildlife road-kill reports through web forms, mobile apps, or social media. Apps are the most common submission method, used for over half of all entries. The project focuses on mapping spatial and temporal hotspots and raising public awareness. Weekly social media updates engage the public and highlight notable reports.

[2] https://inaturalist.nz/

[3] http://srazenazver.cz/en/

[4] https://roadkill.at/en/

[5] https://www.youtube.com/watch?v=xtXumLHGIQI

[6] https://play.google.com/store/apps/details?id=org.obsmapp&hl=en

[7] https://www.theroadlab.co.uk/the-project

2.6.5 Road-kill monitoring – Concluding remarks

Bird road-kill monitoring presents a unique set of challenges that require careful alignment of method with purpose. Across the literature, methods vary in their ability to detect carcasses, cover large spatial areas, or produce data suitable for population-level inference. No single approach is universally applicable. Instead, effective monitoring relies on selecting methods that are repeatable, appropriate for the target species, and suited to the practical constraints and characteristics of the environment.

Vehicle-based surveys remain the most used method due to their scalability and feasibility over long distances. However, they can under-detect small-bodied species, especially at higher speeds or in vegetated verges. Walking or cycling transects offer improved detection but demand greater time and effort. Opportunistic reporting, such as citizen-submitted sightings, offers rapid coverage and insight into rare or locally important events, though it typically lacks information on search effort or absence. Structured citizen science programmes, where volunteers repeatedly survey defined routes, can help bridge these gaps, particularly when paired with digital tools that enable GPS tagging, photo validation, and consistent data formatting.

Technological advances such as dashcams, drones, AI-assisted image analysis, and hands-free mobile apps are increasingly expanding the toolkit available for road-kill monitoring. These tools offer valuable opportunities to improve detection and data quality, particularly when tailored to the challenges of monitoring high-risk bird species in New Zealand. These challenges may include small carcass size, rapid removal by scavengers, and nocturnal activity patterns. However, such technologies are most effective when embedded within structured survey frameworks that account for detection bias, track search effort, and ensure repeatability over time.

In New Zealand, where many native birds are rare, cryptic, or geographically restricted, a flexible, mixed methods approach is likely to offer the strongest basis for robust monitoring. The following section reviews existing sources of bird road-kill data in New Zealand and highlights what is currently known about species affected, locations of concern, and the limitations of available information.

2.7 Bird road-kill in New Zealand

2.7.1 Limitations of existing information

Limited information exists on the impacts of vehicle-caused mortality on avian species or populations in New Zealand, although some reports exist that provide evidence of birds being killed by vehicles and highlight risks to populations and individuals (eg, Beauchamp, 2009a; Brockie, 2007; Brockie et al., 2009; Sadleir & Linklater, 2016). We have only identified nine studies that are primarily dedicated to structured road-kill surveys in New Zealand. For these studies (which are discussed in detail in the following section), reporting, survey methods, sampling designs, and analyses differed, making simple comparisons difficult. Direct comparisons with the international literature are even more difficult, due to differences in New Zealand avifauna. For example, some of New Zealand's endemic bird species have evolved flightlessness in the historical absence of mammalian predators, likely increasing their vulnerability to road mortality (eg, kiwi and weka). Furthermore, these studies were typically not conducted within conservation-sensitive areas, and thus present data are dominated by more common native and introduced species (eg, Sadleir and Linklater (2016) conducted surveys in peri-urban and farmland habitats).

Many of the other references to road-kill of New Zealand birds in the scientific literature come from isolated observations or opportunistic sampling within larger, non-road-kill focused studies (eg, Alley et al., 2007; Trewick et al., 2017). Road-kill information mentioned in these studies often lacks detailed information, such as exact numbers, locations, dates, carcass age and sex, and method of observation or collection.

Caution should be taken when comparing findings and making conclusions from observations collected opportunistically or in the absence of designed studies, especially when low sample sizes are involved. Here are three examples from the literature:

1. Beauchamp et al. (2000) stated, ‘Ferrets were confirmed as a significant predator of weka near Matawai, and only road deaths killed more birds’ (p. 95). This statement was supported by citing Bramley and Veltman (2000), in which only three ferret-killed and six road-killed weka were observed between 1992 and 1993. While these accounts can be helpful in directing future investigations, especially in New Zealand where data are limited, more robust sampling is certainly needed to properly support general statements like these.
2. Stidolph (1971, 1974) attributed the decline in New Zealand pipits (*Anthus novaeseelandiae*) in part to the sealing of roads, which led to increased traffic densities and road speeds. It was further speculated that birds were colliding with vehicles when flying across roads, to and from their nests. Subsequently, this possible correlation between an increase in sealed roads and the decline in pipit numbers was referenced by other publications (Beauchamp, 2009a, 2009b; Garrick, 1981); however, no records of pipit road-kill or data were provided. The only reference we could find in the scientific literature for direct mortality of New Zealand pipits caused by vehicles was a single observation of a road-killed pipit from an unrelated study (Galloway, 2005).
3. Goldberg et al. (2011) states that kererū are prone to collision with vehicles, and that dead birds are routinely submitted to Department of Conservation (DOC) offices and held in freezers. No supporting reference was provided. Similarly, Prendergast et al. (2006) makes the claim that ‘a high proportion of adult kereru have been known to die or become seriously injured after colliding with motor vehicles’ (p. 284), and further adds that ‘collision with motor vehicles after feeding on roadside foliage is considered a major cause of death for kereru in Akaroa Harbour, Banks Peninsula’ (p. 284). This is not discussed in any more detail, but a DOC management plan was referenced (Mander et al., 1998). However, this document did not mention Banks Peninsula, suggesting only that collisions with motor vehicles ‘may be significant causes of death in some areas’ (p. 15), using a study that reported just two radio-tagged deaths (Clout et al., 1995) as support.

In various pieces of the literature road-kill is often mentioned among a list of threats or risks to birds. In many of these cases, the supporting citations are all listed together at the end of the statement so that the reader cannot determine which references refer specifically to which threat, which can lead to an exaggeration of support for the statement. For example, Brunton-Martin et al. (2021) states that ‘by-kill of kea is a concern as they are a long-lived species that suffer from many threats (for instance, climate change, lead poisoning and vehicle strike)’ (p. 1). Three references are provided at the end of the statement; however, only Kennedy (2017), a doctoral thesis, mentions anything related to road-kill and kea (*Nestor notabilis*). Furthermore, within that thesis, the only reference to road-kill is one sentence stating that kea face ‘indirect human-induced mortality (e.g. vehicle strike, lead poisoning, electrocution)’ (p. 11), followed by citing Seal et al. (1991), which, as far as we can determine, refers to a workshop held in Christchurch in 1991, and for which no further information is available. This further highlights the lack of road-kill specific investigations in New Zealand.

In addition to the published scientific literature, much of the information related to road-kill and New Zealand birds was obtained from various government reports or local contacts in the conservation field. Much of this information was focused on New Zealand’s iconic bird species and was therefore often biased by location and species. Sometimes these road-kill deaths were provided as a percentage of ‘total deaths’, but without a consideration of sampling design and effort. Without such, these data on deaths would likely be biased, making ‘total deaths’ an inaccurate measure (eg, penguins dying at sea would not be counted). In these cases, absolute numbers of road-kill or percentage killed of overall population (if those estimates are available) would be more appropriate. In general, caution should be taken when making comparisons using this type of data, as these mortality observations were collected opportunistically, without a standardised sampling approach. Such an approach would allow for direct comparisons (eg, by locations, over time, between similar species, before and after mitigation) and help provide clarity on relative threats to New Zealand birds. Despite these caveats, below we summarise our findings detailing evidence of road-kill of New Zealand birds and impacts on species or populations.

2.7.2 New Zealand structured road-kill surveys

We identified nine structured road-kill surveys conducted in New Zealand in which bird mortality was the primary focus. Eight of these have been published in peer-reviewed journals (Beauchamp, 2009a; Brockie, 2007; Brockie et al., 2009; Burger & Gochfeld, 1992; Flux, 2019; Freeman, 2010; Sadleir & Linklater, 2016; Washington et al., 2008), while a ninth study (Sullivan et al., 2025) is currently available as a preprint and under review for journal publication (in review, *PeerJ*). Summaries of each are provided below.

2.7.2.1 Burger and Gochfeld (1992)

Burger and Gochfeld (1992) reported on live and dead Australian magpies (*Gymnorhina tibicen*) from driving counts in the South Island in 1990. Road-kills of other bird and mammal species were also recorded. Birds were counted along 1,803 km of highway and secondary roads east of the mountains from Kaikōura to Dunedin. It was not reported if a consistent range of speeds was maintained or if the vehicle stopped to inspect carcasses (although the authors distinguished between adult and juvenile bird carcasses). A total of 53 magpie carcasses were observed on the road, all reported to be juveniles. The authors also observed more juvenile magpies feeding on the road than adults, and reported that when vehicles approached, the adults always flew away before the juveniles. Both observations probably explain the high juvenile kills recorded. The authors did not suggest whether avoiding vehicles was a learned behaviour or if these adults were simply the individuals that survived due to behavioural differences as juveniles. However, it was stated that the reason magpies are found on roads in New Zealand is primarily due to eating of road-kill. In addition, eight South Island pied oystercatcher (*Haematopus finschi*), four Australasian harrier (*Circus approximans*), and three mallard (*Anas platyrhynchos*) carcasses were observed, with both adult and juveniles reported for each.

2.7.2.2 Brockie (2007)

Brockie (2007) conducted driving counts for bird and mammal road-kill at two locations in the North Island in attempts to identify ‘hotspots’ (ie, areas where individuals of a species were killed in unusual numbers). Attempts were made to relate road-kill observations to traffic volume using vehicle counts and human traffic accidents; however, it was concluded that the animal hotspots identified did not correlate with spots of heaviest traffic. The author suggests that instead these hotspots may represent areas where animals crowd together or are more likely to encroach on the road. The author estimated that around 20% of small birds observed were not recorded due to the inability to identify to species.

Road-kill counts (n = 1,526) from a 20 km section of road around the Wellington Harbour between 1999 and 2003 resulted in 14 bird species observed. However, only southern black-backed gulls (*Larus dominicanus*) and red-billed gulls (*Chroicocephalus novaehollandiae scopulinus*) were recorded in sufficient numbers (28 and 18, respectively) to infer hotspots. Most of the gull road-kills observed were killed near the Petone Esplanade where these birds are reported to congregate to forage or be fed by people in parked vehicles. The author also mentioned that black shags (*Phalacrocorax carbo*) were recorded in sufficient numbers, but only nine were reported as road-kills, and these data are not presented in the table along with the other abundant species. Four shag carcasses were observed on the Hutt River Bridge, noted as located within their flight-line along the river. The other bird species observed were not listed.

Road-kill counts (*n* = 82) were also made along a 60 km section of road in southern Hawke's Bay between 1982 and 2006. Results include observations of 11 bird species; however, none of these were in sufficient numbers to detect hotspots. As with the Wellington counts, a full list of species observed was not provided.

2.7.2.3 Washington et al. (2008)

Washington et al. (2008) reported on pūkeko road-kill from driving counts in the South Island between November 1998 and October 1999, as well as roadside behaviour from a stationary observation hide. Pūkeko carcasses were counted from 531 trips along the Christchurch Northern Motorway and other nearby minor roads. In total, 20 pūkeko carcasses were observed, 18 of which were observed on the non-elevated section of the roadway, and all were adult birds.

While more live pūkeko individuals were observed along the roadside in spring (37%), the authors found no relationship between monthly numbers of live birds and numbers of road-kill. Additionally, 83% of observations of live pūkeko along the roadside occurred during or within 24 hours of rain and 87% within two weeks of a mowing event.

2.7.2.4 Beauchamp (2009a)

Beauchamp (2009a) conducted cycling counts for road-kill of birds in the North Island for three years between 2005 and 2008. Carcasses were counted between Whangārei and Onerahi, Northland, through peri-urban, farmland, and mangrove habitats.[8]

In this study, a total of 117 bird carcasses were observed, consisting of 17 species. Totals of 42 pūkeko (36%), 23 Eurasian blackbirds (20%) and 12 silvereyes (*Zosterops lateralis*) (10%) were observed, with no other species counts greater than 10 (Table 2.2). The author also noted that it was likely some road-kill was missed, especially of smaller birds located on the sides of the road either directly due to impact or afterwards from traffic-generated wind.

Similar total numbers of bird carcasses were observed for each year; however, the numbers were positively associated with increasing speed limit zones. It was concluded that urban roads with speed limits of 50–60 km/h posed lower risk, with the greater risk coming from areas with higher speed limits. One specific location was noted as having a high number or carcasses observed, which was explained as being a likely crossing point for birds utilising the stream edges of the mangroves. Using July 2006 traffic rates for Riverside Drive, it was estimated that an average of one bird road-kill occurred per 57,415 vehicle movements. The author extrapolated that at least 675,000 birds are killed on sealed roads in New Zealand annually, based on 2007 Land Transport New Zealand statistics and assuming similar road-kill rates elsewhere.

[8] We found some slight discrepancies between the numbers reported in the text when compared to the numbers presented in the tables (eg, total count, by year, introduced species). Here we use the numbers from the tables, as they are presented by species.

Table 2.2 Numbers and species of birds found dead between 2005 and 2008 between Whangārei and Onerahi in the North Island recorded during cycling counts (adapted from Beauchamp, 2009a, p. 96)

Species	No. killed 2005–06	No. killed 2006–07	No. killed 2007–08	TOTAL
Pūkeko	15	16	11	42
Eurasian blackbird	8	9	6	23
Silvereye	4	2	6	12
Red-billed gull	5	2	1	8
European goldfinch	2	3	2	7
Sacred kingfisher	2	–	2	4
Common myna	–	2	2	4
House sparrow	–	1	2	3
Yellowhammer	–	2	1	3
Song thrush	–	1	1	2
Welcome swallow	–	–	2	2
European greenfinch	1	1	–	2
Banded rail	–	1	–	1
Morepork	–	–	1	1
Grey warbler	–	1	–	1
New Zealand fantail	–	–	1	1
Common starling	–	–	1	1
TOTAL	**37**	**41**	**39**	**117**

2.7.2.5 Brockie et al. (2009)

Brockie et al. (2009) conducted driving counts for bird and mammal road-kill along 1,660 km of North Island highways for three separate years, each approximately a decade apart. Birds (*n* = 88) were only 4–10% of total carcasses observed in count years (1984, 1994, and 2005) (Table 2.3). Counts did not occur within the city limits of Whangārei, Auckland, and Hamilton. Road-kill locations were recorded using the vehicle's odometer to the nearest kilometre. The relationship between road-kill counts and traffic volume was investigated for mammals but not birds, likely due to low numbers of the latter. The authors attribute the low numbers of birds observed, in part, to the undercounting of smaller species as well as the seasonal timing of the counts.

Of the 14 bird species observed, 73–86% of road-kill in count years was of four species: pūkeko, Australasian harrier, common myna (*Acridotheres tristis*), and Australian magpie. The latter three are known to scavenge on road-kill. Other bird species observed were red-billed gull, house sparrow (*Passer domesticus*), Eurasian blackbird, black-backed gull, welcome swallow (*Hirundo neoxena*), mallard, silvereye, spur-winged plover (*Vanellus miles*), European goldfinch (*Carduelis carduelis*), and domestic chicken (*Gallus gallus*). These findings reflect the species generally found in peri-urban, farmland ecosystems that major highways travel through.

Table 2.3 Results of driving counts for road-kill of birds along 1,660 km between Lower Hutt and Awanui in the North Island in 1984, 1994, and 2005 (adapted from Brockie et al., 2009, p. 126)

Species	1984	1994	2005	TOTAL
Pūkeko	8	15	5	28
Australasian harrier	3	13	3	19
Common myna	10	2	2	14
Australian magpie	1	0	9	10
Red-billed gull	2	0	2	4
House sparrow	1	0	1	2
Eurasian blackbird	0	0	2	2
Black-backed gull	0	1	1	2
Welcome swallow	0	1	1	2
Mallard	1	0	0	1
Silvereye	1	0	0	1
Spur-winged plover	0	1	0	1
European goldfinch	0	1	0	1
Domestic chicken	0	1	0	1
TOTAL	**27**	**35**	**26**	**88**

2.7.2.6 Freeman (2010)

Freeman (2010) conducted driving counts to estimate road-kill rates of western weka (*Gallirallus australis australis*) in the South Island for two years between 2006 and 2008. Weka carcasses were counted along 25 km of rural roads in the Buller district. A total of 300 carcasses were observed at average rates of 6.1 and 5.9 per kilometre for each year.

More carcasses were found near intersections and on roads with higher traffic speed and volume. Weka road-kill numbers were highest in spring and lowest in autumn and were attributed to life history characteristics. In total, 90% of weka killed were less than three years old. Road-kill counts were also biased towards male weka, but only among older birds. The author mentioned that call counts from the same adult population did not indicate a significant male bias, and suggested that any gender bias in weka road-kill may have additional negative impacts since the species is generally monogamous.

2.7.2.7 Sadleir and Linklater (2016)

Sadleir and Linklater (2016) conducted driving counts for bird and mammal road-kill in the North Island from 2009 to 2014. Carcasses were counted during 92 trips along a 63.2 km route (totalling 5,814 km) through peri-urban and farmland habitats on the Kāpiti Coast near Wellington. Of the 466 bird carcasses observed, 120 were pūkeko (26%) and 16 were Australasian harriers (3%), with the remaining species not listed. Pūkeko numbers varied between years, ranging from 6 to 39, and were most frequently killed where the road was close to wetlands.

Bird carcass densities fluctuated annually but showed no consistent trends across years. However, they showed a marked seasonality corresponding to the September to March breeding season for most New Zealand birds. These trends could indicate possible traffic naivety and inexperience of juvenile birds around roads, particularly when dispersing (Burger & Gochfeld, 1992; Mumme et al., 2000).

2.7.2.8 Flux (2019)

Flux (2019) reported on road-kill of birds from driving counts along 6,893 km of predominantly South Island highways during three weeks in February 2017 as well as 2,398 km in 2018, for a total of 9,291 km. Bird road-kill data presented was a subset of a larger mammal abundance road-kill survey, of which ‘birds were occasionally identified’ (p. 218). A total of 309 bird carcasses were observed in this study. Of which, 206 (of 24 species) were identified (Table 2.4).

A total of 17% (*n* = 53) of all bird carcasses observed were Australasian harriers. Higher numbers of harriers were killed in a reported ‘rabbit problem area’ around central Otago, Pūkaki, and Fairlie than in the rest of the South Island. The author suggests these observations may be related to diet, as European rabbits are one of the main food items of Australasian harriers in New Zealand (Baker-Gabb, 1981). The author also theorised that there may be a behavioural element, noting that black-backed gulls pulled mammal road-kill carcasses to the side of the road before consumption, while harriers simply fed on the carcasses where they were found and attempted to fly away when vehicles approached.

