Tracking ecological restoration: Temporal and spatial patterns of bird communities on the Whangaparāoa Peninsula, New Zealand

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Abstract

Humans have dramatically transformed New Zealand's ecological communities, leading to declining populations or extinction of native fauna. Hunting, habitat loss, and introduced terrestrial mammals are key drivers of these losses. Forest and Bird began the Pest-Free Hibiscus Coast project in 2011 with the aim of eradicating rats, stoats and possums from the Whangaparāoa Peninsula. To evaluate the effectiveness of pest-management and monitor changes in the bird community, volunteers conducted annual November five-minute stationary bird counts across 32 locations between 2013 and 2020.

I used fixed effects models to examine changes in the abundances of the 21 most common species recorded over 2,115 surveys. Using station as a random effect and controlling for the time of day, day of the month, weather, wind levels, survey methodology used and volunteer birding experience, I found 17 bird species remained stable or had significant increases in abundance between 2017 and 2020. The same can be said for 18 species between 2013 and 2020. Overall, abundance trends of common bird species throughout the survey period were comparable with community responses seen in other research from known healthy or predator-free environments.

Using GIS (geospatial information systems), I also analysed species richness and the mean relative abundances of endemic, native, and introduced birds across 17 locations. The richness of endemic birds was more than double that of other comparable areas across Auckland. Principal component analysis revealed greater abundances of the four most common endemic species at locations with more natural features and less manmade features, and vice versa for the four most common introduced species. The four most common native species showed intermediate patterns. These patterns highlight the critical importance of natural habitats to support endemic and some native bird species, and reveal that sufficient natural habitat must be available to maximise the efficacy of pest-management.

This thesis archives the first eight years of bird survey data collected for Hibiscus Coast Forest and Bird. My findings contribute to the growing body of scientific research focused on improving the

conservation of native birds in urban environments and provides important insight into New Zealand's predator-free 2050 goal.

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Thesis outline

Chapter 1 General introduction

This chapter provides background on the changes that have occurred to New Zealand's ecological communities since humans arrived. Deforestation, hunting, and the introduction of mammalian pests are discussed with an emphasis on the impact that these practices have had on New Zealand's birds. A brief history of New Zealand's bird communities and evolutionary history is provided. Pest-management and conservation practices are discussed, and the Predator-free 2050 project is introduced.

Chapter 2 Field sites and general methodology

An overview of the Whangaparāoa Peninsula and the related predator-management projects are discussed. The motivation for monitoring birds as well as monitoring techniques and their limitations are considered. The field methods utilised in this research are introduced and a brief overview of the study site is provided. Amendments made to incomplete data are justified. Rationale for this research is provided.

Chapter 3 Abundance and population trends of endemic, native, and introduced bird species on the Whangaparāoa Peninsula, New Zealand

This chapter summarises and archives the mean abundances of bird species recorded in five-minute stationary surveys from the first eight years of annual November bird counts. Analysis of the short-term (2017 to 2020) and longer-term (2013 to 2020) abundance trends of the 21 most common species are reviewed and discussed.

Chapter 4 **Spatial analysis of common endemic, native, and introduced bird species on the Whangaparāoa Peninsula, New Zealand**

This chapter uses a GIS (geographic information systems) approach to analyse the species richness and mean relative abundances of endemic, native, and introduced bird species across the study site. Coupled with principal component analysis, the results reveal the ecosystems in which common endemic, native, and introduced bird species are more abundant. Conclusions are reasoned for habitat restoration and pest-management.

Chapter 5 **General conclusions and future directions**

This chapter summarises the main findings of this research and acknowledges further analysis that can be performed using the current data. Future directions are recommended.

Appendix 1 **Study site and survey locations**

This appendix provides relevant background information about the 32 locations surveyed in this research. Details include the position of locations and stations, cultural significance, known vegetation, pest-management, and rules regarding dogs. Overhead maps are included.

Appendix 2 **Target bird species**

This appendix provides relevant information and descriptions of the 44 bird species that were targeted in surveys in 2020. Descriptions include each species' New Zealand status, the year of arrival or introduction if applicable, population size, distribution, preferred habitat, behaviours, life history and threats. A photograph of each species is included.

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Chapter 1

General introduction

Abstract

Humans have dramatically modified New Zealand's landscape and ecological communities over the past 800 years. Up to 75% of the country's original forest cover has been lost and over 2,000 plant species and almost 1,300 animal species have been introduced and naturalised. Amongst these introductions are 37 bird species, and 28 terrestrial mammal species - a group that was notably absent from New Zealand's pre-human history. Because New Zealand's birds evolved in the absence of mammalian predators many of them have behavioural and physical adaptations that leave them vulnerable to these evolutionary novel threats. Today, the combined forces of hunting, habitat loss, competition and predation from introduced species has led to declining populations and the extinction of at least 59 of New Zealand's native bird species. Humans have worked to minimise the pressures on native fauna by developing tools which enable predator suppression and eradication. Improved methods of pest-management have facilitated the successful translocation of 41 native bird species, five of which survive today only as translocated populations. With the help of community groups, iwi, organisations and the public, the New Zealand Government is now working towards the ambitious goal of eradicating all rats, stoats and possums from the New Zealand mainland by 2050.

Human impacts and the introduction of exotic fauna to New Zealand

New Zealand is a model depiction of the ecological damage that can result from human impact and the introduction of exotic species to an isolated island (Holdaway, 1989; Norton, 2009). Polynesians were the first humans to inhabit New Zealand, arriving around 800 years ago (Guild & Dudfield, 2009). At this time, non-volant mammals were absent and around 85% of the country's landmass was covered in indigenous forest (Holdaway, 1989, 1999; Taylor & Smith, 1997). The Māori people hunted native birds for food and clothing, ate their eggs, and introduced kurī (Polynesian dogs) (*Canis lupus famaliaris*) and kiore (Polynesian rats) (*Rattus exulans*) which preyed upon the native fauna (Holdaway, 1989, 1999; King, 1984; McGlone, 1983). Trees were harvested for dwellings, canoes and tools, whilst fires were deliberately lit to clear land for occupation, cultivation, tracks, and to drive prey from the bush when hunting (Guild & Dudfield, 2009; McGlone, 1983). By the time Europeans arrived in 1769, the combined impacts of predation, hunting and deforestation were responsible for the extinction of at least 32 native bird species and the destruction of almost 50% of New Zealand's forests (Holdaway, 1989; King, 1984).

By 1769 New Zealand's mainland avian community consisted exclusively of species that occupied vast forest refugia, and those that could cope with the pressures imposed by Māori, kiore and kurī (King, 1984). The arrival of Europeans intensified these pressures, increasing losses to natural habitats and beginning a second and ongoing wave of bird extinctions (Atkinson, 2001; Heather & Robertson, 2015; Maloney & McLean, 1995). Europeans introduced new terrestrial mammals that damage habitat and prey upon and compete with New Zealand's native wildlife. In total, humans are responsible for introducing 54 mammal species, 28 of which have established wild populations (King, 2005; Te Papa Collections Online, 2004).

Many of the first mammalian species that were brought to New Zealand by Europeans were unintentionally introduced. Norway rats (*Rattus norvegicus*), house mice (*Mus musculus*) and cats (*Felis catus*) arrived in the late 1700s as stowaways on ships (King, 1984). Ship rats (*Rattus rattus*) – an arboreal and more agile climber than Norway rats – arrived much later, likely after 1846 (Atkinson, 1973; King, 1984). In addition to preying upon native species, ship rats (and to a lesser extent Norway rats and mice) also outcompeted and limited kiore which are today restricted to Fiordland, Stewart Island and around twelve offshore islands (Atkinson, 1973; Murphy, Russell, Broome, Ryan, & Dowding, 2019; Taylor, 1975). Kiore are now protected on two small islands as part of an agreement with the Ngātiwai iwi who wish to protect the species as knowledge of its origin is recorded in their whakapapa (Māori genealogy) (Parkes, Byrom, & Edge, 2017; Royal, 2007).

Deliberate introductions of exotic mammals for food, commercial opportunity, sport, biocontrol, and to serve as a reminder of the home country occurred until 1913 (King, 1984; Parkes & Murphy, 2003). Species such as goats and pigs that damage and restrict forest understorey, destroy bird's nests and may eat bird's eggs were introduced as early as 1773 (Atkinson, 2001; Department of Conservation, 2006; King, 1984). In the early 1800s escaped European dogs began breeding with feral kurī (Atkinson, 2001; King, 1984). The wild interbred dogs were eventually eradicated by European settlers in the late 1800s, though domestic canines and small packs of feral dogs still remain as predators today (Atkinson, 2001; King, 1984; Taborsky, 1988).

Rabbits were released for food and sport in the 1830s, with overgrazing and burrowing causing loss of vegetation and soil erosion (Peden, 2008). To begin a fur industry, the common brushtail possum (*Trichosurus vulpecula*) was introduced in 1837 (King, 1984; Parkes & Murphy, 2003). Possums destroy and compete with birds for habitat and food, and also predate nesting birds and their eggs (Brown, Innes, & Shorten, 1993; Innes et al., 1999; Smith, Wilson, Moller, & Murphy, 2008). Substantial damage has been caused to indigenous forest undergrowth by deer and five wallaby species which were introduced for hunting in 1851 and 1870 respectively (David, Latham, Latham, & Warburton, 2016; King, 1984; Maynes, 1977; Parkes & Murphy, 2003). European hedgehogs (*Erinaceus europaeus occidentalis*), which opportunistically prey on the eggs and chicks of ground-nesting birds were also introduced in 1870 to help control invertebrate pests (Jones & Norbury, 2006; King, 1984; Parkes & Murphy, 2003).

Figure 1.1: *Photograph of the European hedgehog (Erinaceus europaeus occidentalis). Photo credit: Hayden Pye.*

Rabbit populations rapidly increased to plague numbers by the 1870s, and the New Zealand government and private land owners began introducing mustelids as a means of control (Atkinson, 2001; King, 1984; Peden, 2008). Five ferrets (*Mustela putorius furo*) were released in 1879, followed by larger releases in 1882 and 1883 (King, 1984). From 1884, thousands of ferrets and hundreds of stoats (*Mustela erminea*) and weasels were released onto farmland (King, 1984). Mustelids were unsuccessful at controlling rabbits, and instead the presence of rabbits likely contributed to greater predation of native birds as rabbits attracted mustelids to new areas (Atkinson, 2001; Murphy et al., 2019). By 1890 stoats and weasels had spread into forests and significant declines in native bird populations were reported (King, 1984). Today, stoats are widespread across many habitats and are considered to have had the greatest negative impact of any introduced predator to New Zealand's native fauna (Atkinson, 2001; King & Powell, 2011; Murphy et al., 2019).

Europeans also introduced bird species that compete for habitat and resources, show aggressive behaviour towards, and even predate New Zealand's native avifauna (Duncan, Blackburn, & Cassey, 2006; King, 1984; Turbott, 1961). Attempts to introduce exotic birds began with the liberation of greylag geese (*Anser anser*) in 1773, though successful bird introductions did not occur until 1840 (Duncan et al., 2006; King, 1984). Since then, around 120 exotic bird species have been released following deliberate or accidental introduction (Duncan et al., 2006; King, 1984). Today, 37 of these species are naturalised with wild populations, and another 10 bird species have arrived unassisted and naturally settled in this time (King, 1984; Robertson et al., 2017). Unintentional biosecurity breaches and illegal liberations of exotic bird species still occur, however, strict eradication programmes exist to reduce the spread of avian diseases and to avoid unwanted species competing for food, habitat and nesting sites (Department of Conservation, 2014; Heather & Robertson, 2015).

Europeans themselves also caused a direct decline in native bird populations by hunting them for food, trophies, scientific specimens, and feathers for fashion (Hunter, 2011; King, 1984). Towards the end of the 1800s it was realised that many of New Zealand's native birds would likely succumb to predation, so rare species such as the stitchbird (*Notiomystis cincta*) were intentionally hunted for profits (King, 1984). Changing societal attitudes towards native bird appreciation, national identity, and the growing concerns of anthropogenic environmental impacts helped shape a number of laws to protect native species over the following decades, beginning with the tūī (*Prosthemadera novaeseelandiae*) in 1878 (Miskelly, 2014). Proactive attempts to protect many of New Zealand's native birds continued until the Animal Protection and Game Act 1921-22 (Miskelly, 2014; Turbott, 1961). The Wildlife Act 1953 and its subsequent amendments has protected most native birds since (Miskelly, 2014).

Europeans continued the trends of habitat loss and destruction through environmental modification, particularly during increased and intensive settlement between 1850 and 1920 (Turbott, 1961). Natural swamps , wetlands and forests were destroyed, with slow-growing native trees harvested for resources (Turbott, 1961). Tussock grassland and forests were also burned to convert land for livestock (Hunter, 2011; King, 1984; Turbott, 1961). Intensive deforestation finally ceased in the 1920s and serious attempts at reforestation began, though only with exotic pines grown for timber and pulp

(Clout & Gaze, 1984; King, 1984; Turbott, 1961). These exotic trees do not represent the original floral community, and they are generally harvested every 30 years or so (Clout & Gaze, 1984; King, 1984).

By the 1930s the general pattern of New Zealand's vegetation had stabilised and introduced mammalian predators were widespread and well established (Holdaway, 1999). Today, up to 75% of New Zealand's indigenous forest cover has been lost with just 6.2 million ha of the original 23 million ha remaining (Taylor & Smith, 1997; Te Papa Collections Online, 2004). A further 4 ha of natural habitat is still destroyed every day (Te Papa Collections Online, 2004). At least 59 (approximately one quarter) of New Zealand's native bird species have become extinct since humans settled (Norton, 2009; Robertson et al., 2017; Russell, Innes, Brown, & Byrom, 2015). Combined with landscape modification, habitat loss, competition and hunting, predation has been a driving force behind these extinctions and is the primary cause of population declines in native forest birds today (Bombaci, Pejchar, & Innes, 2018; Holdaway, 1989, 1999; Innes, Kelly, McC. Overton, & Gillies, 2010).

New Zealand's bird communities

Exotic birds were introduced to New Zealand by European settlers for food, sport, biocontrol, and to serve as a reminder of the homeland (Heather & Robertson, 2015; Moon, 2006). Over the past 180 years, introduced birds have dispersed widely across New Zealand and the 37 established species can now be found across a variety of diverse habitats such as coastal areas, wetlands, native and exotic forests, open countryside, tussockland, mountain ranges, urban areas and cities (Heather & Robertson, 2015; King, 1984; Robertson, Hyvönen, Fraser, & Pickard, 2007; Robertson et al., 2017). A single species can occupy more than one of these environments, and may also move between areas or habitats over the day or season (Moon, 2006). The presence of birds (in particular, species that require high quality environments) is a good indicator of ecosystem health and function (Blackwell et al., 2005; Koskimies, 1989).

The distribution and abundance of bird species is determined in part by the size and types of habitat that are available (Lindsey & Morris, 2011). Both native and exotic species occur across a wide range of habitats, but introduced bird species are typically more common in modified environments that experience high anthropogenic activity, or in areas where vegetation has been modified, such as exotic conifer plantations (Barnagaud, Barbaro, Papaïx, Deconchat, & Brockerhoff, 2014; Day, 1995; Moon, 2006). Modified areas may provide introduced species with food or nesting resources that native species do not use or cannot access (Barnagaud et al., 2014). Likewise, they may lack the resources that many native birds require (Heather & Robertson, 2015). The composition of birds around New Zealand's small forest remnants, cities and urban environments thus consist of a wide range of introduced bird species, and fewer native and endemic bird species (Day, 1995; Gill, 1989; Miskelly, 2018).

Native birds dominate in areas of continuous native forest which provide appropriate food resources and nesting opportunities (Barnagaud et al., 2014; Clout & Gaze, 1984). This is particularly true in pest-free environments, as New Zealand's endemic birds can outcompete common native and introduced birds in absence of mammalian predators (Innes et al., 2010; Miskelly, 2018). Although most of the 17 introduced and established songbirds and parrots may be found around the fringes of native forest and scrub, they are rare within dense native vegetation (Barnagaud et al., 2014; Gill, 1989; Miskelly, 2018).

It is worth noting that modified areas and human impacts have benefitted some of New Zealand's native bird species. Many recent native arrivals such as the spur-winged plover (*Vanellus miles*), swamp harrier (*Circus approximans*) and welcome swallow (*Hirundo neoxena neoxena)* have naturally colonised and successfully propagated following the clearance of native forest and the subsequent creation of open areas (Heather & Robertson, 2015; Turbott, 1961). Welcome swallows also use anthropogenic structures as a base when building their nests (Heather & Robertson, 2015). Adaptable forest birds such as fantails (*Rhipidura fuliginosa*) and grey warblers (*Gerygone igata*) have taken advantage of settled and fringe environments, and an increase in open country has expanded the range of New Zealand pipits (*Anthus novaseelandiae*) and paradise shelducks (*Tardona variegata*) (Heather & Robertson, 2015; Turbott, 1961). The morepork (*Ninox novaseelandiae*) exploits anthropogenic light that attracts prey at night, and along with the New Zealand falcon (*Falco novaseelandiae*), has also benefitted from the introduction of small mammals and bird species which provide a source of food (Heather & Robertson, 2015; Turbott, 1961).

Why are New Zealand's birds vulnerable?

New Zealand is the largest section of land on the mostly submerged minicontinent of Zealandia, a section of continental crust that broke away from the supercontinent of Gondwana around 85 million years ago (Cox, Moore, & Ladle, 2016; Mortimer & Campbell, 2014). There are no known terrestrial mammal fossils from New Zealand from this time, and the country may have been entirely, or almost entirely submerged below sea level around 30 to 25 million years ago (Cox et al., 2016; Parkes & Murphy, 2003). New Zealand's endemic fauna thus evolved for millions of years in the absence of terrestrial mammals, and did not encounter them until humans began their introduction around 800 years ago (Holdaway, 1999; Maloney & McLean, 1995; Rastandeh, Brown, & Pedersen Zari, 2018).

The historical predators in New Zealand were diurnal avians – species which rely heavily on sight and sound for hunting (Holdaway, 1999; Maloney & McLean, 1995). Because they did not need to escape from land-dwelling predators, many of New Zealand's birds evolved to become poor fliers or completely flightless, subsequently spending much of their time foraging or nesting close to or on the ground (Heather & Robertson, 2015; Hooson & Jamieson, 2003; Maloney & McLean, 1995; Murphy et al., 2019). Selective pressures caused traits such as cryptic colouration, and defensive strategies like remaining still and silent were effective in avoiding detection from avian predators (Heather & Robertson, 2015; Holdaway, 1999). These strategies are futile against the heightened sense of smell that the mostly nocturnal, omnivorous, fast-maturing, highly fecund mammals that were introduced to New Zealand possess (Holdaway, 1989, 1999).

Many of New Zealand's endemic birds also exhibit tame, naïve, inquisitive, conspicuous and fearless behaviour (Hooson & Jamieson, 2003; King, 1984; Maloney & McLean, 1995). Coupled with low historical predation rates which allowed the evolution of life history traits such as longevity, delayed maturation and low reproductive output, New Zealand's birds were left almost entirely unequipped to deal with the rapid introduction and expansion of predatory terrestrial mammals (Atkinson, 2001; Dowding, 2012). Today, New Zealand's native avifauna consists primarily of species that are the most resilient to change, many of which are more recent colonists from Australia and nearby islands (Holdaway, 1989). Although the populations of many of New Zealand's native and endemic bird species continue to decline, some are increasing, generally due to concentrated and intense species-specific management (Holdaway, 1999; Innes et al., 2010). It is likely that many more New Zealand bird species would be extinct without human intervention (Holdaway, 1999; Innes et al., 2010).

Figure 1.2: *Photograph of the kākāpō (Strigops habroptilis), a large, cryptically coloured, flightless, ground-nesting parrot that freezes when disturbed. Photo credit: Dianne Mason (CC BY 2.0) via Wikimedia Commons.*

As of 2016, 71 bird species are threatened with extinction, with 23 classified as nationally critical (Robertson et al., 2017). Rising global temperatures are expected to threaten these species further by amplifying the rate of predation (Rastandeh et al., 2018). Without effective and continued management, many of New Zealand's native bird populations will continue to decline (Innes et al., 2010). The control of unwanted mammalian predators is therefore imperative to preserve and prevent further losses to New Zealand's native birds and other native fauna and flora (Holdaway, 1999; Norton, 2009; Russell et al., 2015).

Pest-management and New Zealand bird conservation

The first pest-management for conservation purposes began in the early 1900s (Murphy et al., 2019; Tompkins, 2018). Methods of predator suppression and eradication used over the past century include a variety of ground implemented traps and poisons, and aerially applied poison baits (Wilson et al., 2018). As of 2019 the Department of Conservation's annual predator control efforts span around 1 million ha of New Zealand's 26.8 million ha of land (Department of Conservation, 2019). Additional pest control is conducted by landowners, community groups and iwi (Department of Conservation, 2020g).

New Zealand has pioneered predator-free offshore islands and mainland sanctuaries bordered by multi-species predator-proof fences that exclude unwanted species and prevent their reinvasion (Innes et al., 2019; Russell et al., 2015; Wilson et al., 2018). The 1 ha Ruapuke Island (Maria Island) in Auckland's Hauraki Gulf was the first island to be declared pest-free after the eradication of Norway Rats in 1959 (Russell & Broome, 2016; Russell et al., 2015). Advancements in technology such as helicopters, GPS navigation and motorised spreader buckets coupled with the development of slow-acting second generation anti-coagulants has since allowed for complete multi-species eradication from increasingly larger and more complex areas (Broome et al., 2014; Russell & Broome, 2016).

Development of the multi-species predator-proof fence began in 1993 (Zealandia, 2020). In 1999, a 225 ha area in Wellington City's Karori Valley was enclosed with an 8.6 km long fence, beginning Zealandia, the world's first mainland predator-free ecosanctuary (Miskelly, 2018; Zealandia, 2020). Today, New Zealand has over 100 pest-free islands, and 14 fenced mainland ecosanctuaries > 25 ha (Department of Conservation, 2019; Innes et al., 2019). None of the fenced ecosanctuaries are controlled by the Department of Conservation – Tāwharanui Regional Park and Shakespear Open Sanctuary are controlled by Auckland Council, and others are led by communities, iwi and trusts (Innes et al., 2019). There are also a further 51 unfenced mainland ecosanctuaries > 25 ha, all of which require constant pest control in the form of traps and bait (Innes et al., 2019).

Island eradications and fenced mainland ecosanctuaries have allowed for the translocation of threatened bird species to these now predator-free habitats (Murphy et al., 2019). The earliest known translocations of native New Zealand birds were the releases of North Island brown kiwi (*Apteryx mantelli*) and weka (*Gallirallus australis*) on Kawau Island in 1863 and 1864 (Colbourne, 2005; Miskelly & Powlesland, 2013). However, it is unlikely that these translocations were motivated by species conservation as exotic species such as wallaby, zebra and laughing kookaburra (*Dacelo novaguineae*) were also introduced to the island (Colbourne, 2005; Miskelly & Powlesland, 2013). The International Union for Conservation of Nature (IUCN) defines a conservation translocation as "the intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem functions or processes" (IUCN/SSC, 2013).

The first translocations of New Zealand birds that meet the requirement for a conservation translocation were carried out in Fiordland by Richard Henry between 1895 and 1908 (Colbourne, 2005; Hill & Hill, 1987; Miskelly & Powlesland, 2013). Using his dog with a muzzle to locate birds, Henry is responsible for collecting and transporting more than 750 ground-dwelling birds such as the kākāpō (*Strigops habroptilis*), little spotted kiwi (*Apteryx owenii*) and tokoeka (southern brown kiwi) (*Apteryx australis*) to 11 Fiordland islands that introduced mammals had not yet reached (Andrews, 2007; Hill & Hill, 1987). Stoats evaded the islands from 1900, leading to the extirpation of kākāpō and little spotted kiwi (Miskelly & Powlesland, 2013). However, Henry's efforts were not completely in vain as today's populations of tokoeka on three of the Fiordland islands are likely descendants of birds he translocated (Miskelly & Powlesland, 2013). Using trained dogs and handlers to locate protected species and unwanted mammals, insects and weeds is also a conservation method that is still used today (Department of Conservation, 2020b).

Few translocations were attempted until 1964 when the New Zealand Wildlife Service developed a method to translocate North Island saddlebacks (*Philesturnus rufusater*) (Miskelly & Powlesland, 2013). Seven months later the same techniques were used with South Island saddlebacks (*Philesturnus carunculatus*) (Miskelly & Powlesland, 2013). By 2012, 55 of New Zealand's native bird species had been translocated in more than 1,100 releases, with 41 species successfully establishing new populations (Miskelly & Powlesland, 2013). Without conservation translocations New Zealand would have experienced further bird extinctions. Five endemic species survive only as translocated populations, and 10 other species would be restricted to just single wild populations (Miskelly & Powlesland, 2013).

Figure 1.3: *Photograph of the South Island robin (Petroica australis), a species which has had at least 10 successful translocations (Miskelly & Powlesland, 2013). Photo credit: Hayden Pye.*

The Predator Free 2050 programme

In July 2016 the New Zealand Government announced Predator Free 2050, a programme with the goal of eradicating all rats, stoats and possums from mainland New Zealand by 2050 (Department of Conservation, 2019; Murphy et al., 2019; Tompkins, 2018). Predator Free 2050 Limited engaged in workshops with conservation stakeholders and the general public to inspire confidence in and develop strategies to work towards this goal (Department of Conservation, 2019; Tompkins, 2018). Public support is strong nationwide, with surveys conducted in some areas indicating that > 90% of the public supports eradicating mammalian pests from their respective cities (Predator Free Dunedin, 2019; Predator Free Wellington, 2019; Wilson et al., 2018). The success of Predator Free 2050 will benefit ecosystems, native flora and fauna, and New Zealanders themselves by promoting public and environmental health and economic, social and mental wellbeing (Department of Conservation, 2019; Wilson et al., 2018).

The scale of Predator Free 2050 is ambitious and presents a challenge. The New Zealand mainland is almost 265,000km^2, has a growing population of over 5 million people, and spans a diverse range of ecosystems and difficult terrain (Dunstan & Weir, 2020; Murphy et al., 2019). Thus, a stepwise approach is proposed with the short term goal of eradicating at least one mammalian predator by 2025 (Department of Conservation, 2019; Murphy et al., 2019; Tompkins, 2018). To do this, predator suppression must be shifted to predator eradication through the development of new traps, baits, toxins, delivery methods and breakthrough science such as genetic technology (Murphy et al., 2019). Tikanga Māori science must also be acknowledged to promote kaitiakitanga (guardianship, protection and management of the environment) (Department of Conservation, 2019). Nationwide, there are over 5,000 groups and iwi working towards the Predator Free 2050 goal (Department of Conservation, 2020g). Efficiency and success of the programme relies on coordination and strong communication between groups that each have clearly defined roles (Murphy et al., 2019; Tompkins, 2018).

Chapter 2

Field sites and general methodology

Abstract

The Whangaparāoa Peninsula is a narrow stretch of land located 25 kms north of Auckland City on the east coast of New Zealand's North Island. The area is part of the North-West Wildlink – a proposed restoration project that ecologically connects pest-free environments and acts as a corridor and refugia for native species travelling between Tiritiri Matangi Island and North and West Auckland. Hibiscus Coast Forest and Bird began the Pest-Free Hibiscus Coast project in 2011 with the aim of using traps and bait to eradicate rats, stoats and possums from the Whangaparāoa Peninsula. As part of the project, volunteers conducted annual five-minute stationary bird counts across 32 locations during November between 2013 and 2020 to monitor the impacts of pest-management and habitat restoration on the bird community. Data was collected with the intention of assessing bird species richness, abundances, and spatial distributions. The information gathered allows for generalisations to be made about the processes that may have driven change in the bird community and will contribute to the growing body of scientific knowledge attained from urban restoration projects.

Hibiscus Coast Forest and Bird Pest-Free Peninsula

Hibiscus Coast Forest and Bird is a conservation organisation involved in pest-management and habitat restoration on the Whangaparāoa Peninsula, a narrow 11 km stretch of land that covers around 3,100 ha (Forest and Bird, 2020). Located 25 kms north of Auckland City on the east coast of New Zealand's North Island, the peninsula and its adjacent suburbs are home to almost 45,000 people across more than 18,000 dwellings (Forest and Bird, 2020; Stats NZ, 2018). Envisioned by Pauline Smith, Forest and Bird launched the Pest-Free Hibiscus Coast project in 2011 with the mission of creating a predator-free haven for native flora and fauna (Cummings, 2017; Forest and Bird, 2018d).

Figure 2.1: *Map of the Whangaparāoa Peninsula. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Community engagement plays a vital role in the installation and maintenance of the extensive grid of traps and bait stations required to eradicate rats, stoats and possums from the Whangaparāoa Peninsula (Forest and Bird, 2018d). Stakeholders include public and private landowners, iwi, organisations, and volunteers that contribute more than 5,000 annual hours to trapping, administration, communications and event management (Forest and Bird, 2020). Cooperation between these groups is important, as mammalian predators threaten native biodiversity even in low numbers (Cummings, 2017; Norton, 2009; Russell et al., 2015).

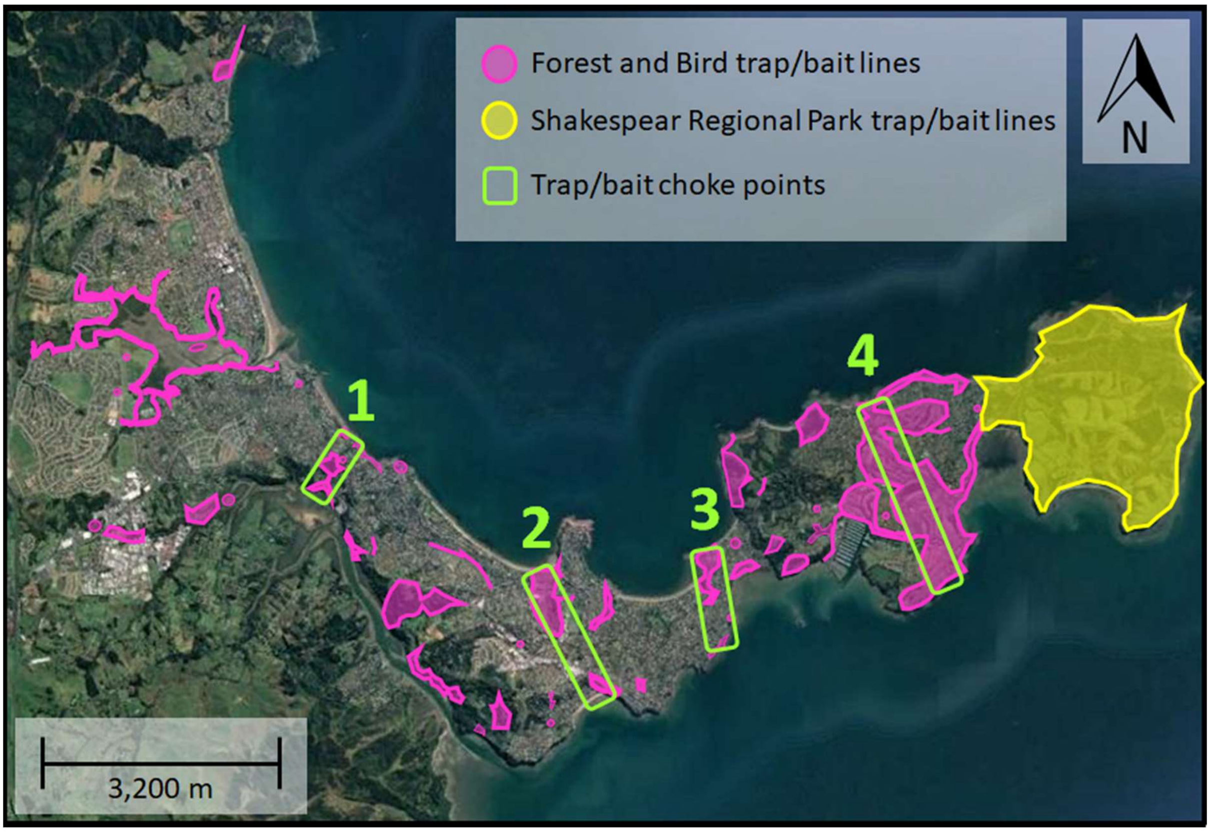

Figure 2.2: *Map showing pest-management controlled by Forest and Bird and at Shakespear Open Sanctuary as of November 2020. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Under the Predator Free 2050 vision, predator eradication will occur at different times across the country (Murphy et al., 2019). The use of natural and artificial barriers are therefore vital to prevent the reinvasion of areas that become pest-free (Murphy et al., 2019). Peninsulas provide an ideal natural barrier as they have limited accessibility by land so are easier to defend from terrestrial invasions (Forest and Bird, 2020; Russell et al., 2015). Between 2014 and 2019, Hibiscus Coast Forest and Bird also focused on installing four predator control lines and choke points using traps and bait stations to prevent the movement of pest species across the narrow peninsula (Forest and Bird, 2020).

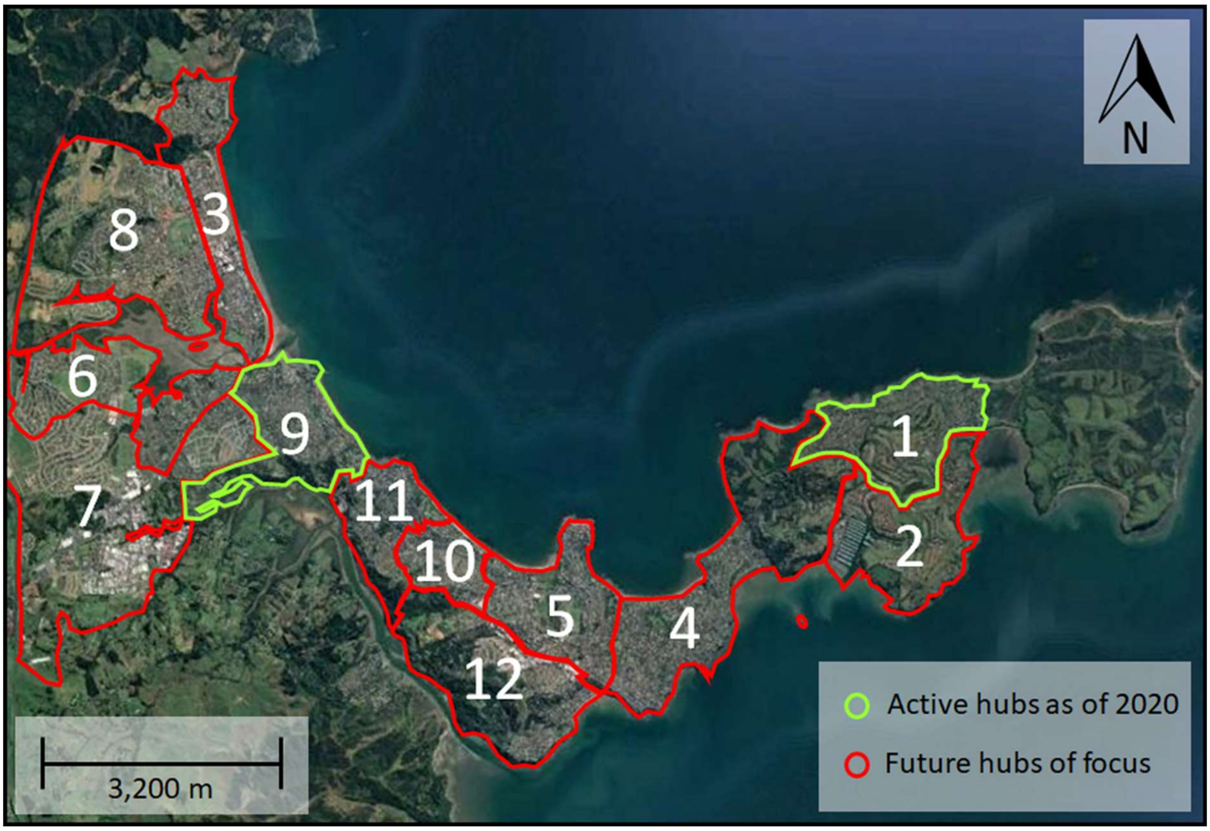

Figure 2.3: *Map showing the Hibiscus Coast hub model. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

In 2020 the Pest-Free Hibiscus Coast project expanded to a hub model. Split into 12 community groups, each hub has around 1,500 to 2,000 properties (Forest and Bird, 2020). The model will focus on individual hubs over time to build networks and unite the community for the common goal of pest-eradication (Forest and Bird, 2020). Forest and Bird aims for one in four households to have a trap on their property (Forest and Bird, 2020). The first two hubs to receive attention are at vital defensive barriers and cover the area where the peninsula meets the mainland in the west, and the first line of defence after Shakespear Open Sanctuary in the east. The habitat restoration and pest-management conducted by Hibiscus Coast Forest and Bird helps to expand and connect natural habitats across the peninsula, and contributes to the North-West Wildlink (Forest and Bird, 2018c, 2018e).

The North-West Wildlink

The North-West Wildlink is a proposed restoration project that ecologically connects pest-free environments and acts as a safe corridor and refuge for native species to travel between Tiritiri Matangi and Waitakere Ark in the Park (Cummings, 2017; Forest and Bird, 2018d). The success of the North-West Wildlink is reliant on the cooperation between conservation groups throughout North and West Auckland.

Figure 2.4: *Illustration of the proposed North-West Wildlink corridor (North-West Wildlink, 2017).*

Tiritiri Matangi

Tiritiri Matangi is a 254 ha predator-free island sanctuary located 3 kms to the east of the Whangaparāoa Peninsula in the Hauraki Gulf (Galbraith & Cooper, 2013; Graham, Veitch, Aguilar, & Galbraith, 2013). The island experienced widespread deforestation during Polynesian settlement and further degradation from European farming practices until the 1970s (Graham et al., 2013). In 1980, Tiritiri Matangi became a scientific reserve and is now managed by the Department of Conservation with the help of volunteers and community groups (Galbraith & Cooper, 2013). Today, it is recognised globally as a model example of a successful community conservation project (Galbraith & Cooper, 2013).

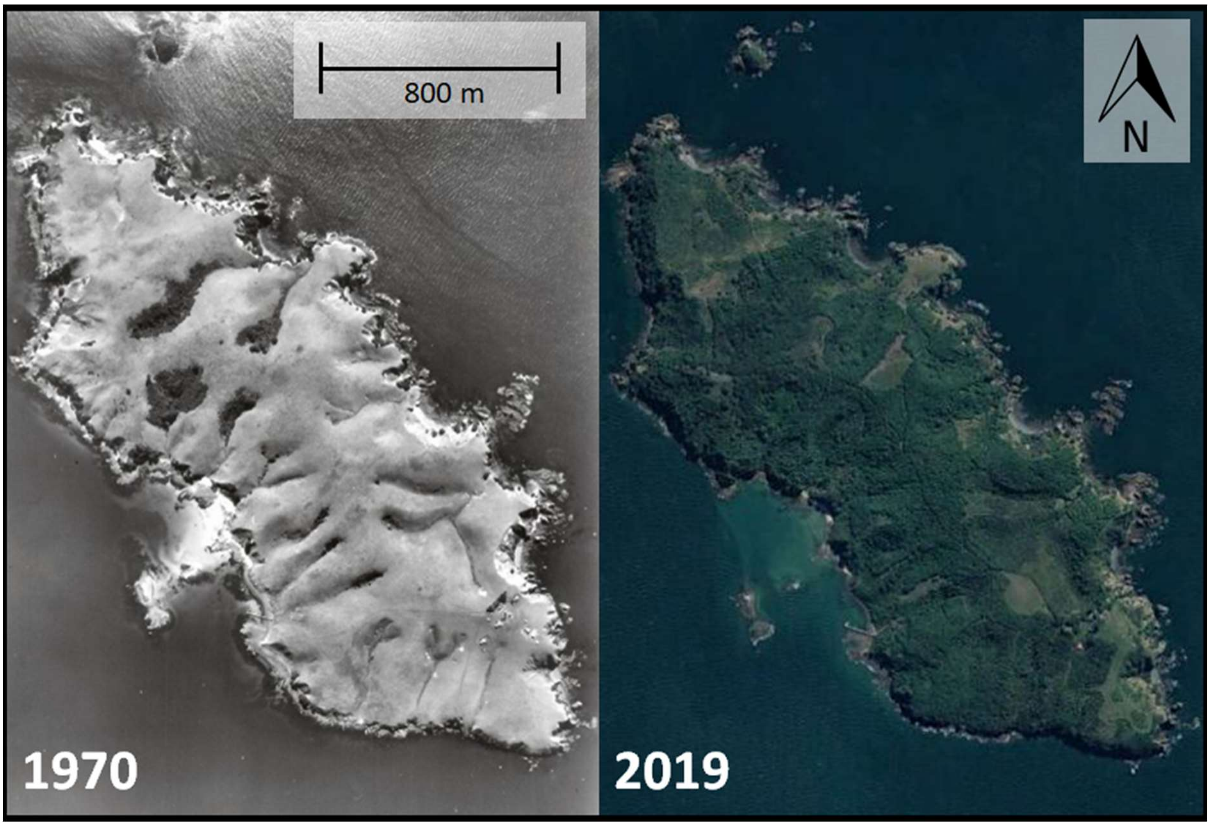

Figure 2.5: *Map of Tiritiri Matangi showing island restoration between 1970 and 2019. 1970 image adapted from Rimmer (2008). 2019 image taken 29 April 2019, adapted from Google Earth Pro (2020).*

12 bird species have been translocated to Tiritiri Matangi since 1973, and restoration planting began in 1984 (Galbraith & Cooper, 2013; Graham et al., 2013). Some of the translocated bird populations have become stable enough to supplement other restoration projects. Amongst these species

are whiteheads (*Mohoua albicilla*), North Island robins (*Petroica longipes*), North Island saddlebacks and stitchbirds (*Notiomystis cincta*) all of which had successful translocations to Shakespear Open Sanctuary in July 2015, April 2016, May 2018 and July 2020 respectively (Auckland Council, 2018b, 2020c; Galbraith & Cooper, 2013; SOSSI, 2015, 2016, 2017).

Figure 2.6: *Map of Tiritiri Matangi in relation to Shakespear Open Sanctuary. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Shakespear Open Sanctuary

Located at the eastern end of the Whangaparāoa Peninsula, Shakespear is the closest mainland point that birds encounter on their journey west from Tiritiri Matangi Island (Forest and Bird, 2018c). Shakespear opened as a regional park in 1972, and the Auckland Council established Shakespear Open Sanctuary, a 500 ha publicly accessible predator-free reserve in 2010 (Innes et al., 2019; SOSSI, 2014c, 2014d). The sanctuary is enclosed in a 1.7 km multi-species predator-proof fence that was constructed between October 2010 and March 2011 (SOSSI, 2014c). All mammalian predators except mice were eradicated by August 2011 (SOSSI, 2014c, 2014e). Extensive trapping and monitoring systems remain in place to ensure that the park remains predator-free (SOSSI, 2014c, 2014e). Shakespear Open Sanctuary opened to the public in December 2011, and today it is New Zealand's most visited wildlife sanctuary (Auckland Council, 2020b; SOSSI, 2014c).

Figure 2.7: *Photograph of the multi-species pest proof fence at Shakespear Open Sanctuary. Photo credit: Hayden Pye.*

Humans have occupied the general area since Polynesians first arrived in New Zealand, and much of the original forest was cleared hundreds of years ago (Auckland Council, 2020b). Today, 3-4 annual community planting days are held with the target of planting 10,000 native seedlings each year (SOSSI, 2014d). Areas are also fenced off to allow natural regeneration to occur (SOSSI, 2014d). The aim is to connect established sections of forest to develop a habitat linkage with Tiritiri Matangi and to provide sufficient environment for reintroduced flora and fauna (SOSSI, 2014d).

Why monitor birds?

Birds are valuable bioindicators as their populations are susceptible to fluctuations from anthropogenic impacts and environmental variation (Koskimies, 1989; Pollack, Ondrasek, & Calisi, 2017; Temple & Wiens, 1989). Birds occupy a variety of ecological niches and their populations can be easily monitored and quantified (Dowding, 2012; Koskimies, 1989; Pollack et al., 2017). In New Zealand, monitoring programmes are designed to detect general trends in bird populations at the scale of local, regional or national levels, and to assess the impact of management plans such as predator control (Dowding, 2012). Monitoring birds also allows managers to detect the presence of unwanted species for biosecurity purposes, and to assess range expansions of established introduced species that may impact native populations (Dowding, 2012).

Monitoring programmes require the collection of data from at least two points in time with the purpose of detecting change in population density, abundance or distribution (Dowding, 2012; Temple & Wiens, 1989). The data collected is analysed to determine if and why change is occurring, and the rate at which changes may be occurring (Dowding, 2012). The knowledge of change is essential in bird conservation as changes can be evaluated to establish if variation is natural, or if it is in response to a known action or management plan (Dowding, 2012). There is currently very little published research available from bird monitoring programmes in urban New Zealand (Mortimer & Clark, 2013).

The five-minute bird count method

Background

Recording the frequency of occurrence of birds from a fixed location over a pre-determined time frame is a standardised method used for monitoring and inferring the species richness and relative abundances of bird populations (Dawson & Bull, 1975; Hartley & Greene, 2012). The five-minute bird count is a method that was developed in New Zealand in the early 1970s to quantify and monitor multiple species of forest birds at once (Hartley, 2012). It is an index that assumes that the relationship between the number of birds recorded and their true populations are positively related and linear (Hartley, 2012; Hartley & Greene, 2012). The method is suitable for providing base line data and has proven particularly valuable in measuring long-term population trends (Hartley, 2012; Hartley & Greene, 2012; Smith & Westbrooke, 2004). Today, the five-minute bird count is the most widely used method to monitor forest bird populations around the world (Hartley & Greene, 2012).

Counting birds is typically uncomplicated for those that are familiar with the sight and sound identification of local bird species (Temple & Wiens, 1989). The count requires the observer to remain stationary at a fixed location and accurately record every bird of each species that is seen or heard over a five-minute period (Hartley, 2012). By remaining stationary observers can devote their full attention to the task and are less affected by topographical and ecological changes that they may encounter if moving (Dawson & Bull, 1975). Results from five-minute counts do not significantly differ from ten-minute counts, allowing efficient sampling of more locations in less time whilst minimising the risk of recording an individual bird more than once (Dawson & Bull, 1975).

Designing a study

To successfully detect short and long term population changes, monitoring should be continual, repeated in the same study area during the same time period each year using comparable methods, and cover most of the target location and its habitat types (Koskimies, 1989). Attempts should be made to control for the effects of weather and temporal changes (Hartley, 2012). Monitoring should include as many bird species as manageable whilst remaining efficient and scientifically valid (Koskimies, 1989). Sufficient power is required to prevent noise (Hartley, 2012). Modifications to the original method must be recognised and remain consistent in terms of sampling constancy, duration, location, precision and observer accuracy (Hartley & Greene, 2012).

Advantages over other bird counting methods

The results of bird counts can vary greatly depending on methodology (Cunningham, Lindenmayer, Nix, & Lindenmayer, 1999). The five-minute bird count is an established, nationally standard method that has been used in New Zealand for over 40 years (Hartley & Greene, 2012). It allows observers to efficiently and simultaneously count multiple species, and is relatively cheap as it typically relies on volunteers to collect data (Hartley & Greene, 2012; Koskimies, 1989). Five-minute bird counts do not require extensive training or expensive technical equipment or resources that are necessary for other bird counting methods (Greene & Efford, 2012; Hartley & Greene, 2012). Multiple counts can be completed in short periods of time, increasing statistical power and decreasing variance (Hartley & Greene, 2012).

Five-minute bird counts are particularly useful for New Zealand's forest birds as many species are often heard more frequently than they are seen, especially in areas with dense vegetation (Dawson & Bull, 1975). Highly active birds which call regularly are also recorded more frequently in stationary counts compared to strip-transects or zig-zag walks where the observer's movements may drown out the sound of calling birds, or impact their behaviour (for example, causing them to flee or cease calling) (Cunningham et al., 1999). Avoiding movement likewise minimises distractions which may cause the observer to miss seeing, hearing or otherwise recording birds (Cunningham et al., 1999; Mortimer & Clark, 2013). It also reduces the chance of recording the same bird more than once, as movements of birds can be detected from a static position with greater accuracy (Mortimer & Clark, 2013).

Five-minute bird counts can be advantageous over distance sampling which is used to estimate true population size. Distance sampling requires practical skill and the use of expensive technical equipment to accurately measure radial distances between the observer and individual birds at their initial point of detection (Drummond & Armstrong, 2019; Greene & Efford, 2012). Many of New Zealand's bird species alter their behaviour by moving closer to, or further away from people, which may obfuscate density data (Dawson & Bull, 1975; Dowding, 2012; Maloney & McLean, 1995). Alternatively, many species are cryptic or their populations too low for accurate density estimates through the measurement of distance (Dowding, 2012; Drummond & Armstrong, 2019; Greene & Efford, 2012).

Limitations of the five-minute bird count method

There is no individual method that is perfect for monitoring all species of birds across differing habitats, so some compromises between efficiency and accuracy are required (Dowding, 2012; Koskimies, 1989). It is therefore important to recognise and understand the influences of error so it can be standardised and controlled for (Dowding, 2012; Koskimies, 1989).

Identification skills may differ between observers, and the skills of an individual may become better or worse over time (Dawson & Bull, 1975; Hartley & Greene, 2012). Factors that affect the observer include their capacity to see and hear the birds that are present, their ability to correctly identify bird species by sight and sound, and their ability to accurately determine their numbers (Dawson & Bull, 1975; Hartley, 2012; Hartley & Greene, 2012). It can be difficult to count species which occur in high numbers, and hard to differentiate between high density multi-species flocks (Hartley & Greene, 2012). Many birds are highly mobile and fast-moving, limiting the ease at which they can be identified (Dowding, 2012). It is also important that observers do not count the same individual bird more than once in the same survey (Hartley & Greene, 2012).

Stationary five-minute bird counts only sample the surrounding habitat, which may include just a single habitat type (Mortimer & Clark, 2013). Habitat may impair the ability to record birds at different survey sites. For example, birds may be identified by sight with greater ease in open areas compared to areas with dense vegetation. Weather conditions, topography, and unrelated urban noises and happenings such as vehicles, foot traffic or domestic animals may also affect bird behaviour or detection rates (Dawson & Bull, 1975; Hartley & Greene, 2012; Mortimer & Clark, 2013).

Birds may alter their behaviour across the day and/or season (Dawson & Bull, 1975; Hartley, 2012). Detectability can vary and may be impacted by whether a species is diurnal or nocturnal, secretive or cryptic, or the density at which they occur (Dowding, 2012). Males may sing more than females, making detection of males more frequent (Dowding, 2012; Smith & Westbrooke, 2004). Juvenile birds are also often more naïve than adults, making them easier to detect (Dowding, 2012). Some species have distinctive shapes, behaviours, and movements that make them easier to identify (Mortimer & Clark, 2013). Smaller passerines that are difficult to detect or identify are likely under-recorded (Mortimer & Clark, 2013). These factors may inflate or reduce recorded occurrences of some species, or demographics of a species.

Methodology utilised in this research

All surveys were completed in the austral spring during the month of November between the hours of 6.00 am to 1.00 pm. Volunteers were advised to complete surveys before 12.00 pm, but data was accepted until 1.00 pm to allow for unexpected delays during field work. To standardise conditions and to prevent influence on bird behaviour and the ability of volunteers to detect birds, it was requested that surveys took place on fine, calm days that lacked heavy wind or precipitation. Binoculars were recommended but were not required.

Survey stations were labelled with flagging tape, triangular plastic markers, or were described with a physical feature (for example, a jetty). Upon arrival at a station, volunteers waited quietly for two minutes to reduce the risk of disturbance and to allow birds to settle. Over this time, volunteers noted their self-described birding ability, the date, time of day, location name, and the weather and wind conditions on the data sheet. After two minutes the volunteer recorded all birds that could be positively identified using sight and sound for five minutes. Upon the conclusion of five minutes the volunteer moved to the next station and repeated the process. Volunteers were instructed to record every known individual bird seen or heard at each station, excluding gulls.

Considerable changes were made to the field methods and survey locations in 2017.

Methodology A

Between 2013 and 2016, only birds that were seen or heard within a 30 m radius of the survey station were recorded. Methodology A was utilised for the first four years of field work (2013 to 2016). The method was also used as a control in 2020.

Methodology B (current and future methodology)

Due to the difficulty for an observer to accurately determine distance and the likely variation between volunteer's estimates, the methodology was amended so that all birds seen or heard at any distance were recorded. Methodology B was implemented from 2017 to 2020 and will continue to be used for all future field work. Some locations and stations were also changed at this time (see Figure 2.9 and Figure 2.10). The changes made to methodology and locations were intended to reduce confounding and to maximize the efficacy of time, movement between locations, and the information gathered.

Volunteer training

Each year, volunteers were invited to a two-hour training session which included a demonstration of field methods and gave the opportunity to ask questions. Volunteers were provided digital information about the locations, and overhead maps with pinpoints at each survey station. Between 2013 and 2016 volunteers were also given a spreadsheet which included a brief description of how to access locations, descriptions of the station positions, and their approximate latitude and longitude coordinates. The spreadsheet was discontinued from 2017 as observation stations were flagged with tape and triangular plastic markers.

Volunteers also received a data sheet to print and complete for each location surveyed (Figure 2.8). The target species included on the data sheet varied from year to year (see Appendix B). From 2013 to 2017 the information requested included the date, observer name, location, the time each survey commenced, and the weather conditions as described by the observer. In 2018, weather conditions were standardised to the options of “sunny”, “partly cloudy”, “overcast”, “light rain” and “rain”. Wind conditions of “none”, “light”, “moderate” and “strong” were also added at this time. In 2018, birds seen and heard were recorded separately, but this was discontinued in 2019.

In 2020, species were ordered alphabetically into groups of common and uncommon species. A notes section was included and volunteers were asked to leave descriptive notes for all uncommon species recorded. A self-assessment of personal birding ability with the options of “beginner,” “intermediate,” or “advanced” was also added. Finally, volunteers were provided a short bird identification guide which included illustrations of the target bird species, habitat preferences, social behaviours, and descriptions of the species’ common calls.

DATE:		LOCATION:				
OBSERVER:		EXPERIENCE:	BEGINNER	INTERMEDIATE	ADVANCED	
WEATHER (CIRCLE ONE):	SUNNY	P/CLOUDY	OVERCAST	LIGHT RAIN	RAIN	NOTES:
WIND (CIRCLE ONE):	NONE	LIGHT	MODERATE	STRONG		
STATION:	1	2	3	4	5	
STATION START TIME:						
COMMON SPECIES	# observed	# observed	# observed	# observed	# observed	
barbary dove						
blackbird						
california quail						
chaffinch						
fantail						
goldfinch						
greenfinch						
grey warbler						
house sparrow						
kingfisher						
mallard						
magpie						
myna						
new zealand pigeon						
paradise shelduck						
pheasant						
pukeko						
rosella						
shining cuckoo						
silvereye						
skylark						
song thrush						
spotted dove						
spur winged plover						
starling						
swamp harrier						
tui						
welcome swallow						
white faced heron						
yellowhammer						
UNCOMMON SPECIES	*** PLEASE LEAVE A NOTE FOR EACH UNCOMMON SPECIES ***					
bellbird						
brown quail						
dunnock						
hihi						
kaka						
kakariki						
long-tailed cuckoo						
morepork						
pipit						
robin						
saddleback						
spotless crake						
tomtit						
whitehead						
OTHER:						

Figure 2.8: *Copy of the 2020 data sheet.*

Study sites on the Whangaparāoa Peninsula

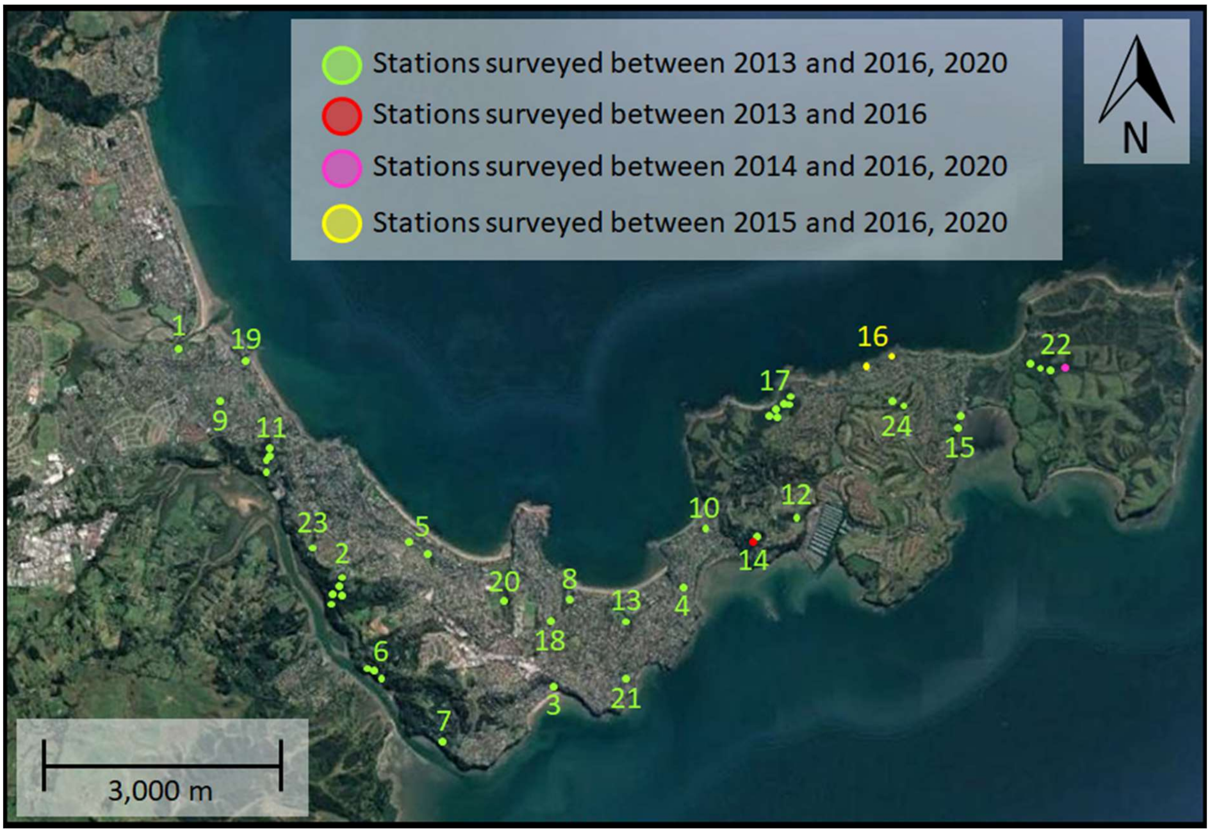

Figure 2.9: *Map of the Whangaparāoa Peninsula showing the locations and each station surveyed using methodology A. Locations (alphabetical order) include Amorino Park[1], Archer's Block[2], Arkles Bay Reserve[3], Browns Walk Reserve[4], D'Oyly Reserve[5], Fairhaven Walk[6], Ferry Road Reserve[7], Garroway Reserve[8], Gilshennan Reserve[9], Hardley Reserve[10], Karaka Cove[11], Laguna Place Reserve[12], Manly Park[13], Matakatia Glade[14], Okoromai Views Reserve[15], Pacific Parade[16], Peter Snell Village[17], Raroa Bush[18], Red Beach Recreational Reserve[19], Stanmore Bay Park[20], Sundown Reserve[21], Waterfall Gully[22], Weiti Views Reserve[23], Whangaparāoa Golf Course[24]. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

The Whangaparāoa Peninsula is primarily residential but has a variety of diverse ecosystems including native forest remnants, shrublands, swamps, wetlands, estuaries, open country, grass fields, and coastal seagrass and dune habitats (Cummings, 2017; Forest and Bird, 2018d; Julian, 2008; SOSSI, 2014a, 2014b). Survey locations were selected by Forest and Bird to represent the diverse ecosystems found across the study site. Volunteers surveyed 108 stations nested in 32 different locations between

2013 and 2020. All stations were located on publicly accessible land, or private land with permission from the owner. Some locations and stations were added, discontinued or moved over the course of this research.

The locations in Figure 2.9 were surveyed in November each year from 2013 to 2016 using methodology A. Each location had between one to six stations. All stations depicted in Figure 2.9 (excluding station 2 at Matakatia Glade) were also surveyed using methodology A in 2020.

Table 2.1: *Table showing the number of locations and stations surveyed annually with methodology A.*

Year	Number of locations	Number of stations	Total surveys
2013	23	43	195
2014	23	44	189
2015	24	46	214
2016	24	46	201
2020	24	45	135

In 2017, all locations were standardised to each have five stations. 14 locations were surveyed in 2017. From 2018, 17 locations were surveyed annually. A full list of the locations and stations monitored, as well as descriptions and relevant information about each can be found in Appendix 1.

Table 2.2: *Table showing the number of locations and stations surveyed annually with methodology B.*

Year	Number of locations	Number of stations	Total surveys
2017	14	70	134
2018	17	85	155
2019	17	85	397
2020	17	85	495

Amendments to raw data

I inherited a spreadsheet which included all data recorded between 2013 and 2018. All data from 2019 and 2020 were first assessed by me before being amassed into the spreadsheet. I contacted volunteers if data was missing (for example, to seek time or weather conditions), to confirm uncommon species that were recorded at unusual locations, or to request further information if required.