Table 2.4 Complete list of birds recorded as road-kill from a single study conducted in the South Island in 2017–18 (9,291 km) (adapted from Flux, 2019, p. 220)

Species	# counted
Australasian harrier	53
Eurasian blackbird	31
Australian magpie	29
Mallard	26
Pūkeko	19
House sparrow	10
Red-billed gull	5
Western weka	5
Song thrush	5
Common starling	3
Silvereye	3
Spur-winged plover	2
Dunnock	2
European goldfinch	2
Morepork	2
Little owl	1
Paradise shelduck	1
Grey teal	1
Pied stilt	1
Welcome swallow	1
Chaffinch	1
European greenfinch	1
Yellowhammer	1
Black-backed gull	1
unidentified ‘sparrow-size’	89
unidentified ‘blackbird size’	14
TOTAL	**309**

2.7.2.9 Sullivan et al. (2025)

Sullivan et al. (2025) demonstrated a practical and replicable approach to monitoring road-kill using smartphone-enabled tools and systematic protocols. The method allows observers to track individual carcasses repeatedly over time, recording detailed metadata such as geolocation, carcass age, condition, position on or near the road, and whether each sighting is a new or previously observed carcass.

Methodology

Surveys can be conducted on foot, by bicycle, or as a passenger in a vehicle. Observations were logged using smartphones equipped with continuous GPS tracking and timestamped shorthand or voice notes. A combination of apps, such as FileMaker Go and Cyclemeter, along with speech-to-text services (eg, AWS Transcribe) enabled efficient, hands-free data collection. Observations included species identification (with uncertainty notation), carcass condition (eg, intact, squashed, fragment), position (eg, left road, verge, grass), and age (eg, fresh, unsure, old). Repeat sightings were marked as 'usual,' allowing for calculation of carcass persistence and detection rates.

Case study

The method was applied along a 16.2 km route between Christchurch and Lincoln, which has been surveyed 2,745 times (mostly by bicycle) between 2003 and 2024, with 1,652 formal surveys conducted between 2012 and 2024 using the complete method. Over this period, 4,034 new road-kill carcasses were observed, 62.4% of which were birds and 31.1% mammals. Notably, 18.2% of bird carcasses were native species.

Key findings

- The most commonly killed bird species were Eurasian blackbird, mallard/grey duck hybrids (*Anas platyrhynchos* × *superciliosa*), house sparrow, and pūkeko.
- Carcass persistence varied significantly by species and condition. Hedgehogs, for example, often remained on the road for months, while small birds typically disappeared within days.
- Carcass position influenced both detection and persistence. Birds like pūkeko and ducks were often found on verges, while hedgehogs predominantly remained on the road surface.
- The estimated road-kill rate of 3,940 to 6,544 animals per 100 km per year falls near the upper range of international figures and exceeds those reported in earlier New Zealand-based road-kill studies.[9] These estimates are approximately 2.5 to 4.3 times higher than those extrapolated by Beauchamp (2009a).

Applications and benefits

The study highlights the value of tracking both new and repeat carcasses to estimate detection probabilities and carcass longevity, which are critical components for correcting bias in road-kill studies. It also shows that smartphones can be used efficiently for high-resolution, long-term road-kill monitoring. Data can be calibrated for infrequent surveys and compared across regions or taxa. The method is well suited for identifying road-kill hotspots and informing species-specific mitigation.

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[9] The reported road-kill rates, which include mammals, birds, and even some larger insects, may partly reflect differences in survey method such as bicycle compared to car-based travel, although this is unlikely to be the sole explanation. It may also be related to the survey route, which followed the outskirts of a large urban centre. This contrast between urban and rural settings, along with factors such as observer proximity, traffic patterns, and surrounding habitat types, may have played a more substantial role in shaping the observed differences in road-kill rates and species composition (Jon Sullivan, Lincoln University, personal communication, 22 March 2025).

Conclusion

Sullivan et al. (2025) provide a scalable, low-cost framework for consistent road-kill monitoring, particularly effective for areas with variable carcass persistence and detection rates. The method is adaptable for different taxa, landscapes, and modes of transport, and enables improved accuracy, comparability, and usefulness of road-kill data. Currently the method requires separate post-processing of data. It has strong potential for integration into conservation planning and impact assessments in New Zealand and globally.

2.7.3 Opportunistic, incidental, and other reports

In addition to structured road-kill surveys, a wide range of opportunistic and incidental observations of bird mortality from vehicle strike have been documented across New Zealand. Many of these records, drawn from both published literature and unpublished sources, are compiled in Appendix B. Although typically unstructured and lacking standardised search effort, opportunistic observations can provide valuable insights when collected in sufficient volume. Contributions from members of the public, government staff, conservation practitioners, and researchers help identify emerging risks, seasonal patterns, and species-specific vulnerabilities that may not be captured in formal surveys. Some examples in the appendix are referenced within the main text or literature review, while others are anecdotal or previously unreported. The next section offers a general overview of the types of observations included.

2.7.3.1 Seabirds

Seabirds, particularly petrels and shearwaters, have been reported as vulnerable to vehicle strike when grounded by artificial lights during nocturnal flight. For example, Westland petrels (*Procellaria westlandica*) and Hutton’s shearwaters are known to become disoriented by streetlights during their fledging periods near Punakaiki and Kaikōura, respectively. Observations include direct accounts of birds struck by vehicles after grounding, and in both cases, temporary warning signage has been deployed, and local mitigation actions have been trialled, including seasonal light reduction.

Among gull species, southern black-backed gulls and red-billed gulls have featured in several surveys, particularly around Wellington, and have been observed scavenging near roadsides. Additional reports cite road-kills near landfills or where feeding by humans encouraged proximity to vehicles.

2.7.3.2 Flightless birds

Flightless birds, especially kiwi, have been frequently reported as road-kill victims in Northland, where roads intersect with known kiwi habitats. North Island brown kiwi (*Apteryx mantelli*) make up the bulk of documented cases, with records from DOC showing road-kill as a consistent cause of mortality over recent decades. Great spotted kiwi (*A. maxima*) and southern brown kiwi (*A. australis*) have also been mentioned in relation to vehicle strike, though with fewer specific records. Notably, road warning signage has been installed in some areas where kiwi presence and road access coincide.

Weka have been involved in vehicle collisions across a range of regions. Several reports detail large numbers of observed mortalities, including 300 individuals recorded in one South Island survey. Other sources recount smaller-scale observations in Northland, Gisborne, and the Bay of Plenty. In some areas, road warning signage has been introduced.

For little penguins, road-kill has been recorded in multiple coastal areas across the country. In Wellington, road proximity to nesting sites has been associated with repeated incidents, although a formal database has only recently been established. On the West Coast, data from the West Coast Penguin Trust indicate that vehicle strikes accounted for approximately half of the recorded penguin deaths between 2006 and 2019. Local mitigation efforts, including fencing and roadside planting, have been implemented in several locations.

Additional reports from Oamaru, Golden Bay, and other regions include records of road-kill and corresponding management actions such as signage, fencing, and underpasses.

2.7.3.3 Wetland and river birds

Pāteke/brown teal (*Anas chlorotis*) have been reported as road-kill victims across their range, particularly on Aotea/Great Barrier Island, where DOC records indicate that vehicle collisions have been one of the leading recorded causes of mortality in some years.

Additional observations have been made in Whangārei and the Coromandel Peninsula. Efforts to mitigate road-kill in pāteke populations have included fencing, signage, and habitat management. For whio/blue duck (*Hymenolaimus malacorhynchos*), a local observer in the North Island reported 12 road-kills over a 20-year period along a road adjacent to stream habitats.

Pūkeko have been repeatedly observed in road-kill surveys and citizen science projects. An iNaturalist NZ initiative in Christchurch, ‘Flat Pukekos’, has compiled nearly 200 observations. Road signs warning of pūkeko crossings have also been installed in some regions. Other wetland birds such as moho pererū/ banded rail (*Hypotaenidia philippensis*) and Australasian bittern have been reported less frequently but include consistent mentions of vehicle collisions, particularly in Northland and the Bay of Plenty. In some cases, community-driven mitigation, such as roadside hedging, has been introduced to reduce the likelihood of birds crossing roads.

2.7.3.4 Carrion-feeding birds

Australasian harriers are frequently noted as one of the top species observed as road-kill from both structured surveys and from wildlife hospital records. The New Zealand falcon (*Falco novaeseelandiae*) has been documented as a vehicle strike victim in both formal tracking studies and as noted from carcasses submitted to DOC.

2.7.3.5 Forest and other birds

Kererū have been consistently observed as road-kill victims across a number of studies and wildlife hospital records. Road-kills appear to occur more frequently in spring and summer months and have been reported from regions including Marlborough, Palmerston North, and Wellington. Kea road-kill has also been observed, with multiple juveniles killed along Milford Road.

Additional records have arisen incidentally through other research efforts, including parasitological and morphological studies, where road-killed birds have been used as specimens. These include mallards, spotted shags (*Phalacrocorax punctatus*), red-billed gulls, weka, pipits, and Australasian harriers. While these observations are often secondary to the primary research goals, they nevertheless reflect the wide taxonomic range of birds affected by vehicle collisions.

Finally, data from the Massey Wildbase Hospital reveal that between 2006 and 2022, 286 native birds were admitted for treatment following vehicle collisions, representing at least 25 different species. Of these admissions, 45% died due to their injuries. Although the records are geographically limited, primarily reflecting cases from the Palmerston North region, they highlight the non-trivial frequency of vehicle-related injuries within a relatively small geographic area.

2.7.4 Broad conclusions

2.7.4.1 Ecological takeaways from New Zealand road-kill data

Data collated in this report demonstrate that bird road-kill in New Zealand affects a wide range of species, environments, and behavioural contexts. Both structured and opportunistic sources show that vehicle collisions impact not only common or generalist species, but also regionally rare, cryptic, and conservation-priority taxa. These include flightless endemics such as kiwi and weka, seabirds, wetland specialists like pāteke, and a variety of forest and open-country species, including kererū and pūkeko.

While mammals dominate many road-kill datasets across New Zealand, birds consistently make up a meaningful proportion of observed vertebrate carcasses. Structured surveys show birds make up between 6% and 26% of vertebrate road-kill, depending on study location and method (Brockie et al., 2009; Flux et al., 2022; Sadleir & Linklater, 2016). More recent intensive surveying suggests even higher proportions, as Sullivan et al. (2025) found birds accounted for 62% of new carcasses along a peri-urban road network, 18.2% of which were native species. These results confirm that bird road-kill is non-trivial, particularly in habitats near wetlands, farmland, or urban edges.

Although broader population-level impacts remain uncertain, these rates suggest that some species may be subject to regular, yet under-recognised, mortality from vehicle collisions. In addition to quantifying mortality, road-kill records offer insight into wider ecological patterns. For example, species frequently struck by vehicles, such as pūkeko, Eurasian blackbird, and Australasian harrier, may reflect dominant avian communities in human-modified environments.

2.7.4.2 Taxa vulnerability characteristics

Certain ecological and behavioural traits elevate the risk of road-kill among New Zealand bird species. Flightless and ground-dwelling birds are particularly vulnerable, especially in areas where roads intersect their habitat or lie close to release sites. Weka, for instance, can suffer high mortality rates on roads, with young dispersing males appearing to be especially at risk (Freeman, 2010). In parts of the South Island, large numbers of weka road-kills have been documented. Similarly, North Island brown kiwi are regularly reported as vehicle-strike victims in Northland, where DOC records and anecdotal accounts consistently identify road-kill as a major cause of mortality in some populations.

The wide-ranging behaviour of kiwi adds complexity to road-kill risk. Adults maintain permanent home ranges, while juveniles may disperse up to 20 km from their natal sites in search of new territories (Potter, 1990; Robertson et al., 2011). Kiwi have been observed using small forest remnants as ‘stepping stones’, crossing open pasture to move between habitat patches. Although road-kill events involving kiwi may be infrequent and scattered, their occurrence across such fragmented landscapes makes risk difficult to predict.

Coastal and wetland species also feature prominently in road-kill records. Little penguins regularly cross coastal roads near nesting colonies, particularly where burrows lie inland of high-traffic routes, such as in Wellington and along the West Coast. Their movements are often highly localised, with risk typically confined to narrow zones near breeding areas. Behavioural differences between populations can influence both the timing of road crossings and the type of mitigation required.

For example, two distinct lineages of little penguins have been identified: the ‘New Zealand type’, found only in New Zealand, and the ‘Australia/Otago’ type, which occurs in both Australia and the Otago region of New Zealand (Grosser et al., 2015). Colonies of the Australia/Otago type are known to come ashore after dusk in ‘rafts’, which are groups of penguins that gather at sea before swimming and walking ashore together. This behaviour may increase their vulnerability to vehicle collisions in areas where roads lie between the sea and nesting sites. As such, locally tailored mitigation strategies may be required depending on the penguin lineage present.

Supporting this, Heber et al. (2008) recorded 30 vehicle-related little penguin deaths on the West Coast. Critically, both parents are required to raise chicks successfully (Numata et al., 2004), meaning that the loss of a single adult may result in the failure of an incubating clutch or dependent brood. This can potentially remove up to three individuals from the population. Given that the viability of little penguin populations is highly sensitive to adult survival (Dann, 1991), even modest levels of road-kill could plausibly contribute to local population declines over time.

Additional species traits further increase vulnerability. Australasian bitterns, for example, exhibit slow, heavy flight and low flight-initiation distances, making them particularly susceptible to collisions. Nocturnal or crepuscular activity patterns, juvenile inexperience, and reluctance to take flight can also elevate road-kill risk, especially among certain age classes. Seabird fledglings such as Hutton’s shearwaters and Westland petrels are vulnerable to light disorientation near coastal settlements, where artificial lighting can cause birds to crash-land and become grounded on roads, making them highly susceptible to passing vehicles.

Water-associated species such as pāteke and pūkeko also show high vulnerability. Pāteke have been recorded as road-kill victims throughout their range, including Aotea/Great Barrier Island, where vehicle collisions are a leading cause of death in some years. These birds move locally between wetlands and pasture and often cross roads near drains or other linear features. Road-crossing points tend to be clustered, especially where habitat corridors intersect with transport infrastructure. Pūkeko frequently move between wetlands and roadside foraging areas and are among the most reported road-kill species in both formal surveys and citizen science initiatives (Washington et al., 2008). Ducks, rails, and other wetland birds are similarly at risk, particularly where their habitat is fragmented by roads.

Kererū are frequently struck by vehicles, especially during the breeding season when their movement through fragmented landscapes increases. Hospital records from Massey Wildbase show consistent admission of injured kererū, Australasian harriers, and other large-bodied birds following collisions. Birds drawn to roads for food represent another high-risk group. Australasian harriers are often killed while feeding on road-kill, especially in areas where carrion is abundant (Flux, 2019). New Zealand falcons may also scavenge along roadsides, and tracked individuals have been killed by vehicles. Mynas and magpies hunting insects near roads suffer elevated mortality as well, particularly juveniles that are less experienced in avoiding traffic.

In contrast, small passerines, cryptic species, and nocturnal birds are likely under-represented in most road-kill datasets. Lower detectability, rapid carcass removal, and the physical destruction of smaller bodies all contribute to reduced reporting, though their actual vulnerability may be higher than records suggest. Carcass persistence varies significantly by species, influencing detectability and the perceived scale of road-kill. For example, Sullivan et al. (2025) observed that while hedgehog carcasses often remained on roads for weeks or even months, small bird carcasses typically disappeared within days. These differences have important implications for survey timing, species bias, and the accurate assessment of road-kill impacts.

2.7.4.3 Road and landscape characteristics

Road-kill risk varies with road type, traffic volume, and surrounding habitat. Roads that traverse wetlands, coastal areas, or other wildlife-rich habitats record disproportionately high bird mortality. Coastal roads are particularly hazardous for seabirds like little penguins crossing between nesting sites and the sea (Heber et al., 2008). Similarly, roads adjacent to farmland and wetland pose risks for species like pūkeko and ducks (Washington et al., 2008).

Specific road features also matter. Road intersections, bridge approaches, and curved sections are often hotspots for collisions, likely due to driver behaviour and wildlife movement patterns (Freeman, 2010; Sadleir & Linklater, 2016). Roadside habitat quality also affects risk. Roads bordered by vegetation that offers food or foraging opportunities can attract more birds, whereas degraded or barren verges tend to reduce bird presence.

2.7.4.4 Seasonal and annual patterns

Seasonality strongly influences bird road-kill patterns in New Zealand. Multiple surveys have reported mortality peaks in spring and early summer, coinciding with breeding, fledging, and juvenile dispersal periods (eg, Freeman, 2010). For example, kererū are more frequently reported as road-kill victims during these months, potentially reflecting increased movement during courtship or foraging. Shearwaters and petrels are especially vulnerable during the fledging period, when disoriented juveniles may crash-land on roads near coastal settlements due to artificial lighting. Pāteke and pūkeko mortality may also rise during periods of high juvenile dispersal or when drying wetland habitat pushes birds into surrounding landscapes. In contrast, bird road-kill appear less frequent in winter, likely due to reduced movement and lower activity levels associated with harsher weather conditions (Flux et al., 2022).

Annual variation in road-kill rates is also evident and may reflect changes in wildlife abundance, weather, and food availability. For instance, road-kill of scavengers such as Australasian harriers increases during years with high rabbit populations, providing more roadside carrion (Flux, 2019).

Long-term, structured monitoring will be essential to distinguish genuine ecological trends from reporting artefacts and to establish baselines against which future changes can be assessed. Given the number of endemic species and species of conservation concern in New Zealand, even modest levels of road mortality may have disproportionate conservation consequences if not adequately understood and managed.

3 Developing a road-kill monitoring protocol

3.1 Principles of sampling design

Developing an effective road-kill monitoring protocol requires careful consideration of the biological, spatial, and temporal factors that influence both the occurrence of vehicle collisions with birds and the likelihood of detecting them. The aim is not simply to document mortality, but to generate reliable, repeatable data that reflect the actual scale and distribution of road-kill events in each context. This is particularly important when protocols are tailored to specific scenarios, such as a focal species, high-risk road sections, or time-limited monitoring programmes. This section outlines key design considerations across four areas: taxa, spatial, temporal, and sampling bias. Together, these considerations provide a framework for developing fit-for-purpose monitoring protocols that are biologically meaningful, logistically feasible, and analytically robust.

3.1.1 Taxa considerations

The traits and behaviours of different bird species strongly influence both their risk of being struck by vehicles and the effectiveness of road-kill monitoring. When designing a road-kill survey protocol for a specific species or group, it is essential to consider how their ecology shapes both their exposure to roads and their likelihood of being detected after a collision. The following considerations can help guide scenario-focused survey design.

3.1.1.1 Body size

Species with larger body sizes (eg, harriers, penguins) are generally more visible and easier to detect, particularly during vehicle-based surveys. In contrast, small-bodied birds (eg, silvereyes) are more likely to be missed, especially at higher travel speeds or when carcasses are partially obscured (Brockie, 2007; Erritzoe et al., 2003). Monitoring protocols that target small species may require slower travel speeds, increased observer vigilance, or foot-based surveys to improve detection.

3.1.1.2 Flight capability and behaviour

Birds that fly may cross roads in ways that reduce their exposure to traffic, but this varies widely depending on flight height, speed, and take-off behaviour. Species that take off slowly, launch from the ground, or fly low over roads are often at greater risk of collision (Bishop & Brogan, 2013). In contrast, flightless birds such as kiwi or weka must cross roads on foot and may be more vulnerable, particularly on roads that bisect their territories or key foraging areas.