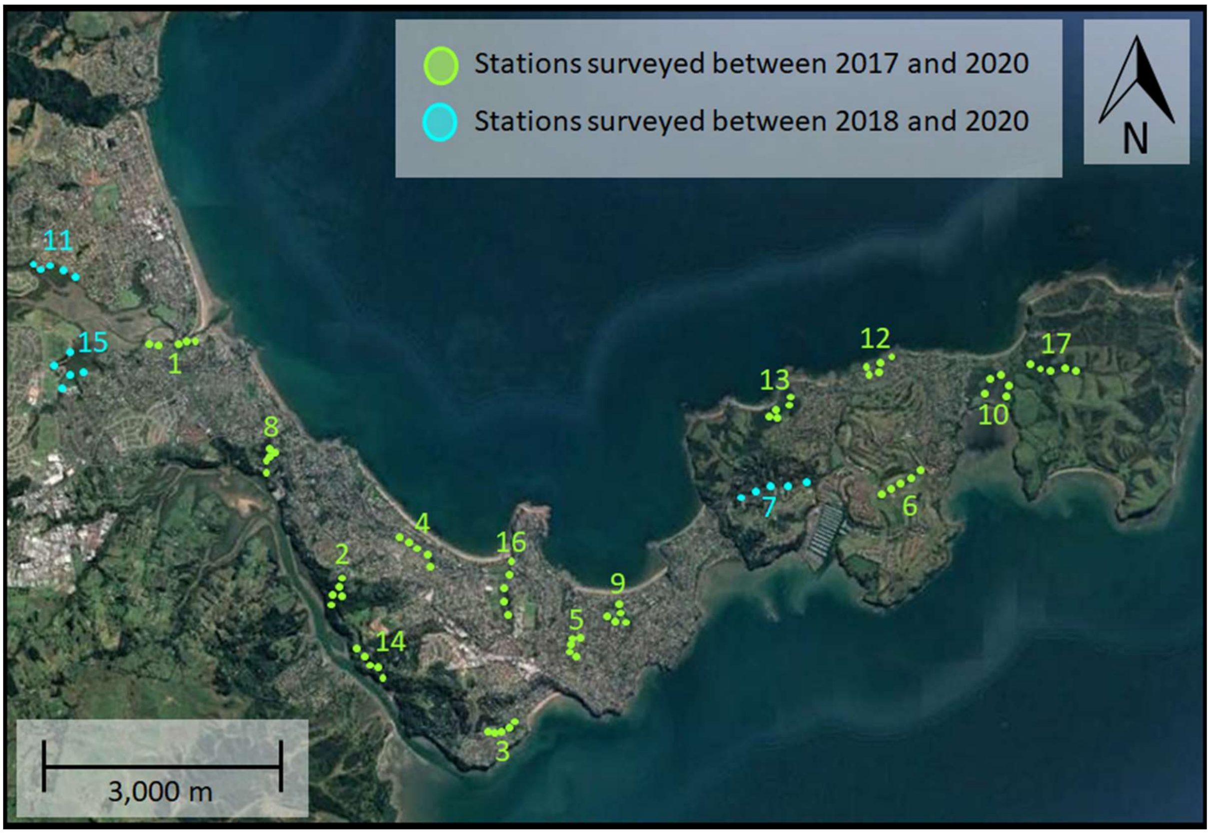

Figure 2.10: *Map of the Whangaparāoa Peninsula showing the locations and each station surveyed using methodology B. Locations (alphabetical order) include Amorino Park[1], Archer's Block[2], Arkles Bay Stormwater Pond[3], D'Oyly Reserve[4], Edith Hopper Park[5], Gulf Harbour Drive[6], Hobbs Road[7], Karaka Cove[8], Manly Park[9], Okoromai Bay[10], Ōrewa Lakeside Drive[11], Pacific Parade[12], Peter Snell Village[13], Riverhaven Drive[14], Silverdale Kingsway[15], Stanmore Bay Park[16], Waterfall Gully[17]. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Amendments to weather and wind data

From 2013 to 2017 volunteers did not have options for weather conditions and instead wrote their own descriptions. I translated all weather conditions described by volunteers between 2013 and 2017 to their closest option from 1. "Sunny," 2. "Partly cloudy," 3. "Overcast," 4. "Light rain," and 5. "Rain." A mid-point was coded if more than one option was described.

Weather data was absent from all 2017 data, and wind conditions were not added to the data sheet until 2018. I obtained historical weather conditions for 2017, and wind data from 2013 to 2018 using Timeanddate.com (2021). Weather and wind data from Timeanddate.com (2021) was typically recorded in 30 minute periods (though in rare occurrences, in periods of up to 2 hours) and is indicative of the Auckland area as a whole. Data from Timeanddate.com (2021) were translated as follows:

Table 2.3: *Timeanddate.com (2021) weather data translations.*

Timeanddate.com (2021) weather	Translation
Passing clouds	Sunny
Scattered clouds	Sunny
Partly sunny	Partly cloudy
Broken clouds	Partly cloudy
More clouds than sun	Partly cloudy
Overcast	Overcast
Sprinkles. Partly sunny	Light rain

Table 2.4: *Timeanddate.com (2021) and Ventusky.com (2021) wind data translations.*

Wind speed	Translation
0-5 km/h	No wind
6-15 km/h	Light wind
16-25 km/h	Moderate wind
26 km/h+	Strong wind

Weather conditions were also added for the few surveys where data were missing between 2013 and 2016. However, no data were available from Timeanddate.com (2021) between 21 November 2016 and 30 November 2016. Historical data required between this time were instead taken from Ventusky.com (2021), which was available in periods of 3 hours and had cloud cover and wind data from four areas within the study site. No precipitation was recorded over this time.

Table 2.5: *Ventusky.com (2021) weather data translations.*

Ventusky.com (2021) weather	Translation
0-25% cloud coverage	Sunny
25-50% cloud coverage	Partly cloudy
51%+ cloud coverage	Overcast

Amendments to time

If no times were recorded at all, surveys were set to the mid-point of 9.30 am to avoid any impact to results when scaling. If a single time was recorded, subsequent surveys were set to have occurred every 15 minutes.

Amendments to birding experience/ability

Self-assessments for volunteers from 2020 were applied to surveys from previous years if applicable. I endeavoured to gather experience levels for all volunteers between 2017 and 2020. I contacted past volunteers where details were available, and the Forest and Bird co-ordinators provided abilities for eight volunteers. I was unable to obtain experience levels for three volunteers – two from 2017 (39 surveys) and one from 2018 (10 surveys). I was also unable to obtain contact details for most of the volunteers between 2013 and 2016 thus did not seek experience levels from them.

After deliberation over the data collected by volunteers of unknown ability in 2017 and 2018, I assigned one of the volunteers as "beginner" as they had recorded 0 observations for grey warblers (*Gerygone igata*) across all 19 of their surveys. Grey warblers are a common species which call regularly but are small and are often difficult to see unless familiar with the species. A complete lack of grey warblers recorded over 19 surveys lead me to believe that this volunteer was likely a beginner. The remaining two volunteers (20 surveys 2017, 10 surveys 2018) were assigned an ability of intermediate to avoid impacting results when scaling predictors.

Amendments to birds recorded

A record of 111 goldfinches (*Carduelis carduelis*) at a single station in 2016 was removed from the data pool as it was likely an error in data entry.

Removal of surveys from the data set

Surveys were removed from the data set if they were completed outside of the hours of 6.00 am to 1.00 pm, or on days that were not in November. Surveys were not used if they were completed at locations or stations that were monitored for a single year only. One set of surveys (one location, five stations) was removed from the data set to avoid pseudo-replication as two volunteers surveyed the location together and submitted separate data sheets. Finally, one set of surveys was removed due to expressed uncertainty by the volunteer.

Overview of amendments to data by year

2013 195/208 surveys submitted were included in the raw data. Weather data was translated from volunteer descriptions in 190 surveys. Weather data was added to five surveys, and wind data to 195 surveys. A time of 9.30 am was added to five surveys.

2014 189/189 surveys submitted were included in the raw data. Weather data was translated from volunteer descriptions and wind data was added to 189 surveys. A time of 9.30 am was added to six surveys.

2015 214/214 surveys submitted were included in the raw data. Weather data was translated from volunteer descriptions in 205 surveys. Weather data was added to nine surveys, and wind data to 214 surveys. A time of 9.30 am was added to 19 surveys.

2016 201/202 surveys submitted were included in the raw data. Weather data was translated from volunteer descriptions in 182 surveys. Weather conditions were added to 19 surveys, and wind conditions to 201 surveys. A time of 9.30 am was added to 26 surveys. Staggered times in 15-minute intervals were added to six surveys.

2017 134/158 surveys submitted were included in the raw data. Weather and wind conditions were added to 134 surveys. A time of 9.30 am was added to 20 surveys. Experience levels were applied for two people across 39 surveys.

2018 155/180 surveys submitted were included in the raw data. A time of 9.30 am was added to eight surveys. An experience level was applied for one person across 10 surveys.

2019 397/427 surveys submitted were included in the raw data. Staggered times in 15-minute intervals were added to 62 surveys.

2020 495/515 surveys submitted were included in the raw data.

Research rationale

Urban restoration projects are a relatively new concept in New Zealand and there is still much to be learned. The last two decades have seen an increase in community groups, organisations, iwi and the general public collaborating and using practices such as pest-management and restorative planting to improve biodiversity and ecosystem function in their local areas (Clarkson & Kirby, 2016; Department of Conservation, 2020g). It is important to determine how bird communities may respond to these conservation efforts, particularly in areas that experience high anthropogenic activity. There are currently very few published examples of bird monitoring projects from New Zealand's urban environments.

This research analysed eight years of data from stationary five-minute bird counts collected during the formative years of an urban restoration project on the Whangaparāoa Peninsula. I investigated the abundances and population trends of the 21 most abundant bird species in the study site to see how the bird community may be changing. I also performed spatial analysis on the four most common birds from each classification of endemic, native, and introduced species to establish the environments that different birds may utilize in urban landscapes. Understanding these trends will further inform the current goal of restoring native biodiversity on the Whangaparāoa Peninsula and will provide understanding of the impacts of conservation management for urban bird communities.

Data was collected by volunteers using citizen science. This method offers educational opportunities, provides meaningful participation in environmental care, and improves human connection with the natural world (Clarkson & Kirby, 2016). The results from this combined scientific and sociological approach will offer confidence in the feasibility of urban environments to provide for native and endemic birds. The information gathered will allow for generalizations about the processes that may have driven change. It will provide insight into the feasibility of Predator Free 2050, as well as demonstrate expected changes that similar urban restoration projects may experience both in New Zealand, and on other island nations. This thesis will archive valuable information from the early years of this project and will contribute to the growing body of scientific research focused on improving the conservation of New Zealand's native birds.

Chapter 3

Abundance and population trends of endemic, native, and introduced bird species on the Whangaparāoa Peninsula, New Zealand

Abstract

Anthropogenic impacts to New Zealand's ecological communities are responsible for declining populations or extinction of native fauna. A key driver of these losses is predation from introduced mammalian predators. Forest and Bird began the Pest-Free Hibiscus Coast project in 2011 with the aim of using traps and bait to eradicate rats, stoats and possums from the Whangaparāoa Peninsula on Auckland's North Shore. As part of this project volunteers associated with Forest and Bird conducted annual November five-minute stationary bird counts between 2013 and 2020 to monitor changes in the bird community and evaluate the effectiveness of pest-management. Two methodologies were utilised – one included recording birds seen or heard within a 30 m radius, and the other had no distance limitations. I used fixed effects models to examine changes in the abundances of the 21 most common bird species recorded during 2,115 surveys. Using station as a random effect and controlling for the time of day, day of the month, weather, wind levels, methodology used and volunteer birding experience, I found 17 bird species remained stable or had significant increases in abundance between 2017 and 2020. The same can be said for 18 species between 2013 and 2020. Overall, abundance trends of common bird species throughout the survey period were comparable with community responses seen in other biodiversity studies from known healthy or predator-free environments. These results suggest that most of the common bird species on the Whangaparāoa Peninsula have healthy populations for an urban environment. As such, continued pest-management, ecological restoration and biodiversity monitoring is critically important.

Introduction

Anthropogenic activity has dramatically altered New Zealand's ecological communities over the past 800 years (Guild & Dudfield, 2009; King, 1984; Russell et al., 2015). Humans have hunted native species, modified land, and caused losses of up to 75% of the country's original forest cover (King, 1984; Taylor & Smith, 1997; Te Papa Collections Online, 2004). Around 2,000 plant species and almost 1,300 animal species have been introduced and are now naturalised (Robertson et al., 2017; Sullivan, Timmins, & Williams, 2005; Te Papa Collections Online, 2004). Amongst these introductions are 37 bird species and 28 terrestrial mammal species (Robertson et al., 2017; Te Papa Collections Online, 2004). Terrestrial mammals are a group that were not present during New Zealand's pre-human history, and so New Zealand's endemic avifauna have evolved in their absence (Te Papa Collections Online, 2004). Since humans arrived, the combined forces of habitat loss, hunting, competition and predation has led to dramatically declining populations, and in 59 cases (approximately one quarter) leading to extinction of native bird species (Bombaci et al., 2018; Heather & Robertson, 2015; Russell et al., 2015). Many extant native birds are still at risk despite focused conservation efforts (Robertson et al., 2017).

Predation from introduced mammals is now the primary cause of decline in New Zealand's native forest bird populations (Innes et al., 2010). Because New Zealand's birds evolved in the absence of mammalian predators, many of them have physical and behavioural adaptations that leave them vulnerable to these evolutionary novel threats (Heather & Robertson, 2015). Many species are poor fliers or completely flightless, spending much of their time close to or on the ground (Heather & Robertson, 2015; Maloney & McLean, 1995; Moon, 2006). Some species have also evolved naïve, inquisitive and conspicuous behaviours, leaving them defenceless against predators (Blackburn, Cassey, Duncan, Evans, & Gaston, 2004; Heather & Robertson, 2015; Starling-Windhof, Massaro, & Briskie, 2011). The control of introduced predatory mammals is therefore imperative to preserve and restrict further losses to New Zealand's endemic birds and other native fauna and flora (Innes et al., 2010; Norton, 2009; Russell et al., 2015).

In 2011, Hibiscus Coast Forest and Bird launched the Pest-Free Hibiscus Coast programme with the aim of creating a safe zone for native flora and fauna by eradicating rats, stoats and possums from the Whangaparāoa Peninsula (Forest and Bird, 2020). Whangaparāoa and its surrounding suburbs are primarily urban and are home to a rising population of more than 44,500 residents (Stats NZ, 2018). The area features a diverse community of native birds, insects and lizards, and provides an important stepping-stone habitat for species travelling between Tiritiri Matangi and the mainland beyond the peninsula (Forest and Bird, 2020; North-West Wildlink, 2017).

The Whangaparāoa peninsula is an ideal location for mainland pest eradication as its elongated shape limits accessibility by land, minimising reinvasion of unwanted terrestrial species (Bombaci et al., 2018; Russell et al., 2015). Current efforts to re-establish native birds include amplifying predator trap and bait lines, planting native vegetation, controlling weeds, and reintroducing endemic bird species to Shakespear Open Sanctuary – a predator-free fenced ecosanctuary at the eastern end of the peninsula (Auckland Council, 2018a, 2018b; Forest and Bird, 2018c, 2020; SOSSI, 2015, 2017). Combined, these processes guide regeneration and help the ecological community better represent its natural composition. In turn, species that have become locally extinct can safely return to the area naturally or by translocation (Ralph, Ralph, & Long, 2020).

Birds are valuable bioindicators as they occupy a variety of ecological niches and their populations are susceptible to fluctuations caused by anthropogenic activity and environmental variation (Koskimies, 1989; Pollack et al., 2017; Temple & Wiens, 1989). There is currently very little published literature relating to avian biodiversity in New Zealand's urban environments (Mortimer & Clark, 2013). In 2013, Forest and Bird began annual five-minute stationary bird counts to monitor changes and detect trends in the abundances of bird species as a result of pest-management and ecological restoration. A total of 2,115 bird surveys were conducted by volunteers across 108 stations during November each year between 2013 and 2020.

In this study, I predicted that the abundances of common native species – particularly endemic species – would increase over time following ongoing pest control and habitat restoration. This thesis serves to summarise and archive the first eight years of bird abundance data, and to further assist Forest and Bird in the management of pest control, ecological restoration, and biodiversity monitoring. This project also encourages education and awareness of Whangaparāoa's diverse avian community by giving residents the opportunity to collect data using citizen science.

Methodology

Study site and sample design

Field research took place on the Whangaparāoa Peninsula, a narrow 11 km stretch of land 25 kms north of Auckland City on the east coast of New Zealand's North Island. From 2018 the study area expanded to include the adjacent mainland suburbs of Kingsway, Millwater and Ōrewa. A total of 108 stations nested in 32 locations were monitored using stationary five-minute bird counts between 2013 and 2020. Locations and the position of stations were selected by Hibiscus Coast Forest and Bird. The habitats selected included urban streets, parks, gardens, grass fields, exotic forest, native forest remnants, shrublands, wetlands, and the boundaries of estuaries and ponds.

A map showing the general placement of the 32 locations is provided in Figure 3.1. Some locations and stations were added, discontinued, or moved over time and as such, the locations and stations monitored varied annually. These changes were made in an effort to improve the selection of locations across the region. A full list of these changes can be found in Chapter 2 under "study sites". Detailed descriptions of each location including cultural significance, known vegetation, nearby pest-management, and rules regarding dogs can be found in Appendix 1. A summary of the total number of locations, stations and surveys completed each year is provided in Table 3.1.

All data were collected during the austral spring in the month of November between the hours of 6.00 am to 1.00 pm on days convenient for the volunteer. To standardise conditions and to minimise influence on bird behaviour and the ability of volunteers to detect birds, it was requested that surveys took place on fine, calm days that lacked strong winds or heavy precipitation (Hartley & Greene, 2012). November was selected as it is the breeding season for most of New Zealand's bird species and over this time many species are conspicuous in their vocalisations, activities, and territorial and courtship displays (Cockrem, 1995; Graham et al., 2013). Bird communities are also more speciose in November because migrating species such as shining cuckoo (*Chrysococcyx lucidus*) and long tailed-cuckoo (*Eudynamys taitensis*) return to New Zealand to breed (Graham et al., 2013; Heather & Robertson, 2015).

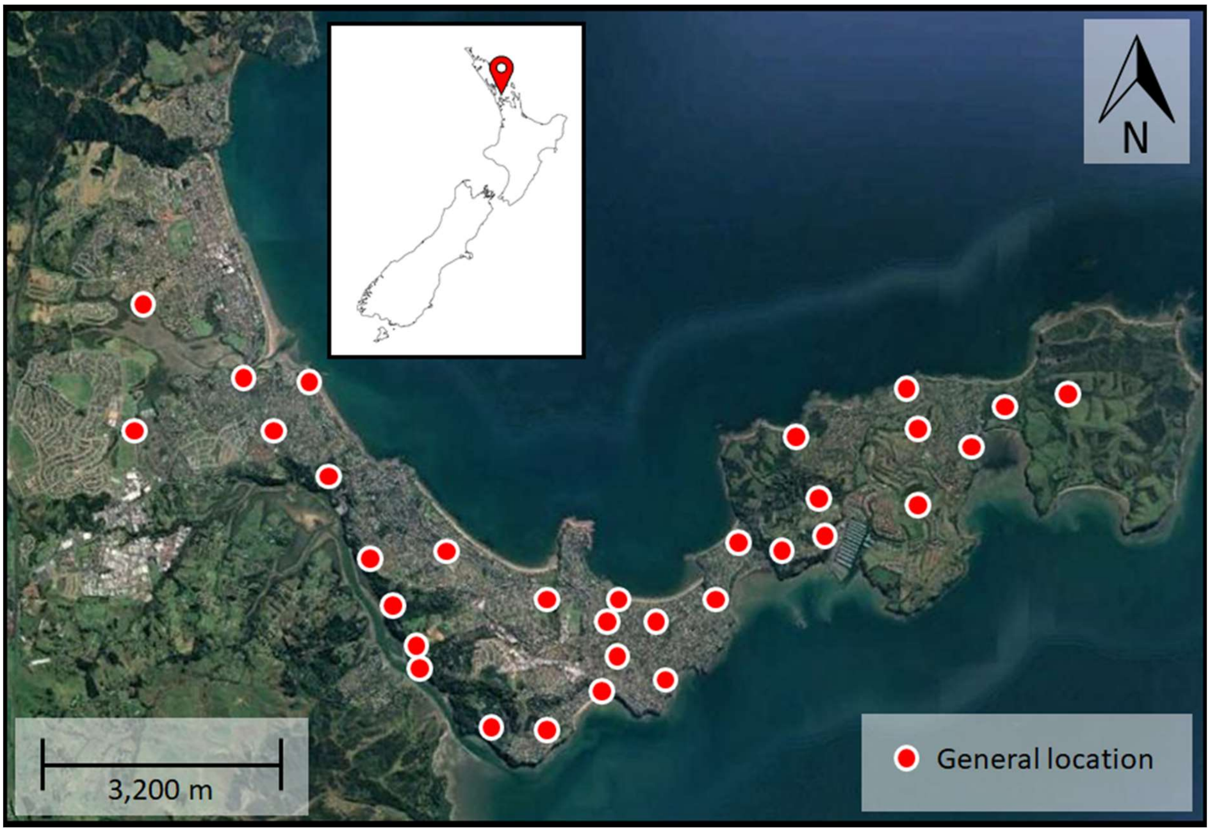

Figure 3.1: *Map showing the Whangaparāoa Peninsula and the 32 locations that were surveyed between 2013 and 2020 (nested stations not included). Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Field methods

Volunteers were typically assigned 3 to 4 locations (or up to 20 survey stations) each year. It was intended for all stations to be monitored a minimum of three times per survey season by three different volunteers, however this was not always possible.

Upon arrival at a station, volunteers waited quietly for two minutes to reduce the risk of disturbance and to allow birds to settle. Over this time, volunteers noted their self-described birding ability, the date, time of day, location name, and the weather and wind conditions on the data sheet.

After the two minutes, volunteers recorded all birds that could be positively identified at or flying above the station using sight and sound for five minutes. Care was taken to avoid counting the same individual bird more than once. Upon conclusion of the five minutes, volunteers moved to the next station and repeated the process. Target bird species and the year that each species was included on the data sheet can be found in Appendix 2. An example of the 2020 data sheet and the amendments made to the data recorded over time can be found in Chapter 2 under "volunteer training" and in Figure 2.8.

Table 3.1: *The number of locations and stations surveyed annually with each methodology.*

Year	Methodology	Locations	Stations	Total surveys
2013	A	23	43	195
2014	A	23	44	189
2015	A	24	46	214
2016	A	24	46	201
2017	B	14	70	134
2018	B	17	85	155
2019	B	17	85	397
2020	A	24	45	135
2020	B	17	85	495

Changes to field methodology:

Methodology A

Between 2013 and 2016, only birds that were seen or heard within a 30 m radius of the survey station were recorded. Due to the difficulty involved in accurately determining distance and the likely variation between volunteer's estimates of 30 m, this methodology was discontinued after the first four years of sampling (2013 to 2016).

Methodology B

From 2017 onwards, distance limitations were abandoned and all birds that were seen or heard at any distance were recorded. Use of methodology B will continue for future surveys. 2017 also saw considerable changes in survey locations (see Chapter 2 Figure 2.9 and 2.10 under "study sites").

Control of methodology

Earlier years of this project helped to recognise manageable issues in the methodology, the locations surveyed, and amendments that should be made to the data recorded. Although these changes make analysing trends across the entire span challenging, the amendments were considered important improvements which benefitted data collection by improving accuracy and allowing for more reliable analysis in the long term (see Chapter 2). To better understand the specific impact of the changed methodology on estimated abundance levels, all stations that were surveyed between 2013 and 2016 were also surveyed in November 2020 using methodology A (excluding one station which was inaccessible due to dangerous terrain – see Appendix 1). 45 stations across the original 24 locations were monitored three times. Subsequent surveys at the same locations were completed on different days.

I solely conducted the 2020 methodology A surveys to avoid confusing volunteers over methodological differences and the positions of locations/stations. As such, there are limitations to this approach. Firstly, I am likely to have greater birding experience than the overall average of the volunteers. Additionally, to assist with distance limitations, I created maps using Google Earth Pro (2020) which depicted a 30 m radius around each station. These resources were not available to volunteers thus radius estimates likely differed greatly between volunteers and stations between 2013 and 2016. I acknowledge that estimating if a bird was < 30 m away was often still difficult, even with these maps. Many volunteers expressed they were keen to include birds in surveys, thus it is reasonable to expect that some volunteers may have occasionally recorded birds seen or heard > 30 m away.

Software and statistical analysis

Statistical analysis was performed using R version 4.0.3 in RStudio desktop 1.3.1093 (2020). I categorised species into groups of introduced species, endemic species, and native species. "Introduced" species are classified as those that are found in New Zealand as a result of anthropogenic introduction over the past 180 years. "Endemic" species are native species that evolved and are found only in New Zealand. "Native" species are those that are also found in other countries and that have naturally colonised New Zealand without the aid of humans. Survey effort differed between stations and years, thus the mean abundances of each species between 2017 and 2020 were calculated by taking the mean of each species at each station each year.

$$\mu_{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \bar{x}_3 \ldots + \bar{x}_n}{n}$$

Fixed effects models were produced using r-package nlme. Changes in abundances of the 21 most abundant species between 2017 and 2020 were examined by scaling predictors and calculating estimates for the fixed factors of year, day of the month, time of day, weather conditions, wind conditions and experience of the observer. Predictors were scaled to reveal the influence of each fixed factor with greater accuracy. Station was entered as a random effect. Likewise, the changes in abundances of the same common species between 2013 and 2020 were examined by scaling data and controlling for the fixed factors of year, day of the month, time of day, weather conditions, wind conditions, and in this case, the methodology used. Station was again a random effect. Models were produced on both raw bird abundances and log transformed abundances. The use of both analyses reduced skew caused by dramatic differences in flock sizes observed within and between species.

Limitations in methodology

It is well known that bird count data are noisy. No individual method is perfect for monitoring all species of birds across different habitats (Dowding, 2012). Birds are often quick and highly mobile, and some species are cryptic which impacts their detectability (Dowding, 2012). Volunteers may differ in their ability to identify birds by sight and sound. They may also be limited by their capacity to see or hear birds, and their ability to accurately identify species and their numbers (Dawson & Bull, 1975; Hartley, 2012; Hartley & Greene, 2012). Environmental factors and urban distractions such as traffic or dog walkers may also affect bird behaviour or hinder the ability of volunteers to detect birds (Dawson & Bull, 1975; Hartley & Greene, 2012).

Amendments to recorded survey data (for example, where data has been partially or incorrectly recorded), or reasons that surveys were removed from the data pool are discussed in further detail in Chapter 2. Acknowledging these changes and limitations allowed for control during analysis and consideration when drawing conclusions.

Results

Mean abundances of species recorded between 2017 and 2020 using methodology B

1,181 five-minute surveys conducted between 2017 and 2020 were analysed. 41 of the 44 target species were recorded at least once. Species recorded included 19 introduced, 9 native and 13 endemic species.

Four species had an average abundance > 1 per survey, and nine species > 0.5 per survey. Tūī (*Prosthemadera novaseelandiae*) were the most abundant species with an average abundance of 2.44 (SE = 0.9). Four of the top five most abundant species were introduced species. Nine of the top ten species were Passeriformes, with the eastern rosella (*Platycercus eximius*), a Psittaciform as the 10th most common species recorded. The species with the lowest mean abundance was the North Island tomtit (*Petroica macrocephala toitoi*) with a single individual recorded (and photographed) in 2019. Morepork (*Ninox novaseelandiae novaseelandiae*), North Island kākā (*Nestor meridionalis septentrionalis*) and North Island robin (*Petroica longipes*) were not recorded between 2017 and 2020.

Abundances of many of the less common species recorded were too low to provide sufficient statistical power for quantitative analysis. In this study, I wanted to ensure there were at least four species of each category, therefore I organised species into descending order by overall abundance until at least four species from each classification were present in the species set. This resulted in the analysis of 21 species, including 12 introduced species (house sparrow (*Passer domesticus*), blackbird (*Turdus merula*), myna (*Acridotheres tristis*), song thrush (*Turdus philomelos*), starling (*Sturnus vulgaris*), eastern rosella, goldfinch (*Carduelis carduelis*), chaffinch (*Fringilla coelebs*), mallard (*Anas platyrhynchos*), greenfinch (*Carduelis chloris*), barbary dove (*Streptopelia risorii*), spotted dove (*Streptopelia chinensis*)), 5 native species (silvereye (*Zosterops lateralis*), welcome swallow (*Hirundo neoxena neoxena*), sacred kingfisher (*Todiramphus sanctus*), pūkeko (*Porphyrio melanotus*), spurwing plover (*Vanellus miles*)) and 4 endemic species (tūī, grey warbler (*Gerygone igata*), fantail (*Rhipidura fuliginosa*), kererū (*Hemiphaga novaseelandiae*)).

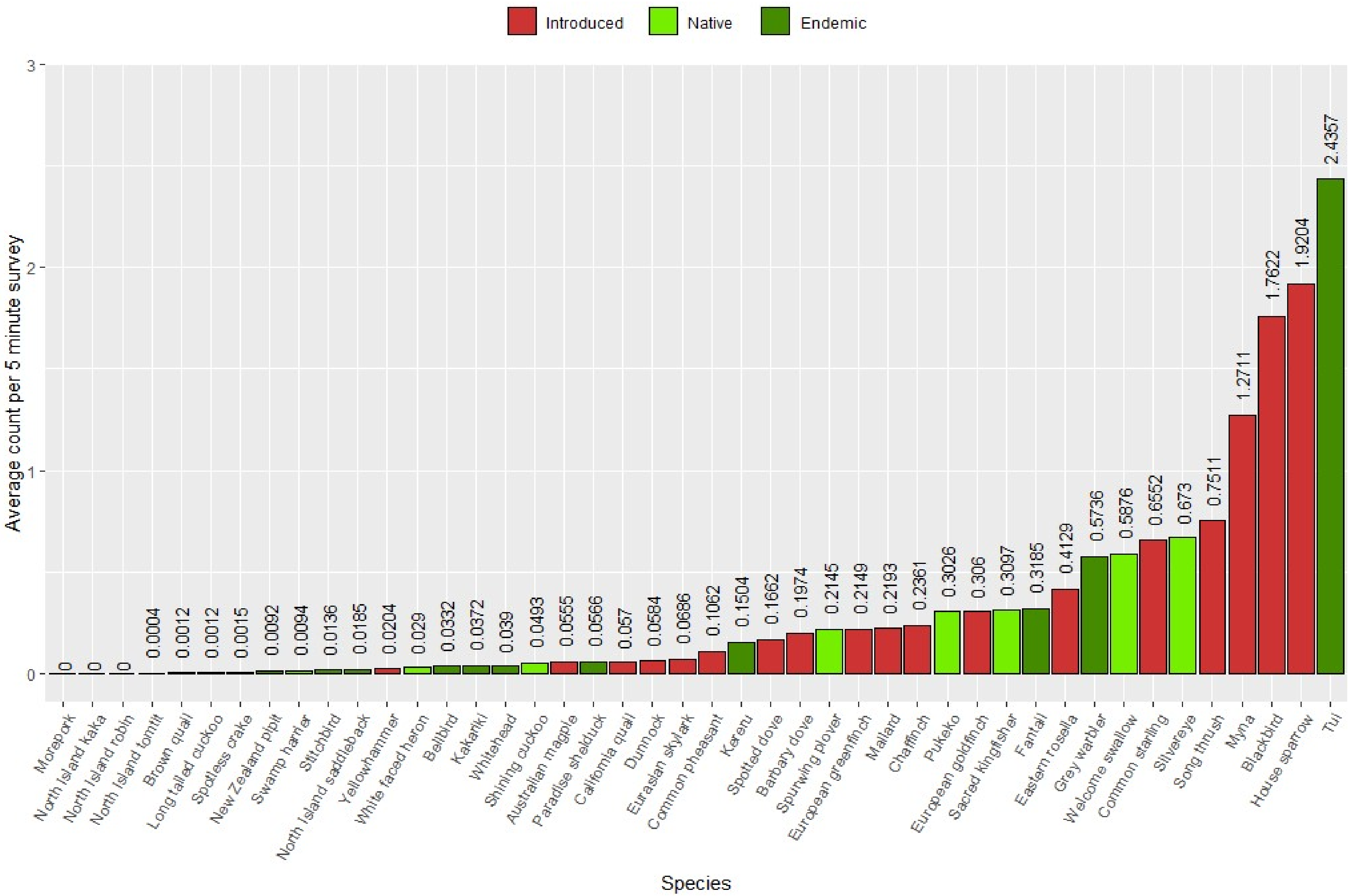

Figure 3.2: *Bar chart showing the mean abundance of each species recorded during five-minute surveys using methodology B between 2017 and 2020.*

Scaled fixed effects model of raw data using methodology B (2017 to 2020)

Table 3.2 shows the effect sizes and P-values for the number of individuals seen as a response variable. Station was a random effect and fixed factors include the year, day during the month, time of day, weather conditions, wind conditions, and the experience level of volunteers.

Year predicted positive increases in the abundances of tūī, blackbirds and barbary doves between 2017 and 2020. Conversely, there were significant declines in the abundances of song thrushes, starlings and mallards. Very strong but not statistically significant negative trends were also apparent for silvereyes.

Day of November predicted higher abundances of song thrushes, starlings and spotted doves closer to the beginning of the month. Greenfinches show similar trends but with no statistical significance. Tūī and chaffinches were significantly more abundant later in the month. House sparrows also show very strong but not statistically significant trends towards higher abundances in the latter half of the month.

The time of day significantly predicted higher abundances of blackbirds, song thrushes, spurwing plovers, barbary doves and spotted doves during the earlier half of the morning. Mallards show similar tendencies but with no significance. Eastern rosellas show very strong but not statistically significant trends for higher abundances in the latter half of the morning.

Weather condition predicted that kererū were significantly more abundant during fine or partly cloudy weather. Tūī show similar but not statistically significant trends. Grey warblers, fantails and kingfishers were significantly more abundant during light rain or rain. Chaffinches also show marginal but not statistically significant trends towards waning weather conditions.

Wind as a predictor suggests that tūī, grey warblers, rosellas, chaffinches, greenfinches and spotted doves were significantly more abundant when there was no wind, or wind was light. Pūkeko show similar but not significant trends. Song thrushes appear significantly more abundant during periods of moderate or strong winds. Welcome swallows show strong trends towards these conditions, but with no statistical significance.

Table 3.2: *Scaled fixed effects model using 2017 to 2020 methodology B raw data. Number of individuals seen as a response variable is examined using the fixed factors of year, day during November, time of day, weather conditions, wind conditions, and experience level of the observer. Station is a random effect (bold = significant, * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001).*

Species	New Zealand classification	Year		November		Time		Weather		Wind		Experience	
		Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value
Tūī	Endemic	0.135	**0.018***	0.231	**<0.001*****	-0.038	0.514	-0.107	0.055	-0.152	**0.012***	0.389	**<0.001*****
House sparrow	Introduced	0.029	0.717	0.161	0.051	0.084	0.298	0.014	0.861	0.033	0.690	0.326	**<0.001*****
Blackbird	Introduced	0.114	**0.043***	0.002	0.978	-0.261	**<0.001*****	-0.011	0.835	0.076	0.199	0.223	**<0.001*****
Myna	Introduced	0.069	0.147	0.075	0.129	0.046	0.346	-0.016	0.725	-0.076	0.133	0.314	**<0.001*****
Song thrush	Introduced	-0.095	**0.004****	-0.070	**0.041***	-0.153	**<0.001*****	-0.050	0.121	0.093	**0.008***	0.037	0.285
Silvereye	Native	-0.070	0.055	0.039	0.301	-0.041	0.264	-0.051	0.152	-0.043	0.260	0.190	**<0.001*****
Starling	Introduced	-0.130	**0.044***	-0.150	**0.026***	-0.038	0.558	0.063	0.314	0.076	0.264	0.374	**<0.001*****
Welcome	Native	0.038	0.307	-0.025	0.530	-0.062	0.104	0.032	0.389	0.074	0.064	0.183	**<0.001*****
Grey warbler	Endemic	0.035	0.176	0.009	0.739	0.022	0.396	0.093	**<0.001*****	-0.114	**<0.001*****	0.150	**<0.001*****
Eastern rosella	Introduced	0.039	0.144	0.022	0.435	0.052	0.058	0.014	0.599	-0.142	**<0.001*****	0.115	**<0.001*****
Fantail	Endemic	-0.012	0.562	0.010	0.641	-0.033	0.102	0.060	**0.002****	-0.030	0.159	-0.039	0.070
Sacred	Native	0.006	0.694	-0.028	0.107	-0.005	0.773	0.039	**0.016***	-0.017	0.325	0.077	**<0.001*****
Goldfinch	Introduced	0.006	0.797	-0.014	0.593	0.004	0.868	0.006	0.809	-0.035	0.181	0.179	**<0.001*****
Pūkeko	Native	-0.043	0.108	-0.025	0.356	-0.018	0.496	0.015	0.556	-0.054	0.054	0.051	0.071
Chaffinch	Introduced	0.020	0.244	0.081	**<0.001*****	0.017	0.321	0.028	0.093	-0.051	**0.005****	0.102	**<0.001*****
Mallard	Introduced	-0.100	**0.005****	-0.016	0.661	-0.061	0.092	0.000	0.995	-0.023	0.542	0.083	**0.028***
Greenfinch	Introduced	0.025	0.239	-0.039	0.075	0.033	0.118	0.022	0.285	-0.046	**0.038***	0.118	**<0.001*****
Spurwing plover	Native	0.009	0.713	0.003	0.896	-0.115	**<0.001*****	0.031	0.186	0.002	0.945	0.045	0.079
Barbary dove	Introduced	0.050	**0.005***	0.001	0.950	-0.069	**<0.001*****	-0.013	0.431	0.030	0.107	0.016	0.397
Spotted dove	Introduced	-0.005	0.769	-0.033	**0.036***	-0.054	**0.001*****	0.009	0.571	-0.034	**0.036***	0.048	**0.003****
Kererū	Endemic	0.021	0.129	0.013	0.356	0.010	0.493	-0.031	**0.022***	-0.021	0.149	0.061	**<0.001*****

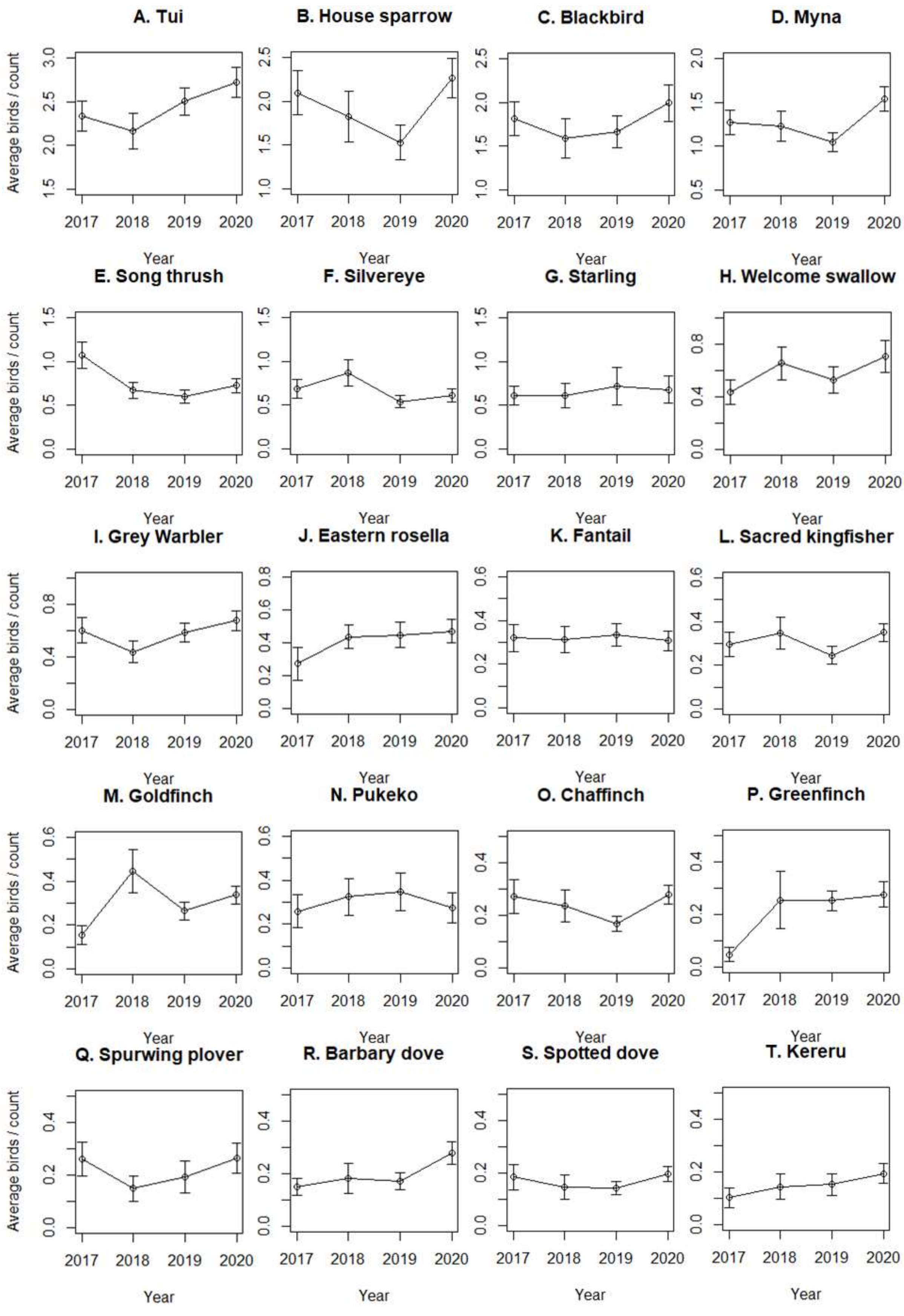

Figure 3.3: *Line graphs showing the mean abundances of common species between 2017 and 2020 using methodology B. Mallard not included. Note that the vertical scale differs between species.*

Experience level predicted that 16 of the 21 species were recorded in significantly higher numbers by expert level birders. Pūkeko and spurwing plovers show strong similar trends but with no statistical significance. Fantails show strong but not statistically significant trends towards being more abundant when recorded by beginner birders. No trends emerge for song thrushes or barbary doves.

Line graphs of common species using methodology B (2017 to 2020)

Figure 3.3 shows apparent positive trends in the abundances of tūī (Figure 3.3A), welcome swallows (Figure 3.3H), rosellas, (Figure 3.3J), goldfinches (Figure 3.3M), greenfinches (Figure 3.3P), barbary doves (Figure 3.3R) and kererū (Figure 3.3T). House sparrows (Figure 3.3B), blackbirds (Figure 3.3C) and mynas (Figure 3.3D) also show increases in abundance despite periods of decline.

The mean abundances of starlings (Figure 3.3G), grey warblers (Figure 3.3I), fantails (Figure 3.3K), sacred kingfishers (Figure 3.3L), pūkeko (Figure 3.3N), chaffinches (Figure 3.3O), spurwing plovers (Figure 3.3Q) and spotted doves (Figure 3.3S) remained relatively stable. Silvereyes (Figure 3.3F) experienced some fluctuations and a slight negative trend was apparent. There was a decline in the mean abundance of song thrushes (Figure 3.3E).

Scaled fixed effects model of log transformed data using methodology B (2017 to 2020)

Table 3.3 shows the effect sizes and P-values for the number of individuals seen as a response variable. Station was a random effect and fixed factors include the year, day during the month, time of day, weather conditions, wind conditions, and the experience level of volunteers.

Year predicted positive increases in the abundance of barbary doves. Tūī, blackbirds, grey warblers and kererū show marginal but not statistically significant increases in abundance. Song thrushes, silvereyes, starlings and mallards declined significantly. Pūkeko exhibit marginal but not statistically significant decreases in abundance.

Day of November shows that song thrushes, starlings, greenfinches and spotted doves were significantly more abundant on days earlier in the month. Kingfishers show comparable trends but with no statistical significance. In contrast, tūī, house sparrows, mynas and chaffinches were significantly more abundant on days later in the month.

Table 3.3: *Log transformed scaled fixed effects model using 2017 to 2020 methodology B data. Number of individuals seen as a response variable is examined using the fixed factors of year, day during November, time of day, weather conditions, wind conditions, and experience level of the observer. Station is a random effect (bold = significant, * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001).*

Species	New Zealand classification	Year		November		Time		Weather		Wind		Experience	
		Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value
Tūī	Endemic	0.012	0.099	0.028	**<0.001***	-0.003	0.736	-0.006	0.421	-0.014	0.075	0.054	**<0.001***
House sparrow	Introduced	0.005	0.575	0.021	**0.017***	0.007	0.418	0.001	0.864	0.001	0.929	0.041	**<0.001***
Blackbird	Introduced	0.013	0.075	-0.007	0.320	-0.027	**<0.001***	-0.003	0.687	0.014	0.059	0.031	**<0.001***
Myna	Introduced	0.012	0.114	0.017	**0.032***	0.006	0.460	-0.001	0.871	-0.011	0.150	0.059	**<0.001***
Song thrush	Introduced	-0.018	**0.006****	-0.017	**0.012***	-0.027	**<0.001***	-0.015	0.056	0.016	**0.020***	0.011	0.096
Silvereye	Native	-0.017	**0.008****	0.006	0.387	-0.007	0.308	-0.012	**0.047***	-0.005	0.432	0.043	**<0.001***
Starling	Introduced	-0.014	**0.031***	-0.016	**0.023***	-0.006	0.346	-0.003	0.613	0.012	0.082	0.052	**<0.001***
Welcome	Native	0.003	0.629	-0.007	0.283	-0.010	0.096	0.001	0.805	0.016	**0.010****	0.031	**<0.001***
Grey warbler	Endemic	0.009	0.091	-0.001	0.899	0.003	0.548	0.020	**<0.001***	-0.022	**<0.001***	0.039	**<0.001***
Eastern rosella	Introduced	0.006	0.223	0.003	0.641	0.007	0.176	0.007	0.174	-0.026	**<0.001***	0.028	**<0.001***
Fantail	Endemic	-0.004	0.390	0.003	0.543	-0.008	0.099	0.013	**0.003****	-0.006	0.230	-0.004	0.351
Sacred	Native	0.001	0.720	-0.007	0.092	-0.001	0.819	0.009	**0.021***	-0.005	0.264	0.021	**<0.001***
Goldfinch	Introduced	0.001	0.816	-0.005	0.344	-0.001	0.800	0.001	0.833	-0.004	0.418	0.038	**<0.001***
Pūkeko	Native	-0.008	0.071	-0.003	0.495	-0.005	0.242	0.001	0.765	-0.011	**0.019***	0.007	0.145
Chaffinch	Introduced	0.004	0.284	0.020	**<0.001***	0.003	0.535	0.008	0.058	-0.012	**0.006****	0.026	**<0.001***
Mallard	Introduced	-0.009	**0.032***	-0.005	0.270	-0.006	0.154	-0.001	0.861	-0.007	0.096	0.008	0.064
Greenfinch	Introduced	0.006	0.145	-0.009	**0.032***	0.007	0.107	0.006	0.141	-0.010	**0.025***	0.028	**<0.001***
Spurwing plover	Native	-0.001	0.878	0.002	0.614	-0.021	**<0.001***	0.004	0.393	0.001	0.879	0.009	**0.038***
Barbary dove	Introduced	0.010	**0.012***	0.000	0.949	-0.018	**<0.001***	-0.002	0.527	0.007	0.120	0.003	0.459
Spotted dove	Introduced	-0.001	0.723	-0.008	**0.040***	-0.013	**<0.001***	0.001	0.779	-0.008	**0.033***	0.014	**<0.001***
Kererū	Endemic	0.006	0.061	0.004	0.281	0.002	0.499	-0.009	**0.006****	-0.004	0.247	0.016	**<0.001***

The time of day significantly predicted that abundances of blackbirds, song thrushes, spurwing plovers, barbary doves and spotted doves were higher during the earlier half of the morning. Welcome swallows and fantails show comparable but not statistically significant trends.

Weather condition predicted that silvereyes and kererū were significantly more abundant during fine or partly cloudy weather. Song thrushes show similar but not statistically significant trends. In contrast, grey warblers, fantails and kingfishers were significantly more abundant during periods of light rain or rain. Chaffinches also show strong but not statistically significant trends towards higher abundance during rainy conditions.

Wind condition predicted that grey warblers, rosellas, pūkeko, chaffinches, greenfinches and spotted doves were significantly more abundant when there was no wind, or wind was light. Tūī and mallards also show comparable but not significant trends. Song thrushes and welcome swallows were significantly more abundant when wind levels were moderate or strong. Blackbirds and starlings share strong inclinations towards these tendencies, but with no statistical significance.

Experience as a predictor reveals that 16 of the 21 species were recorded in higher abundances by expert level birders. Song thrushes and mallards show similar but not statistically significant trends. No trends emerged for fantails, pūkeko or barbary doves.

Line graphs of common species using log transformed methodology B data (2017 to 2020)

Figure 3.4 shows positive trends in the mean abundances of tūī (Figure 3.4A), welcome swallows (Figure 3.4H), rosellas (Figure 3.4J), goldfinches (Figure 3.4M), greenfinches (Figure 3.4P), barbary doves (Figure 3.4R) and kererū (Figure 3.4T).

House sparrows (Figure 3.4B), blackbirds (Figure 3.4C), mynas (Figure 3.4D), silvereyes (Figure 3.4F), grey warblers (Figure 3.4I), fantails (Figure 3.4K), kingfishers (Figure 3.4L), chaffinches (Figure 3.4O), spurwing plovers (Figure 3.4Q) and spotted doves (Figure 3.4S) all remained relatively stable. Pūkeko (Figure 3.4N) appeared to trend positively between 2017 and 2019 but had their lowest mean abundance in 2020. A slow decline was apparent for starlings (Figure 3.4G), and a strong decline for song thrushes (Figure 3.4E).

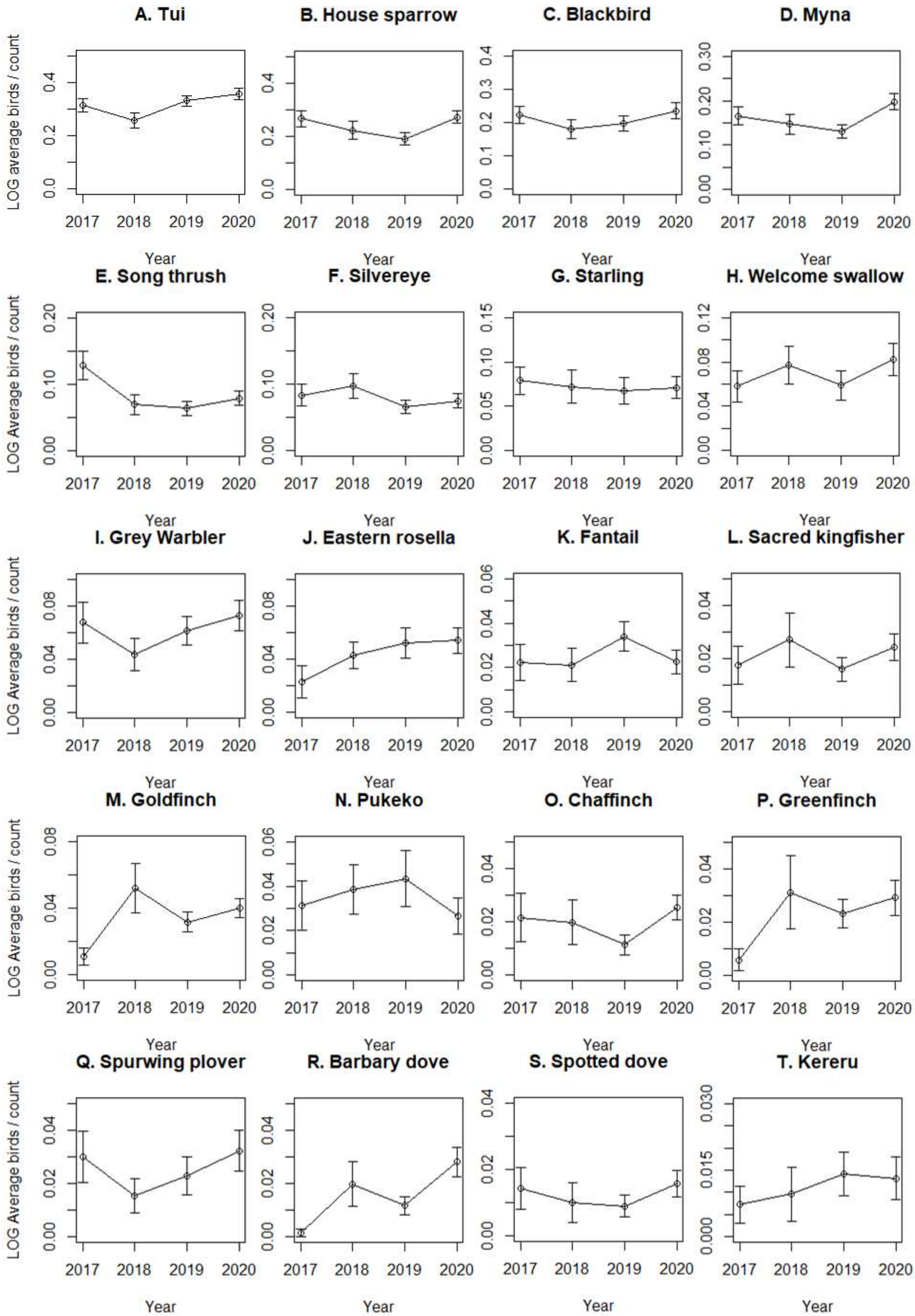

Figure 3.4: *Log transformed line graphs showing the mean abundances of common species between 2017 and 2020 using methodology B. Mallard not included. Vertical scale differs between species.*

Scaled fixed effects model of the raw data using methodology A and B (2013 to 2020)

A total of 2,115 five-minute surveys were conducted – 934 surveys using methodology A and 1,181 surveys using methodology B. Table 3.4 shows the effect sizes and P-values for the number of individuals seen as a response variable. Station was a random effect and fixed factors include the year, day during the month, time of day, weather conditions, wind conditions, and the methodology used.

Year predicted significant increases in the abundances of tūī, silvereyes, grey warblers, greenfinches, barbary doves and spotted doves. There were positive but not statistically significant trends for goldfinches. The abundances of song thrushes, fantails and kingfishers declined significantly.

Day of November predicted that starlings, welcome swallows, kingfishers and greenfinches were significantly more abundant on days earlier during the month. Rosellas show similar trends but with no statistical significance. Tūī, silvereyes and chaffinches were significantly more abundant in the latter half of the month.

Time of day predicted significantly higher abundances of tūī, blackbirds, song thrushes, welcome swallows, spurwing plovers, barbary doves and spotted doves earlier in the morning. Silvereyes and goldfinches share similar but not statistically significant inclinations.

Tūī, kingfishers and spurwing plovers showed strong but not statistically significant trends towards higher abundances during fine or partly cloudy conditions. Grey warblers were significantly more abundant during light rain or rain. Song thrushes share this trend but with no statistical significance.

Wind predicted that tūī, mynas, silvereyes, grey warblers, rosellas, goldfinches, chaffinches, mallards, greenfinches, spotted doves and kererū were significantly more abundant when there was no wind or wind was light. Pūkeko share this trend but with no statistical significance.

Methodology predicted that silvereyes were significantly more abundant under methodology A. In contrast, tūī, mynas, rosellas, kingfishers and spurwing plovers were significantly more abundant under methodology B. House sparrows, song thrushes and greenfinches show a positive but not statistically significant inclination towards higher abundances under methodology B.

Table 3.4: *Scaled fixed effects model using all 2013 to 2020 raw data. Number of individuals seen as a response variable is examined using the fixed factors of year, day during November, time of day, weather conditions, wind conditions, and survey method. Station is a random effect (bold = significant, * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001).*

Species	New Zealand classification	Year		November		Time		Weather		Wind		Methodology	
		Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value
Tūī	Endemic	0.181	**0.002****	0.147	**<0.001*****	-0.084	**0.031***	-0.071	0.056	-0.136	**0.001*****	0.245	**0.001****
House sparrow	Introduced	-0.112	0.178	0.076	0.158	0.068	0.215	0.060	0.251	-0.091	0.115	0.183	0.062
Blackbird	Introduced	-0.024	0.679	-0.041	0.279	-0.154	**<0.001*****	-0.004	0.912	0.006	0.888	0.080	0.263
Myna	Introduced	-0.066	0.183	-0.022	0.483	-0.019	0.557	0.006	0.860	-0.095	**0.006****	0.174	**0.002****
Song thrush	Introduced	-0.070	**0.047***	-0.012	0.587	-0.081	**0.001*****	-0.039	0.083	0.035	0.153	0.071	0.083
Silvereye	Native	0.120	**0.008****	0.113	**<0.001*****	-0.053	0.079	-0.003	0.920	-0.104	**0.001*****	-0.282	**<0.001*****
Starling	Introduced	-0.069	0.246	-0.097	**0.012***	-0.035	0.374	0.039	0.297	-0.049	0.239	0.073	0.302
Welcome	Native	0.038	0.311	-0.055	**0.020***	-0.062	**0.011***	0.033	0.161	0.012	0.630	0.012	0.775
Grey warbler	Endemic	0.102	**0.001*****	-0.008	0.671	0.004	0.822	0.072	**<0.001*****	-0.093	**<0.001*****	0.034	0.310
Eastern rosella	Introduced	-0.005	0.879	-0.032	0.099	0.017	0.396	-0.024	0.215	-0.085	**<0.001*****	0.075	**0.027***
Fantail	Endemic	-0.061	**0.010****	0.016	0.288	-0.011	0.479	0.017	0.263	-0.023	0.166	0.033	0.218
Sacred	Native	-0.042	**0.026***	-0.035	**0.004****	-0.010	0.415	0.022	0.061	-0.022	0.100	0.081	**<0.001*****
Goldfinch	Introduced	0.046	0.091	-0.018	0.306	-0.031	0.089	0.007	0.670	-0.064	**0.001*****	-0.042	0.157
Pūkeko	Native	-0.039	0.132	-0.011	0.508	-0.021	0.221	0.002	0.902	-0.033	0.070	0.041	0.190
Chaffinch	Introduced	-0.014	0.506	0.054	**<0.001*****	0.016	0.229	0.009	0.490	-0.061	**<0.001*****	-0.014	0.511
Mallard	Introduced	-0.056	0.116	0.003	0.907	-0.022	0.343	-0.003	0.908	-0.050	**0.042***	0.042	0.326
Greenfinch	Introduced	0.051	**0.010****	-0.052	**<0.001*****	0.006	0.652	0.018	0.168	-0.044	**0.002****	0.040	0.076
Spurwing	Native	-0.016	0.495	-0.004	0.794	-0.073	**<0.001*****	0.025	0.084	-0.013	0.404	0.055	**0.036***
Barbary dove	Introduced	0.049	**0.003****	0.004	0.730	-0.055	**<0.001*****	-0.015	0.153	0.007	0.555	0.013	0.473
Spotted dove	Introduced	0.036	**0.033***	-0.010	0.374	-0.041	**<0.001*****	0.016	0.141	-0.032	**0.009****	-0.005	0.805
Kererū	Endemic	0.009	0.555	-0.002	0.865	0.000	0.989	-0.008	0.421	-0.031	**0.004****	0.026	0.147

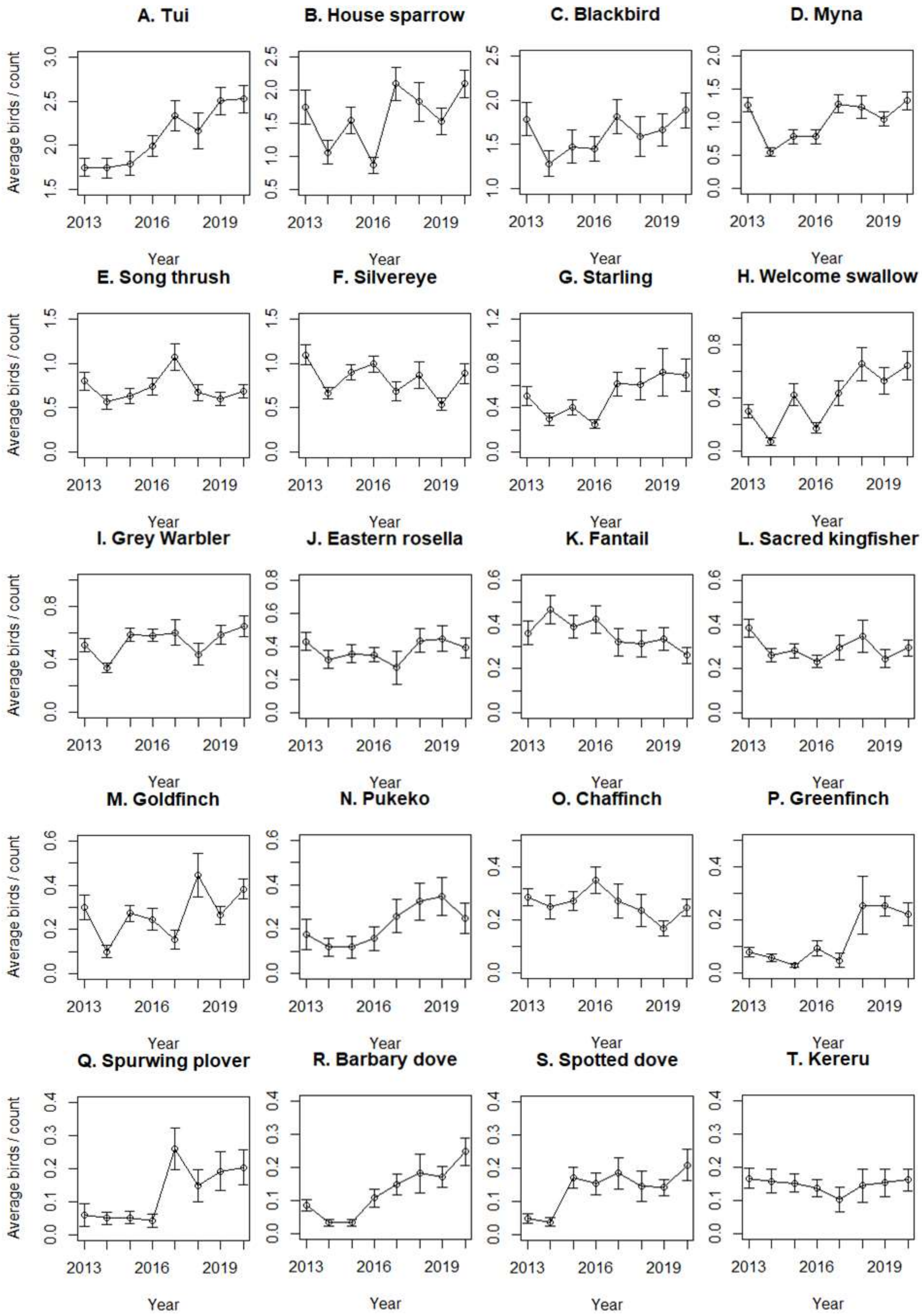

Figure 3.5: *Line graphs showing the mean abundances of common species between 2013 and 2020 using both methodologies. Mallard not included. Note that the vertical scale differs between species.*

Line graphs of common species using methodology A and B (2013 to 2020)

Figure 3.5 shows positive trends in the abundances of tūī (Figure 3.5A), welcome swallows (Figure 3.5H), greenfinches (Figure 3.5P), spurwing plovers (Figure 3.5Q), barbary doves (Figure 3.5R) and spotted doves (Figure 3.5S). The abundances of house sparrows (Figure 3.5B), starlings (Figure 3.5G), grey warblers (Figure 3.5I) and goldfinches (Figure 3.5M) fluctuated over time but also trended positively.