3.1.1.3 Activity patterns

The daily activity period of a species influences when it is most likely to encounter vehicles. Nocturnal birds such as morepork (*Ninox novaeseelandiae*) or petrels are at greater risk from night-time traffic, and their carcasses may be harder to detect unless surveys are conducted early in the morning before removal by scavengers or road maintenance. Diurnal species, by contrast, may be better detected during daylight surveys. Aligning survey timing with the activity patterns of the target species can improve both detection and ecological relevance.

3.1.1.4 Road interaction behaviour

Some birds actively use road surfaces or verges for foraging, basking, or scavenging. This behaviour increases their risk of collision and may warrant survey designs that include wider road verges or focus on specific habitat features (Morelli et al., 2014). Species that feed on invertebrates on warm road surfaces, or those attracted to road-kill such as harriers, are frequently recorded in road-kill studies and may require different monitoring strategies than species that only cross roads occasionally.

3.1.1.5 Carcass appearance

Plumage colour affects how easily a carcass is seen against different road or vegetation backgrounds. For species that blend into the substrate, slower speeds or on-foot surveys may improve detectability. Some species are more likely to be struck in ways that fragment or degrade the carcass, making identification difficult. Birds with fragile body structures or those more likely to be hit head-on may be less likely to remain intact and recognisable (Guinard et al., 2015; Slater, 2002). This has implications for observer training and for survey frequency, especially if species-level identification is important.

3.1.1.6 Conservation relevance

Species of conservation concern may warrant specific survey approaches regardless of whether they are easily detected or commonly struck. Even low rates of road mortality can be significant for small or declining populations. Where rare or endemic species are a focus, protocols may need to prioritise accurate species identification, finer spatial resolution, or increased frequency to capture rare events.

3.1.2 Spatial considerations

Effective road-kill monitoring begins with careful spatial planning, as the location and distribution of survey routes directly shape the insights that can be drawn. Decisions about which roads to include and how much distance to survey affect the usefulness, comparability, and interpretability of the data collected. Key spatial variables such as traffic volume, surrounding habitat, road structure, and observer access also influence both wildlife presence and the likelihood of detecting carcasses. These considerations should be weighed against the specific goals of the survey, whether to detect hotspots, monitor certain taxa, or evaluate the effectiveness of mitigation.

3.1.2.1 Location selection (targeted vs representative)

Monitoring can be designed to focus on specific high-risk locations or to represent conditions across a broader area. Targeted surveys may prioritise sites near known wildlife crossings, habitat corridors, or areas of past mortality. This approach is often best suited to mitigation design or when monitoring a species of conservation concern. Alternatively, a representative sampling strategy spreads effort across multiple sites or road types to characterise overall patterns and trends. Both approaches are valid, and the choice should reflect the ecological questions or management goals guiding the survey.

3.1.2.2 Transect length

The length of each road transect should balance spatial coverage with the level of detail required. Longer sections may increase the likelihood of detecting rare events or low-frequency mortality but may also reduce the number of times each section can be revisited. Shorter transects allow for more intensive or frequent monitoring, which can improve estimates of persistence and detection. Survey type also affects what is feasible: vehicle-based surveys can cover longer distances, while walking surveys are more appropriate for short, high-resolution sections where detection accuracy is critical.

3.1.2.3 Road characteristics

Road type, speed, and traffic volume directly affect collision risk and also constrain where and how surveys can be conducted. Sealed roads, multi-lane highways, and high-traffic areas may have higher road-kill rates but present greater risks to observers. In contrast, unsealed or low-speed roads may offer safer access and better visibility but lower encounter rates. Protocols may need to adjust survey timing, stopping locations, or observer positioning to accommodate different road conditions.

3.1.2.4 Road verge conditions and surrounding land use

The structure of road verges and the habitat types bordering the road can influence both the presence of wildlife and the detectability of carcasses. Tall grass, dense shrubbery, or roadside barriers can obscure smaller carcasses from view. Similarly, certain habitat edges such as forest or wetland margins may funnel bird movement across roads, increasing collision risk. Recording verge conditions and nearby land use during surveys can help interpret observed patterns and refine future site selection.

3.1.2.5 Survey scale and replication

The number of sites included and their spatial distribution should reflect both the survey objective and the expected frequency of road-kill. A single-site survey may offer detailed insight into local mortality but may not be broadly applicable. Including multiple sites across different road types or landscapes strengthens the ability to detect broader patterns or compare between conditions. Spatial replication also supports statistical inference and helps distinguish random events from consistent trends.

3.1.3 Temporal considerations

The timing of road-kill surveys plays a critical role in determining what is recorded. Both the time of day and the time of year influence the likelihood of wildlife–vehicle collisions and the chances of detecting carcasses. Temporal design should reflect the ecology of the focal species while also accounting for carcass persistence, observer safety, and the need for consistency across survey events.

3.1.3.1 Time of day

Wildlife activity patterns vary over the course of a day, meaning that collisions are more likely to occur at certain times. Many bird species are most likely to encounter roads around dawn and dusk, such as penguins returning to shore, while nocturnal species like morepork and petrels are more likely to be struck during the night. The time of day a survey is conducted can therefore influence which species are detected and how soon after death the carcass is recorded. Morning surveys may be more optimal for detecting overnight mortality before scavengers. Survey timing also affects visibility, with low sun angles or glare potentially impairing detection, especially for small or cryptic species. Observer safety may also be influenced by lighting conditions and traffic levels during early morning or evening periods.

3.1.3.2 Time of year and seasonality

Road-kill incidence often varies seasonally in response to life history events such as migration, breeding, and fledging. For example, increased mortality has been observed during nesting periods when adult birds frequently cross roads to provision chicks, or during fledging periods when inexperienced juveniles are more vulnerable to traffic (Grilo et al., 2009; Santos et al., 2011). Some studies have also noted peaks in road-kill during post-breeding dispersal or seasonal movements associated with weather or resource availability. Seasonal environmental factors can also affect carcass visibility and decomposition. Rain, frost, or vegetation growth may obscure carcasses, while higher temperatures may accelerate decomposition and reduce the time window for detection. For these reasons, seasonal timing should be matched to periods of known risk for focal species, and should also consider detection conditions.

3.1.3.3 Survey frequency

Survey frequency determines how often a given road section is visited and strongly affects the number of carcasses detected. Carcasses that persist for only short periods may be missed if surveys are too infrequent. For example, studies have shown that small bird carcasses may be removed or decompose within 24 to 48 hours (Antworth et al., 2005; Flint et al., 2010). More frequent surveys increase the probability of detection and improve the reliability of estimates but may not be feasible across large areas. The ideal interval between surveys depends on the target species, expected carcass persistence, and resource availability. Frequent surveys may be particularly important for taxa with rapid removal rates or during high-risk periods.

In a comparative study by Guinard et al. (2023), road-kill was surveyed using two distinct approaches: daily monitoring by highway patrol agents and monthly surveys conducted by an ecologist. The daily surveys involved patrollers driving at typical traffic speeds (80–90 km/h) while engaged in other duties, with only basic training in wildlife identification. Despite these limitations, patrollers reliably detected large-bodied species. In contrast, the ecologist-led surveys were conducted monthly at reduced speeds (~40 km/h) with a dedicated observer and driver team. These surveys proved more effective at detecting small-bodied species and provided more detailed biological information. The study concluded that the two methods were complementary, with each approach detecting different subsets of road-kill. This highlights the value of combining multiple survey frequencies and personnel types to generate a more complete understanding of species-specific road mortality.

3.1.3.4 Duration of the monitoring programme

The length of the monitoring period influences what types of patterns can be detected. Short-term surveys may be useful for capturing acute mortality events, such as seasonal peaks or responses to roadworks, but may miss longer-term variation. Long-term monitoring allows for the detection of trends, evaluation of mitigation effectiveness, and the identification of emerging hotspots. This is especially important for rare species, species with high interannual variation in road use, or when assessing the impact of gradual changes in traffic patterns or land use (Loss et al., 2014). Programmes that span multiple years and include repeated seasonal sampling are more likely to generate findings that are both reliable and broadly applicable. One approach classifies road-kill hotspots as stable, emerging, or disappearing, based on spatiotemporal patterns in carcass or crash data, allowing for an objective assessment of how collision risk changes over time (Bíl et al., 2019).

3.1.3.5 Consistency and traffic-related timing

Surveys should be conducted at consistent intervals and under comparable conditions to avoid introducing temporal bias. Inconsistency in the day of the week, time of day, or seasonal timing can affect both mortality patterns and detection probability. Traffic-related timing is a key factor. Weekday versus weekend differences, public holiday surges, and commuter peaks can all alter traffic volume and, in turn, wildlife behaviour. For instance, some birds may adjust their movement or foraging activity in response to traffic density (Cooke et al., 2020). Surveys conducted during high-traffic periods may miss carcasses due to faster degradation or may be biased towards species that are active during those times. To reduce confounding effects, survey protocols should standardise the time and day of sampling, or account for traffic variation in the analysis.

3.1.4 Sampling bias

Multiple methods have been used to monitor road-kill at species or site-specific scales (van der Ree, Smith, & Grilo, 2015). These approaches can be broadly divided into two categories:

1. **Passive monitoring** is typically opportunistic and lacks a formal experimental design. Examples include:
    a. police or road agency reports
    b. citizen science initiatives.

   These methods are low-cost and can provide broad spatial coverage but may be inconsistent or incomplete.
2. **Active monitoring** follows a predetermined, structured survey design. Examples include:
    a. government-mandated surveys (quality may vary depending on resourcing)
    b. research-driven surveys (usually more rigorous and question-focused).

Regardless of the method used, road-kill data are often subject to bias. Common issues include:

- over-representation of easily detectable species (eg, large-bodied birds)
- underestimation of true mortality due to carcass removal by scavengers, wind, or vehicle disturbance.

These biases can make it difficult to compare results across studies and may obscure the actual scale of road-kill impacts (Guinard et al., 2012).

Reducing bias in estimates of road-kill abundance improves the accuracy of assessments of impacts on populations, communities, or species, and supports more reliable evaluation of mitigation measures intended to reduce these impacts. One review reported that out of 645 publications discussing research issues related to wildlife–vehicle collisions, only 7% were primarily focused on methodology (Pagany, 2020). Guinard et al. (2015) suggested that to reduce bias in road-kill surveys, three parameters need to be quantified:

1. **persistence** (the probability that the carcass was not removed from the road between counts, or the inverse of carcass disappearance)
2. **entry** (the probability that a new carcass appears on the road between counts)
3. **detectability** (the probability of detecting the carcass).

3.1.4.1 Persistence

Persistence probability refers to the likelihood that a carcass remains present and visible on the road between two survey visits, without being removed by scavengers, vehicles, weather, or human activity. If carcasses disappear quickly and surveys are too infrequent, mortality can be significantly underestimated. While scavenging is widely acknowledged as a major factor influencing carcass persistence, its effects are rarely quantified in detail (Guinard et al., 2015).

Although carcass persistence appears to vary widely, few studies have quantified rates. In New Zealand, some limited data are available: Freeman (2010) reported that weka carcasses typically disappeared within 1 to 48 hours, while Beauchamp (2009a) observed that pūkeko and morepork carcasses could persist for several days to months, depending on conditions. In the USA, Antworth et al. (2005) found that 73% of bird carcasses disappeared within 36 hours. Similarly, Flint et al. (2010) recorded low overall persistence among waterfowl in Alaska, with fewer than 50% of carcasses remaining after just one day.

Scavenging rates can vary between years, seasons, and even times of day (Guinard et al., 2012). In some cases, persistence has been found to be lower during the breeding season (spring), likely due to increased scavenger activity (Guinard et al., 2015). However, in a UK study, corvids, identified as primary diurnal scavengers, showed lower scavenging rates in spring, possibly due to alternative food sources such as lambing fields (Slater, 2002). Schwartz et al. (2018) observed that the number of carcasses removed peaked during the early morning hours, while another study reported peak removal shortly before and after sunrise, with a second smaller peak just after dusk (Slater, 2002).

In addition to scavenging, persistence rates can be affected by traffic and environmental conditions. Carcasses may be crushed by vehicles or displaced by wind and rain. Smaller-bodied birds such as passerines are particularly vulnerable to wind displacement caused by passing traffic, which can blow them into roadside vegetation and out of view (Beauchamp, 2009a; Guinard et al., 2012). Carcass age also influences persistence, as older carcasses tend to be less attractive to scavengers, potentially because they are less recognisable, more degraded, or embedded in the road surface (Guinard et al., 2015). Seasonal variation in the effects of carcass age has also been observed. For instance, Guinard et al. (2012) found that persistence probability was lower in spring, possibly due to weather-related degradation or heightened scavenger activity.

As an example of a carcass persistence trial, Teixeira et al. (2013) conducted a study in Brazil monitoring road-kill over four consecutive days and across 10 surveys over the course of a year. Surveys were performed using a vehicle travelling at approximately 40–50 km/h, with two observers in addition to the driver. On the first day of each survey, all carcasses visible on the road lanes and paved shoulders were recorded. These carcasses were then revisited over the following three days to determine how many remained, providing persistence estimates across the 0–3 day interval.

3.1.4.2 Entry

Entry probability refers to the likelihood that a new carcass appears within the survey area during the interval between two counts, or the probability that an animal is struck and killed during that specific time period. This distinction is crucial for differentiating between carcasses that were missed during previous surveys and those that are truly new.

Unlike persistence and detectability, which focus on whether a carcass remains or is observed, entry reflects the timing of the mortality event. Without accounting for entry, it is difficult to determine whether a carcass recorded during a survey is truly new or simply overlooked in a previous count. This challenge is particularly relevant in high-frequency monitoring, where observers may unintentionally re-record carcasses or miss freshly killed animals that appeared shortly after the last survey.

Entry rates are influenced by multiple factors, including traffic volume, animal movement patterns, time of day, and season. For example, road-kill rates often peak at dawn or dusk, when wildlife activity and traffic overlap, or during migratory and breeding seasons, when animals are more mobile (Grilo et al., 2009; Santos et al., 2011). Teixeira et al. (2013), in their persistence trial in Brazil, indirectly captured entry by surveying across multiple days and identifying which carcasses were newly recorded between intervals. Carefully designed studies that mark or geolocate carcasses can help differentiate fresh entries from prior detections, thereby improving entry rate estimates.

Although few studies explicitly quantify entry, it remains an important consideration for interpreting road-kill trends and designing appropriate survey intervals. If the gap between surveys is too long, many new carcasses may appear and then disappear before the next count, resulting in underestimates of mortality. On the other hand, in short-interval surveys, failing to distinguish new from old carcasses could lead to inflated counts or misinterpretation of spatial or temporal patterns.

Given the unpredictability of road-kill events and their dependence on wildlife movement near roads, researchers aiming to estimate entry rates could benefit from integrating carcass surveys with species-specific activity data (eg, camera traps, acoustic monitors, or GPS tracking). These tools can help identify periods of elevated collision risk, offering indirect insights into when new carcasses are most likely to appear.

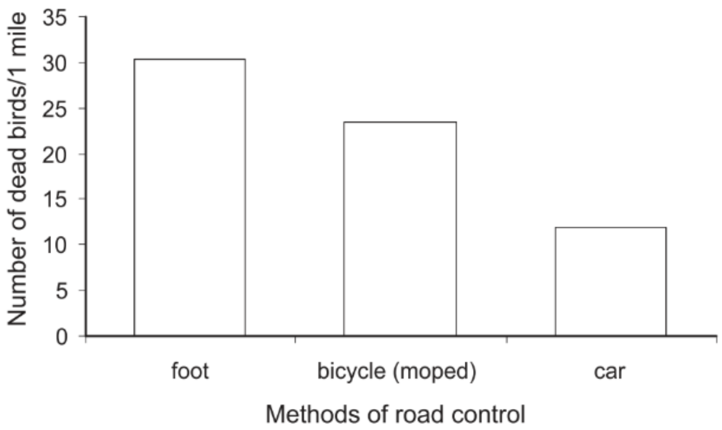
3.1.4.3 Detectability

Finally, detection probability is the chance that an observer will notice and record a carcass that is present during a survey. Detection can be influenced by factors such as observer experience, species size, position on the road, or environmental conditions. Accurately accounting for all three probabilities – persistence, entry, and detectability – is essential for generating reliable estimates of wildlife–vehicle collision rates and reducing systematic bias in survey data.

Not considering detection rates can lead to underestimates in total mortality, particularly when carcasses are overlooked due to survey method or observer limitations. Since studies often rely on a variety of methods to monitor road-kill, results are typically not directly comparable (Erritzoe et al., 2003; Collinson et al., 2014). Teixeira et al. (2013) found that when carcass persistence and detectability were not accounted for, bird mortality was underestimated, though this bias did not appear for mammals, highlighting the need for taxon-specific adjustments.

Detection probability is influenced by several key factors, including survey method (walking, cycling, or driving), observer experience, vehicle speed, carcass size, and the carcass's position on or near the road. Multiple studies have shown that walking surveys produce higher detection rates than surveys at higher speeds, such as cycling or driving (Erritzoe et al., 2003; Podolsky et al., 1998) (Figure 3.1). Guinard et al. (2012) found that although driving surveys could be equally effective in detecting bird carcasses located directly on the road surface, they were less effective at detecting those on road verges.

Figure 3.1 The number of dead birds found in relation to the way the roads were surveyed (reprinted from Erritzoe et al., 2003, p. 79, adapted from Hodson & Snow, 1965)



Driving surveys are often used for their efficiency in covering long distances, but their higher speeds and reduced flexibility to stop and investigate can introduce bias, particularly under-detecting smaller or obscured species. These studies often focus on large-scale spatial or temporal patterns of bird road mortality, such as seasonal peaks or road-type comparisons. The key advantages of vehicle-based surveys include the ability to cover long distances, replicate routes consistently, and detect road-kill that may otherwise go unreported. They are also cost-effective, particularly when integrated into routine travel or conducted by volunteers. However, detection probability is reduced for small-bodied birds, and survey results may be biased by carcass persistence, observer fatigue, and verge visibility (Santos et al., 2011; Teixeira et al., 2013). Some studies have proposed the use of certain technologies to improve accuracy, such as dashcams or vehicle-mounted detection systems (Guedes et al., 2019; Sillero et al., 2018). The use of detection dogs has also been increasingly adopted for locating bird carcasses, with studies showing they consistently outperform human observers in detecting carcasses of various sizes across a range of environmental conditions (Domínguez del Valle et al., 2020).

For studies focused on small-bodied birds such as passerines, walking or cycling surveys may be more appropriate despite covering shorter distances. These slower methods improve the likelihood of detecting and correctly identifying carcasses, especially those partially hidden in vegetation. Pedestrian surveys offer higher detection rates for small or cryptic species, particularly in dense vegetation or gravel shoulders. This method allows for more accurate carcass counts, detailed assessment of condition, and collection of microhabitat variables (Loss et al., 2014; Slater, 2002). However, walking surveys are time-intensive, limiting the total area that can be covered. Surveyor fatigue, uneven terrain, and visual obstructions from vegetation may also influence detectability. Cycling surveys are best suited to low-traffic roads with wide shoulders or designated cycle lanes, offering a compromise between speed and visibility. Additionally, increasing survey frequency for small species helps reduce the number of carcasses missed due to rapid removal.