Pūkeko (Figure 3.5N) were trending positively though a decrease in abundance in 2020 halted this trend. Blackbirds (Figure 3.5C) and mynas (Figure 3.5D) experienced periods of decline, though abundances were roughly the same, or slightly higher in 2020 compared to 2013. The abundances of eastern rosellas (Figure 3.5J) and kererū (Figure 3.5T) remained relatively stable.

Negative trends were apparent for silvereyes (Figure 3.5F), fantails (Figure 3.5K), kingfishers (Figure 3.5L) and chaffinches (Figure 3.5O). Song thrushes (Figure 3.5E) also declined despite a positive trend between 2014 and 2017.

Scaled fixed effects model of the log transformed data using methodology A and B (2013 to 2020)

Table 3.5 shows the effect sizes and P-values for the number of individuals seen as a response variable. Station was a random effect and fixed factors include the year, day during the month, time of day, weather conditions, wind conditions, and the methodology used.

Year predicted significant increases in the abundances of tūī, silvereyes, grey warblers, goldfinches, greenfinches and barbary doves between 2013 and 2020. Spotted doves also show positive but not statistically significant trends. The abundances of fantails and kingfishers declined significantly. Song thrushes show emerging negative trends, but they were not statistically significant.

Day of November reveals that blackbirds, starlings, welcome swallows, kingfishers and greenfinches were significantly more abundant on days earlier in the month. Rosellas share this trend but with no statistical significance. In contrast, tūī, silvereyes and chaffinches were significantly more abundant on days later in the month.

Table 3.5: *Log transformed scaled fixed effects model using all 2013 to 2020 data. Number of individuals seen as a response variable is examined using the fixed factors of year, day during November, time of day, weather conditions, wind conditions, and survey method. Station is a random effect (bold = significant, * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001).*

Species	New Zealand classification	Year		November		Time		Weather		Wind		Methodology	
		Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value	Effect	P-value
Tūī	Endemic	0.026	**0.002****	0.020	**<0.001*****	-0.009	0.103	-0.006	0.288	-0.015	**0.007****	0.028	**0.003****
House sparrow	Introduced	-0.006	0.541	0.007	0.220	0.006	0.323	0.011	0.071	-0.013	**0.040***	0.012	0.300
Blackbird	Introduced	0.001	0.947	-0.012	**0.018***	-0.018	**0.001*****	-0.001	0.846	0.003	0.557	0.016	0.103
Myna	Introduced	-0.011	0.172	-0.004	0.401	-0.006	0.283	0.004	0.430	-0.016	**0.004****	0.033	**0.001*****
Song thrush	Introduced	-0.012	0.085	-0.004	0.415	-0.016	**<0.001*****	-0.009	**0.047***	0.003	0.464	0.011	0.188
Silvereye	Native	0.021	**0.007****	0.021	**<0.001*****	-0.007	0.162	-0.001	0.774	-0.022	**<0.001*****	-0.055	**<0.001*****
Starling	Introduced	-0.003	0.679	-0.010	**0.033***	-0.005	0.315	-0.002	0.699	-0.008	0.115	0.001	0.860
Welcome	Native	0.008	0.216	-0.009	**0.031***	-0.010	**0.016***	0.003	0.455	0.003	0.509	0.000	0.984
Grey warbler	Endemic	0.020	**0.001*****	-0.003	0.391	-0.001	0.898	0.015	**<0.001*****	-0.020	**<0.001*****	0.003	0.659
Eastern rosella	Introduced	0.001	0.844	-0.007	0.056	0.001	0.821	-0.003	0.374	-0.017	**<0.001*****	0.014	**0.042***
Fantail	Endemic	-0.012	**0.029***	0.003	0.356	-0.003	0.408	0.003	0.302	-0.006	0.125	0.006	0.289
Sacred	Native	-0.011	**0.020***	-0.009	**0.005****	-0.003	0.413	0.006	0.060	-0.006	0.095	0.019	**<0.001*****
Goldfinch	Introduced	0.013	**0.017***	-0.004	0.267	-0.008	**0.034***	0.002	0.555	-0.013	**0.001*****	-0.011	0.064
Pūkeko	Native	-0.007	0.108	-0.001	0.730	-0.004	0.120	0.000	0.931	-0.006	**0.037***	0.008	0.134
Chaffinch	Introduced	-0.002	0.659	0.014	**<0.001*****	0.003	0.325	0.003	0.355	-0.016	**<0.001*****	-0.005	0.345
Mallard	Introduced	-0.004	0.297	-0.002	0.499	-0.002	0.403	-0.001	0.751	-0.007	**0.011***	0.005	0.279
Greenfinch	Introduced	0.012	**0.003****	-0.013	**<0.001*****	0.001	0.719	0.005	0.090	-0.010	**<0.001*****	0.008	0.101
Spurwing	Native	-0.003	0.428	0.000	0.866	-0.014	**<0.001*****	0.003	0.227	-0.002	0.592	0.011	**0.015***
Barbary dove	Introduced	0.011	**0.006****	0.001	0.699	-0.014	**<0.001*****	-0.004	0.136	0.001	0.676	0.004	0.359
Spotted dove	Introduced	0.007	0.053	-0.002	0.405	-0.010	**<0.001*****	0.003	0.204	-0.008	**0.003****	0.000	0.959
Kererū	Endemic	0.003	0.398	0.000	0.853	0.000	0.966	-0.002	0.314	-0.007	**0.008****	0.005	0.261

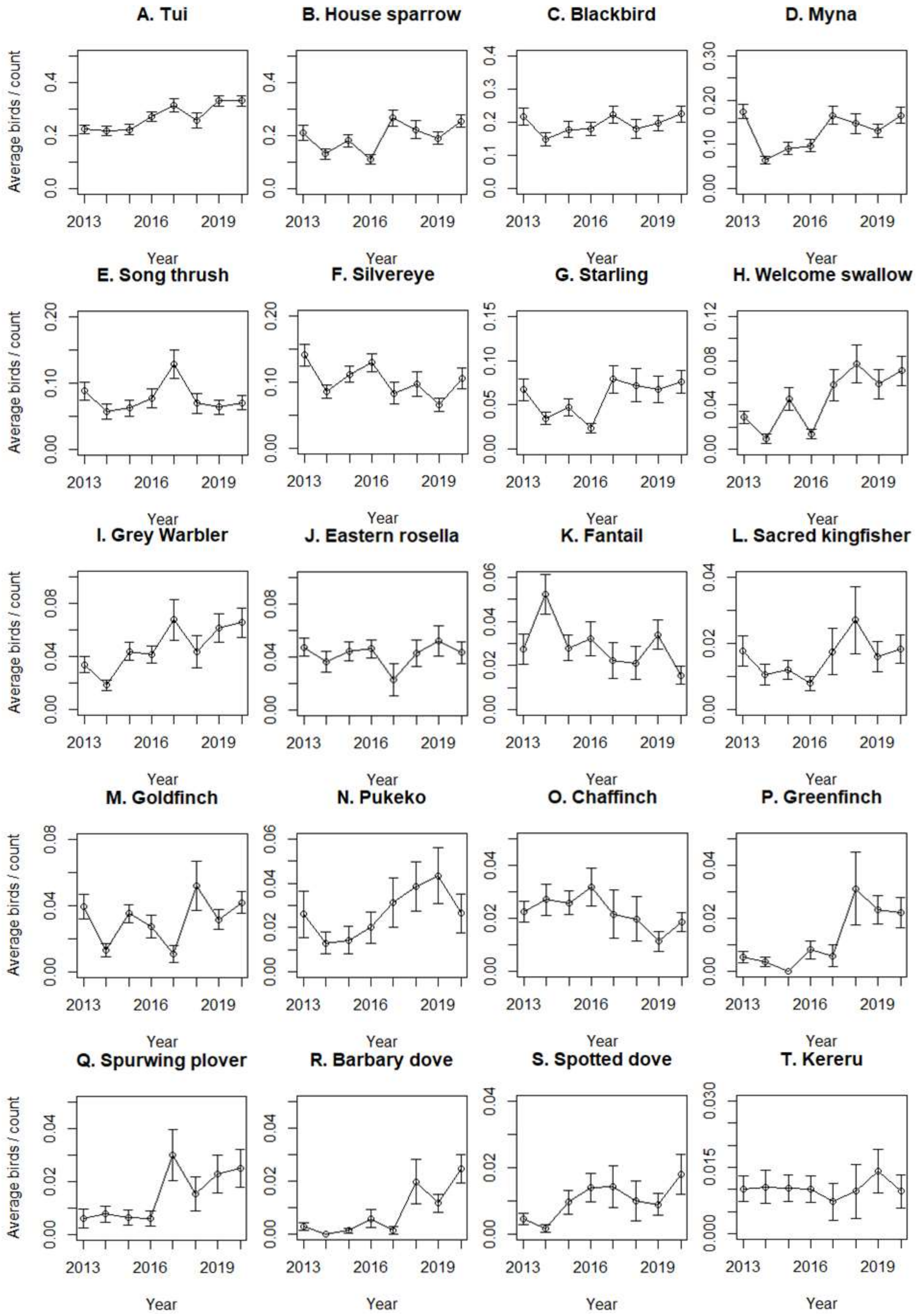

Figure 3.6: *Log transformed line graphs showing the mean abundances of common species between 2013 and 2020 using both methodologies. Mallard not included. Vertical scale differs between species.*

The time of day predicted higher abundances of blackbirds, song thrushes, welcome swallows, goldfinches, spurwing plovers, barbary doves and spotted doves earlier in the morning.

Song thrushes were significantly more abundant during fine or partly cloudy weather. Grey warblers were significantly more abundant in light rain or rain. House sparrows and greenfinches show similar but not statistically significant trends towards waning weather conditions.

Tūī, house sparrows, mynas, silvereyes, grey warblers, rosellas, goldfinches, pūkeko, chaffinches, mallards, greenfinches, spotted doves and kererū were significantly more abundant when there was no wind, or wind was light. Kingfishers share this trend but with no statistical significance.

Silvereyes were significantly more abundant when recorded under methodology A. Goldfinches share this trend but were not statistically significant. Tūī, mynas, rosellas, kingfishers and spurwing plovers were significantly more common under methodology B.

Line graphs of common species using log transformed methodology A and B data (2013 to 2020)

Figure 3.6 shows positive trends in the abundances of tūī (Figure 3.6A), welcome swallows (Figure 3.6H), grey warblers (Figure 3.6I), greenfinches (Figure 3.6P), spurwing plovers (Figure 3.6Q), barbary doves (Figure 3.6R) and spotted doves (Figure 3.6S). Pūkeko (Figure 3.6N) appeared to be increasing in abundance between 2014 and 2019 but a decline in 2020 means that abundances were relatively the same in 2020 as they were in 2013.

House sparrows (Figure 3.6B), mynas (Figure 3.6D) and starlings (Figure 3.6G) experienced periods of decline but they all had relatively similar abundances in 2013 and 2020. Goldfinches (Figure 3.6M) fluctuated, but their abundances remained relatively stable along with blackbirds (Figure 3.6C), rosellas (Figure 3.6J), kingfishers (Figure 3.6L) and kererū (Figure 3.6T).

Song thrush (Figure 3.6E) abundances declined despite a positive trend between 2014 and 2017. Negative trends were apparent for silvereyes (Figure 3.6F), fantails (Figure 3.6K) and chaffinches (Figure 3.6O).

Discussion

Mean abundance of species between 2017 and 2020 using methodology B

41 target bird species including 19 introduced, 9 native and 13 endemic species were recorded between 2017 and 2020. Similar recent biodiversity studies recorded 28 (17 introduced, 7 native, 4 endemic) and 31 (18 introduced, 8 native, 5 endemic) of these species respectively across nine volcanic cones and 19 reserves in Auckland (Hill, Pawley, & Bishop, 2020; Landers, Hill, Ludbrook, Wells, & Bishop, 2019). Comparatively, species richness – particularly of endemic birds – suggests that the avian community on the Whangaparāoa Peninsula is healthy for an urban environment.

The endemic tūī was the most abundant species recorded, with a mean abundance of 2.44. Four of the top five most abundant species were introduced and only three other species (house sparrow, blackbird, myna) had a mean abundance > 1. Of the 21 most abundant species, 12 were introduced (house sparrow, blackbird, myna, song thrush, starling, eastern rosella, goldfinch, chaffinch, mallard, greenfinch, barbary dove, spotted dove), five were native (silvereye, welcome swallow, sacred kingfisher, pūkeko, spurwing plover), and four endemic (tūī, grey warbler, fantail, kererū). The most abundant species reflect the findings of other urban bird surveys across Auckland within the same time period (Hill et al., 2020; Landers et al., 2019).

It should be considered that comparing mean abundances between bird species assumes that all species are equally detectable and does not account for the unique physical or behavioural characteristics of each species (Dawson & Bull, 1975; Hartley, 2012; Hartley & Greene, 2012). Despite this, it is probable that the order in which the most common species are recorded is approximately correct and the mean abundances are therefore a reliable reflection of the likelihood of seeing or hearing each species across the study site.

Changes in mean abundance across the study period

Tūī and barbary doves show the strongest positive trends with increases in abundance over both survey periods. These trends are apparent regardless of methodological change. Increasing abundances of tūī are consistent with the findings of the New Zealand Garden Bird survey and similar urban biodiversity surveys in Auckland (Brandt, MacLeod, Howard, Gormley, & Spurr, 2020; Hill et al., 2020). Tūī benefit greatly from pest-management, and abundances have increased dramatically following eradication and restoration planting on nearby Tiritiri Matangi Island (Galbraith & Cooper, 2013; Graham et al., 2013; Miskelly, 2018; Ruffell & Didham, 2017). Although it is difficult to quantify the forces driving change, supporting research indicates that continued pest-management and ecological restoration on the Whangaparāoa Peninsula will facilitate further increases in tūī abundance.

Barbary doves are currently somewhat infrequent across Whangaparāoa, though increases in abundance are supported by general claims of population expansion (Chambers, 2009; Heather & Robertson, 2015). Their success is likely supported somewhat by artificial food sources provided by humans (Higgins & Davies, 1996). Barbary doves are also one of the few species where observer ability does not significantly impact recorded abundances.

Blackbirds show marginal (log transformed) and significant (raw data) increases in abundance between 2017 and 2020. No trends emerge between 2013 and 2020. These short-term and longer-term results are respectively consistent with results from the New Zealand Garden Bird Survey (Brandt et al., 2020). Brandt et al. (2020) also found long-term declines in blackbird abundances throughout much of the Rodney District, thus blackbird abundances may be relatively healthy in the study site compared to the surrounding area. It should be considered that blackbirds may hinder ecological restoration as they are a significant vector in the dispersal of the seeds of weed species (Williams, 2006).

The abundances of grey warblers significantly increased between 2013 and 2020. Emerging positive trends also appear between 2017 and 2020, but with no statistical significance. There were no significant differences between the abundances of grey warblers recorded and the methodology used, so it appears that increases are likely a true biological change. Consistent future use of methodology B may confirm this. Grey warblers are common in urban areas with native vegetation, thus ecological restoration should continue to support the species (Day, 1995). However, increasing abundances of tūī may restrict grey warblers (Graham et al., 2013; Miskelly, 2018). Supplementary bird feeding by humans may also have negative impacts by displacing grey warblers from vegetation around feeders (Galbraith, Beggs, Jones, & Stanley, 2015).

The abundances of greenfinches, goldfinches and spotted doves increased with some significance between 2013 and 2020. No trends emerge between 2017 and 2020. The methodology used did not significantly impact the recorded abundances of any of the three species. Results from Brandt et al. (2020) support an increase in greenfinches, but conflict with reports of widespread declines of goldfinches across Auckland. Contradictions may arise from methodological differences – the Garden Bird Survey records the maximum number of a species recorded at one time over an hour and is held in winter when goldfinches may make local movements and form large flocks (Heather & Robertson, 2015; Higgins, Peter, & Cowling, 2006; Manaaki Whenua - Landcare Research, 2021). Small changes to large mobile flocks, or no/minimal records of flocks in some years may infer decreasing abundances. General claims support that spotted doves are increasing around Auckland (Heather & Robertson, 2015; Thomas, 2020). Spotted doves dominate urban Auckland bird feeders, thus populations may be assisted by supplementary feeding opportunities (Galbraith, Jones, Beggs, Parry, & Stanley, 2017).

Kererū abundances appear stable, though a marginally positive trend is apparent in the 2017 to 2020 log transformed data. Kererū are often sedentary and remain silent and difficult to detect when perched, thus they may be under-represented in five-minute counts (Mander, Hay, & Powlesland, 1998; Moon, 1996). The Department of Conservation acknowledges that five-minute distance estimates cannot detect changes in kererū abundances < 30% in small forested areas 200 m x 200 m with < 25 stations (Mander et al., 1998). In contrast to my results, Brandt et al. (2020) found an increase in the study site of > 100% between 2014 and 2019 with hour long counts. Extended survey durations may increase the detection of kererū (Johnson, 1995). Kererū are also one of the few common endemic species that significantly benefit from pest-control (Ruffell & Didham, 2017). They experienced positive breeding success following rat control at nearby Wenderholm Regional Park, and abundances reported on Tiritiri Matangi between 2006 and 2010 mirror my results, inferring that populations are healthy on the Whangaparāoa Peninsula (Clout, Denyer, James, & McFadden, 1995; Graham et al., 2013). Kererū have remained stable, though evidence suggests that the current methodology is insufficient to detect change in abundance. Separate biodiversity surveys with extended durations may be required for more accurate kererū counts.

There were no significant changes in the abundances of house sparrows, chaffinches or mynas. These findings are generally supported by Brandt et al. (2020). Chaffinch abundances appear somewhat healthy in Whangaparāoa as declines are reported throughout most of the Rodney District (Brandt et al., 2020). Mynas are considered a pest species as they compete for food and nesting sites with native birds and prey upon indigenous fauna (Grarock, Tidemann, Wood, & Lindenmayer, 2012; NZ Landcare Trust, 2016; Tiritiri Matangi Open Sanctuary, 2010a). Although their abundances are not currently increasing, future management may be required to minimise their impacts on native and endemic birds.

The abundances of welcome swallows, eastern rosellas and spurwing plovers also show no change. Welcome swallows remained stable on Tiritiri Matangi between 1987 and 2010, and national populations are stable (Graham et al., 2013; Robertson et al., 2017). Rosella abundances may be underestimated due to their behaviour (Galbraith, Fraser, Clout, & Hauber, 2011). Galbraith et al. (2011) recommends survey durations of 25 minutes for accurate rosella counts. Pūkeko abundances have also remained stable, though positive trends were emerging until 2020.

Abundances of both fantails and sacred kingfishers remained stable between 2017 and 2020, though significant declines are apparent between 2013 and 2020. Kingfisher abundances are significantly higher under methodology B, thus declines may be greater than they appear. Declines in both species may be a result of competition for food or nesting sites with mynas, starlings, house sparrows, tūī, or whiteheads (Graham et al., 2013; Grarock et al., 2012; Higgins, 1999; Miskelly, 2018). It appears that the abundances of fantails and kingfishers have stabilised, though future research may reveal further declines, particularly in response to predicted increases of tūī (Graham et al., 2013; Miskelly, 2018).

Silvereye abundances decreased between 2017 and 2020 but increased between 2013 and 2020. The species has experienced declines throughout New Zealand including most of the surrounding Rodney District over the past 10 years, and Tiritiri Matangi since 1987 (Brandt et al., 2020; Graham et al., 2013; Miskelly, 2018). Reasons for decline are not well understood. Silvereyes may be particularly sensitive to predation – they are common victims of domestic cats in Auckland, and abundances are negatively impacted by mynas, though there is little evidence to suggest that pest-management has a significant positive impact on the species (Gillies & Clout, 2003; Grarock et al., 2012; O'Donnell & Hoare, 2012; Ruffell & Didham, 2017). Silvereyes were more abundant under methodology A, likely as they are small, fast-moving and often identified at close-range by their high-pitched calls (Heather & Robertson, 2015). A smaller survey area may increase their detection rate by reducing distraction from species further afield. Volunteers with greater skill levels also recorded silvereyes in higher abundances, so beginner birders may have under-represented their true numbers. However, this is possible for almost all common species. It is difficult to establish the reasons for change in silvereye populations in New Zealand, this research included. Future research may help explain trends.

The abundances of song thrushes, starlings and mallards declined significantly between 2017 and 2020. Mallard populations have been in national decline since 1985, and Brandt et al. (2020) reports declines in starling abundances (Heather & Robertson, 2015). Declines in starlings may be a result of harassment or competition with mynas (Higgins et al., 2006). Starlings may limit native and endemic cavity-nesting birds, though there is little evidence to support this in New Zealand (Flux, 2017).

There is also significant evidence that song thrushes declined between 2013 and 2020. As methodological changes increased the size of areas surveyed, it is logical to assume that decreases in the mean abundance of song thrushes over the full set of data represents a true biological change. Brandt et al. (2020) also reports declines in the study area and surrounding Rodney District between 2009 and 2019. The reasons for change are unknown, though declines over three decades in Britain were linked to high juvenile mortality – possibly in relation to predators, pesticides, farming practices, land drainage and adverse weather conditions (Robinson, Green, Baillie, Peach, & Thomson, 2004). Song thrushes are also common prey to domestic cats in Auckland (Gillies & Clout, 2003).

Conclusions

The endemic tūī was the most abundant species recorded between 2017 and 2020. Abundances of 17 of the most common bird species remained either stable or had significant increases between 2017 and 2020. The same can be said for 18 species between 2013 and 2020. The strongest positive trends in abundance were seen in tūī and barbary doves. Declines seen in fantails and sacred kingfishers between 2013 and 2020 stabilised between 2017 and 2020 and may be a result of complex interactions which indicate a positive community shift towards improving conditions for native and endemic bird species on the Whangaparāoa Peninsula. Declining trends in common native and endemic bird species may re-emerge as competitive endemic species become more abundant (Graham et al., 2013; Miskelly, 2018).

Various factors likely contribute to the results found, though these findings coupled with the successful reintroduction of four endemic species to Shakespear Open Sanctuary suggest that effective pest-management and ecological restoration have contributed to preventing the decline of most endemic, native, and introduced bird species on the Whangaparāoa Peninsula. The bird community is expected to continue changing because of conservation management and alterations to the urban landscape. Future surveys using consistent and established methodology will help confirm the current trends and emerging patterns found in this research. The results from the formative years of this urban restoration project will provide valuable information for other similar urban restoration projects in New Zealand and on island nations.

Chapter 4

Spatial analysis of common endemic, native, and introduced bird species on the Whangaparāoa Peninsula, New Zealand

Abstract

New Zealand's urban landscapes are transformed and fragmented. Urban bird communities are often characterised by low species richness and greater abundances of introduced bird species. In 2011, Forest and Bird launched the Pest-Free Hibiscus Coast project – a community-driven restoration project that aims to eradicate rats, stoats and possums from the Whangaparāoa Peninsula. To evaluate the effects of pest-management on the bird community, volunteers associated with Forest and Bird conducted annual November five-minute stationary bird counts between 2017 and 2020. A total of 1,181 surveys were completed across 17 locations. Using GIS (geospatial information systems), I analysed species richness, the relative abundances of species categorised as endemic, native and introduced, and the relative abundances of selected focal bird species in relationship to habitat characteristics at the location. The richness of endemic bird species was more than double that of similar recent biodiversity surveys across the Auckland area. I found relative abundances of > 0.5 for endemic and native species at locations that had an average > 65% coverage of woody and marshland vegetation. Principal component analysis revealed greater abundances of the four most common endemic species at locations where there were more natural features and less manmade features, and vice versa for the four most common introduced species. The four most common native species had mixed habitat preferences. These analyses indicate that in addition to predator control, natural habitats are vital for endemic and some native species in urban areas. This research reveals locations of interest for conservation management and provides valuable data for similar urban restoration projects in New Zealand.

Introduction

Around ¾ of the Earth's terrestrial surface has been modified by humans over the past 50,000 years (Ellis, 2015). New Zealand has experienced rapid widespread deforestation and habitat destruction in a comparatively short period of time (Holdaway, 1989; McGlone, 1989). Approximately 85% of New Zealand's landmass was covered with indigenous forest when humans first arrived some 800 years ago (Guild & Dudfield, 2009; Taylor & Smith, 1997; Te Papa Collections Online, 2004). Following centuries of harvest for dwellings and resources, as well as fires lit to clear land for occupation, agriculture, transport and hunting, just 23% of the original forest cover remains (McGlone, 1983; Taylor & Smith, 1997; Te Papa Collections Online, 2004; Turbott, 1961). In addition, humans drained swamps and wetlands, modified tussock grasslands, created pastures, built cities, urban landscapes and roads, and replaced indigenous forest with exotic plantations that do not represent the original floral community (Clout & Gaze, 1984; Taylor & Smith, 1997; Turbott, 1961). Patterns in New Zealand's vegetation roughly stabilised by the 1930s, though an estimated 4 ha of natural habitat is still destroyed each day (Holdaway, 1999; Te Papa Collections Online, 2004).

Urban bird communities are often characterised by low species richness, greater abundances of introduced bird species, and an increase in total bird abundance (Catterall, Green, & Jones, 1989). Native species that occupy lowland ecosystems – especially those in areas with high anthropogenic activity – are exposed to threats such as urban, industrial and transport activities, pollution, habitat loss and modification, competition, predation from exotic species, and the effects of climate change (Grimm et al., 2008; McGlone, 1989; Sala et al., 2000; Taylor & Smith, 1997). Conservationists must assess these threats and their combined impacts to maximise the desired effects from their management decisions.

Hibiscus Coast Forest and Bird launched the Pest-Free Hibiscus Coast programme in 2011 with the aim of creating a refuge for native flora and fauna by eradicating rats, stoats and possums from the Whangaparāoa Peninsula (Forest and Bird, 2020). The area and its surrounding suburbs are primarily residential and are home to a rising population of more than 44,500 (Stats NZ, 2018). The Whangaparāoa Peninsula also features a diverse community of native and endemic birds, insects and lizards, and provides an important stepping-stone habitat for species travelling between Tiritiri Matangi and the mainland beyond the peninsula (Forest and Bird, 2020; North-West Wildlink, 2017).

Effective biodiversity conservation in urban New Zealand requires an understanding of how endemic, native, and introduced species use the environment. Loss of suitable natural habitat and predation from exotic mammals are interacting forces that are driving native forest bird decline and extirpation (Innes et al., 2010; Ruffell & Didham, 2017). Efforts to re-establish native bird populations across Whangaparāoa include amplifying predator trap and bait lines, planting native vegetation, controlling weeds, and reintroducing endemic bird species to Shakespear Open Sanctuary – a predator-free fenced ecosanctuary at the eastern end of the peninsula (Auckland Council, 2018a, 2018b; Forest and Bird, 2018c, 2020; SOSSI, 2015, 2017). Combined, these processes will guide regeneration so the ecological community can better resemble its natural composition. In turn, species that have become locally extinct can safely return to the area naturally, or by translocation (Ralph et al., 2020).

To monitor the impacts of pest-management and habitat restoration on the local bird community, Hibiscus Coast Forest and Bird conducted annual November five-minute stationary bird counts between 2017 and 2020. Here, I explored how natural and manmade landscape features impact the species richness and relative abundances of endemic, native, and introduced bird species. Using satellite images, I quantified the landscape features found within a 1 ha circle around each survey station in a two-dimensional plane. Using a GIS (geographic information systems) approach coupled with principal component analysis, I predicted that the relative abundances of common endemic species would be greater in areas that have more natural features and less manmade features, and vice versa for common introduced species. I also predicted that common native species – some of which are recent colonisers – would show intermediate patterns, depending on the species. Understanding the environments that different bird species utilise in urban environments is critical in order to maximise the effectiveness of conservation effort and resources.

The findings reported in this chapter will aid Forest and Bird in pest-management and ecological restoration across the Whangaparāoa Peninsula and will provide valuable insight for similar urban restoration projects in New Zealand.

Methods

Study site and sample design

Field research took place on the Whangaparāoa Peninsula, a narrow 11 km stretch of land 25 kms north of Auckland City on the east coast of New Zealand's North Island. A total of 17 locations, each with 5 nested stations were monitored between 2017 and 2020 using five-minute stationary bird counts. 14 locations (70 stations) were monitored in 2017. The study area expanded to include the adjacent mainland suburbs of Kingsway, Millwater and Ōrewa in 2018, increasing the study site to 17 locations (85 stations) from 2018. Locations and the positions of stations were selected by Hibiscus Coast Forest and Bird. Habitats included urban streets, parks, gardens, grass fields, exotic forest, native forest remnants, shrublands, wetlands, and the boundaries of estuaries and ponds. A map of the locations and stations is provided in Figure 4.1. Detailed descriptions of each location including cultural significance, known vegetation, pest-management and rules regarding dogs is provided in Appendix 1.

All data were collected between the hours of 6.00 am and 1.00 pm on days that were convenient for the volunteer. To standardise conditions and to minimise influence on bird behaviour and the ability of observers to detect birds, it was requested that surveys took place on fine, calm days that lacked strong winds or heavy precipitation (Hartley & Greene, 2012). November was selected as it is the breeding season for most of New Zealand's bird species, and they are more conspicuous in their vocalisations, activities, and territorial and courtship displays (Cockrem, 1995; Graham et al., 2013). Bird communities are also more speciose in November because migrating species such as the shining cuckoo (*Chrysococcyx lucidus*) and long tailed-cuckoo (*Eudynamys taitensis*) return to New Zealand to breed (Graham et al., 2013; Heather & Robertson, 2015).

Field methods

Volunteers were typically assigned three to four locations (15 to 20 stations) each year. Forest and Bird aimed to survey each station at least three times by three different volunteers each November, though this was not always possible.

Upon arrival at a station, volunteers waited quietly for two minutes to reduce the risk of disturbance and to allow birds to settle. Volunteers noted their self-described birding ability, the date, time of day, location name, and the weather and wind conditions on the data sheet. After the two minutes, volunteers recorded all birds that could be positively identified at or flying above the station using sight and sound for five minutes. Care was taken to avoid counting the same individual bird more than once. Upon conclusion of the five minutes, volunteers moved to the next station and repeated the process. Some target bird species were added over the course of research. Changes to target species can be found in Appendix 2. An example of the 2020 data sheet is provided in Chapter 2, Figure 2.8.

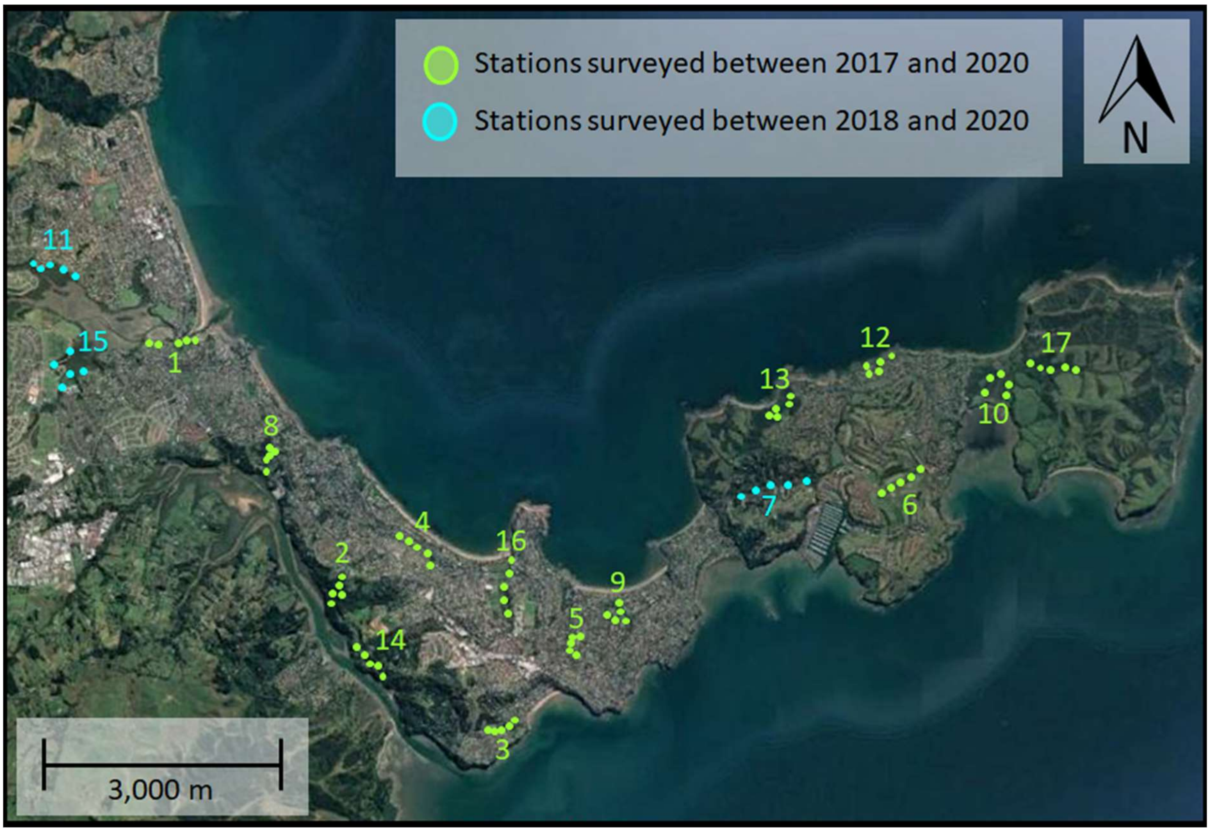

Figure 4.1: *Map of the Whangaparāoa Peninsula showing the locations and each station surveyed between 2017 and 2020. Locations (alphabetical order) include Amorino Park[1], Archer's Block[2], Arkles Bay Stormwater Pond[3], D'Oyly Reserve[4], Edith Hopper Park[5], Gulf Harbour Drive[6], Hobbs Road[7], Karaka Cove[8], Manly Park[9], Okoromai Bay[10], Ōrewa Lakeside Drive[11], Pacific Parade[12], Peter Snell Village[13], Riverhaven Drive[14], Silverdale Kingsway[15], Stanmore Bay Park[16], Waterfall Gully[17]. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Landscape feature analysis

Landscape features were analysed by measuring a 1 ha circle around each survey station using Google Earth Pro version 7.3.3.7699 (2020). A two-dimensional aerial screenshot of each station was taken at a height of 45 m and imported into ImageJ version 1.53b (Rasband, 2020). Outlines were traced around the landscape categories within each circle using the polygons selection tool. Categories were defined as: 1. Grass (including unvegetated soil, bark and dirt tracks), 2. Trees (including shrubbery, mangroves, wetland vegetation), 3. Buildings (including houses, sheds, playground structures), 4. Anthropogenic surfaces (including roads, carparks, sealed tracks, footpaths, pavers, empty stormwater drains, sports courts), 5. Water (including stormwater ponds, streams, estuaries, ocean, tidal mudflats, sand, rocks, pools) and 6. Marshes (low vegetation such as glasswort (*Salicornia sp.*)). Pixel counts were calculated using the histogram tool, and the percentage of landscape features at each station was calculated by dividing the number of pixels in each category by the total pixel count of each circle.

Software and statistical analysis

Statistical analysis was performed using R version 4.0.3 in RStudio desktop 1.3.1093 (2020). Classification richness includes every species that was recorded at any of the five stations across all years (2017 to 2020) at each location. Classifications include "introduced," "endemic" and "native." "Introduced" species are species that are found in New Zealand as a result of anthropogenic introduction over the past 180 years. "Endemic" species are native species that evolved and are found only in New Zealand. "Native" species are species that are also found in other countries and have naturally colonised New Zealand without the aid of humans.

In this analysis I consider both species richness and abundance. I also report the evenness of species richness from each classification (i.e. endemic, native or introduced) at each location, defined as "proportion". Survey effort differed between stations, locations, and years. Mean classification abundance estimates were calculated by summing the annual means of each classification at each station within a location, divided by the number of stations within the location (five), and summing all means from each location divided by the number of years the location was surveyed. The relative mean abundance for each classification was also calculated to infer species composition at each location.

Figure 4.2: *Aerial view showing landscape feature analysis at A. Arkles Bay Stormwater Pond station 2, B. Gulf Harbour Drive station 3, C. Lakeside Drive station 2, D. Okoromai Bay station 2, E. Pacific Parade station 1 and F. Waterfall Gully station 5. Satellite images taken 24 April 2019, adapted from Google Earth Pro (2020).*

The mean coverage of landscape features at each location was calculated by combining the percentage of each category from all five stations at a location and dividing by five. GIS maps were produced using the r-packages maptools, mapplots and prettymapr. Because different habitat types can covary with each other, I used principal component analysis to create composite variables from each landscape feature category. Principal component scores vary orthogonally to each other, and so this allowed me to understand which key habitat characteristics were reliable predictors of focal species abundances. The focal species (henceforth "common" species) were selected in Chapter 3 (Figure 3.2) by organising species into descending order by overall abundance to determine the four most abundant species from each classification of endemic, native, and introduced. These species are among the most frequently recorded bird species across the study site, and their abundances provide sufficient statistical power to infer trends of each classification.

Limitations in methodology

It is well known that bird count data are noisy. No individual method is perfect for monitoring all species of birds across different habitats (Dowding, 2012). Birds are often quick and highly mobile, and some species are cryptic which impacts their detectability (Dowding, 2012). Volunteers may differ in their ability to identify birds by sight and sound. They may also be limited by their capacity to see or hear birds, and their ability to accurately identify species and their numbers (Dawson & Bull, 1975; Hartley, 2012; Hartley & Greene, 2012). Environmental factors and urban distractions such as traffic or dog walkers may affect bird behaviour or hinder the ability of volunteers to detect birds (Dawson & Bull, 1975; Hartley & Greene, 2012). In order to reduce some of this noise, some surveys were removed from the data pool. The reasons for this are discussed in detail in Chapter 2 under the "amendments to raw data" section.

The number of stations surveyed made biomass estimates of the native and introduced floral species at each station impractical. Accordingly, landscape feature analysis is based on coverage percentage from a two-dimensional aerial view. The maturity and height of vegetation is not considered.

Results

Species recorded between 2017 and 2020

A total of 1,181 five-minute stationary bird counts were analysed. 41 of the 44 target species were recorded at least once. This includes 19 introduced, 13 endemic, and 9 native species.

Table 4.1: *Table showing each species recorded between 2017 and 2020.*

Common name	Scientific name	Classification
Australian magpie	*Gymnorhina tibicen*	Introduced
Barbary dove	*Streptopelia risorii*	Introduced
Bellbird	*Anthornis melanura*	Endemic
Brown quail	*Coturnix ypsilophora*	Introduced
California quail	*Callipepla californica*	Introduced
Chaffinch	*Fringilla coelebs*	Introduced
Common myna	*Acridotheres tristis*	Introduced
Common pheasant	*Phasianus colchicus*	Introduced
Common starling	*Sturnus vulgaris*	Introduced
Dunnock	*Prunella modularis*	Introduced
Eastern rosella	*Platycercus eximius*	Introduced
Eurasian blackbird	*Turdus merula*	Introduced
Eurasian skylark	*Alauda arvensis*	Introduced
European goldfinch	*Carduelis carduelis*	Introduced
European greenfinch	*Carduelis chloris*	Introduced
Grey warbler	*Gerygone igata*	Endemic
House sparrow	*Passer domesticus*	Introduced
Long-tailed cuckoo	*Eudynamys taitensis*	Endemic
Mallard	*Anas platyrhynchos*	Introduced
New Zealand fantail	*Rhipidura fuliginosa*	Endemic
Kererū	*Hemiphaga novaseelandiae*	Endemic
New Zealand pipit	*Anthus novaseelandiae*	Endemic
North Island saddleback	*Philesturnus rufusater*	Endemic
North Island tomtit	*Petroica macrocephala toitoi*	Endemic
Paradise shelduck	*Tadorna variegate*	Endemic
Pūkeko	*Porphyrio melanotus*	Native
Red-crowned parakeet	*Cyanoramphus novaezelandiae*	Endemic
Sacred kingfisher	*Todiramphus sanctus*	Native
Shining cuckoo	*Chrysococcyx lucidus*	Native
Silvereye	*Zosterops lateralis*	Native
Song thrush	*Turdus philomelos*	Introduced
Spotless crake	*Porzana tabuensis*	Native
Spotted dove	*Streptopelia chinensis*	Introduced
Spur-winged plover	*Vanellus miles*	Native
Stitchbird	*Notiomystis cincta*	Endemic
Swamp harrier	*Circus approximans*	Native
Tūī	*Prosthemadera novaeseelandiae*	Endemic
Welcome swallow	*Hirundo neoxena neoxena*	Native
White-faced heron	*Egretta novahollandiae*	Native
Whitehead	*Mohoua albicilla*	Endemic
Yellowhammer	*Emberiza citronella*	Introduced

Mean richness and proportions of species classification

The lowest total number of species recorded was 21 at Manly Park. The highest total number of species recorded was 35 at Okoromai Bay. The mean number of species recorded was 26.65.

The mean proportions of species classification were 0.55 introduced, 0.24 native and 0.21 endemic. This community make-up was relatively consistent across most locations. Exceptions include Ōrewa Lakeside Drive which had a high richness of introduced species and low richness of endemic species. Endemic species comprised > 0.25 at Archer's Block, Gulf Harbour Drive, Okoromai Bay and Waterfall Gully. See Figure 4.1 for location references.

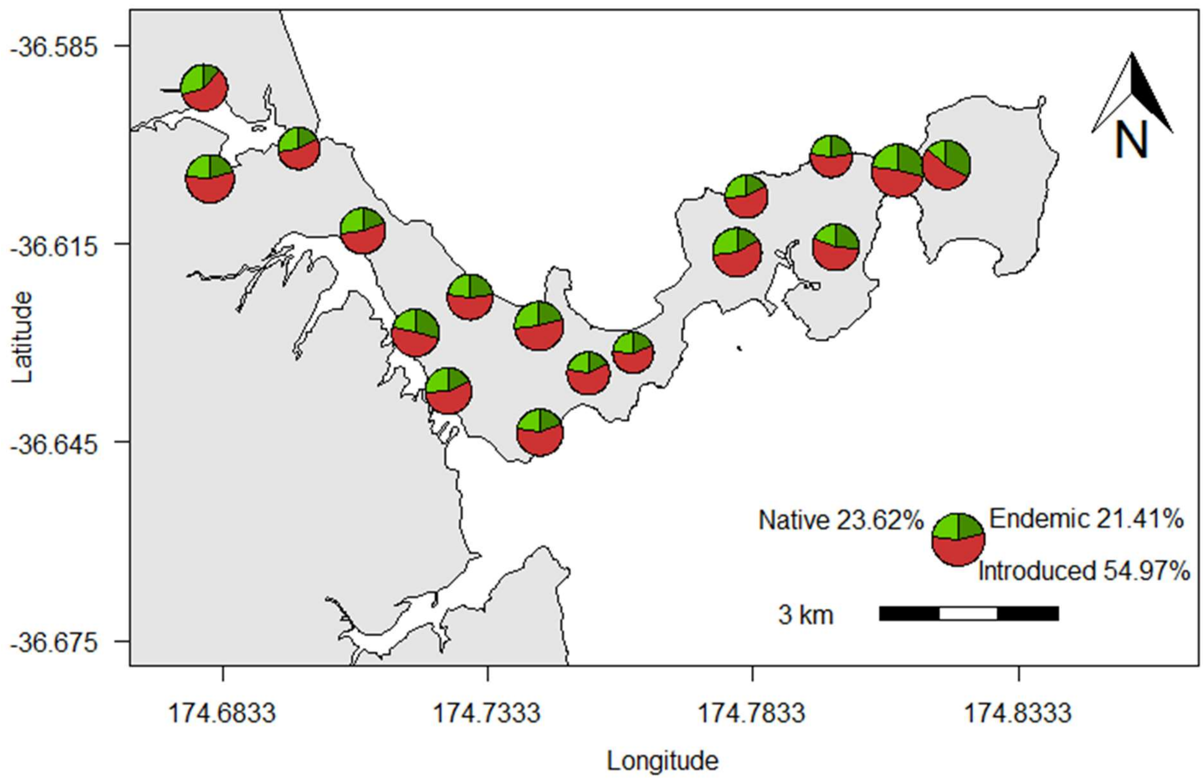

Figure 4.3: *GIS showing the proportion of species classification across each location. Pie chart size indicates species richness – smaller circles indicate less species; larger circles indicate more species.*

An average of 14.65 introduced species were recorded, and the mean proportion of introduced species was 0.552. The lowest number of introduced species was 12 at Amorino Park, Manly Park, and Pacific Parade. The highest number of introduced species was 17 at Hobbs Road and Okoromai Bay. Okoromai Bay also had the lowest proportion of introduced species (0.486) and was the only location where introduced species proportions were < 0.5. The highest proportion of introduced species was 0.609 at Edith Hopper Park.

An average of 6.29 native species were recorded, and the mean proportion of native species was 0.237. The lowest richness of native species was four at Waterfall Gully, which also had the lowest proportion of native species (0.133). The highest number of native species was eight at Hobbs Road, Okoromai Bay, Ōrewa Lakeside Drive and Stanmore Bay Park. Ōrewa Lakeside Drive also had the highest proportion of native species (0.296).

An average of 5.71 endemic species were recorded, and the mean proportion of endemic species was 0.214. The lowest number of endemic species was three at Ōrewa Lakeside Drive, which also had the lowest proportion of endemic species (0.111). The highest richness of endemic species was 10 at both Okoromai Bay and Waterfall Gully. Waterfall Gully also had the highest proportion of endemic species (0.333).

Table 4.2: *Table showing species richness and the proportions of species classification across locations.*

Location	Introduced species	Native species	Endemic species	Total
Amorino Park	12 (0.546)	6 (0.273)	4 (0.182)	22
Archer's Block	14 (0.5)	6 (0.214)	8 (0.286)	28
Arkles Bay Stormwater Pond	16 (0.593)	6 (0.222)	5 (0.185)	27
D'Oyly Reserve	14 (0.539)	6 (0.231)	6 (0.231)	26
Edith Hopper Park	14 (0.609)	5 (0.217)	4 (0.174)	23
Gulf Harbour Drive	15 (0.556)	5 (0.185)	7 (0.259)	27
Hobbs Road	17 (0.567)	8 (0.267)	5 (0.167)	30
Karaka Cove	14 (0.539)	7 (0.269)	5 (0.192)	26
Manly Park	12 (0.571)	5 (0.238)	4 (0.191)	21
Okoromai Bay	17 (0.486)	8 (0.229)	10 (0.286)	35
Ōrewa Lakeside Drive	16 (0.593)	8 (0.296)	3 (0.111)	27
Pacific Parade	12 (0.546)	5 (0.227)	5 (0.227)	22
Peter Snell Village	13 (0.565)	6 (0.261)	4 (0.174)	23
Riverhaven Drive	15 (0.556)	7 (0.259)	5 (0.185)	27
Silverdale Kingsway	16 (0.552)	7 (0.241)	6 (0.207)	29
Stanmore Bay Park	16 (0.533)	8 (0.267)	6 (0.2)	30
Waterfall Gully	16 (0.533)	4 (0.133)	10 (0.333)	30
Mean	14.647 (0.55)	6.294 (0.236)	5.706 (0.214)	26.647

Mean abundances and relative abundances of bird classifications

The mean abundance (i.e. the total number of birds seen of all species) across all locations was 14.344 individual birds per five-minute survey (Table 4.3). Introduced species had a mean abundance of 8.492 and a mean relative abundance of 0.59. Native species had a mean abundance of 2.197 and a mean relative abundance of 0.15. Endemic species had a mean abundance of 3.655 and a mean relative abundance of 0.25. There were three clusters of locations where introduced species dominated, and vice versa with native and endemic species combined.

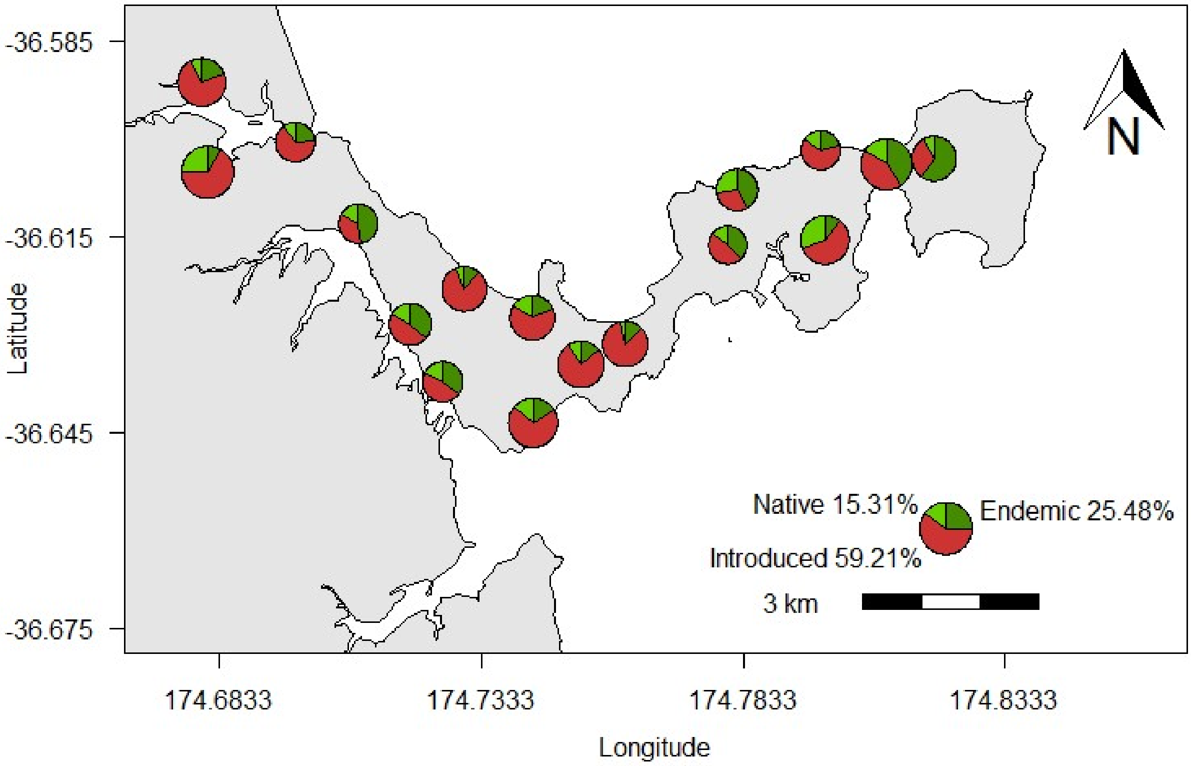

Figure 4.4: *GIS showing the mean relative abundance of species classification across each location. Pie chart sizes indicate bird abundance – smaller circles indicate lower total abundances; larger circles indicate greater total abundances.*

Clusters where all locations had > 0.5 mean relative abundance of introduced species include 1. Ōrewa Lakeside Drive, Silverdale Kingsway and Amorino Park, 2. D'Oyly Reserve, Stanmore Bay Park, Arkles Bay Stormwater Pond, Edith Hopper Reserve and Manly Reserve, and 3. Gulf Harbour Drive and Pacific Parade. Clusters where all locations had > 0.5 mean relative abundance of native/endemic species include 1. Karaka Cove, Archer's Block and Riverhaven Drive, 2. Hobbs Road and Peter Snell Village, and 3. Okoromai Bay and Waterfall Gully.

Hobbs Road had the lowest mean abundance of birds with 10.477. Silverdale Kingsway had the highest mean abundance of birds with 19.677.

Karaka Cove had the lowest mean abundance of introduced birds with 3.771, however, Peter Snell Village had the lowest relative mean abundance with 0.309. In contrast, Silverdale Kingsway had the highest mean abundance of introduced birds with 13.105, and Manly Park had the highest mean relative abundance with 0.833.

Table 4.3: *Table showing the mean abundance and mean relative abundance of species classification at each location.*

Location	Mean introduced	Mean native	Mean endemic	Mean total count
Amorino Park	7.291 (0.651)	1.184 (0.106)	2.718 (0.243)	11.193
Archer's Block	6.047 (0.473)	2.082 (0.163)	4.663 (0.365)	12.792
Arkles Bay Stormwater Pond	12.326 (0.706)	2.384 (0.137)	2.752 (0.158)	17.462
D'Oyly Reserve	11.984 (0.826)	0.852 (0.059)	1.676 (0.115)	14.512
Edith Hopper Park	11.96 (0.769)	1.527 (0.098)	2.067 (0.133)	15.554
Gulf Harbour Drive	10.039 (0.592)	5.229 (0.308)	1.699 (0.1)	16.967
Hobbs Road	4.94 (0.472)	1.573 (0.15)	3.963 (0.378)	10.477
Karaka Cove	3.771 (0.342)	1.933 (0.175)	5.333 (0.483)	11.037
Manly Park	12.312 (0.833)	0.505 (0.034)	1.962 (0.133)	14.779
Okoromai Bay	8.166 (0.434)	3.036 (0.161)	7.601 (0.404)	18.802
Ōrewa Lakeside Drive	12.185 (0.729)	1.379 (0.083)	3.141 (0.188)	16.705
Pacific Parade	6.867 (0.626)	1.742 (0.159)	2.358 (0.215)	10.967
Peter Snell Village	3.86 (0.309)	3.402 (0.272)	5.243 (0.419)	12.505
Riverhaven Drive	5.425 (0.465)	2.104 (0.18)	4.138 (0.355)	11.667
Silverdale Kingsway	13.105 (0.666)	4.903 (0.249)	1.669 (0.085)	19.677
Stanmore Bay Park	9.389 (0.649)	2.353 (0.163)	2.717 (0.188)	14.459
Waterfall Gully	4.7 (0.329)	1.153 (0.081)	8.433 (0.59)	14.286
Mean	8.492 (0.592)	2.197 (0.153)	3.655 (0.255)	14.344

Manly Park had the lowest mean abundance of native birds with 0.505, and the lowest mean relative abundance with 0.034. D'Oyly Reserve, Edith Hopper Drive, Ōrewa Lakeside Drive and Waterfall Gully also recorded native mean relative abundances of < 0.1. Gulf Harbour Drive had the highest mean abundance of native species with 5.229, as well as the highest mean relative abundance with 0.308.

Silverdale Kingsway had the lowest mean abundance of endemic birds with 1.669, and the lowest mean relative abundance with 0.085. D'Oyly Reserve, Edith Hopper Park, Gulf Harbour Drive and Manly Park also recorded endemic mean relative abundances of < 0.15. Waterfall Gully had the highest mean abundance of endemic birds with 8.433, and the highest mean relative abundance with 0.59.

Mean coverage of landscape features at each location

Trees and grass were the two most common landscape categories, and were the only categories present at all locations. Karaka Cove, Archer's Block, Riverhaven Drive, Peter Snell Village and Waterfall Gully all had > 0.75 tree coverage. Waterfall Gully had the highest coverage of tree habitat with 0.97. Ōrewa Lakeside Drive, Silverdale Kingsway, Stanmore Bay Park, Hobbs Road and Okoromai Bay also had > 0.5 tree coverage. Arkles Bay Stormwater Pond had the lowest coverage of trees (0.26). It also had the highest coverage of anthropogenic surfaces with 0.21, and one of the highest coverages of buildings with 0.12.

Grass coverage was > 0.25 at Silverdale Kingsway, Amorino Park, D'Oyly Drive, Stanmore Bay Park, Arkles Bay Stormwater Pond, Edith Hopper Park, Manly Park, Gulf Harbour Drive and Okoromai Bay.

Buildings were present at all locations excluding Archer's Block, Okoromai Bay and Waterfall Gully. Pacific Parade had the highest building coverage (0.14). Anthropogenic surfaces were present at all locations except Peter Snell Village and Waterfall Gully.

Water was present at 10 of the 17 locations, but was only > 0.05 at Amorino Park, Arkles Bay Stormwater Pond, Pacific Parade and Stanmore Bay Park. Marsh habitat was present at six locations but had < 0.02 coverage at five locations. Marsh accounted for 0.16 coverage at Okoromai Bay.

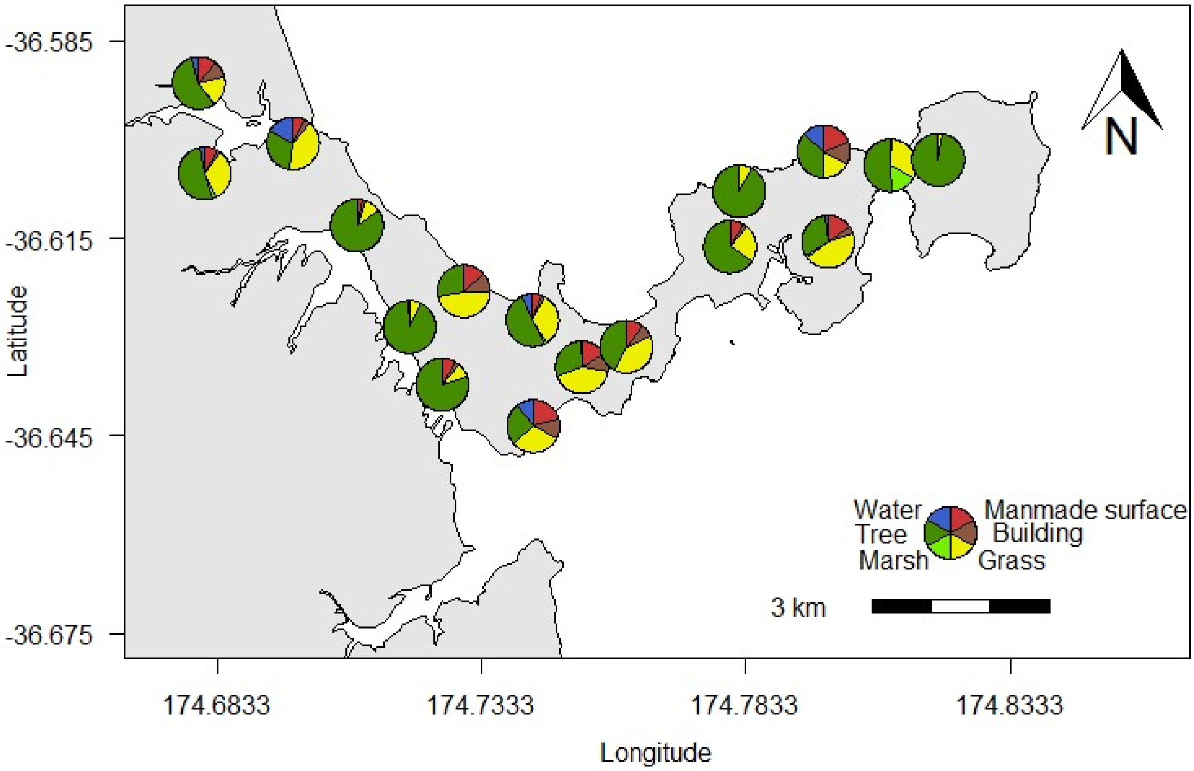

Figure 4.5: *GIS showing pie charts of the mean relative coverage of landscape categories at locations.*

Table 4.4: *Mean relative coverage of landscape categories at locations.*

Location	Grass	Tree	Building	Manmade surface	Water	Marsh
Amorino Park	40.92%	31.3%	4.57%	6.34%	16.87%	0%
Archer's Block	7.26%	92.14%	0%	0.17%	0.43%	0%
Arkles Bay Stormwater Pond	30.83%	25.73%	12.06%	20.87%	10.51%	0%
D'Oyly Reserve	45.83%	27.72%	12.59%	13.31%	0.55%	0%
Edith Hopper Park	42.34%	29.65%	11.17%	16.24%	0.6%	0%
Gulf Harbour Drive	45.41%	31.71%	4.05%	15.35%	1.92%	1.56%
Hobbs Road	23.24%	65.55%	2.81%	8.4%	0%	0%
Karaka Cove	10.45%	84.08%	1.82%	3.65%	0%	0%
Manly Park	38.89%	43.25%	6.86%	11%	0%	0%
Okoromai Bay	31.93%	51.2%	0%	1.32%	0%	15.55%
Ōrewa Lakeside Drive	17.7%	55.61%	10.37%	11.33%	4.49%	0.49%
Pacific Parade	16.66%	37.24%	13.85%	19.14%	13.11%	0%
Peter Snell Village	7.32%	92.48%	0.16%	0%	0.05%	0%
Riverhaven Drive	8.69%	80.31%	2.35%	8.66%	0%	0%
Silverdale Kingsway	32.91%	52.2%	1.91%	8.11%	3.21%	1.66%
Stanmore Bay Park	32.95%	51.05%	2.47%	5.35%	6.8%	1.38%
Waterfall Gully	2.94%	97.06%	0%	0%	0%	0%

Principal component analysis

The PC1 habitat index had a standard deviation of 1.633 and explained 44.44% of variance in habitat. When PC1 was higher there were more trees and areas of marsh, and less anthropogenic surfaces, buildings, grass, and water (Table 4.5).