Guinard et al. (2012) recommended tailoring survey methods to road context and research goals. They suggested using driving surveys for sections longer than 15–20 km, and walking surveys for shorter segments where detailed detection is needed. To improve the reliability of detection estimates, calibration surveys can be conducted by intensively walking selected sub-sections of the driving transect. These targeted surveys allow for the estimation of detection probabilities, helping to correct for under-detection in less intensive, vehicle-based surveys. The authors also advocated for surveys to be conducted at least once per season, with each section of road surveyed multiple times (ideally three or more) to improve estimates of both persistence and detection.

Driving survey protocols vary widely, with vehicle speeds ranging depending on road type, legal limits, or safety constraints. Faster speeds increase the likelihood of missing smaller carcasses, resulting in an over-representation of larger-bodied species (Erritzoe et al., 2003). For example, in New Zealand, car-based surveys have recorded fewer bird carcasses than bicycle-based ones. Brockie (2007), who surveyed at 50 km/h in urban areas and 100 km/h on highways, reported that 20% of small bird carcasses and 2% of larger animal carcasses could not be identified to species level. Similarly, Flux (2019) found that about one-third of bird road-kill recorded from a moving vehicle could not be identified.

Although smaller species are more reliably detected at lower speeds, carcasses have been detected at speeds of 40–60 km/h and even up to 100 km/h (Brockie, 2007; Collinson et al., 2014). However, most studies do not explicitly incorporate detection probabilities into their analyses. Without this, observed counts cannot be confidently related to true mortality, undermining the reliability of comparisons between surveys or across studies.

One example of this is the study by Collinson et al. (2014) in South Africa, which developed a standardised detection protocol using simulated road-kill. The study assessed detection rates under different conditions such as vehicle speed, time of day, observer type, and carcass size, using artificial carcasses placed at known locations. They found that speeds above 50 km/h greatly reduced detection rates, while 30 km/h was considered too slow to be practical. The study also determined that, while detection rates did not differ between the observer acting as driver or passenger, significant differences were seen between trained and untrained observers. Additionally, time of day in relation to the sun (sun above, in, or behind the observer's eyes) and the position of road-kill on the road, irrespective of size, had no significant effect on detections.

3.1.5 Health and safety considerations

Conducting bird road-kill surveys along state highways presents significant health and safety challenges. Walking or cycling can improve carcass detection (Wang et al., 2022), but these methods are often hazardous and impractical on high-speed roads. Vehicle-based surveys conducted well below the speed limit may be safer for personnel but can create traffic risks and delays, as other drivers may not anticipate or tolerate a slow-moving vehicle. Such operations could disrupt traffic and require careful planning to prevent accidents. Given these risks, all road-kill monitoring on state highways must place health and safety at the forefront. Survey teams should develop clear safety plans, including traffic management measures where required, such as scheduling surveys during low-traffic periods, using warning signage or escort vehicles, and ensuring high-visibility clothing is worn. Robust safety protocols are essential to protect both surveyors and the public.

Guidance for work carried out within the legal road corridor is available in the *New Zealand Guide to Temporary Traffic Management* (Waka Kotahi NZ Transport Agency, 2023b). Such work should be supported by a Traffic Management Plan and include a thorough risk assessment outlining the nature of the work and how it will be conducted.

3.2 Principles of data analysis and presentation

3.2.1 Aligning analysis with survey design

Effective analysis of road-kill data relies on maintaining consistency with the original survey design. Variations in survey frequency, transect length, and observer effort can significantly influence data interpretation. For example, directly comparing data from daily surveys with monthly surveys without appropriate standardisation can result in misleading conclusions. Thus, using metrics like carcasses per kilometre or per survey day helps to standardise results, enabling more accurate comparisons across studies and time periods.

Moreover, the analytical approach should be tailored to the study's objectives. If the goal is to identify spatial hotspots, geospatial tools must be selected carefully. While traditional kernel density estimation (KDE) has been widely used in ecological studies, it is designed for general spatial distributions and is not well suited to linear transport networks such as roads. For this reason, KDE+ has been developed specifically to identify hotspots along linear features, making it a more appropriate tool for analysing road-kill data in the context of transport corridors (Bíl & Andrášik, 2020; see also Centrum dopravního výzkumu [Transport Research Centre], 2025). Conversely, when the objective is to explore changes over time, temporal trend analyses may utilise time-series or seasonal decomposition methods to detect patterns across specific periods.

3.2.2 Addressing sampling bias and uncertainty

Sampling bias is a critical concern in road-kill studies. Two primary sources of bias are carcass persistence and detectability. To mitigate these biases, correction factors should be applied where possible. For example, incorporating carcass persistence and detectability rates into mortality estimates can provide more accurate assessments. When correction is not feasible, it’s essential to acknowledge these limitations and interpret findings as minimum estimates.

3.2.3 Summary metrics and visualisation

Presenting road-kill data effectively requires the use of standardised metrics and clear visualisations. Commonly used metrics include:

- **carcasses per kilometre**, which normalises data based on survey distance
- **carcasses per survey effort**, which accounts for the time or number of surveys conducted
- **species composition percentages**, which highlights the proportion of different species affected.

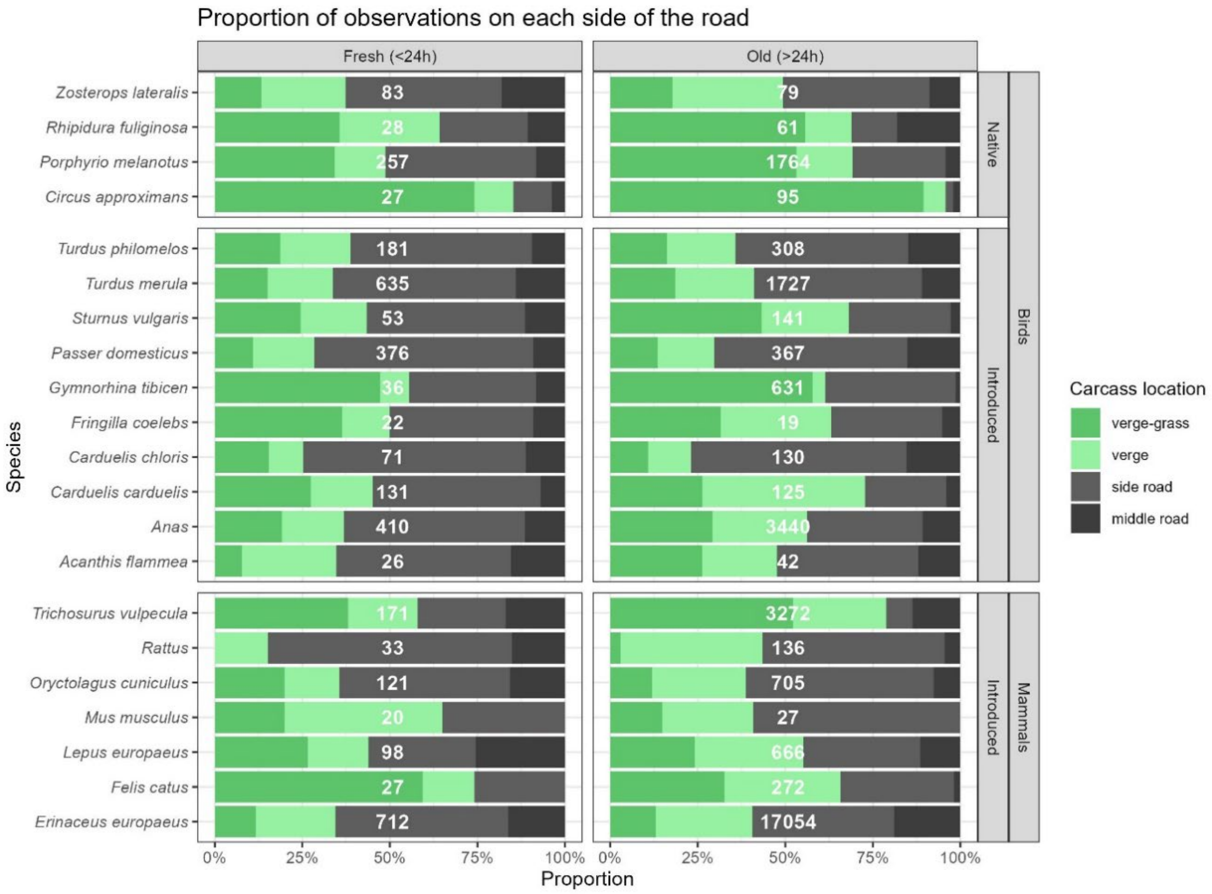
Visual tools such as heatmaps can identify spatial hotspots, while temporal graphs can reveal seasonal trends. Graphical visualisations are particularly useful for illustrating changes in road-kill observations before and after interventions, such as the installation of wildlife underpasses, adjustments to speed limits, or the removal of roadside vegetation. Where relevant, integrating vehicle speed data from traffic radars can further improve interpretation of speed-related effects by capturing actual traffic behaviour rather than relying solely on posted limits. These systems may also record vehicle direction and inter-vehicle spacing, providing additional context for assessing risk patterns. These tools can help clarify trends, highlight the effects of mitigation measures, and make results more accessible to a wider audience.

The following examples use real road-kill data collected in New Zealand (Sullivan et al., 2025). Although examples 2–5 are based on relatively short road sections with low numbers of recorded road-kill, they are intended to demonstrate the types of comparisons that can be made and how these might be visually presented.

3.2.3.1 Example 1: Location of carcasses on road

Figure 3.2 presents a visual summary of road-kill observations by road position. It highlights two key patterns: considerable variation among species in where carcasses were located on or beside the road, and a tendency for Australasian harriers in particular to be found almost entirely off the road surface.

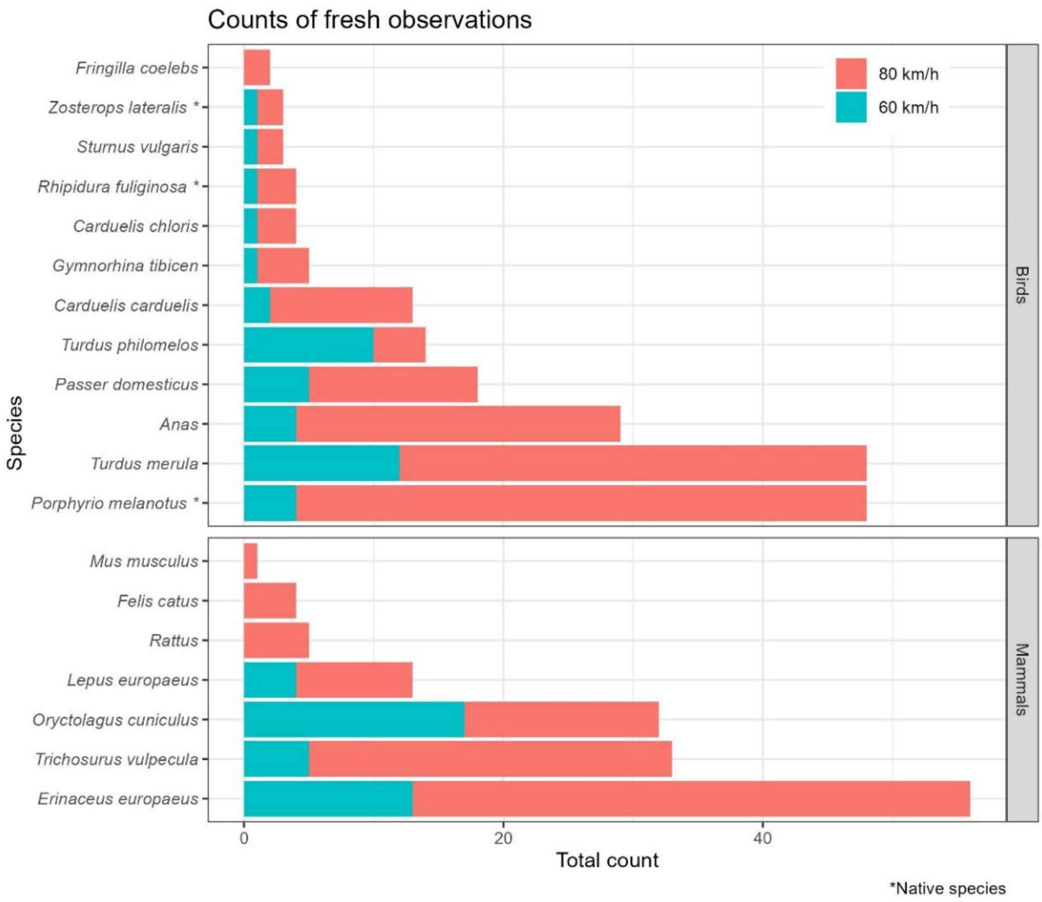
Figure 3.2 Proportion of carcasses recorded in different parts of the road along a route between Christchurch and Lincoln, for avian and mammalian species with at least 20 fresh observations collected over 12 years (2012–2024). White numbers inside each bar indicate the total number of fresh or old observations for each species where a detailed location was recorded. (Adapted from Sullivan et al., 2025, p. 13.)



3.2.3.2 Example 2: Change in speed limit

Figure 3.3 presents road-kill observations from two adjacent road sections with different speed limits, illustrating how speed may influence mortality rates.

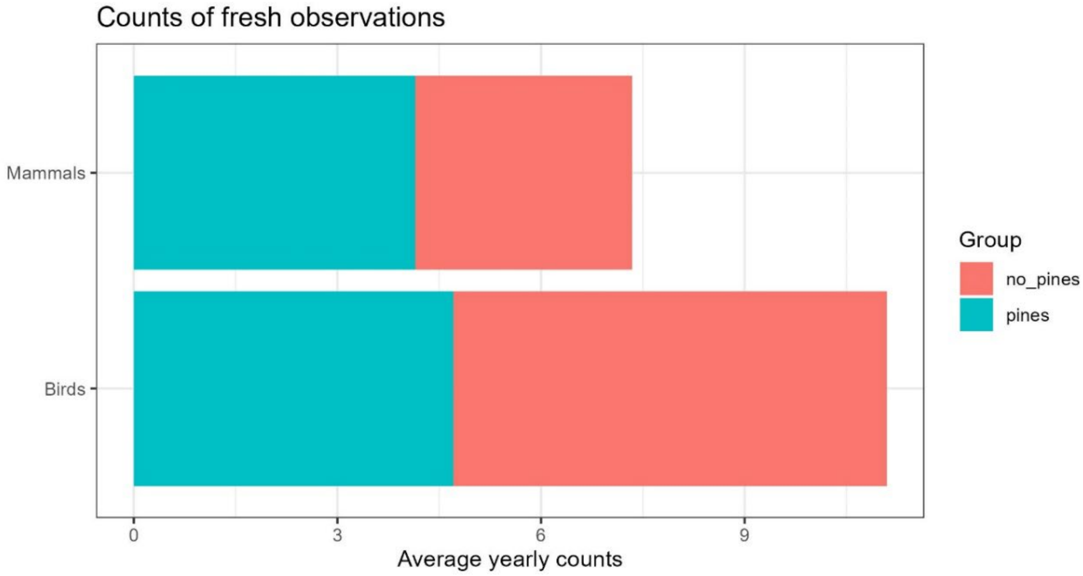
Figure 3.3 Total number of road-kill observations over 10 years (2014–2024) from two adjacent road sections, each approximately 500 m in length, between Christchurch and Lincoln. A change in speed limit occurs between the two sections, shifting from 60 km/h (green bars) to 80 km/h (red bars). (Data from Sullivan et al., 2025.)



3.2.3.3 Example 3: Removal of pine trees alongside road

Figure 3.4 presents road-kill data collected before and after the removal of tall pine trees alongside the road, allowing comparison of mortality patterns over time.

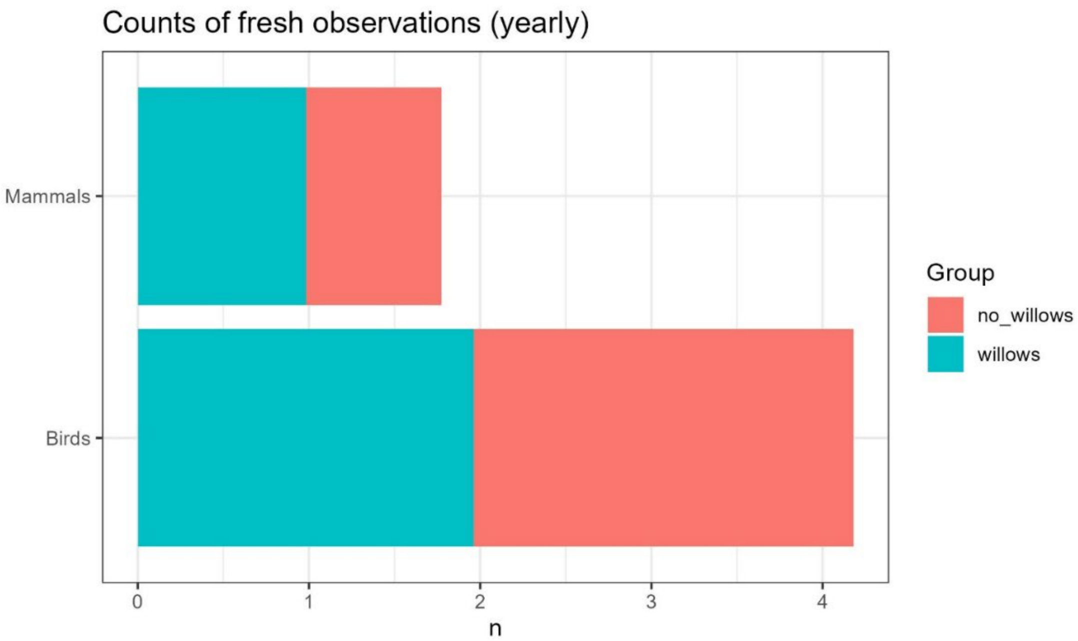
Figure 3.4 **Yearly average of fresh (less than 24 hours old) road-kill observations from a 100 m road section between Christchurch and Lincoln. This section previously had a stand of tall pine and eucalyptus trees along the roadside. Green bars represent data collected before tree removal (2014–2022) and red bars represent data collected after removal (2023–2024). (Data from Sullivan et al., 2025.)**



3.2.3.4 Example 4: Removal of willow trees alongside road

Figure 3.5 presents a second example of roadside vegetation removal, showing road-kill trends before and after willow trees were cleared.

Figure 3.5 **Yearly average of fresh (less than 24 hours old) road-kill observations from a 250 m road section between Christchurch and Lincoln. This section previously had a stand of willows along the roadside. Green bars represent data collected before tree removal (2014–2016) and red bars represent data collected after removal (2017–2024). (Data from Sullivan et al., 2025.)**



3.2.3.5 Example 5: Urban development

Figure 3.6 presents a comparison of road-kill observations between a developing residential area and a nearby unchanged farmland section.

Figure 3.6 Yearly average of fresh (less than 24 hours old) road-kill observations from 2014 to 2024 across two 450 m road sections between Christchurch and Lincoln. The blue bars represent a section that transitioned from farmland to residential housing (with most construction occurring in 2015 alongside a speed limit reduction from 80 to 50 km/h), while the red bars represent an adjacent section of pastoral farmland where the landscape and speed limit (80–100 km/h) remained unchanged. (Data from Sullivan et al., 2025.)

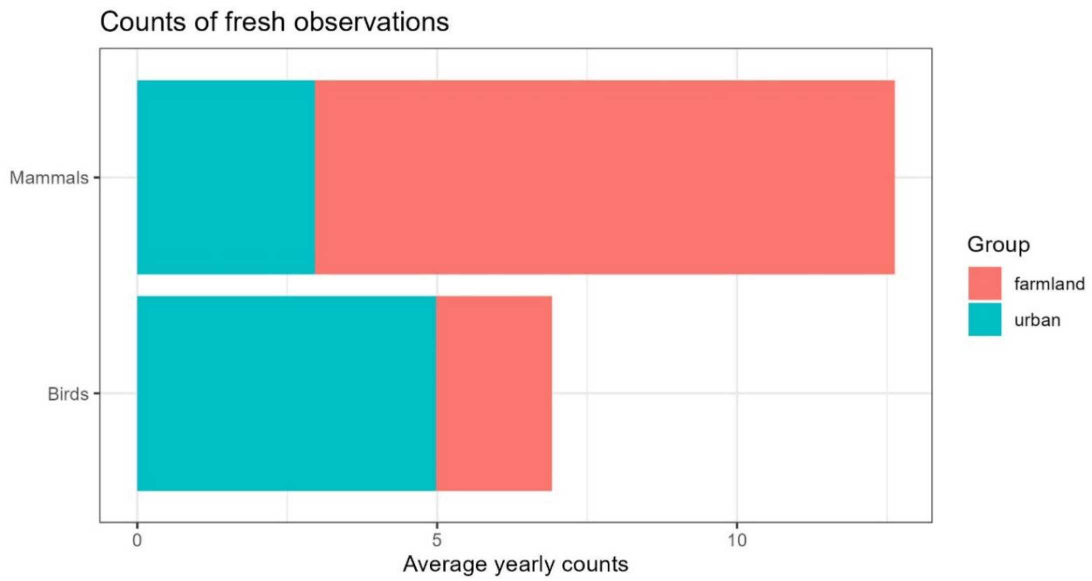


Figure 3.7 Aerial images of the two 450 m road sections used in Example 5, both located between Christchurch and Lincoln. The left image shows the urbanised section, which transitioned from farmland to residential housing during the study period. The right image shows the adjacent farmland section, where the surrounding landscape remained unchanged. Both routes are outlined in blue. Images sourced from Google Earth.

3.2.4 Framing results for management and communication

Interpreting and communicating road-kill data should be done within the broader ecological and management context. Understanding species-specific behaviours, habitat preferences, and movement patterns can elucidate observed mortality trends. For example, increased road-kill incidents during breeding seasons may indicate heightened movement across roads.

Effective communication involves tailoring the presentation of findings to the intended audience. When engaging with policymakers, it is important to highlight the relevance of road-kill data for informing conservation priorities and improving road safety. For public audiences, emphasising the ecological consequences and practical solutions can help build understanding and encourage support for mitigation efforts.

3.3 Example protocol templates for bird road-kill monitoring in New Zealand

The following are example protocol templates that illustrate practical, New Zealand-specific approaches to bird road-kill monitoring. These include structured transect surveys, high-casualty hotspot monitoring, and citizen science initiatives.

3.3.1 Protocol Template A: Monitoring threatened ground-nesting birds

Species focus: North Island brown kiwi (*Apteryx mantelli*), pāteke/brown teal (*Anas chlorotis*), and kororā/little penguin (*Eudyptula minor*)

Location: Northland forests, Aotea wetlands, and coastal areas of the West Coast

3.3.1.1 Overview and rationale

This section presents a unified monitoring approach for three high-priority native bird species in New Zealand: the North Island brown kiwi, pāteke, and kororā. These species were selected based on conservation status, vulnerability to road mortality, and the feasibility of targeted monitoring.

Although the three species differ ecologically, they share several demographic and behavioural traits that enable a broadly similar monitoring protocol, with only minor adjustments needed to reflect species-specific habitat use and movement patterns:

- ground-dwelling or low-flying movement
- small to medium body size (~1–2 kg)
- nocturnal or crepuscular activity
- proximity to roads in active population regions
- high conservation value.

A broadly similar monitoring design can be used, with adaptations to each species' ecology and habitat context.

3.3.1.2 Core monitoring framework (shared across species)

Survey method

Low-speed (20–40 km/h) vehicle-based surveys by a driver-observer team or a solo driver-observer if an effective hands-free option is available.

Timing

Surveys should occur early in the morning, shortly after dawn (typically between 05:30 and 08:30 am). This timing:

- captures carcasses from overnight strikes
- maximises daylight visibility
- reduces observer fatigue and traffic risk.

Transect lengths

Transects should vary in length based on species ecology and landscape configuration.

- **Kiwi: 5–10 km**: Kiwi have large home ranges and disperse over long distances through forest and pasture mosaics. Road-kill events, even if infrequent, may be widely scattered across the landscape. A 5–10 km transect length allows for broad coverage of potential crossing points while remaining logistically manageable during a morning survey.
- **Pāteke: 3–6 km**: Pāteke move locally between wetlands and pasture, often staying within a few hundred metres of habitat edges. Road crossings tend to occur in clustered areas, especially where roads and drains intersect. Shorter transects capture these fine-scale spatial patterns and have proven effective when monitoring other waterfowl.
- **Kororā: 2–4 km**: Kororā tend to cross roads at specific, narrow coastal zones when returning from the sea to burrows. Their movement is highly localised, and road-kill risk is typically restricted to a few hundred metres near nesting colonies. Short transects in these areas allow precise monitoring and minimise survey time in remote or hazardous terrain.

Carcass detection and handling

When a carcass is observed:

- record GPS coordinates, date, time, species, condition, and location on or beside road
- take photographs for ID verification
- move the carcass off the road if safe, and mark the site with biodegradable flagging tape
- do not remove carcasses unless authorised.

Detection aids like binoculars or smartphone zoom may help assess suspected carcasses from within the vehicle, but likely only at lower speeds.

Personnel and training

- Surveys should ideally be conducted by two people – one as the driver and one as the observer – although a solo driver-observer may be acceptable if a safe and effective hands-free option is available.
- Observers must be trained in basic bird ID, safe survey practices, and digital data tools.
- Where possible, collaborate with DOC staff, iwi, or local conservation trusts for local knowledge, such as likely bird crossing points, seasonal movement patterns, or recent carcass reports.

Bias correction options

For each species, detectability and carcass persistence trials can improve data interpretation. Trials may involve placing surrogate carcasses and measuring removal rates. Carcass visibility experiments (eg, placing test models) may also support bias estimation.

3.3.1.3 Species-specific adaptations

Table 3.1 summarises the key ecological traits, survey design elements, and logistical considerations that differ between kiwi, pāteke, and kororā. These adaptations ensure the shared protocol is tailored appropriately to each species' behaviour, habitat, and detectability.

Table 3.1 Summary of species-specific adaptations for ground bird road-kill monitoring protocols in New Zealand.

Feature	Kiwi	Pāteke	Kororā
Body size	Medium (2–3 kg)	Small (~1 kg)	Small (~1–1.5 kg)
Activity pattern	Nocturnal	Crepuscular to nocturnal	Nocturnal (return from sea at night)
Habitat	Forest edges, pasture, fragmented native bush	Wetlands, pasture edges, estuarine margins	Coastal scrub, rocky burrows near sea
Survey frequency	4× per year (3 consecutive days)	6× per year (2 consecutive days)	Monthly (Apr–Jul), bi-monthly (Aug–Mar)
Transect length	5–10 km	3–6 km	2–4 km
Detection challenges	Rare events, may be scavenged rapidly	May be obscured by verge vegetation	May be scavenged quickly, hard to see at verge
Local partners	Kiwi Coast, DOC Northland	DOC Aotea, local landowners, community trusts	DOC West Coast, Penguin Trusts

3.3.1.4 Summary

This protocol creates a flexible yet standardised foundation for long-term monitoring of at-risk ground birds. It allows for consistent national data collection while supporting site-specific adaptations.

Kiwi: 4× per year (3 consecutive days)

Rationale: Kiwi are nocturnal, largely resident birds with large, overlapping home ranges. Their movement is relatively consistent throughout the year, although juveniles may disperse. Road-kill events are rare and spatially dispersed, so infrequent but intensive surveys are appropriate.

Recommended frequency: Quarterly surveys spaced across seasons (eg, March, June, September, December), with each consisting of 3 consecutive morning transects. This repetition improves the chance of capturing low-frequency events and accounts for variable carcass persistence.

Pāteke: 6× per year (2 consecutive days)

Rationale: Pāteke are highly mobile within their home ranges and may cross roads between wetland roosting and feeding sites. Movement intensity and breeding activity peak in spring and summer, particularly between September and February. Rainfall and seasonal water levels may also affect movement.

Recommended frequency: Surveys every 2 months (eg, February, April, June, August, October, December), with 2 consecutive survey days to capture variable daily carcass appearance and improve detection. Higher frequency would better reflect seasonal variability in behaviour and risk exposure.

Kororā: Monthly (Apr–Jul), every 2 months (Aug–Mar)

Rationale: Kororā face peak road-kill risk between April and July, when they are returning from ocean foraging and looking for places to nest. Carcass persistence may be short due to heavy traffic on motorways, and carcasses may be missed without regular checks.

Recommended frequency: Monthly surveys from April to July and every two months from August to March. All surveys should occur in the early morning following known nightly activity. This balances coverage of high-risk periods with logistical feasibility while still acknowledging ongoing but reduced risk during other periods.

3.3.2 Protocol Template B: Monitoring multi-species road-kill hotspots on state highways

Species focus: Multiple species (eg, harrier, pūkeko, kererū, and other more common road-kill birds)

Location: High-casualty road corridors (eg, state highways or other high-traffic roads near major wetlands)

3.3.2.1 Overview and rationale

New Zealand's state highways intersect a wide range of productive habitats and ecosystems, including wetlands, farmland, and riparian corridors, areas that support high bird activity (eg, Australasian harriers scavenge near verges, and pūkeko and kererū forage in roadside vegetation). Reports of bird road-kill in these habitats are not uncommon, but systematic monitoring has rarely been undertaken.

This protocol targets areas with frequent multi-species bird strikes, particularly along state highways where roadside habitats are known to support high bird activity. Unlike targeted species protocols, it captures broader mortality patterns and may help inform infrastructure-related mitigation at a larger scale.

3.3.2.2 Core monitoring framework

Survey method

- Driving-based surveys, conducted once weekly, using a consistent route and schedule.
- Regular surveys conducted by a driver-observer team (with the observer trained in the protocol, but not necessarily an avian expert). Supplemental surveys will include an ecologist or another expert in bird identification serving as the observer.
- Speed will generally align with legal limits; however, where safe and permitted, monthly expert-led surveys may operate at slower speeds, such as 40–50 km/h, to improve detection.
- The addition of vehicle-mounted cameras to supplement visual surveys and capture carcasses missed in real time is recommended if a system has been identified and tested for use in New Zealand.

Timing

- Conduct surveys once per week, ideally on the same weekday, and within a 3-hour morning window (07:00–10:00 am).
- Supplement weekly surveys with additional monthly surveys using an expert as the observer.
- Repeat surveys year-round to capture full seasonal variation.
- Avoid surveying during poor visibility (eg, heavy rain, fog).
- Surveys should either avoid periods of above-average traffic (eg, school or public holidays) or include them consistently each year.

Transect length

- Choose a 15–20 km road segment with:
  - documented or suspected high mortality
  - bordering wetland, farmland, or forest edge habitat
  - adequate shoulder width and visibility.

- Divide into 1 km subsegments for fine-scale spatial analysis.
- Map infrastructure features (eg, median barriers, culverts, signage) using GIS overlays for additional analysis potential.

Observation and recording

- Record all visible bird carcasses.
- Prioritise safe driving through continuous observation (ie, no stopping).
- If a vehicle-mounted camera system is used, footage should be reviewed weekly, allowing retrospective verification and capture of otherwise missed events.

Data fields

- Date and time
- Vehicle speed
- 1 km sections (or subtotals) for observations
- Species (or taxonomic group)
- Position on road (centre, verge, shoulder)
- Adjacent land use (eg, wetland, pasture, urban fringe)
- Carcass condition (fresh, scavenged, degraded)
- Road context: signage, fencing, culvert proximity
- Observer ID and vehicle/camera information

Personnel and training

- Two trained individuals per survey: one dedicated driver, one observer.
- Weekly observer: Training in basic bird ID, species group classification, survey safety, and mobile data entry.
- Monthly observer: Ecologist or another expert in bird identification.
- If a vehicle-mounted camera system is used, setup, use, and footage review methods should be standardised and documented.

Bias correction options

- Select 1 km road sections, prioritised for safety. These can be supplemented further through walking surveys. The road sections can be used as subsamples within a driving survey framework, allowing for the calculation of detection probabilities.
- Carcass persistence trials can be conducted seasonally using surrogate carcasses (eg, poultry), placed in verge/road positions.
- Compare persistence across road zones, seasons, and habitat types to correct raw detection data.
- There is potential to implement a control–treatment design in future years – for example, by installing signage midway along the transect to test its effect on bird mortality rates. Weather and scavenger activity should be logged to support detectability correction.

3.3.2.3 Summary

This high-casualty monitoring protocol template provides a contrasting model to single-species protocols by targeting frequent, multi-species road-kill events in high-traffic environments. By design it may generate larger volumes of data, is scalable, and is adaptable for future experimental work. It enables the detection of mortality clusters and trialling of technological solutions such as dashcams and automated image processing. Potential insights gained through long-term use may support strategic investment in mitigation along highways and inform broader national efforts to quantify wildlife–road conflict.

3.3.3 Protocol Template C: Nationwide citizen science protocol for pūkeko

Species focus: Primary focus on pūkeko, with optional recording of other identifiable bird species

Location: Nationwide: any accessible roads where participants can safely conduct observations, with a focus on urban, peri-urban, and rural areas

3.3.3.1 Overview and rationale

Pūkeko are an ideal flagship species for a citizen science road-kill monitoring initiative due to their widespread distribution, high visibility, and frequent presence near roads. Their distinctive appearance makes them easy for the public to recognise, supporting outreach, education, and large-scale data collection efforts. Citizen science has proven to be a powerful tool for wildlife monitoring, particularly when broad spatial and temporal coverage is needed. Focusing on pūkeko provides an accessible entry point for public participation in road ecology while contributing valuable data. With standardised guidance and low barriers to involvement, this monitoring protocol template has strong potential to deliver widespread, complementary data alongside more intensive professional road-kill monitoring.

3.3.3.2 Core monitoring framework

Survey types

Participants can choose from two core methods:

1. **Opportunistic observations**
    a. Report bird road-kill sightings encountered during regular travel (eg, driving to work, walking the dog).
    b. Submit via mobile app such as iNaturalist NZ using a generic ‘roadkill’ tag, adding to the current ‘Flat Pukekos’ tag, or creating a new, project-specific tag (eg, ‘Pūkeko Patrol Project’).
2. **Structured roadside surveys**
    a. Volunteers commit to regularly surveying a defined road segment (eg, their route from home to work).
    b. Volunteers check the transect at least monthly, but ideally once every two weeks (but not more frequently so as to minimise repeat counts).
    c. The project should run year-round, with emphasis on high-risk periods such as peak breeding and fledging months (August–November).
    d. Walking, cycling, or slow driving (20–40 km/h) permitted, depending on road type and safety.
    e. Volunteers fill out a monitoring form for every survey, whether they observed carcasses or not, thus including absence data.
    f. Structured participation may be ideal for schools, community conservation groups, or local councils.
    g. Participants will be encouraged to choose safe, familiar roads, including low-speed rural roads, urban edges and parks, farm roads, or roads with known bird presence, such as along wetlands.

Species focus and data fields

While the project prioritises pūkeko, participants may also record other large or recognisable birds such as kererū, ducks, magpies, and gulls. The aim is to build confidence in observers while still gathering relevant data.

Standard data fields include**:**

- date and time
- species (or taxonomic group)
- carcass condition (fresh, degraded, scavenged)
- position on road (centre, verge, shoulder)
- carcass condition (fresh, scavenged, degraded)
- adjacent land use (eg, wetland, pasture, urban fringe)
- a ‘none observed’ tick box (to allow effort data to be recorded)
- observer ID
- average vehicle speed
- optional GPS location, when safely done (eg, through a hands-free monitoring device, a second observer, or geo-referenced photo).

Outreach and engagement

To increase visibility and participation:

- leverage social media to feature community findings, maps, and seasonal summaries
- create leaderboards or digital badges to reward regular contributors
- encourage schools or community groups to ‘adopt a road’ section
- align outreach with events such as Conservation Week, Bird of the Year, or regional biodiversity festivals.

Bias correction and data limitations

While citizen science offers extensive reach, limitations include:

- detection bias: people are more likely to report in accessible areas or only when carcasses are obvious
- sampling effort bias: data may be clustered around urban centres
- misidentification: especially for juveniles or scavenged remains.

Mitigation strategies include:

- encouraging photo submissions (when safely possible)
- providing targeted ID support
- integrating public data with any overlapping existing structured surveys.

Analysis will focus on presence-only and relative frequency metrics, not absolute mortality estimates.

Table 3.2 provides some solutions to anticipated challenges with this protocol.

Table 3.2 Anticipated challenges and solutions for Protocol Template C

Challenge	Solution
Inconsistent data quality	Require photos, offer ID support, use expert review where needed.
Uneven geographic participation	Target under-represented areas through outreach and school programmes.
Safety concerns	Emphasise not stopping on high-speed roads; recommend low-risk areas.
Data validation	Compare with formal survey data where available; flag outliers.

3.3.3.3 Summary

This citizen science protocol provides a nationwide, scalable framework for monitoring pūkeko and other road-killed bird species. By combining accessibility, public engagement, and a focus on a charismatic, frequently affected species, it encourages meaningful participation in wildlife monitoring. Data collection will emphasise presence-only and relative frequency metrics rather than absolute mortality estimates, making it practical for large-scale volunteer involvement. The resulting data have the potential to complement formal surveys, inform mitigation priorities, and enhance broader community awareness. This monitoring protocol template also offers a flexible foundation for future citizen-led road-kill monitoring initiatives across New Zealand.

4 Recommendations

4.1 Road-kill monitoring recommendations

Effective monitoring of bird road-kill in New Zealand requires a combination of opportunistic and structured approaches, tailored to its unique avifauna and road networks. Opportunistic observations, such as those collected through platforms like iNaturalist NZ, provide valuable geographic reach and can capture rare or unexpected events, even though they are presence-only and lack information on search effort. Continued promotion of citizen science contributions remains an important tool for expanding national coverage at minimal cost.

At the same time, structured surveys on consistent road sections are essential, particularly in areas where vulnerable species are present. A promising strategy is a dual-observer framework described by Guinard et al. (2023), in which trained ecologists conduct slower, monthly surveys to better detect small or cryptic species, while patrollers such as council or roading contractors collect data more frequently on larger-bodied species during their routine activities. These complementary approaches can together yield more representative and reliable datasets across different size classes and habitats.

New technologies offer additional opportunities to strengthen monitoring frameworks. Adapting or developing a smartphone application capable of hands-free, voice-based data entry along fixed routes would greatly improve the consistency and quality of collected data, allowing users, including members of the public, conservation groups, and government workers, to measure bird road-kill rates per kilometre surveyed. Dashcams and vehicle-mounted cameras could further support monitoring efforts, especially in remote or low-traffic areas where bird road-kill events may be less common but still ecologically significant. Although such systems have demonstrated success overseas, they would require further refinement and validation to suit New Zealand conditions, particularly for small-bodied or nocturnal bird species.