Table 4.5: *Table showing the values of each composite variable category from PC1 analysis.*

PC1 composite variable	Value
Tree	0.5748
Water	-0.1152
Building	-0.4843
Grass	-0.4038
Anthropogenic surface	-0.5034
Marsh	0.0731

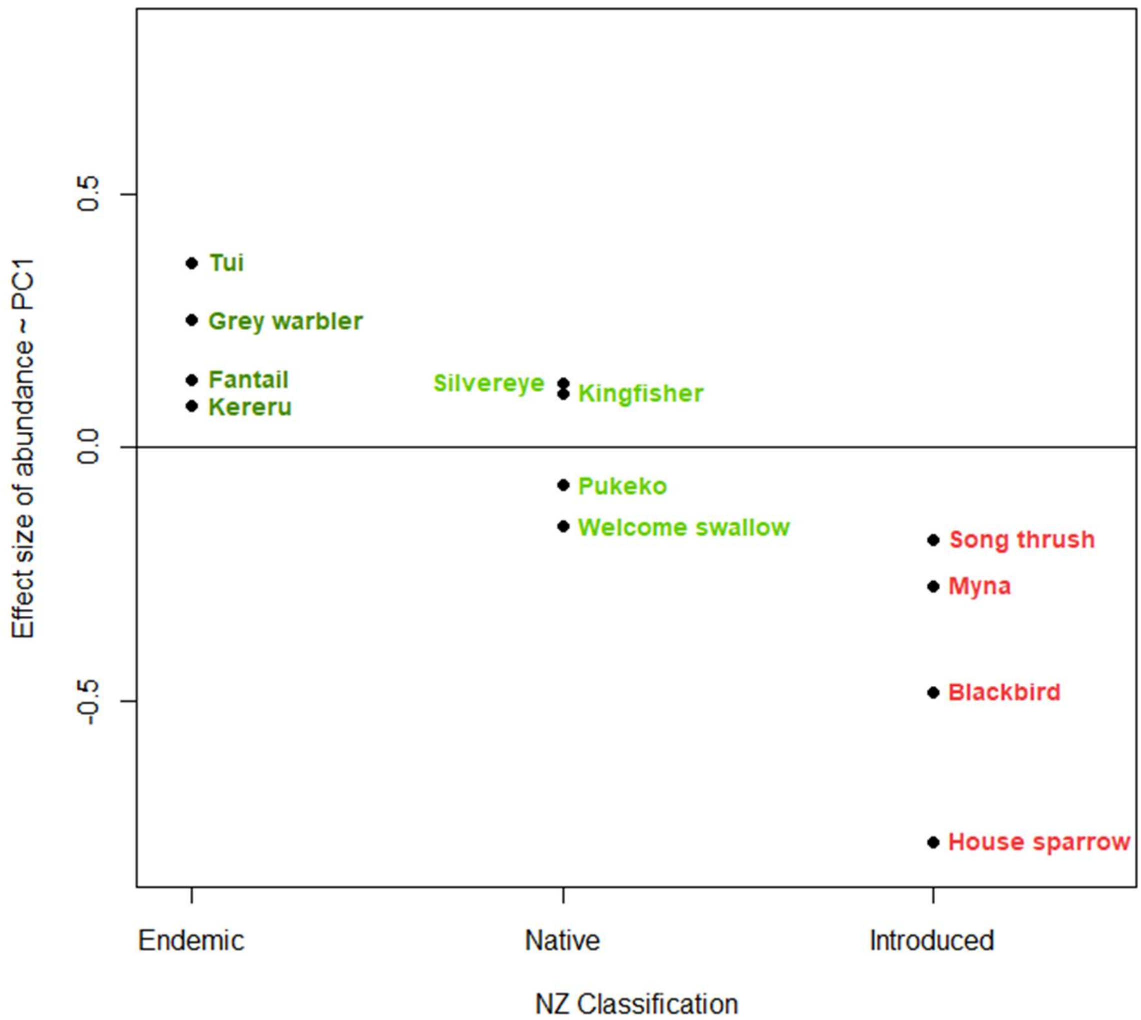

Figure 4.6: *The relative abundances of common species in relation to PC1 habitat index.*

For the 12 focal "common" species I ran a linear regression to see how well PC1 predicted abundance of each species across all 17 locations (Figure 4.6). The effect size of PC1 was highly significant in predicting the abundances of all 12 common species (Table 4.6). PC1 predicted that all common endemic bird species have higher relative abundances in habitats that are more natural – particularly those with more trees and less manmade features like anthropogenic surfaces, buildings, and grass. The relative abundances of native silvereyes and kingfishers share this trend, though pūkeko and welcome swallows had higher relative abundances in habitats with less trees and more manmade features. All four common introduced bird species had higher relative abundances in habitats with less trees and marsh, and more manmade features.

Table 4.6: *Table showing the effect size of PC1 predicting the abundance of each common species.*

Species	Classification	Effect size of PC1 predicting abundance	P-value	Adjusted R-Squared
Tūī	Endemic	0.3652	0.000***	0.0676
Fantail	Endemic	0.1334	0.000***	0.0899
Grey warbler	Endemic	0.2512	0.000***	0.1692
Kererū	Endemic	0.0821	0.000***	0.0634
Silvereye	Native	0.1274	0.000***	0.0252
Kingfisher	Native	0.1061	0.000***	0.0829
Welcome swallow	Native	-0.1547	0.000***	0.0294
Pūkeko	Native	-0.0737	0.000***	0.013
Blackbird	Introduced	-0.4822	0.000***	0.1116
Myna	Introduced	-0.2725	0.000***	0.0617
House sparrow	Introduced	-0.7776	0.000***	0.1735
Song thrush	Introduced	-0.1808	0.000***	0.0598

Discussion

As a key conservation manager, Hibiscus Coast Forest and Bird must effectively allocate their resources and time to control pests and restore natural habitats on the Whangaparāoa Peninsula. Considerations of how and why endemic, native, and introduced birds use environments is imperative to make successful and efficient management decisions. My results indicate that anthropogenic landscape modification greatly impacts the spatial patterns of bird species on the Whangaparāoa Peninsula.

Classification richness

41 target bird species were recorded. This included 19 introduced, 9 native and 13 endemic species. Similar recent biodiversity surveys in Auckland recorded 28 of the target species (17 introduced, 7 native, 4 endemic) across nine volcanic cones, and 31 target species (18 introduced, 8 native, 5 endemic) across 19 reserves (Hill et al., 2020; Landers et al., 2019). The results of this research suggest that the richness of all classifications – particularly endemic bird species – are particularly good on the Whangaparāoa Peninsula.

The proportion of species from each classification was relatively similar between locations despite the range of species (21 to 35). Introduced species comprised ≥ 0.5 at 16 of the 17 locations (mean 0.55). Native and endemic species shared somewhat equal proportions (mean 0.24 and 0.21 respectively), with the greatest deviances at the locations furthest east and west. In the west, proportions of native species at Ōrewa Lakeside Drive comprised 0.3, and endemic species 0.11. This location was beyond the confines of the pest control choke points discussed in Chapter 2 (Figure 2.2), though traps and bait stations were installed from June 2018 (Wilkinson, 2020). Kererū – one of the few common endemic species to significantly benefit from pest-management were not recorded here (Ruffell & Didham, 2017). Their absence, as well as the absence of all but the three most common endemic species may be influenced by the lack of pest-management until relatively recently. The high proportion of native species may be explained by higher tolerances to pest mammals, and the low richness and proportion of competitive endemic species (Graham et al., 2013; Miskelly, 2018).

This trend was reversed at Waterfall Gully where the proportions of endemic species comprised 0.33, and natives 0.13. The high proportion of endemic species here is unsurprising – Waterfall Gully has been predator-free since 2011 and has also welcomed four translocated endemic bird species since 2015, three of which were recorded in this research (Auckland Council, 2018b, 2020c; Galbraith & Cooper, 2013; SOSSI, 2014c, 2015, 2016, 2017). The low proportion of native species is likely a result of competition with endemic birds (Miskelly, 2018). Okoromai Bay also borders the exterior of Shakespear and has the greatest richness of endemic and native species. This may be attributed to the diversity of natural habitat with support from species dispersal – i.e. the halo effect from Shakespear Open Sanctuary.

Mean relative abundances of endemic, native, and introduced species

10 of the 17 locations had a mean relative abundance > 0.5 of introduced species. There were three clusters comprised of seven locations where endemic species accounted for > 0.25 mean relative abundance, and where native and endemic species combined made up > 0.5 (up to 0.69) mean relative abundance. All locations in these clusters had > 65.6% coverage of trees and marsh, and five of the seven locations have had pest-management since at least 2016 (some as early as 2011 – see Appendix 1). These locations are likely healthy environments, as urban areas typically feature greater abundances of introduced bird species (Catterall et al., 1989).

In contrast, there were three clusters comprised of 10 locations where introduced species accounted for > 0.5 (up to 0.83) mean relative abundance. All 10 locations had < 56.1% (with as little as 25.7%) coverage of trees and marsh. This finding suggests that the relative abundances of endemic, and some native species are strongly influenced by higher coverage of trees and marshland, and low coverage of buildings, anthropogenic surfaces, grass, and water. The opposite is true for introduced species, and some native species. My results indicate that the coverage of trees or marshland habitat required for native and endemic species to dominate may lie somewhere between 56% and 65%.

Principal component analysis

PC1 as a composite quantification of habitat types predicted bird abundances, and this may be explained in part by each species' known habitat preferences. PC1 predicted that all four common endemic species had higher abundances in areas with greater coverage of natural features such as trees and marshes, and less coverage of water, and manmade features such as anthropogenic surfaces, buildings, and grass. Although New Zealand's modern floral community varies considerably from its historical composition, habitats with plenty of woody or marshland vegetation represent the indigenous environment more accurately than highly modified locations with many manmade features (King, 1984).

The relative abundances of tūī and grey warblers were most positively predicted by PC1. This is supported by Ruffell and Didham (2017) who found that forest cover positively impacts the abundances of both species. Tūī and grey warblers have adapted well to anthropogenic change, but require trees for nesting and food sources (Heather & Robertson, 2015; Moon, 1996). Flowering vegetation and the availability of nectar influences tūī distributions, whilst grey warblers are generally absent from areas lacking trees as they feed in the upper canopy on invertebrates, seeds and small fruit (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002; Stevens, 2006). The abundances of tūī may increase dramatically in response to effective predator control, and they can quickly outcompete many common bird species when predators are absent (Department of Conservation, 2020r; Graham et al., 2013; Miskelly, 2018). Sufficient suitable natural habitat and pest-management thus influences both species.

The relative abundances of fantails and kererū also show positive effects under PC1. Fantails are common in fringe environments where vegetation provides cover (Higgins et al., 2006). Research by Deconchat, Brockerhoff, and Barbaro (2009) suggests that other environmental features likely have little influence on fantail abundances, assuming vegetation coverage is sufficient. In contrast to kererū, the abundances of fantails may decline following effective pest-management in response to increasing abundances of competitive endemic species (Graham et al., 2013; Miskelly, 2018; Ruffell & Didham, 2017). Kererū nest in trees and are frugivorous, thus native fruiting vegetation influences their distributions (Heather & Robertson, 2015; Higgins & Davies, 1996; Moon, 1996; Stevens, 2006). The effects of PC1 on kererū may be under-represented due to survey methodology (see Chapter 3). Regardless, my findings indicate that the abundances of fantails and kererū are influenced by sufficient suitable natural habitat.

Native silvereyes and sacred kingfishers also showed positive responses to PC1. Silvereyes frequently visit modified areas, but they require vegetation for food and nesting sites, and are almost strictly arboreal in their selection of perches (Catterall et al., 1989; Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). In some of New Zealand's forests, the biomass of silvereyes outweigh that of any other species (Heather & Robertson, 2015). Kingfishers have benefitted from habitat modification and the creation of fringe habitats in which they hunt (Heather & Robertson, 2015; Higgins, 1999). They are not primarily a forest species, but they do nest in tree cavities and will perch on vegetation, natural formations and manmade objects and structures (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996; Stevens, 2006). Despite both species demonstrating that they are somewhat adaptable to environmental modification, this research highlights the importance of vegetation and natural habitat to support silvereyes and kingfishers.

Pūkeko and welcome swallows show a negative response to PC1 and are more common in areas that have been modified by humans. A preference for modified environments is consistent with the natural arrival and dispersal of both species following widespread deforestation and the creation of open grassy spaces (Department of Conservation, 2020l; Heather & Robertson, 2015). Welcome swallows also take advantage of artificial water sources and anthropogenic structures on which they build their nests (Heather & Robertson, 2015; Higgins et al., 2006).

The relative abundances of all four common introduced species were negatively predicted by PC1. They were thus more frequent in areas with more manmade features, and less natural features. This is consistent with the knowledge that most of New Zealand's introduced songbirds are relatively rare within forests (Barnagaud et al., 2014; Gill, 1989; Miskelly, 2018). When vegetation is present, introduced birds are more common around smaller remnants compared to continuous tracts (Stevens, 2006). Field guides support evidence that all four species are frequent in modified habitats – particularly blackbirds, which are New Zealand's most widespread avian species (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Robertson et al., 2017). Of the 12 common species analysed, house sparrows showed the strongest response to PC1. House sparrows are particularly abundant in areas with high anthropogenic disturbance, and Australian research found higher relative abundances in areas further from forests (Catterall et al., 1989; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006).

Supplementary feeding using grains and bread may also positively influence the abundances of introduced birds – particularly house sparrows – in modified environments (Galbraith et al., 2015). High abundances of introduced species may negatively influence native and endemic species – grey warblers may decline up to 50%, likely from other birds occupying the vegetation in which they forage (Galbraith et al., 2015). Residents in urban areas may attract native and endemic birds with fruit, nectar and sugar-water, though research in Wellington found that only 10% of people who feed birds specifically target native and endemic species (Forest and Bird, 2018a; Parker, 2009). Although supplementary feeding may attract some native and endemic birds, non-targeted supplementary feeding in urban areas likely benefits introduced bird species at the expense of native and endemic species.

Sources of error

I made no distinction between native or exotic vegetation, nor for heights, maturity, or distribution. These factors all contribute somewhat to the spatial distribution of birds. Bird abundances are typically greater where trees are clumped rather than scattered (Day, 1995). Abundances of native and endemic birds are greater in environments with increased coverage of native vegetation, and vice versa for exotic vegetation (Stevens, 2006). Native and endemic bird conservation programmes are likely more successful around native forests, though the presence of exotic vegetation within native forest does not impact native and endemic bird abundances (Deconchat et al., 2009). Although there are unknown factors in this research, my results indicate that the relative abundances of silvereyes, kingfishers, and all four common endemic species are positively influenced by greater coverage of woody or marshland vegetation, and lower coverage of manmade features.

Conclusions

My findings reveal that natural habitats are important for the conservation of endemic and some native forest bird species. The overall richness of endemic species, and the high relative abundances of native and endemic birds in some locations indicate that parts of the Whangaparāoa Peninsula are relatively healthy ecosystems for urban environments. This research suggests that > 65% vegetation coverage is required for the abundances of native and endemic bird species to exceed that of introduced species. Pest-management alone is unlikely to offset the negative impacts of habitat loss and it is thus of little use in areas where natural resources are too low to support native and endemic species (Ruffell et al., 2015). Targeted and intensified efforts to protect and expand the regeneration of Whangaparāoa's existing natural habitats with diverse native vegetation will serve to reduce pressures on native and endemic birds by providing valuable habitat and food resources (Grimm et al., 2008; Sullivan, Meurk, Whaley, & Simcock, 2009). Regenerative planting should be combined with pest-management, particularly in areas with low vegetation coverage. These efforts should aid the natural self-reintroduction of endemic species such as tomtits, bellbirds and kākā (*Nestor meridionalis*), and facilitate the dispersal and expansion of translocated endemic species (Chambers, 2009; Heather & Robertson, 2015; Ruffell & Didham, 2017). This research serves to assist Forest and Bird in the effective and efficient management of habitat restoration on the Whangaparāoa Peninsula.

Chapter 5

General conclusions and future directions

Abstract

This thesis archives valuable information for future review of the Whangaparāoa project and provides important insight for similar urban restoration projects elsewhere. Five-minute stationary bird count data collected by volunteers during annual November surveys between 2017 and 2020 revealed that the richness of introduced bird species exceeded that of endemic and native species combined at 16/17 locations on the Whangaparāoa Peninsula. The combined relative abundances of native and endemic bird species was > 0.5 at 7/17 locations, each where > 65% of the surrounding area was covered with natural habitat. Patterns of species richness, proportions of species classification richness, relative abundance, and the distribution of species highlight the critical importance of natural habitats to support endemic and some native bird species in urban environments. They also reveal that sufficient natural habitat must be available to maximise the efficacy of pest-management. 17/21 common bird species remained stable or had significant increases in abundance between 2017 and 2020, and 18/21 between 2013 and 2020. The abundances of native and endemic bird species on the Whangaparāoa Peninsula appear healthy and in general are either stable or increasing. Continued use of the current methodology will allow for increasingly accurate results and better-informed conclusions to be drawn from longer term datasets.

General conclusions

Here, I have summarised the first eight-years of survey data gathered by volunteers during annual November five-minute stationary bird counts across the Whangaparāoa Peninsula between 2013 and 2020. This thesis archives valuable information for future review and provides important insight for similar urban restoration projects across New Zealand and elsewhere.

My research revealed that the Whangaparāoa Peninsula has a relatively healthy avifaunal community for an urban New Zealand environment. Although proportions of introduced species richness exceeded ≥ 0.5 at 16/17 locations between 2017 and 2020, the richness of targeted endemic species recorded on the Whangaparāoa Peninsula more than doubled that of recent biodiversity surveys across Auckland's reserves and volcanic cones (Hill et al., 2020; Landers et al., 2019). The 21 most common bird species included 12 introduced, five native, and four endemic species. 17 of these species remained stable or had significant increases in abundance between 2017 and 2020, and 18 species between 2013 and 2020. These results testify to the importance of maintaining or increasing the predator control operations currently underway in the area.

The relative abundances of native and endemic species combined was > 0.5 at 7/17 locations between 2017 and 2020. Of note is that all seven of these locations had > 65% coverage of natural habitat. Analysis of the four most common endemic, native, and introduced species (selected so there were enough observations to infer trends) confirmed that endemic birds were more abundant at locations that had greater coverage of trees and marshes, and less coverage of water and manmade features such as buildings, grass and anthropogenic surfaces. Introduced species showed the opposite trends, and native species showed intermediate patterns, depending on the species. This result emphasizes the critical importance of the availability of sufficient natural habitat in urban landscapes to support native and endemic bird species. It also highlights that the Whangaparāoa Peninsula has numerous sites with relatively diverse avian communities, as abundances of introduced bird species normally dominate urban environments (Catterall et al., 1989). Natural regeneration and continued native plantings by Forest and Bird, Shakespear Open Sanctuary and private landowners will serve to expand and connect fragmented habitats across the study site, providing suitable habitat for the species that they wish to protect.

Selected trends of common endemic, native, and introduced species

The endemic tūī (*Prosthemadera novaseelandiae*) was the most abundant species, and abundances increased steadily over the eight-year study period. It is difficult to quantify the forces behind these increases, though it appears that suitable natural habitat combined with pest-management have benefitted tūī in particular (Graham et al., 2013; Miskelly, 2018; Ruffell & Didham, 2017). Results from published research indicates that it is highly likely that tūī abundances will continue to increase across the study site over the coming years (Graham et al., 2013; Innes et al., 2010; Miskelly, 2018).

Like tūī, kererū (*Hemiphaga novaseelandiae*) significantly benefit from pest-management, and my results reveal the importance of natural habitat for the species (Fea, Linklater, & Hartley, 2020; Ruffell & Didham, 2017). Abundances have remained stable and match those of predator-free Tiritiri Matangi Island between 2006 and 2010, thus populations appear healthy (Graham et al., 2013). It is possible that the survey methodology is unsuitable to accurately detect change in kererū abundances – longer survey durations such as those of the New Zealand Garden Bird Survey may provide a more accurate depiction of kererū trends. Indeed, outside of the research described here, there is evidence to suggest that abundances may be increasing in the study site (Brandt et al., 2020; Clout et al., 1995).

Appropriate natural habitat is important for the abundances of grey warblers (*Gerygone igata*), which appear to have increased between 2013 and 2020. A positive but not statistically significant trend was also present between 2017 and 2020. Increasing abundances of grey warblers should also benefit shining cuckoos (*Chrysococcyx lucidus*) as they are brood parasites of the grey warbler (Gill, 1982; Heather & Robertson, 2015). However, some research suggests that food competition between grey warblers and whiteheads (*Mohoua albicilla*) can negatively impact grey warbler abundances (Gill, 1982; Graham et al., 2013; Innes et al., 2010).

Fantails (*Rhipidura fuliginosa*) and sacred kingfishers (*Todiramphus sanctus*) had higher abundances at locations with more natural features and less manmade features. However, both species experienced significant declines between 2013 and 2020 but appeared stable in the 2017 to 2020 dataset. These declines may be a response to increasing abundances of competitive endemic species such as tūī and whiteheads (Graham et al., 2013; Miskelly, 2018). Research in Australia also found mynas (*Acridotheres tristis*) aggressively displace grey fantails (*Rhipdura albiscapa*) and some native cavity-nesting species, thus the presence of mynas may negatively impact the abundances of kingfishers and fantails (Grarock et al., 2012). Predation from mammalian pests or domestic cats are unlikely catalysts (Fea et al., 2020; Gillies & Clout, 2003; Morgan et al., 2009)

Silvereyes (*Zosterops lateralis*) were the most abundant native species between 2017 and 2020. It is difficult to extrapolate their abundance trends, which appeared to increase significantly between 2013 and 2020, but significantly decline between 2017 and 2020. Silvereyes have declined nationally since 2009, and reasons for the decline are unknown (Brandt et al., 2020). Resulting competition with endemic birds following the eradication or suppression of pest mammals, and the regeneration of dense forest undergrowth may influence some of these trends (Diamond & Veitch, 1981; Fea et al., 2020; Innes et al., 2010). As such, the declines seen between 2017 and 2020 may continue as species like tūī become more common. Silvereyes are also common victims of domestic cats, thus concentrated efforts by pet owners may help minimise negative trends (Gillies & Clout, 2003; Morgan et al., 2009).

Pūkeko (*Porphyrio melanotus*) and welcome swallows (*Hirundo neoxena neoxena*) had higher abundances in modified areas with fewer natural features. These trends may be explained in part by the known habitat preferences of both species, which established naturally in New Zealand following widespread deforestation and the creation of open grassy habitats (Department of Conservation, 2020l; Heather & Robertson, 2015; Higgins et al., 2006). The abundances of pūkeko and welcome swallows remained stable throughout this research. It is unlikely that domestic cats have limited increases in welcome swallow abundances, though cats do prey upon pūkeko and their chicks (Morgan, 2002; Morgan et al., 2009). Welcome swallows also remained stable on nearby predator-free Tiritiri Matangi between 1987 and 2010, but pūkeko abundances have declined since 1999 (Graham et al., 2013). Significant declines in pūkeko abundances may emerge in the future.

The four most common introduced species – house sparrow (*Passer domesticus*), blackbird (*Turdus merula*), myna, and song thrush (*Turdus philomelos*) – made up four of the top five most abundant species between 2017 and 2020. All of these species had higher abundances in areas with more manmade features and less natural features. Population trends in these species are varied. Blackbird abundance increased and song thrush abundance decreased between 2017 and 2020. Song thrushes have likely decreased since 2013. House sparrows and mynas have both remained stable. These patterns are relatively consistent with data from the New Zealand Garden Bird Survey (Brandt et al., 2020). Another introduced species of note is the barbary dove (*Streptopelia risorii*), the 19th most abundant species between 2017 and 2020. Apart from tūī, barbary doves are the only species to show consistent significant increases in abundance throughout the entire study period. The abundance of barbary doves are expected to continue to increase.

It is important to consider that there are many complex interactions between species, their environment, food webs and behaviours. As the community shifts in composition, some species will increase in abundance, and others will likely decrease (Innes et al., 2010; Miskelly, 2018). Although it may seem contradictory in the fight to protect native and endemic species, declines in the abundances of common native and endemic species like fantails and silvereyes may be a result of increases in the abundances of other endemic species, or to overall improvements in ecosystem health (Innes et al., 2010; Miskelly, 2018). Published literature suggests that tūī and kererū may be the only common endemic species whose abundances will significantly increase in response to pest-control, though intensified pest-management will likely facilitate increases in the abundances and dispersal of less common species such as whiteheads and possibly bellbirds (Fea et al., 2020; Ruffell & Didham, 2017). Species such as kākā (*Nestor meridionalis septentrionalis*) may also naturally recolonise.

Overall, my analysis reveals encouraging discoveries. The abundances of native and endemic bird species on the Whangaparāoa Peninsula are generally either stable or increasing. The richness and abundances of endemic species are particularly healthy when compared to similar biodiversity research across the Auckland area. My results highlight that pest-management should be combined with environmental restoration to maximise conservation benefits. Sufficient natural habitat for endemic and some native birds is critical for healthy urban bird communities.

Future directions

The increasing number of annual surveys and volunteer participation indicates that there is growing public interest in the protection of native and endemic flora and fauna on the Whangaparāoa Peninsula. Anecdotally, I have also received positive feedback in my interaction with volunteers who are excited to educate themselves and be involved in citizen science. Continued increasing support is very encouraging both in terms of future research and for working towards the goal of creating a pest-free urban environment.

Possible further analysis of the current data includes reviewing the abundance trends of all target species, though the abundances of many species may be too low to provide adequate statistical power for quantitative analysis. Analysis of individual species across each location would provide in depth detail on the bird community and ecosystem health, and specific actions that may be beneficial at each location.

To monitor the long-term trends of birds across the study site, surveys should continue indefinitely as planned. The first four years of data (2013 to 2016) allowed for changes in methodology and locations to be refined. Continued use of the current methodology will allow for more accurate results and better-informed conclusions to be drawn in the future. Nevertheless, the research so far has clearly indicated that native and endemic bird abundances on the Whangaparāoa Peninsula are relatively healthy for an urban environment. Native and endemic bird species likely have a promising future provided pest-management continues to expand alongside the prioritisation of conserving remaining native habitats and encouraging more native plantings in developed areas. Habitat restoration in conjunction with effective pest-management will positively impact the richness and abundance of New Zealand's native and endemic birds in urban environments.

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Appendix 1

Study site and survey locations

This appendix provides a description of the locations surveyed over the course of this research. Survey station position may have deviated between years due to environmental change, loss or addition of obvious landmarks, or to make stations easier for volunteers to locate or access. Stations that have remained within 30 m of their original position are represented by a single marker. Stations known to have moved > 30 m are identified.

The vegetation described primarily includes the flora visible from public viewing points across each location. Pest-management by Shakespear Open Sanctuary at Okoromai Bay and Waterfall Gully is up to date as of March 2020. Pest-management by Hibiscus Coast Forest and Bird is up to date as of November 2020. The position of traps and bait stations was subject to change over time. As such, the depicted traps and bait stations should primarily be used as an indication of the intensity of pest-management at each location. Known instances where pest-management has intensified over time is included, though, this should be assumed for all locations with pest-management. Private pest control (including around 300 backyard traps) is not included (Hanwell, 2020).

Known changes to land use is described. In reference to dogs, "control" is defined by Auckland Council (2019a) as "the owner is able to obtain an immediate and desired response from the dog." If not specifically mentioned, it should be assumed that dogs must be leashed or are prohibited.

Mana whenua is defined as "territorial rights, power from the land, authority over land or territory, jurisdiction over land or territory - power associated with possession and occupation of tribal land. The tribe's history and legends are based in the lands they have occupied over generations and the land provides the sustenance for the people and to provide hospitality for guests" (Moorfield, 2011).

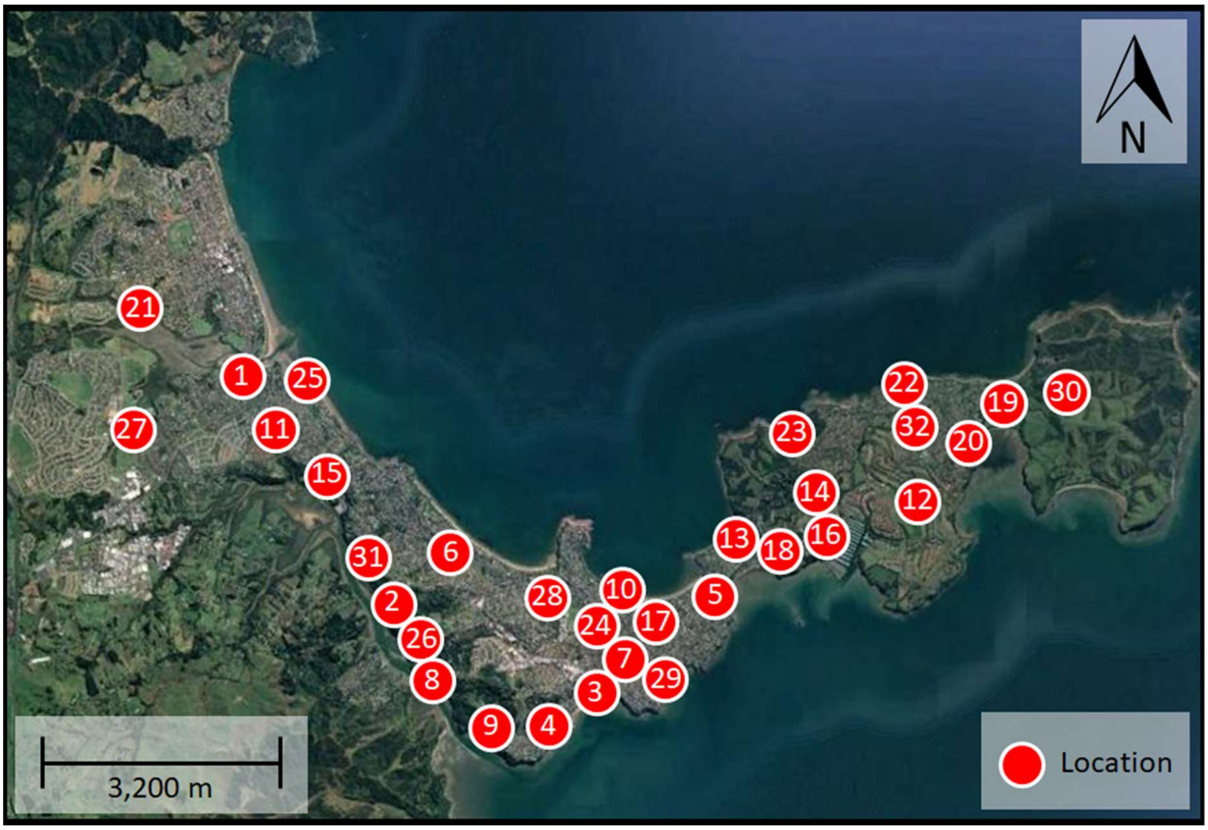

Figure A1.1: *Map of the Whangaparāoa Peninsula showing the locations surveyed. Locations (alphabetical order) include Amorino Park[1], Archer's Block[2], Arkles Bay Reserve[3], Arkles Bay Stormwater Pond[4], Browns Walk Reserve[5], D'Oyly Reserve[6], Edith Hopper Park[7], Fairhaven Walk[8], Ferry Road Reserve[9], Garroway Reserve[10], Gilshennan Reserve[11], Gulf Harbour Drive[12], Hardley Reserve[13], Hobbs Road[14], Karaka Cove[15], Laguna Place Reserve[16], Manly Park[17], Matakatia Glade[18], Okoromai Bay[19], Okoromai Views Reserve[20], Ōrewa Lakeside Drive[21], Pacific Parade[22], Peter Snell Village[23], Raroa Bush[24], Red Beach Recreational Reserve[25], Riverhaven Drive[26], Silverdale Kingsway[27], Stanmore Bay Park[28], Sundown Reserve[29], Waterfall Gully[30], Weiti Views Reserve[31], Whangaparāoa Golf Course[32]. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Amorino Park – surveyed 2013 to 2020

Located on the southern side of the Ōrewa Estuary, Amorino Park is a mown grass esplanade reserve of significant cultural mana whenua (Auckland Council, 2019b; Cummings, 2017). Remnant vegetation is minimal and the surrounding terrestrial landscape is primarily urban residential (Cummings, 2017). The estuary vegetation comprises mangrove (*Rhizophoa sp.*) and saltmarsh species (Cummings, 2017). The original station (monitored 2013 to 2016, 2020) is located by a walking path near scattered pōhutukawa (*Metrosideros excelsa*) and gum (*Eucalyptus sp.*) trees. The five stations monitored from 2017 are adjacent the Te Ara Tahuna / Ōrewa Estuary Path - a wide, sealed cycling and walking path that is often busy (Auckland Council, 2019b, 2020a). Dogs are permitted off leash under control in grassed areas but must be leashed along the walkway (Auckland Council, 2012, 2019a). Pest-management began on the south-west side of the estuary in January 2018, the northern side in April 2018, and to the east of the bridge in September 2020 (Wilkinson, 2020).