Building on methods like those outlined by Sullivan et al. (2025), which combine hands-free data capture with geo-referenced carcass records, offers a scalable and adaptable model for future road-kill monitoring. Embedding these technologies within structured survey designs, and ensuring efforts are standardised and repeatable, will be key to improving both detection rates and the long-term utility of the data collected.

4.2 Road-kill mitigation recommendations

Bird road-kill mitigation in New Zealand should be based on a combination of targeted, evidence-based interventions, adapted to specific species, landscapes, and road types. Based on international best practice and emerging New Zealand data, we propose the following measures as potential mitigation options.

1. **Species- and site-specific mitigation planning**
    a. Prioritise mitigation in areas where at-risk or high-conservation-value species (eg, kiwi, pāteke, penguins, kererū) are known or likely to interact with roads.
    b. Focus efforts on identified road-kill hotspots, using structured monitoring data rather than solely relying on anecdotal observations.
2. **Fencing combined with crossing structures**
    a. Where appropriate, install wildlife exclusion barriers designed to funnel birds towards safe crossing points such as underpasses or culverts.
    b. Fencing alone is often insufficient and should be coupled with crossing opportunities to avoid entrapment and mortality at fence ends.

   c. The placement of crossings should be based on bird movement patterns, habitat features, and known flight paths or travel corridors.
   d. Identify and mitigate potential ecological traps associated with road infrastructure (eg, culverts, catchpits, noise walls), ensuring safe passage or effective exclusion for vulnerable species.
   e. In some overseas settings, lightweight mesh flight diverter screens have been installed to guide birds to fly over high-traffic roads. These may offer a lower-cost alternative to noise barriers in specific contexts, though further evaluation is needed before broader application.
   f. At-grade wildlife crossings, which guide animals across roads at surface level using features such as fencing entry points, textured substrates, and driver warning signage, may be a useful option where vertical separation is not feasible. Although primarily trialled overseas with large mammals, they could potentially be adapted for flightless birds at predictable crossing points.

3. **Speed management at high-risk sites**
   a. Implement reduced speed zones (either permanent or seasonal) at known bird-crossing points for species of conservation concern, particularly during breeding or fledging periods (eg, near coastal penguin colonies or during kiwi chick dispersal periods).
   b. Use dynamic signage (eg, triggered by wildlife detectors or programmed for known high-risk periods such as penguin movement times) where feasible to alert drivers only when birds are likely to be present.

4. **Roadside vegetation management**
   a. Avoid establishing or retaining habitat features that attract birds to the road corridor, such as mown grassy verges or fruiting plants at vehicle height. Where planting is needed, prioritise species and structures that discourage roadside use.
   b. Techniques may include managing fruiting or flowering plants near verges, removing low vegetation that attracts ground foraging, or planting dense tall vegetation that discourages birds from crossing at vehicle height.

5. **Lighting management to minimise disorientation**
   a. Use shielded, downward-facing lights near coastal or seabird colony areas, and consider reducing intensity or shifting wavelength, as seabirds are highly sensitive to bright, broad-spectrum lighting.
   b. Minimise non-essential lighting during high-risk periods (eg, fledging), and consider motion-activated or timed lighting to reduce unnecessary illumination.

6. **Signage and public awareness campaigns**
   a. Install species-specific warning signs in targeted locations, especially where driver vigilance can make a difference (eg, kiwi zones).
   b. Augment physical signs with education campaigns explaining seasonal risks, the conservation value of affected species, and what to do if injured wildlife is found.

7. **Monitoring, adaptive management, and evaluation**
   a. Mitigation measures should be accompanied by structured before–after monitoring (such as using Before–After, Control–Impact (BACI) designs), with at least a representative sample evaluated to build confidence in their effectiveness and support broader application.
   b. Adapt and refine mitigation strategies based on monitoring outcomes and emerging research.
   c. Data from citizen science programmes (eg, iNaturalist NZ) can supplement formal monitoring where properly validated.

8. **Integration with wider road planning and upgrades**
    a. Incorporate road-kill mitigation early in new road design and major upgrade projects, as retrofitting is often more difficult and costly.
    b. Where possible, design habitat elements (eg, wetlands, planting) to align on the same side of the road as existing habitat, minimising the need for birds to cross.
    c. Ecological impact assessments for roads should include explicit consideration of bird road-kill risks and mitigation planning.

4.3 Incorporating bird road-kill into ecological impact assessments: Guidance for NZTA projects

4.3.1 Purpose

This section provides guidance for incorporating bird road-kill risk into ecological impact assessments (EcIAs) developed under NZTA's planning framework. While bird road-kill has received limited formal assessment in New Zealand, international evidence suggests it can be a significant source of avian mortality, particularly for ground-nesting, flightless, or low-flying species near roads (Guinard et al., 2015; Loss et al., 2014; Santos et al., 2013). The guidance below outlines where bird road-kill might be considered within the EcIA process, what types of species and habitats may be at risk, and what forms of mitigation may be appropriate depending on context. It is intended as a first-stop reference to help planners, ecologists, and infrastructure designers incorporate this under-recognised source of avian mortality into project development in a realistic, proportionate, and New Zealand-specific manner.

4.3.2 When is bird road-kill relevant to EcIAs?

Bird road-kill is most likely to be ecologically significant when the proposed works intersect areas of high bird activity, vulnerable taxa, or landscape features that concentrate movement. The following triggers should prompt consideration of road-kill within an EcIA:

1. **Proximity to habitats associated with bird congregation or movement**
    a. *Wetlands, estuaries, and floodplains*, especially in low-lying areas with open sight lines or roads running parallel to watercourses. These may support pūkeko, waterfowl, oystercatchers, stilts, crake, bittern, and herons.
    b. *Coastal margins and seabird colonies*, where fledglings may be disoriented by lights (eg, penguins, shearwaters) or adults cross roads during foraging trips (Dann, 1991; Deppe et al., 2017).
    c. *Native forest edges*, particularly where roads interrupt continuous canopy, leading to low-altitude crossings by kererū, tūī, or robins (Clevenger et al., 2003; Guinard et al., 2015).
    d. *Farmland and scrub habitat* supporting open-country birds such as harriers and pipits.
2. **Landscape or road characteristics that increase risk**
    a. *Curving roads with vegetated or obstructed verges*, where limited visibility reduces driver reaction time and increases the likelihood of strikes (Ramp et al., 2005).
    b. *Long, straight sections of high-speed road*, where birds may misjudge vehicle speed and timing, particularly in areas with recent upgrades or widened shoulders.
    c. *Roads adjacent to predator-managed habitats*, where elevated bird densities due to increased breeding success (eg, kiwi) may raise the probability of road-kill (Robertson et al., 2011).

d. *Documented hotspots*, based on existing strike data from anecdotal reports, iNaturalist, council records, or resource consent processes.

3. **Species of high ecological or public concern**

   a. *Threatened or endemic species* likely to occur in the project footprint or zone of influence (eg, kiwi, bittern, whio, pāteke).

   b. *Charismatic or culturally significant species*, such as kea, weka, or penguins, which may prompt heightened community and iwi concern, even if strike-risk is low.

   c. *Flightless or ground-dwelling birds*, where any mortality event may be significant at the local scale (eg, kiwi, weka, fernbird).

4.3.3 Which bird groups are most vulnerable to road-kill?

Rather than relying on species lists alone, EcIA authors can assess functional vulnerability based on traits, behaviours, and habitat use. International and local studies suggest the groups shown in Table 4.1 warrant close attention.

Table 4.1 Bird groups likely to be most vulnerable to road-kill in New Zealand

Ecological group	Risk rationale	Examples (NZ context)
Ground-nesting or foraging birds	Spend time on or near road surfaces; slow to flush	Oystercatchers, stilts, bitterns
Flightless birds	Cannot escape oncoming traffic; may cross roads during dispersal	Kiwi, weka, penguins
Low-flying forest birds	Cross at vehicle height, especially when canopy is broken	Kererū, tūī, robins
Wetland/estuarine birds	Attracted to roadside ditches or ephemeral ponds	Bitterns, crakes, pūkeko, herons, ducks
Scavengers or road-edge foragers	Attracted to insects, seeds, or carrion on road surface	Australasian harriers, magpies, gulls
Seabirds during fledging season	Disoriented by light; grounded birds may wander onto roads	Hutton's shearwaters, grey-faced petrels
Long-legged waders or plovers	Bold, visible birds but often remain on the road too long	Pied stilts, shore plovers

Many of these species exhibit site fidelity, which could lead to localised population effects if repeated mortality at the same road segment occurs (Taylor & Goldingay, 2009).

4.3.4 How should road-kill risk be incorporated into EcIAs?

4.3.4.1 Zone of influence

Under NZTA's *Ecological Impact Assessment Guidelines* (Waka Kotahi NZ Transport Agency, 2023a), the zone of influence can include areas beyond the project footprint where indirect or cumulative effects may occur. For birds, this includes:

- movement corridors intersected by the road
- edge effects on nearby nesting or foraging habitat
- areas where vehicle-related mortality may reduce local population viability.

4.3.4.2 Baseline data and predictive indicators

Where no prior road-kill data exist, use:

- *species traits* (eg, low flight, ground foraging, nocturnality)
- *local habitat use* (eg, proximity to wetlands or forest margins)
- *road layout and traffic speed* (eg, sharp curves with limited visibility, or long straight sections with high posted speed limits)
- *seasonal activity patterns* (eg, breeding, dispersal, fledging).

4.3.4.3 Effects management hierarchy

Use the 'effects management hierarchy' of *Avoid* > *Minimise* > *Remedy* > *Offset* > *Compensate* (Waka Kotahi NZ Transport Agency, 2023a). Where detectability is low and impacts are uncertain, a precautionary approach should be exercised, particularly for threatened or high-profile species, that identifies a wide range of potential effects and the features likely to moderate or amplify them.

4.3.5 Mitigation options: A tiered approach

The scale and certainty of impact should guide the depth of mitigation. Options range from proactive infrastructure changes to simple awareness-based interventions. Where mitigation is implemented, follow-up monitoring should assess efficacy (Rytwinski et al., 2016).

Premium (high-cost, high-impact)

- **Wildlife overpasses/underpasses** with fencing to direct bird movement (used experimentally in New Zealand – eg, for penguins)
- **Vegetation bridging** to reconnect forest canopies (tested in Australia; Clevenger et al., 2003)
- **Road realignment or bridging** to avoid high-risk habitat patches
- **Automated deterrent systems** (eg, lighting, acoustic cues) – limited but emerging evidence
- **Targeted carrion removal** at known scavenger hotspots – potentially high-impact for species like harriers

Mid-tier (targeted, cost-sensitive)

- **Vegetation management** to discourage foraging along road verges
- **Fencing or barrier vegetation** in known strike areas (effective for flightless birds, although it must be carefully designed to avoid creating hazards for low flying species)
- **Seasonal speed management zones** during fledging or breeding
- **Culverts or bridge spans** preserving wetland/stream bird access

Foundational (low-cost or early-stage options)

- **Signage** alerting drivers to bird activity (especially kiwi, penguins, or gulls)
- **Inclusion of road-kill risk** in environmental management plans for post-construction monitoring
- **Engagement with communities or iwi** to report road-kill events

4.3.6 Implementation and best practice recommendations

- Include bird road-kill as a distinct source of avian mortality in EcIA templates and assessment matrices.
- Engage wildlife specialists early, especially if the project intersects known or likely habitats for susceptible birds.

- Apply a precautionary lens, particularly for threatened or low-density species.
- Ensure consistency with broader environmental planning frameworks, including any biodiversity management or offsetting requirements relevant to the project.
- Coordinate with DOC, local government, conservation trusts, and mana whenua, who may have unpublished knowledge or active species management plans.

4.3.7 Policy alignment

Considering the impacts of vehicle collisions on New Zealand birds within EcIAs may help support:

- NZTA's *Ecological Impact Assessment Guidelines*, especially sections 2.2 'Establishing the EcIA study area', 4.3.2 'Output/reporting', and 5.1 'Mitigation'[10]
- NZTA's *Z/19 Taumata Taiao – Environment and Sustainability Standard*[11]
- NZTA's *Toitū Te Taiao – Our Sustainability Action Plan*[12]
- the National Policy Statement for Indigenous Biodiversity, which emphasises the importance of avoiding adverse effects on threatened species and habitats[13]
- the Resource Management Act 1991 – particularly sections 5 and 6(c), concerning the protection of indigenous biodiversity and ecological processes.[14]

4.3.8 Conclusion

While the full scale of the impacts of vehicle collisions on birds in New Zealand is not fully understood, its inclusion in EcIAs may be warranted where project footprints intersect known habitat, likely movement corridors, or vulnerable species. By integrating international research and approaches, local species ecology, and road planning principles, NZTA projects could play a role in identifying and addressing this potential issue. The guidance above is intended to serve as a general reference or starting point for consistent, precautionary, and ecologically informed impact assessment.

4.4 Future research

Despite growing recognition of bird road-kill as a conservation and animal welfare concern, significant knowledge gaps remain. Addressing these will require a combination of long-term monitoring, targeted ecological studies, and evaluation of mitigation effectiveness. Based on the findings and limitations outlined in this report, the following areas warrant further research.

1. **Long-term and national-scale monitoring**

There is a need for standardised, long-term road-kill monitoring programmes across New Zealand. Current data are fragmented and often short-term, limiting our ability to assess trends over time, compare regions, or evaluate the cumulative impact of road mortality on bird populations. Establishing consistent survey protocols

[10] https://www.nzta.govt.nz/assets/resources/ecological-impact-assessment-guidelines/Ecological-impact-assessment-guidelines.pdf

[11] https://www.nzta.govt.nz/assets/Highways-Information-Portal/Technical-disciplines/Environment-and-social-responsibility/Standards-and-guidelines/Z19-Taumata-Taiao-Environmental-and-Sustainability-Standard.pdf

[12] https://www.nzta.govt.nz/assets/resources/toitu-te-taiao-our-sustainability-action-plan/sustainability-action-plan-april-2020.pdf

[13] https://environment.govt.nz/acts-and-regulations/national-policy-statements/national-policy-statement-for-indigenous-biodiversity/

[14] https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

and sampling designs, particularly for threatened or range-restricted species, would support robust EcIAs and enable evidence-based management. We have provided some road-kill monitoring protocol template examples as a first step.

2. **Species-specific vulnerability and movement ecology**

More detailed research is required to understand the behavioural and ecological traits that influence road-kill risk in New Zealand birds. This might include fine-scale movement research such as telemetry or GPS studies to identify crossing points, dispersal corridors, and seasonal movement patterns. Focus should be given to ground-dwelling, flightless, and wetland species, including kiwi, weka, pāteke, and penguins. Understanding the spatial ecology of these species in landscapes affected by roads is critical to designing effective mitigation.

3. **Carcass detection, persistence, and observer bias**

Quantifying carcass persistence and detectability under different environmental and road-use conditions is vital to improve the accuracy of road-kill estimates. Building on recent efforts such as Sullivan et al. (2025), further experimental trials with tagged carcasses and remote detection methods (eg, vehicle-mounted cameras, AI-assisted imagery, or drones) could reduce sampling bias and allow better extrapolation from observed data.

4. **Evaluation of mitigation measures**

Relatively few mitigation actions in New Zealand have been systematically evaluated for their impact on bird road-kill. Future research should prioritise assessing the effectiveness of measures such as fencing, signage, habitat modification, and lighting changes. High-quality experimental design is essential when testing such interventions, as demonstrated in recent European trials of scent-based barriers (Bíl, Sedoník, et al., 2024). Studies should aim to quantify outcomes at the population level, where feasible, and distinguish between changes in behaviour and actual reductions in mortality.

5. **Socio-ecological dimensions and public engagement**

Citizen science has emerged as a promising tool for collecting road-kill data, but its full potential has yet to be realised. Future research could explore ways to improve data quality, participant training, and spatial coverage. Additionally, studies examining public attitudes, road-user behaviour, and the social acceptability of mitigation options could help guide policy and investment decisions.

5 Conclusions

This report brings together diverse data sources to provide a detailed overview of bird mortality associated with vehicle collisions in New Zealand. Drawing on structured surveys, opportunistic observations, and expert accounts, the findings highlight the variety of native and introduced species affected by road-kill and the ecological contexts in which these events occur. Although mammals dominate many road-kill datasets, birds consistently represent a meaningful proportion of recorded fatalities, including species of high conservation concern.

Species most at risk include ground-dwelling and flightless birds, wetland and coastal specialists, scavengers, and those drawn to roads for food. Vulnerability reflects a combination of ecological traits, seasonal movements, life stage, and the configuration of the surrounding landscape. Road-kill events are frequently concentrated near wetlands, forest margins, and coastal nesting sites, and are often highest during breeding, fledging, and juvenile dispersal periods. While the broader demographic impacts remain difficult to quantify, localised mortality could have serious consequences for slow-reproducing or range-restricted species, particularly where other threats are also present.

Current monitoring efforts in New Zealand remain limited and often lack the spatial and temporal consistency needed to support robust EcIAs or inform targeted mitigation. Nonetheless, the available evidence clearly demonstrates that road mortality is not a trivial issue. Better data, especially from long-term, standardised programmes, are essential for identifying high-risk species and locations, guiding investment in mitigation, and understanding cumulative effects.

Addressing bird road-kill requires a coordinated research and management response. This includes improved monitoring, evaluation of mitigation strategies, consideration of species-specific movement patterns, and broader engagement with the public and transport planners. With many of New Zealand's native birds already facing significant conservation pressures, vehicle collisions represent an important, and currently underappreciated, source of mortality that warrants more systematic attention.

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Appendix A: New Zealand bird species discussed in this report

Table A.1 List of New Zealand bird species discussed in this document. The national conservation status is determined by the Department of Conservation using the New Zealand Threat Classification System (Robertson et al., 2021).

Scientific name	Common name	Order	Conservation status
Acridotheres tristis	Common myna	Passeriformes	Introduced
Anas chlorotis	Pāteke/brown teal	Anseriformes	Threatened: Nationally Increasing
Anas gracilis	Tētē-moroiti/grey teal	Anseriformes	Not Threatened
Anas platyrhynchos	Mallard	Anseriformes	Introduced
Anas platyrhynchos × superciliosa	Mallard/grey duck hybrid	Anseriformes	Hybrid between native and introduced species
Anthus novaeseelandiae	Pīhoihoi/New Zealand pipit	Passeriformes	At Risk: Declining
Apteryx australis	Tokoeka/southern brown kiwi	Apterygiformes	Threatened: Nationally Endangered
Apteryx mantelli	Kiwi-nui/North Island brown kiwi	Apterygiformes	Not Threatened
Apteryx maxima	Roroa/great spotted kiwi	Apterygiformes	Threatened: Nationally Vulnerable
Athene noctua	Little owl	Strigiformes	Introduced
Botaurus poiciloptilus	Australasian bittern	Pelecaniformes	Threatened: Nationally Critical
Carduelis carduelis	European goldfinch	Passeriformes	Introduced
Carduelis chloris	European greenfinch	Passeriformes	Introduced
Circus approximans	Kāhu/Australasian harrier	Accipitriformes	Not Threatened
Emberiza citrinella	Yellowhammer	Passeriformes	Introduced
Eudyptula minor	Kororā/little penguin	Sphenisciformes	At Risk: Declining
Falco novaeseelandiae	Kārearea/New Zealand falcon	Falconiformes	Threatened: Nationally Increasing
Fringilla coelebs	Chaffinch	Passeriformes	Introduced
Gallirallus australis australis	Weka (western)	Gruiformes	Not Threatened
Gallirallus australis greyi	Weka (North Island)	Gruiformes	At risk: Relict
Gallirallus philippensis	Moho pererū/banded rail	Gruiformes	At Risk: Declining
Gallus gallus	Domestic chicken	Galliformes	Domestic
Gerygone igata	Riroriro/grey warbler	Passeriformes	Not Threatened
Gymnorhina tibicen	Australian magpie	Passeriformes	Introduced
Haematopus finschi	Tōrea/South Island pied oystercatcher	Charadriiformes	At Risk: Declining
Hemiphaga novaeseelandiae	Kererū/New Zealand pigeon	Columbiformes	Not Threatened
Himantopus himantopus	Poaka/pied stilt	Charadriiformes	Not Threatened

Scientific name	Common name	Order	Conservation status
Hirundo neoxena	Warou/welcome swallow	Passeriformes	Not Threatened
Hymenolaimus malacorhynchos	Whio/blue duck	Anseriformes	Threatened: Nationally Vulnerable
Larus dominicanus	Karoro/southern black-backed gull	Charadriiformes	Not Threatened
Larus novaehollandiae scopulinus	Tarāpunga/red-billed gull	Charadriiformes	At Risk: Declining
Nestor notabilis	Kea	Psittaciformes	Threatened: Nationally Critical
Ninox novaeseelandiae	Ruru/morepork	Strigiformes	Not Threatened
Passer domesticus	House sparrow	Passeriformes	Introduced
Phalacrocorax carbo	Māpunga/black shag	Suliformes	At risk: Relict
Phalacrocorax punctatus	Kawau tikitiki/spotted shag	Suliformes	Threatened: Nationally Vulnerable
Porphyrio melanotus	Pūkeko	Gruiformes	Not Threatened
Procellaria westlandica	Tāiko/Westland petrel	Procellariiformes	At Risk: Naturally Uncommon
Prunella modularis	Dunnock	Passeriformes	Introduced
Puffinus huttoni	Kaikōura tītī/Hutton’s shearwater	Procellariiformes	Threatened: Nationally Vulnerable
Rhipidura fuliginosa	Pīwakawaka/New Zealand fantail	Passeriformes	Not Threatened
Sturnus vulgaris	Common starling	Passeriformes	Introduced
Tadorna variegata	Pūtangitangi/paradise shelduck	Anseriformes	Not Threatened
Todiramphus sanctus	Kōtare/sacred kingfisher	Coraciiformes	Not Threatened
Turdus	Song thrush	Passeriformes	Introduced
Turdus merula	Eurasian blackbird	Passeriformes	Introduced
Vanellus miles	Spur-winged plover	Charadriiformes	Not Threatened
Zosterops lateralis	Tauhou/silvereye	Passeriformes	Not Threatened

Appendix B: Opportunistic and incidental observations of bird road-kill in New Zealand

This appendix compiles records of bird road-kill in New Zealand based on opportunistic sightings, incidental observations, and other sources outside formal survey efforts. It includes species-level accounts drawn from published literature, conservation databases, personal communications, and local reporting. Where possible, information is provided on location, timing, and any associated mitigation actions. This collection is intended as a resource to support broader understanding of the species and areas affected by vehicle collisions. A summary of key observations from this appendix is presented in section 2.7.3 of the main text.

B.1 Seabirds

Petrels in New Zealand and elsewhere have been grounded by lights when they fly at night, leaving them at risk of being struck by vehicles (Rodríguez et al., 2017). In New Zealand, this has occurred for both Westland petrels at Punakaiki and for Hutton's shearwaters at Kaikōura, both of which breed inland of the towns concerned and are attracted to the lights at night. Although not common, road signs warning motorists of both petrels and shearwaters have been placed along roads in New Zealand (Figure B.1) to increase awareness and reduce motorists' likelihood of hitting birds that are on the road.

B.1.1 Westland petrels

- Westland petrels are confined to a single breeding location in a forest south of Punakaiki, West Coast, where ~4,000 pairs breed annually.
- From a DOC 2007–2021 database (Buller-Kawatiri Office, Westport, accessed 9 December 2021), 18 of 280 (6%) 'downed petrels' were classified as 'hit by car', some which were able to be captured and safely released.
- In 2019, NZTA upgraded the Punakaiki streetlights to LEDs, which led to concerns of an increase in the likelihood of Westland petrels becoming disoriented and grounded. In late 2021, working with the Westland Petrel Conservation Trust, NZTA agreed to turn off the lights during the November–December fledging period in an attempt to reduce the likelihood of young Westland petrels being downed by lights and thus reduce the risk of being hit by vehicles (Warren & Stuart-Monteath, 2022).

B.1.2 Hutton's shearwaters

- Young Hutton's shearwaters become disoriented by bright lights when they fledge from their colonies and fly to sea from mid-March to early April. Many groundings occur around the Kaikōura township, especially along coastal roads and often during overcast weather (Deppe et al., 2017).
- The Hutton's Shearwater Charitable Trust and DOC rely heavily on volunteers to assist in collecting crash-landed birds for release.
- During 2006–2016, the number of grounded shearwaters observed varied from 10 to 274 annually (less than 1% of total fledglings). Grounded numbers per night varied, ranging from 3 to 113.
- Rescue campaigns took place during three years (2014–2016), over which a total of 429 fledglings were observed grounded, with 28 (7%) found dead. Of the observed mortalities, few resulted from the grounding events themselves. Most were from secondary causes, predominantly road-kill and to a lesser extent predation.

- Greater numbers of grounded birds were observed during new moons (ie, less moon light), possibly as a result of when artificial light may be having a greater effect) (Deppe et al., 2017).

Figure B.1 Westland petrel road warning sign at Punakaiki (left). Hutton's shearwater road warning sign, temporarily put out in March and April in Kaikōura (right). Both signs were installed to increase awareness and reduce motorists' likelihood of hitting birds that are on the road. (Reprinted from Dickison, 2021 (left) and Brown, 2017 (right).)

B.1.3 Gulls

- Southern black-backed and red-billed gulls were counted (28 and 18, respectively) in a road-kill survey near Wellington, with most of the road-kills observed near where people fed birds from parked vehicles (Brockie, 2007).
- Southern black-backed and red-billed gulls were also counted in three other road-kill surveys (Beauchamp, 2009a; Brockie et al., 2009; Flux, 2019).
- In addition to the Beauchamp (2009a) survey results, the authors noted that black-backed gulls were killed along the road near an active Northland landfill in 2005, as well as 'a few' red-billed gulls killed when foraging on rubbish spilled on the road near Whangārei.

B.2 Flightless birds

B.2.1 Kiwi

There are five known species of kiwi, with a number of subspecies. Vehicle collisions are listed among the threats to kiwi by Sporle (2017), referencing a DOC Threatened Species Recovery Plan (Holzapfel et al., 2008) that notes that road-kill does occur. An updated recovery plan by Germano et al. (2018) also identifies a range of threats to kiwi but does not provide additional detail on vehicle-related mortality.

Some evidence is available that multiple kiwi species have been identified as victims of collisions with vehicles:

North Island brown kiwi

- Collisions with vehicles have been reported mainly for North Island brown kiwi, and mainly in Northland, which has been attributed to the area being where relatively high kiwi densities and roads coincide (J. Scrimgeour, DOC, personal communication, November 2021).
- As North Island brown kiwi populations grow there is potential for an increase in risk of collisions with vehicles (Germano et al., 2018).

- Of 194 kiwi deaths reported in Northland between 1990 and June 1995, 12 (6%) were road-kills, mainly from unpaved, gravel roads through forested areas, compared to 135 caused by dogs (Pierce & Sporle, 1997).
- A national database of kiwi deaths is kept by the DOC Kiwi Recovery Group; however, the majority of information is from Northland. Of the 1,159 kiwi deaths recorded from 1989 to 2021, 200 (17%) were reported as road-kills, compared to 463 (40%) caused by dogs.
- Two specific areas have been highlighted as possible kiwi road-kill hotspots where potential monitoring could take place, including around Whangārei, Northland (A. Wiles, DOC, personal communication, 2022) and around Kerikeri, Bay of Plenty (C. Vestena, DOC, personal communication, 2022).
- A study investigated gizzard contents from 50 kiwi carcasses, 12 of which were struck by vehicles (Reid et al., 1982). Locations and dates of the 12 road-kill kiwi were not provided.

Great spotted kiwi

- Of eight great spotted kiwi translocated into The Nina Valley in North Canterbury in 2015, one bird was killed by a vehicle on the highway, 10 km from the release site (J. Sullivan, personal communication, March 2022).
- In St Arnaud, Tasman, two kiwi road warning signs were placed along roads near Nelson Lakes National Park in an attempt to increase awareness and reduce motorists' likelihood of hitting kiwi that are on the road (Figure B.2). At the time of installation, great spotted kiwi were not thought to be using areas near the road; however, the signs were also considered to have advocacy value (Gasson, 2005).

Southern brown kiwi

- The skulls of road-kill carcasses of kiwi, labelled as southern brown kiwi, were collected and used for a morphology study; however, numbers, locations, and dates were not provided (Johnston & Mitchell, 2021).

Figure B.2 One of two kiwi road warning signs installed near St Arnaud, Tasman (reprinted from Beeson, 2015)

B.2.2 Weka

There are reports of weka killed in collisions with vehicles throughout New Zealand.

- A two-year road-kill survey conducted in the South Island reported 300 weka road-kills (Freeman, 2010).
- Five weka road-kill were observed in another road-kill survey in the South Island, although locations were not included (Flux, 2019).

- The DOC Threatened Species Recovery Plan for weka reports that 93 road-kill weka carcasses were recorded from 7,060 km in north Westland, West Coast, in 1997, although no more information was provided (Beauchamp et al., 1999).
- Six of eleven North Island weka (*Gallirallus australis greyi*) mortalities identified between 1992 and 1993 near Rakauroa, Gisborne, were caused by collisions with vehicles, as well as three from ferret predation, one trapped, and one unknown cause of death (Bramley & Veltman, 2000).
- Thirteen dead weka were observed from a 25 km section of road in the Gisborne district, during an 18-month road project (R. Gardner, Fulton Hogan, Gisborne, email to Carol Bannock of NZTA ca 7 March 2022).
- A dead adult male weka was observed beside the road at Te Aroha in Waikato, 10 km south-west of a translocation site (Beauchamp et al., 2000).
- During a 30 km driving commute from Waimana to Whakatāne, in the Bay of Plenty, weka (and pūkeko) road-kills were frequently seen, with numbers observed sometimes reaching ‘double digits’ (G. Payze, Bay of Plenty Regional Council, personal communication, March 2022).
- Road signs warning motorists of weka were placed alongside roads in New Zealand in an attempt to increase awareness and reduce motorists’ likelihood of hitting birds that are on the road (eg, Figure B.3).

Figure B.3 Weka and road warning sign installed on the West Coast, South Island (Source: Gould, 2006)

B.2.3 Kororā/little penguins

Little penguins are the smallest penguin in the world. They feed at sea but come ashore to nest along the New Zealand coast. Two types (known as lineages) of little penguins exist: the ‘New Zealand type’, restricted to New Zealand only, and the ‘Australia/Otago’ type, which occurs in both Australia and in the Otago region of New Zealand. Little penguin colonies of the Australia/Otago type are known to come ashore after dusk in ‘rafts’ (ie, groups of penguins congregating at sea, swimming ashore and walking to nesting sites in groups). In New Zealand, this behaviour has not been observed in little penguins outside of the Otago population (Grosser et al., 2015).

Vehicle-caused mortalities of little penguins have occurred in both penguin types in New Zealand and Australia (Harrigan, 1992; Heber et al., 2008; Hocken, 2000). One location in Australia reported up to 20% of the little penguin population being killed on roads each year. Following the installation of a traffic control system, mortality was observed at ‘less than a few percent’ (Dann, 1991).

B.2.3.1 Wellington

- Bull (2000) attributed an increase in little penguin deaths and a decline in the breeding population to coastal roading and increased development around the shores of Wellington, although no further information was provided.
- In addition to presenting results from a road-kill count survey, Brockie (2007) reported two independent observations of little penguin carcasses. These were found two years apart, within 50 m of each other, along the Hutt motorway, 7 km north of Wellington.
- Vehicle-related deaths of penguins have been recorded throughout Wellington Harbour and the South Coast, largely due to their proximity to roads and the need to cross them. While hotspots have been noted in areas like Miramar and Eastbourne, road-kill can potentially occur anywhere along these coastal zones (B. Tandy, DOC, personal communication, March 2022).
- It has been suggested that most penguin deaths occur in the breeding season, from June to December (K. Shaw, Forest and Bird – Places for Penguins, personal communication, May 2022).
- No database on penguin deaths around Wellington has historically been kept, so no reliable statistics exist. However, as of 2022, all penguin deaths known to 'Places for Penguins' in the Wellington area have been uploaded to iNaturalist NZ[15] (K. Shaw, Forest and Bird – Places for Penguins, personal communication, May 2022).
- Some effort has been made to reduce the rate of penguins being hit by vehicles in the Wellington area, including the installation of some road warning signs in an attempt to increase awareness and reduce motorists' likelihood of hitting penguins that are on the road. Additionally, vegetation was planted in an attempt to maximise available nesting habitat on the seaward side of the road. Some consider constructing fencing in an attempt to prevent penguins from crossing certain sections of a road to be quite difficult and costly due to little penguins being solitary nesters and having nests spread out over large areas (B. Tandy, DOC; K. Shaw, Forest and Bird – Places for Penguins, personal communication, December 2021).
- Installation of penguin exclusion barriers has been required as part of development consents for the Te Ara Tupua and Tupua Horo Nuku shared paths, reducing little penguin access to roads and rail lines in several high-risk harbour-edge areas (R. Uys, Greater Wellington Regional Council, personal communication, May 2025).

B.2.3.2 West Coast

Heber et al. (2008) reported 30 little penguin mortalities due to vehicles in the Buller district, West Coast, South Island. While dates of fatalities were not known for all individuals, 15 were identified as occurring between August and December 2006.

The following information on penguin mortality was sourced from a 2006–2022 database covering the West Coast (Buller, Greymouth, and Westland). It also includes details on attempted mitigation strategies, such as fencing installed in the Buller district to prevent penguins from crossing certain road sections (I. Perkins, West Coast Penguin Trust, personal communication, March 2022).

- A total of 446 little penguin deaths were recorded from 2006 to 2022. Of those, 212 (47.5%) were caused by vehicles, followed by 'other' (151 deaths, 33.9%) and dogs (83 deaths, 18.6%).
- Three penguin fences were installed on the seaward side of the highway in the Buller district to prevent penguins from utilising nesting habitat on the other side of the road (Figure B.4). The fences were

[15] https://inaturalist.nz/projects/dead-penguins

constructed using black geosynthetic mesh, and gates were put in to allow public access to the beaches (Figure B.5).

1. A trial 100 m fence was installed south of Punakaiki – March 2012.
2. A 2.6 km fence was installed between Meybille Bay and Limestone Creek – around June 2014.
3. A 300 m section of fence was installed near Seal Island – prior to the 2015 breeding season.

Based on data from the mortality database for the Buller district, the percent road-kill of all observed mortalities was lower when the fences were in place (36%) than before (68%; $P < 0.05$, Fisher's exact test; analysis done for this review) (Figure B.6).

Few road-kills (0–1 per year) have been reported in areas where the fences are present, although some are still occurring elsewhere.

Figure B.4 Three coastal penguin fences installed in Buller, West Coast, along the highway to prevent road-kill. See text for descriptions of each. (Source: I. Perkins, West Coast Penguin Trust, personal communication, March 2022.)

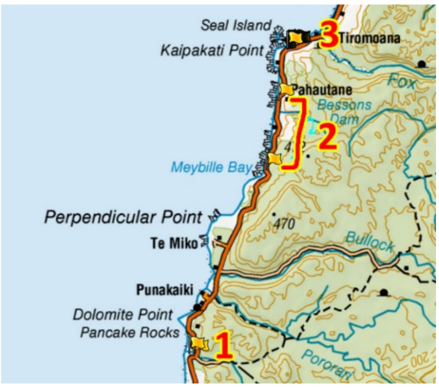
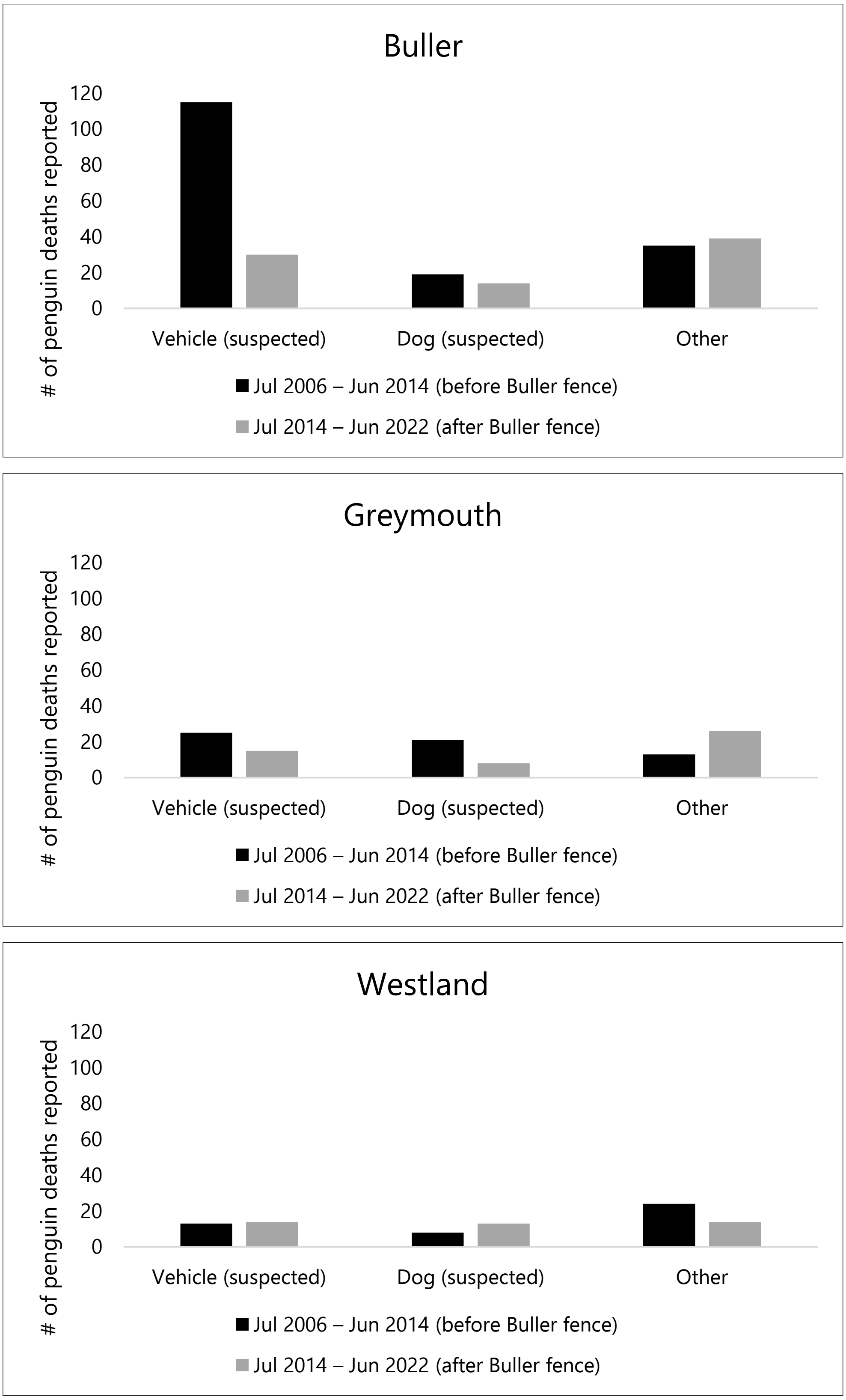


Figure B.5 Examples of penguin fences installed along the highway in the West Coast. (Sources: (top) I. Perkins, West Coast Penguin Trust, personal communication, March 2022; (bottom) Chumko, 2020, photo by John Bisset.)

Figure B.6 Little penguin (*Eudyptula minor*) mortality data from the West Coast, South Island, before (July 2006 to June 2014) and after (July 2014 to June 2022) a 2.6 km coastal fence was installed in the Buller district. (Adapted from data provided by the West Coast Penguin Trust.)



B.2.3.3 Oamaru, Otago

A study from North Otago, between 1994 and 1998, determined that of 213 little penguin carcasses inspected, 22 (10%) died because of collisions with vehicles. Most road-killed penguins were from Oamaru (20 of 22), with the author attributing this to the proximity of the Oamaru penguin colonies to the roads servicing the town. Although carcasses were collected opportunistically, this was the first study in New Zealand to attempt to categorise the cause of death in little penguins (Hocken, 2000).

The following information was obtained from the Oamaru Blue Penguin Colony, which has a penguin mortality database, though the database has not been maintained regularly in recent years (P. Agnew, Oamaru Blue Penguin Colony, personal communication, May 2022).

- Low numbers of road-kills have been reported in the last few years; up to five was suggested.
- In the 2000s, Waitaki District Council, in response to lobbying by a local resident, lowered the speed limit to 30 km and installed some speed cameras in an area where penguins were known to regularly cross the road.
- A road sign warning drivers that they were approaching an area where penguins cross the road was installed near a road section of the Oamaru Harbour that was the most common site of recorded penguin road-kill (Figure B.7).
- A penguin underpass was installed to reduce the likelihood of penguins crossing the road when approaching or leaving their nesting sites (Figure B.8).
- The location was chosen based on ‘where the majority of penguins crossed’; however, some road crossings still occur in places nearby.
- One of the primary reasons for building the underpass was to reduce vehicle and penguin traffic coinciding with when visitors were leaving the penguin colony after viewings.
- There are very few road-kill incidents reported, so the success of the underpass is currently measured by how many penguins use it, rather than measuring any change in numbers of road-killed penguins. However, there is currently not consistent monitoring.

Figure B.7 Penguin road warning sign installed in Oamaru (Source: Google, 2023)

Figure B.8 Little penguins using an underpass installed to allow access to nesting habitat without crossing the road (reprinted from Dunlop, 2016)

B.2.3.4 Golden Bay/Mohua

The following information was obtained from the Mohua (Golden Bay) Blue Penguin Trust on penguin road-kill and mitigation in Golden Bay, Tasman district, South Island.

- Most penguin road mortalities recorded in Golden Bay are reported by the public (C. McConville, Mohua (Golden Bay) Blue Penguin Trust, personal communication, May 2022).
- In 2009, DOC officer Greg Knapp installed penguin nesting boxes at Port Tarakohe, near Ligar Bay, in response to the 'considerable number of penguins being killed on the road'.
- Two penguin road-kills were observed at Pākawau in May and June 2020.
- Between July 2019 and September 2020, 10 penguin road-kills were reported on the road between Pōhara and Ligar Bay.
- Two LED traffic signs were installed between Pōhara and Ligar Bay in September 2020 in an attempt to increase awareness and reduce motorists' likelihood of hitting birds that are on the road. The signs were positioned at each end of a section of road where penguins were observed regularly crossing to reach nests in limestone bluffs (Figure B.9). Three additional penguin road-kills were reported in 2020 for this area after the traffic signs were installed; however, some sign malfunctions were occurring at the time.
- Two large road warning signs (2.4 × 1.8 m) were also installed at the Ligar Bay headland and opposite the Pōhara Hall in an attempt to increase awareness and reduce motorists' likelihood of hitting birds that are on the road (Figure B.10).

Figure B.9 LED traffic signs installed between Pōhara and Ligar Bay, Golden Bay (Source: C. McConville, Mohua (Golden Bay) Blue Penguin Trust, personal communication, May 2022)

Figure B.10 One of two large (2.4 × 1.8 m) penguin road warning signs installed near Ligar Bay, Golden Bay (Source: C. McConville, Mohua (Golden Bay) Blue Penguin Trust, personal communication, May 2022)

B.3 Wetland and river birds

B.3.1 Pāteke/brown teal

Pāteke are documented as being both struck by vehicles and run over by their wheels. These reports have occurred throughout their distribution, including from Aotea/Great Barrier Island and near Whangārei and Coromandel Peninsula. The impact of road-kill is thought to be higher on Aotea due to more roads within major pāteke habitat. According to the DOC Threatened Species Recovery Plan for pāteke, 'many birds are killed on roads each year in all management areas', with additional risk posed by increased coastal development (O'Connor et al., 2007, p. 8). In some locations 5–10% of pāteke can be killed on roads annually, a rate similar to predation; however, no further information on these reported rates are available (DOC, 2011). Table B.1 summarises the relative contribution of road-kill to pāteke mortality across different regions, based on carcasses that were recovered.

Table B.1 Causes of death of pāteke adapted here from three sources discussed in the text, including Alley et al. (2007), Watts et al. (2016), and a 1995–2017 DOC database (S. Giblin, DOC, personal communication, 29 November 2021)

Cause of death	Northland	Aotea/Great Barrier Island	Coromandel	Other North Island areas	Cause of death
Predation	137	263	10	4	**414** (39%)
Starvation	4	115	4	1	**124** (12%)
Road-kill	1	222	8	–	**231** (22%)
Disease	0	7	–	1	**8** (1%)
Miscellaneous	10	31	–	–	**41** (4%)
Unknown	51	178	2	–	**231** (22%)
Total	**203**	**816**	**24**	**6**	**1,049**

B.3.1.1 Aotea/Great Barrier Island

- Between 2000 and 2005, the cause of death of 160 wild pāteke was determined from carcasses recovered by DOC staff from different areas of the North Island. In total, 36 deaths were attributed to road-kill, of which 27 were from Aotea (Alley et al., 2007). Both vehicle-caused 'impact collisions' and 'compression injuries' were reported.
- A larger 1995–2017 database from DOC shows 33% of pāteke deaths on Great Barrier Island were caused by road-kill (194 of 565), followed by 136 from predation, 46 from starvation, 22 from other causes, and 167 deaths for which the cause was unknown (S. Giblin, DOC, personal communication, 29 November 2021).
- A study of radio-tagged pāteke reported that 2 of 205 deaths on Great Barrier Island (2001–2010) and none of 180 deaths in Northland (2001–2011) were attributed to road-kill (Watts et al., 2016). The leading cause of pāteke deaths reported at both locations was predation, totalling 47% and 69%, respectively.
- Another brief mention of a pāteke road-kill from Great Barrier Island was found in Moore and Battley (2003). The study investigated using wing fat to detect starvation, and 10 individuals used in the study were road-kill.

B.3.1.2 Coromandel Peninsula

- Multiple road-killed birds were observed from a population of pāteke that had been translocated to Port Charles on the Coromandel Peninsula. Consequently, mitigation measures such as fencing and signage were discussed as options to attempt to reduce road-kills (A. Holzapfel, DOC, personal communication, November 2021), but it is unclear if any of the options were implemented.
- One site has been identified as a potential high risk of road-kill near the Waikawau Bay Campsite (N. Kelly, DOC, personal communication, March 2022), although no information on road-kill numbers has been made available.

B.3.1.3 Mitigation for pāteke

- An action item considered 'essential' in the DOC Threatened Species Recovery Plan for pāteke at both Aotea/Great Barrier Island and Whangārei proposes methods to minimise deaths by erecting signage (action item 1.4; Figure B.11), advocating for careful driving, constructing judder bars, and managing culverts for safe access below the roads (O'Connor et al., 2007).
- Additional mitigation suggestions include draining puddles at the side of roads to reduce site attractiveness and erect fencing (Figure B.12) across regular flight paths (eg, streams between flock site and estuary) to elevate the heights of flying birds (DOC, 2011).

Figure B.11 Pāteke road warning sign installed (reprinted from DOC, 2011, p. 11, photo by Joanna Sim)

Figure B.12 Fencing erected in an attempt to reduce pāteke road-kill on Aotea/Great Barrier Island (reprinted from DOC, 2011, p. 26, photo by Joanna Sim)

B.3.2 Whio/blue duck

- A part-time resident of Ruatāhuna, west of Gisborne, North Island, has observed 12 road-killed whio along the Murupara-Waikaremoana road over the past 20 years or so. Carcasses were found along road sections adjacent to streams and rivers, with specific locations recorded (P. Timoti, Manaaki Whenua – Landcare Research, personal communication, 2022).
- Road signs alerting motorists the presence of whio have been placed alongside roads in New Zealand in an attempt to increase awareness and reduce motorists' likelihood of hitting birds that are on the road.

B.3.3 Pūkeko

- Pūkeko road-kills were observed in a number of road-kill surveys (Beauchamp, 2009a; Brockie et al., 2009; Sadleir & Linklater, 2016; Washington et al., 2008).
- A road-kill survey for pūkeko reported 20 carcasses near Christchurch from 1998 to 1999 (Washington et al., 2008).
- Recent monitoring for pūkeko road-kills has been conducted in the Styx River catchment in Christchurch, including creating a project called 'Flat Pukekos' in iNaturalist NZ[16]. From late November 2021 to 12 May 2022, 97 observations were made from a 35 km transect, with a driving speed of 60 km/h (A. Shadbolt, Christchurch City Council, personal communication, March 2022).

[16] https://www.inaturalist.org/projects/flat-pukekos

- Road signs warning motorists of pūkeko have been placed alongside roads in New Zealand in an attempt to increase awareness and reduce motorists' likelihood of hitting birds that are on the road (Figure B.13).

Figure B.13 Pūkeko road warning sign installed in Waikanae (Source: Nathan, 2006)

B.3.4 Moho pererū/banded rail

- Between two and three banded rail carcasses a year were reportedly observed on two 100 m sections of non-highway road in Northland. Collisions with vehicles are thought to occur due to birds flapping, running, or flying across the roads at heights just above the ground (J. Griffin, Northland Regional Council, personal communication, March 2022).
- It was also suggested by J. Griffin that Northland has more roads through or near rail habitat than anywhere else in New Zealand, providing multiple options for potential road-kill surveys.

B.3.5 Matuku-hūrepo/Australasian bittern

- From records collated between April 2009 and June 2011 throughout New Zealand, 13 Australasian bittern road-kills were reported, as well as 11 injuries from 'collision with cars and unknown causes' (O'Donnell & Robertson, 2016, p. 160).
- Among 103 Australasian bittern deaths recorded in one compiled dataset from 1996 to 2023, 23 were attributed to vehicle collisions based on autopsies and field observations (Williams et al., 2025).
- For individuals held in captivity and treated for injuries, it is reported that few survive following release back in the wild (Williams & Brady, 2014).
- Two road-kills were observed at the same time near Hot Water Beach, Waikato (Stewart, 2017).
- During 2003 to 2006, five bitterns were killed on the road adjacent to the Nukuhou Saltmarsh in Ōhiwa Harbour, Bay of Plenty. It was reported that birds were commonly seen feeding in farmland drains opposite the wetlands, resulting in the local community planting a native hedge along the road to prevent bitterns from either walking, or flying too low, across the road. Bitterns have not been observed in this saltmarsh since December 2018 (S. Slade, Nukuhou Saltmarsh Care Group, personal communication, November 2021).
- Road signs warning motorists of bitterns have been placed alongside roads in New Zealand in an attempt to increase awareness and reduce motorists' likelihood of hitting birds that are on the road (Figure B.14).

Figure B.14 Bittern road warning signs installed in Te Korowai-o-Te-Tonga/South Head Peninsula, Auckland region (left, reprinted from Warne, 2021) and Coromandel (right, reprinted from Tantau, 2020)

B.4 Carrion-feeding birds

B.4.1 Kārearea/New Zealand falcon

- Two of 21 (10%) radio-tagged New Zealand falcons, from a 5-year study in Marlborough, South Island, were killed from collisions with vehicles (Fox & Wynn, 2010).
- Another study mentioned collecting genetic samples from frozen specimens of New Zealand falcons that were killed by collisions with vehicles and submitted to various DOC area offices (Trewick & Olley, 2016).
- Both adult and juvenile falcons have been reported feeding on carrion, including on roads (Horikoshi et al., 2018).

B.4.2 Australasian harrier

- Australasian harriers were the most common bird treated at Massey Wildbase Hospital for injuries resulting from collisions with vehicles (Figure B.17; B. Gartrell, Massey Wildbase Hospital, personal communication, May 2022). This is likely due to their tendency to feed on carrion and other road-kill directly on or alongside roads. These birds were primarily from areas near Palmerston North.

B.5 Forest and other birds

B.5.1 Kererū/New Zealand pigeon

- Two of 75 radio-tagged kererū between 1983 and 1990 were killed from collisions with vehicles at Pelorus Bridge, Marlborough. The authors also observed ‘at least two’ additional kererū road-kills during the same time (Clout et al., 1995).
- A total of 146 kererū (76 live and 70 dead) were assessed for injuries sustained from collisions with vehicles and structures between 1996 and 2009. Birds were collected from various sources. In total, 70 individuals had injuries from collisions with vehicles, with injuries to the wing being the most common. Numbers of injuries from collisions with both vehicles and structures varied between months, with more generally occurring during spring and summer (Figure B.15) (Cousins et al., 2012).
- Lucerne trees were removed along a 2.5 km stretch of State Highway 2 near Wellington in 2018 following concerns that it was attracting kererū to feed near traffic (Heron, 2018; Urban Wildlife Trust, n.d.). The planting had previously contributed to an estimated 100 kererū deaths per year, with no kererū road-kill reported at the site since its removal.

- Kererū were the third most common bird treated at Massey Wildbase Hospital for injuries resulting from collisions with vehicles (Figure B.17; B. Gartrell, Massey Wildbase Hospital, personal communication, May 2022). These birds were primarily from areas near Palmerston North.

Figure B.15 Numbers of kererū colliding with vehicles and infrastructure from 1996 to 2009 (reprinted from Cousins et al., 2012, p. 569)

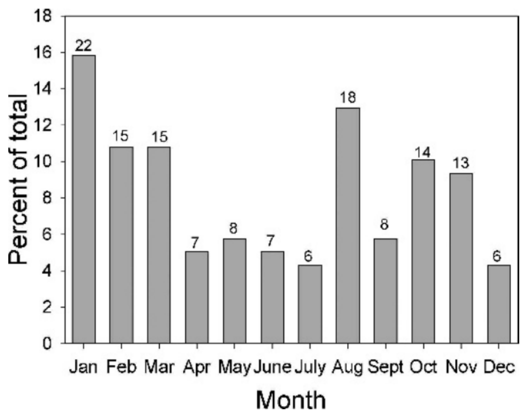


FIGURE 1. Numbers of kereru (*Hemiphaga novaeseelandiae*) by month that had collided with vehicles and infrastructure ($n=139$), collected from Department of Conservation offices, lower North Island, New Zealand. Data collected span 1996–2009. Sample sizes are given above the bar. Southern Hemisphere seasons: summer (December–February), autumn (March–May), winter (June–August), and spring (September–November). Note that not all birds analyzed had associated dates.

B.5.2 Kea

- Five kea were reported hit and killed by vehicles on Milford Road in Southland, four of which were juveniles (‘Five kea killed by vehicles on Milford Rd’, 2024).
- Road signs warning motorists of kea have been placed alongside roads in New Zealand in an attempt to increase awareness and reduce motorists’ likelihood of hitting birds that are on the road (Figure B.16).

Figure B.16 Kea road warning sign (reprinted from Simcock et al., 2022, p. 129)

B.6 Other studies

B.6.1 Parasitology studies

Although road-kill is not the focus of most parasitology research, road-killed birds are sometimes opportunistically used for parasite sampling. These instances rarely include consistent location, timing, or carcass context data, but they still represent a potential supplementary source of road-kill records, particularly in regions or for species where formal monitoring is lacking. Highlighting such examples helps demonstrate the fragmented but widespread nature of road-kill data in New Zealand and shows how non-target studies can contribute useful information when compiling broader wildlife mortality datasets.

Below are some examples of New Zealand parasitology studies that have utilised road-kill specimens.

- Parasites were collected from road-kill carcasses of mallards (in 2013) and a spotted shag (unknown year) from Otago, South Island (Blasco-Costa et al., 2016).
- Lice were collected from road-killed weka provided by DOC staff (Trewick et al., 2017).
- Parasites were collected from two red-billed gull carcasses found as road-kill near Kaikōura, South Island, in December 1976 and January 1977 (Clark, 1978).
- A road-killed New Zealand pipit, collected near Christchurch in 1999, was sampled for parasites (Galloway, 2005).
- Australasian harrier road-kills were examined for parasites from carcasses collected in Otago between 2017 and 2022 (Presswell & Bennett, 2024).

B.6.2 Birds injured as a result of collisions with vehicles: Massey Wildbase Hospital records

The following information was obtained from Massey Wildbase Hospital in Palmerston North, North Island, which keeps records of wild birds treated for injuries (B. Gartrell, Massey Wildbase Hospital, personal communication, May 2022).

Biases in the data were acknowledged. The hospital only treats native wildlife, so non-natives are not recorded. Wildlife patients are geographically biased by threat status. Common native species tend to come exclusively from the lower North Island, especially the Manawatū-Whanganui catchment area near Palmerston North where Wildbase is located. The threatened species can come from all over New Zealand, but over this period the catchment area has decreased as other wildlife hospitals have begun operating, especially in the South Island (eg, in Dunedin and Christchurch).

- Between 2006 and 2022, 2,953 native birds were admitted to the hospital. Of these, 286 cases (10%) were identified as being hit-by-car or in an accident with a motor vehicle (Figure B.17).
- Of these 286 collisions with vehicles cases, 129 (45%) died. Some birds were euthanised due to their injuries.

Figure B.17 Number of native birds hit-by-car or in an accident with a motor vehicle that were treated at Massey Wildbase Hospital between 2006 and 2022. Of these 286 birds, 129 (45%) died from their injuries or were euthanised. (Source: B. Gartrell, Massey Wildbase Hospital, personal communication, May 2022.)