Figure A1.2: *Map of Amorino Park including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Archer's Block – surveyed 2013 to 2020

Archer's Block is a 25 ha section of publicly owned riparian land that runs between the Weiti River and Whangaparāoa Road (Forest and Bird, 2018d; Julian, 2008). Some survey stations may have moved small distances, but all have remained within their original 30 m radius. The five stations are located along a track within the 20 ha native bush comprised of tōtara (*Podocarpus totara*), kahikatea (*Dacrycarpus dacrydioides*), pūriri (*Cupressus macrocarpa*), kānuka (*Kunzea ericoides*), kōwhai (*Sophora sp.*), kauri (*Agathis australis*), treeferns, introduced pines (*Pinus sp.*) and macrocarpas (*Cupressus macrocarpa*) (Forest and Bird, 2018d; Julian, 2008). The ecological quality of the bush is high along the estuary and reduces to moderate quality further inland (Julian, 2008). Although mostly obscured by forest, the Weiti River and mangroves are visible from station five. The unmaintained grass area on the property is used for horse riding (Forest and Bird, 2018d). Bait and trap lines were first installed in November 2014, with efforts intensified over time (Forest and Bird, 2018d).

Figure A1.3: *Map of Archer's Block including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Arkles Bay Reserve – surveyed 2013 to 2016, 2020

Arkles Bay Reserve is a mown grass reserve that borders residential properties and a coastal forest of moderate to high quality (Julian, 2008). Native vegetation includes pōhutukawa, pūriri, kohekohe (*Dysoxylum spectabile*), nīkau (*Rhopalostylis sapida*), māhoe (*Melicytus chathamicus*), kawakawa (*macropiper excelsum*), and coastal karamū (*Coprosma robusta*) (Julian, 2008). Weeds include species of agapanthus (*Agapanthus sp.*) (Julian, 2008). The single station was surveyed from 2013 to 2016, and again in 2020. Pest-management in the reserve and the bordering forest began in November 2016 (Wilkinson, 2020).

Figure A1.4: *Map of Arkles Bay Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Arkles Bay Stormwater Pond – surveyed 2017 to 2020

Station one is at the northern end of the Ferry Road children's playground, a 3,770 m^2 grass mown reserve used for informal recreation and play (Auckland Council, 2019b). Dogs are permitted under control off leash in this reserve when the playground is not in use (Auckland Council, 2019a). Stations two to four are along the southern side of the stormwater pond. The forest to the north comprises native kānuka, māhoe, māpou (*Myrsine australis*), ponga (*Cyathea dealbata*), hangehange (*Geniostoma ligustrifolium*) and exotic pines (Julian, 2008). Station five is within Arkles Strand Reserve, a 1,940 m^2 maintained grass reserve that links Arkles Strand and McKenzie Avenue via a walking path (Auckland Council, 2019b). The two traps around the stormwater pond were installed in November 2016 (Wilkinson, 2020).

Figure A1.5: *Map of Arkles Bay Stormwater Pond including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Browns Walk Reserve – surveyed 2013 to 2016, 2020

Browns Walk Reserve is a 5,417 m^2 grass mown reserve that acts as a walking path between Brown Street and Tindalls Bay Road (Auckland Council, 2019b). The reserve is steep, sloping downwards to the north-west. The single station was surveyed from 2013 to 2016, and again in 2020. Dogs are permitted under control off leash (Auckland Council, 2012, 2019a). Trap and bait stations were installed in the reserve and the surrounding area from November 2016 (Wilkinson, 2020).

Figure A1.6: *Map of Browns Walk Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

D'Oyly Reserve – surveyed 2013 to 2020

D'Oyly Reserve is a 750 m elongated grass mown reserve with walkways, seated rest stops and a playground. Stations two and four were surveyed 2013 to 2016, and all five stations from 2017. Native vegetation includes harakeke (*Phormium tenax*), kōwhai and kōwharawhara (*Astelia solandri*) (Panuku Development Auckland, 2019). Wetland restoration began in 2018 with the reinstatement of 250 m of natural stream to improve drainage, and the planting of 20,000 native plants along the streambank to prevent soil erosion (Auckland Council, 2018a; Panuku Development Auckland, 2016, 2019). Mandarin (*Citrus reticulata*) and plum (*Prunus sp.*) trees were also planted (Auckland Council, 2018a). Prior to restoration the reserve was ecologically poor, but today it provides habitat for birds and freshwater marine species, and natural filtration processes prevent pollutants from entering the ocean (Panuku Development Auckland, 2016). Dogs are permitted under control off leash (Auckland Council, 2012, 2019a). Pest-management began in October 2020 (Wilkinson, 2020).

Figure A1.7: *Map of D'Oyly Reserve including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Edith Hopper Park – surveyed 2017 to 2020

Edith Hopper Park is a 25,916 m^2 reserve that acts as a recreational area, play space, and walking connection between neighbouring residential streets (Auckland Council, 2019b). The five survey stations border a mown grass field, the Hibiscus Coast Netball Club, and the Whangaparāoa Tennis Club (both clubs are outdoors). There is an open stormwater drain along the western edge of the park between stations two to four, and along the southern edge of the netball courts (Auckland Council, 2019b). Station five is located south of an asphalt carpark, near a large oak tree (*Quercus sp*.) (Auckland Council, 2019b). Dogs are permitted under control off leash within the park (Auckland Council, 2012, 2019a). There is no known pest-management.

Figure A1.8: *Map of Edith Hopper Reserve including the survey stations. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Fairhaven Walk – surveyed 2013 to 2016, 2020

The stations at Fairhaven Walk are located in a coastal kānuka, kōwhai, pōhutukawa, pūriri, mangrove and tree fern forest (Auckland Council, 2019b; Julian, 2008). Introduced vegetation includes pampas grass (*Cortaderia selloana*) (Julian, 2008). Although considered as low to moderate ecological quality in 2006, conditions have improved and the mangrove forest and pōhutukawa/pūriri forest are now of significant natural value (Auckland Council, 2019b; Julian, 2008). Stations one and two are within the forest along a rugged walking track that runs adjacent to the Weiti River. Station three is on the edge of an overgrown clearing. Julian (2008) notes that the pūriri was heavily damage by possums during vegetation surveys in 2006. The live cage traps and single trap station in the south-east were installed in March 2017 (Wilkinson, 2020). Pest-management along Fairhaven Walk itself began in September 2020 (Wilkinson, 2020).

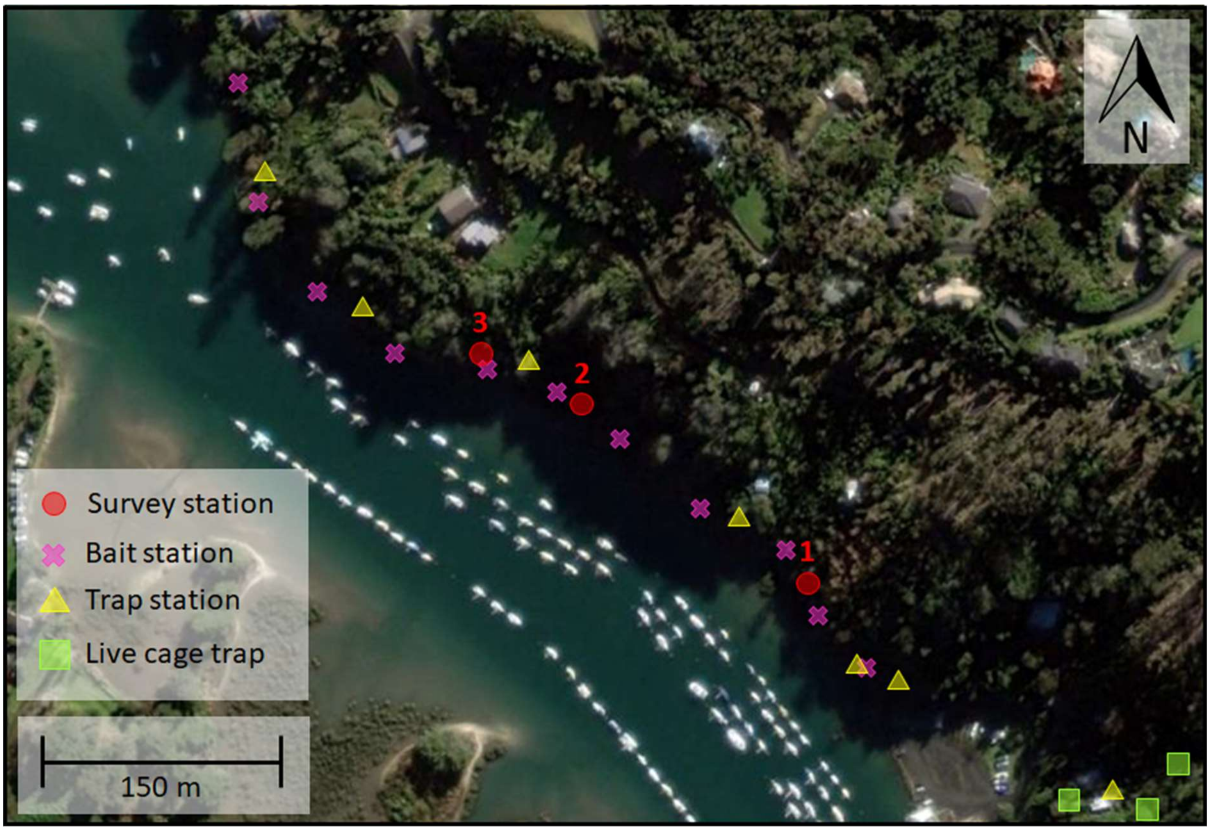

Figure A1.9: *Map of Fairhaven Walk including the survey stations and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Ferry Road Reserve – surveyed 2013 to 2016, 2020

Ferry Road Reserve is a steep north facing 3,439 m^2 grass mown reserve bordering the Weiti River mouth and Karepiro Bay (Auckland Council, 2019b). It is one of the most sheltered areas on the southern side of the peninsula and is used for informal recreation and as a connection between Wade River Road and the Weiti River (Auckland Council, 2019b; Julian, 2008). The single station was surveyed from 2013 to 2016, and again in 2020. The narrow coastal forest on the southern edge of the reserve is of moderate to high quality and consists of a mix of pōhutukawa, pūriri, kōwhai and native shrubs like harakeke and tree daisies (*Olearia sp*.) (Auckland Council, 2019b; Julian, 2008). Introduced pampas grass is also present. Dogs are permitted under control off leash (Auckland Council, 2012, 2019a). Pest-management began in the surrounding streets from November 2016, and in the reserve itself from September 2020 (Wilkinson, 2020).

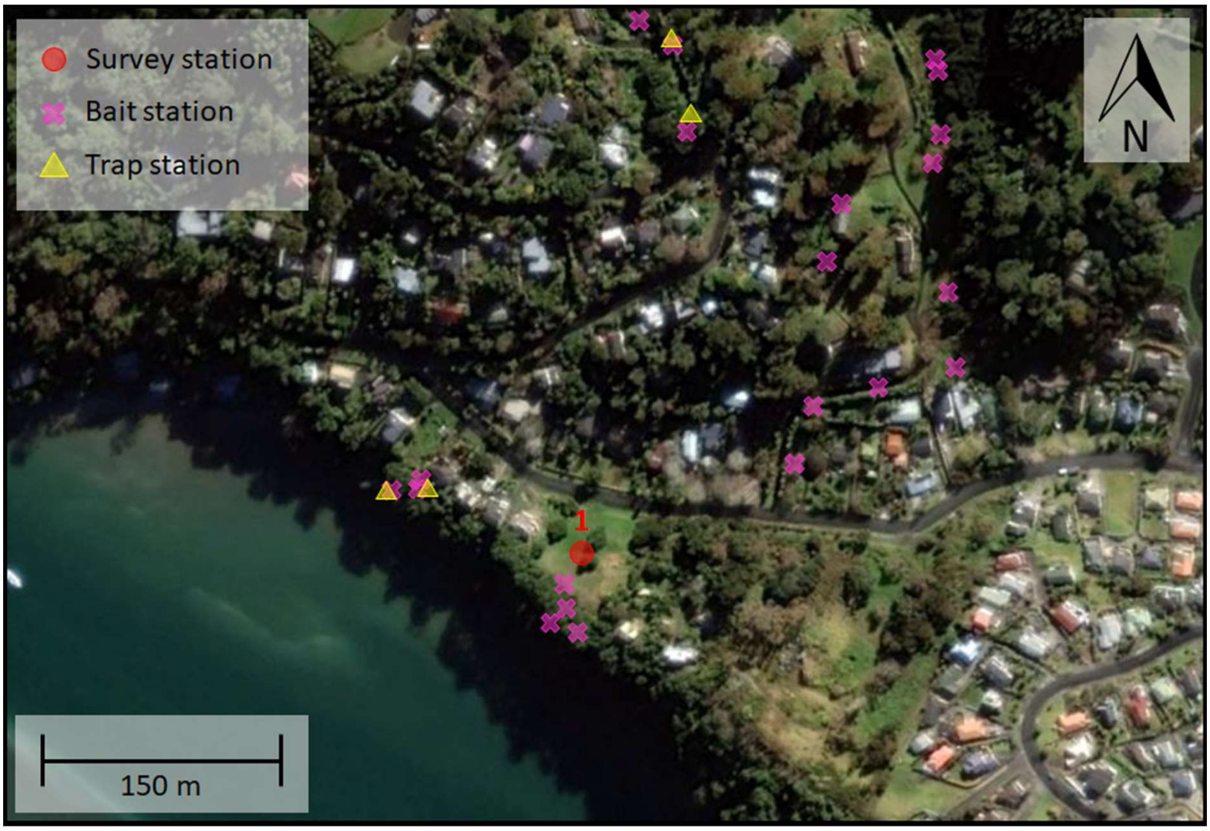

Figure A1.10: *Map of Ferry Road Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Garroway Reserve – surveyed 2013 to 2016, 2020

Garroway Reserve (also known as Shuttleworth Reserve) is a 18,387 m^2 reserve that is used for informal recreation and as a walking link between Shuttleworth Place and Morton Drive (Auckland Council, 2019b). The single station was surveyed from 2013 to 2016, and again in 2020. The bush to the west of the survey station is a moderate quality three to four metre tall mānuka (*Leptospermum scoparium*) and kānuka forest with māhoe beneath (Auckland Council, 2019b; Julian, 2008). Exotic vegetation includes wattle (*Acacia sp.*), acmena (*Acmena sp.*), watsonia (*Watsonia sp.*) and arum lily (*Zantedeschia aethiopica*) (Julian, 2008). Dogs are permitted under control off leash in the reserve (Auckland Council, 2012, 2019a). Bait and trap stations were installed from September 2017 (Wilkinson, 2020).

Figure A1.11: *Map of Garroway Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Gilshennan Reserve – surveyed 2013 to 2016, 2020

Gilshennan Reserve is a 7,666 m^2 grass mown recreational reserve that provides a walking link via pathway between the neighbouring residential streets (Auckland Council, 2019b). It is also a play space and an area for informal recreation (Auckland Council, 2019b). There is a children's playground which falls within the 30 m radius of the single station that was surveyed from 2013 to 2016, and again in 2020. Dogs are permitted under control off leash in the reserve (Auckland Council, 2012, 2019a). There is no known active pest-management in the area.

Figure A1.12: *Map of Gilshennan Reserve including the survey station. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Gulf Harbour Drive – surveyed 2017 to 2020

Gulf Harbour Drive is a two-lane road that runs between the first and ninth holes of the 40 ha Gulf Harbour Country Club. The golf club falls within trapping choke line number four (Forest and Bird, 2018d). All five stations run along the road under scattered trees with views of the swamp, wetland, lake and maintained grass at the course. Stations one and five border residential properties. The constructed lake is of low to moderate ecological quality and has patches of native lake clubrush (*Schoenoplectus tabernaemontani*), mānuka, cabbage trees (*Cordyline australis*) and harakeke, as well as a small amount of gorse (*Ulex europaeus*) (Julian, 2008). The trees around this large open green space are thought to provide an important stepping stone habitat for birds moving west between Shakespear Open Sanctuary and Matakatia Glade (Cummings, 2017). Bait stations were installed from November 2016, and trap stations in April 2017 (Wilkinson, 2020).

Figure A1.13: *Map of Gulf Harbour Drive including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Hardley Reserve – surveyed 2013 to 2016, 2020

Hardley Reserve is a 5,462 m^2 mown grass reserve with scattered trees (Auckland Council, 2019b). It provides an area for informal recreation and acts as a play space for the residents of Manly (Auckland Council, 2019b). Part of the children's playground is included in the 30 m radius of the single station that was surveyed from 2013 to 2016, and again in 2020. Dogs are permitted under control off leash in the reserve (Auckland Council, 2012, 2019a). Pest-management outside of the reserve in the south-west began in November 2016, but the bait stations within the reserve are more recent (Wilkinson, 2020).

Figure A1.14: *Map of Hardley Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Hobbs Road – surveyed 2018 to 2020

The survey stations on Hobbs Road are located along a 950 m length of road. Station one borders a highly diverse gumland shrubland featuring large, old mānuka and kōhūhū (*Pittosporum tenuifolium*), as well as akepiro (*Olearia furfuracea*), koromiko (*Hebe salicifolia*), kūmarahou (*Pomaderris kumeraho*), tauhinu (*Ozothamnus leptophyllus*), tūrutu (*Dianella nigra*), harakeke, karamu, mingimingi (*Coprosma rhamnoides*), giant cutty grass (*Gahnia xanthocarpa*) and wīwī (*Schoenus tendo*) (Julian, 2008). The gumland vegetation around stations two to five is ecologically poor and is a mix of mostly mānuka and introduced pines, gums and wattles (Julian, 2008). Exotic flora is overtaking the native vegetation along the road (Julian, 2008). There are no known traps or bait stations on Hobbs Road, but the pest-management seen to the west and south began in November 2016 and August 2018 (Wilkinson, 2020). Bait stations were also installed at the marina (south-east) in July 2019 (Wilkinson, 2020).

Figure A1.15: *Map of Hobbs Road including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Karaka Cove – surveyed 2013 to 2020

Karaka Cove lies in trapping choke line one and was the first reserve on the peninsula to use bait stations, installed in January 2014 (Forest and Bird, 2018b, 2018d). Karaka Cove is culturally significant to mana whenua and is an archaeological site of Māori origin (Auckland Council, 2019b). Stations one to four were monitored from 2013. All five stations were monitored from 2017. Station one is situated in a mown grass area and overlooks the saltmarshes and mangrove forest scrub in the Weiti River (Auckland Council, 2019b). Dogs are permitted under control off leash here but must be leashed in the bush (Auckland Council, 2012, 2019a). Stations two to four are located along a walking trail within a primarily four to six m tall kānuka forest of moderate ecological quality (Julian, 2008). Other native flora includes cabbage trees, māpou, kūmarahou, pūriri, pōhutukawa and kauri (Auckland Council, 2019b; Forest and Bird, 2018b; Julian, 2008). There is a boot scrubbing station at the bush entrance to prevent kauri dieback disease. Station five borders an unmaintained grass section.

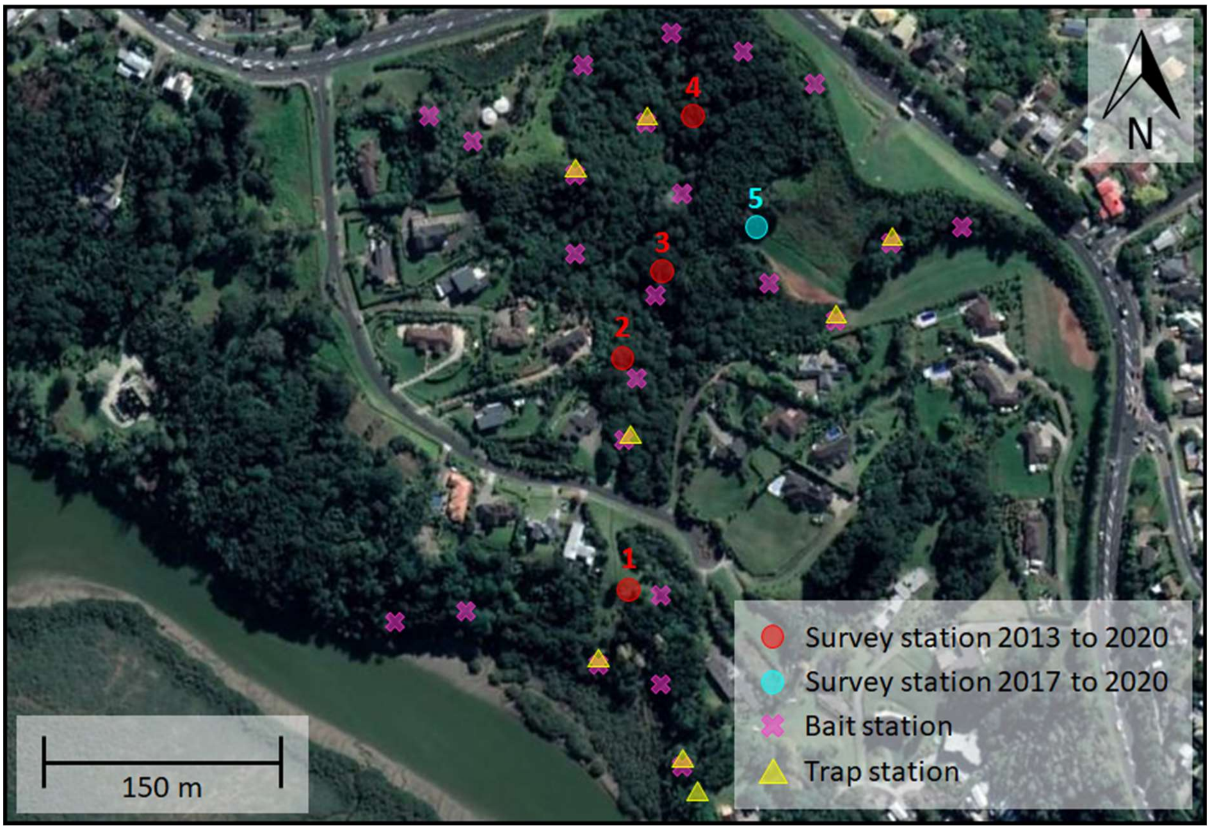

Figure A1.16: *Map of Karaka Cove including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Laguna Place Reserve – surveyed 2013 to 2016, 2020

Laguna Place Reserve is a 13,508 m^2 valley reserve that provides an informal recreation space and a walking connection between the surrounding streets (Auckland Council, 2019b). It features a regenerating mānuka and kānuka scrub forest of significant natural value, as well as native wetland remnants (Auckland Council, 2019b; Julian, 2008). Other native vegetation includes dense tree ferns, mamaku (*cyathea medullaris*), pōhutukawa, pūriri and kūmarahou (Auckland Council, 2019b; Julian, 2008). The wetland remnants have many weed species, including kikuyu (*Cenchrus clandestinus*), wooly nightshade (*Solanum mauritianum*), Chinese privet (*Ligustrum sinense*), gorse and pampas (Julian, 2008). There is a bridge over a stormwater drainage channel within 30 m of the survey station (Auckland Council, 2019b). Dogs are permitted under control off leash (Auckland Council, 2012, 2019a). Pest-management began in October 2016 and has been intensified over time, particularly around the marina in July 2019 (Wilkinson, 2020).

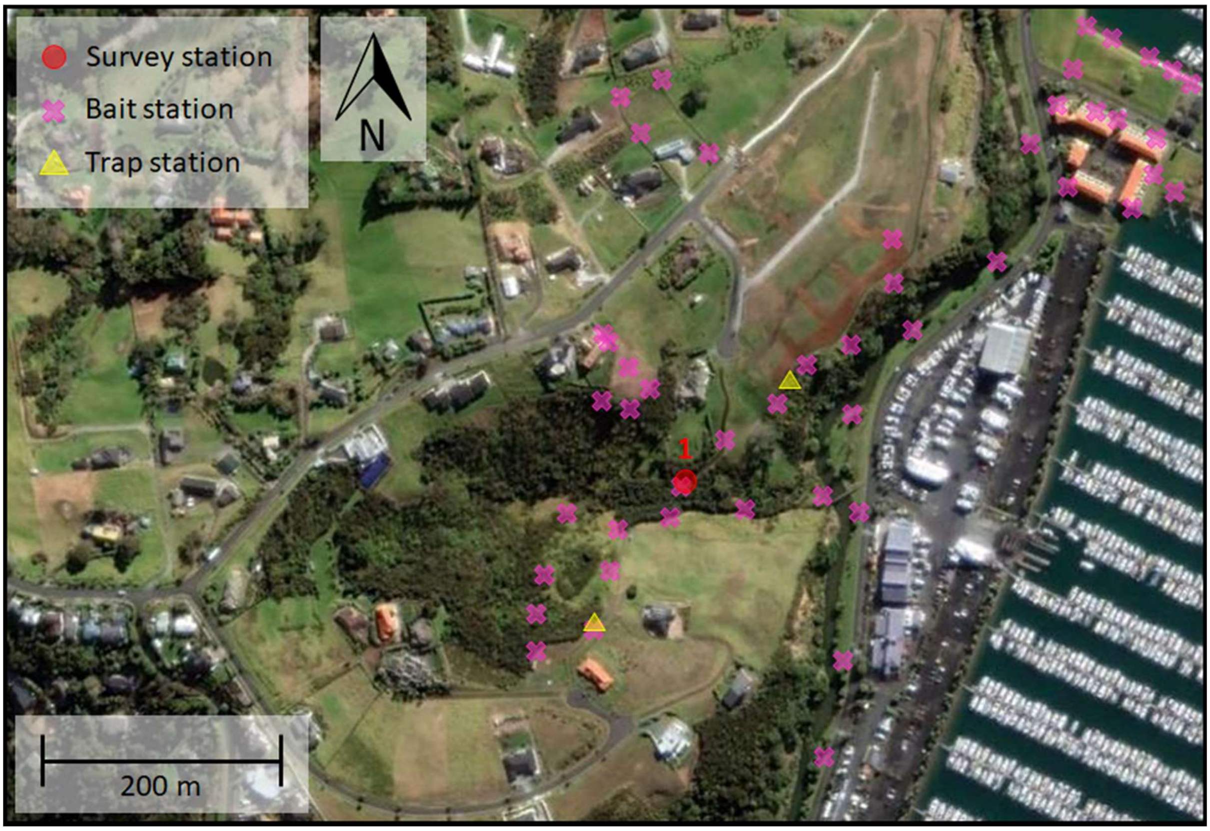

Figure A1.17: *Map of Laguna Place including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Manly Park – surveyed 2013 to 2020

Manly Park is a 86,007 m^2 grass mown public recreation reserve that is regularly used for high-profile outdoor community musical and sporting events (Auckland Council, 2019b). The reserve is of significant cultural mana whenua (Auckland Council, 2019b). The single historical station was surveyed annually from 2013 to 2016, and again in 2020. The current stations have been surveyed each year since 2017. Stations one to four are located under scattered trees around the border of the reserve. Station five is located next to a children's playground and is separated from the other stations by Laurence Street. Dogs must be controlled and on a leash around station five in summer (Labour weekend until 1 March) from 10.00 am to 5.00 pm (Auckland Council, 2012, 2019a). Dogs may be under control off leash at all other times, but must be leashed if the playground is in use (Auckland Council, 2012, 2019a). There is no pest-management in place at Manly Park.

Figure A1.18: *Map of Manly Park including the survey stations. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Matakatia Glade – surveyed 2013 to 2016, 2020

The survey stations at Matakatia Glade are located along an unmaintained walking trail that connects the surrounding streets (Auckland Council, 2019b). Both stations were surveyed from 2013 to 2016, however, only station one was surveyed in 2020 due to difficulty in navigating the steep terrain. Matakatia Glade is biodiverse and provides important food sources, breeding grounds, and refuge for wildlife moving across the fragmented forests on the peninsula (Cummings, 2017). The native broadland forest is high quality and dominated by pōhutukawa and pūriri with some kauri, kōwhai, kānuka, coastal karamū and māhoe (Julian, 2008). Exotic species include gorse, gum species, flame trees, loquat (*Eriobotrya japonica*), wattles, macrocarpa and agapanthus (Julian, 2008). Dogs are permitted in the bush under control on a leash (Auckland Council, 2012, 2019a). Pest-management in the surrounding area began in May 2019 (Wilkinson, 2020). Traps that do not appear to be controlled by Forest and Bird were also seen around station 1 during surveys in 2020.

Figure A1.19: *Map of Matakatia Glade including the survey stations and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Okoromai Bay – surveyed 2017 to 2020

Okoromai Bay is a mostly planted freshwater and saline wetland that has been restored from pasture (SOSSI, 2014a, 2014b). Natural processes and drainage have been impacted by the haphazard planting of native harakeke, mānuka and cabbage trees between 2007 and 2009, and the raised causeway which is lined with planted Norfolk Island hibiscus (*Lagunaria patersonia*), Chatham Island ake ake (*Olearia traversii*) and eucalyptus gum species (SOSSI, 2014b). The natural salt marsh contains glasswort (*Salicornia sp.*) and the remnants of mangroves and salt marsh ribbonwood (*Plagianthus divaricatus*) (SOSSI, 2014b). Dogs were permitted under control off leash until November 2019 (Auckland Council, 2012, 2019a). They are still permitted on the flat grass areas but must be controlled and on leash on all tracks and the beach (Auckland Council, 2019a). Dogs are prohibited from the beach between 9.00 am to 7.00 pm in Summer (Auckland Council, 2012, 2019a).

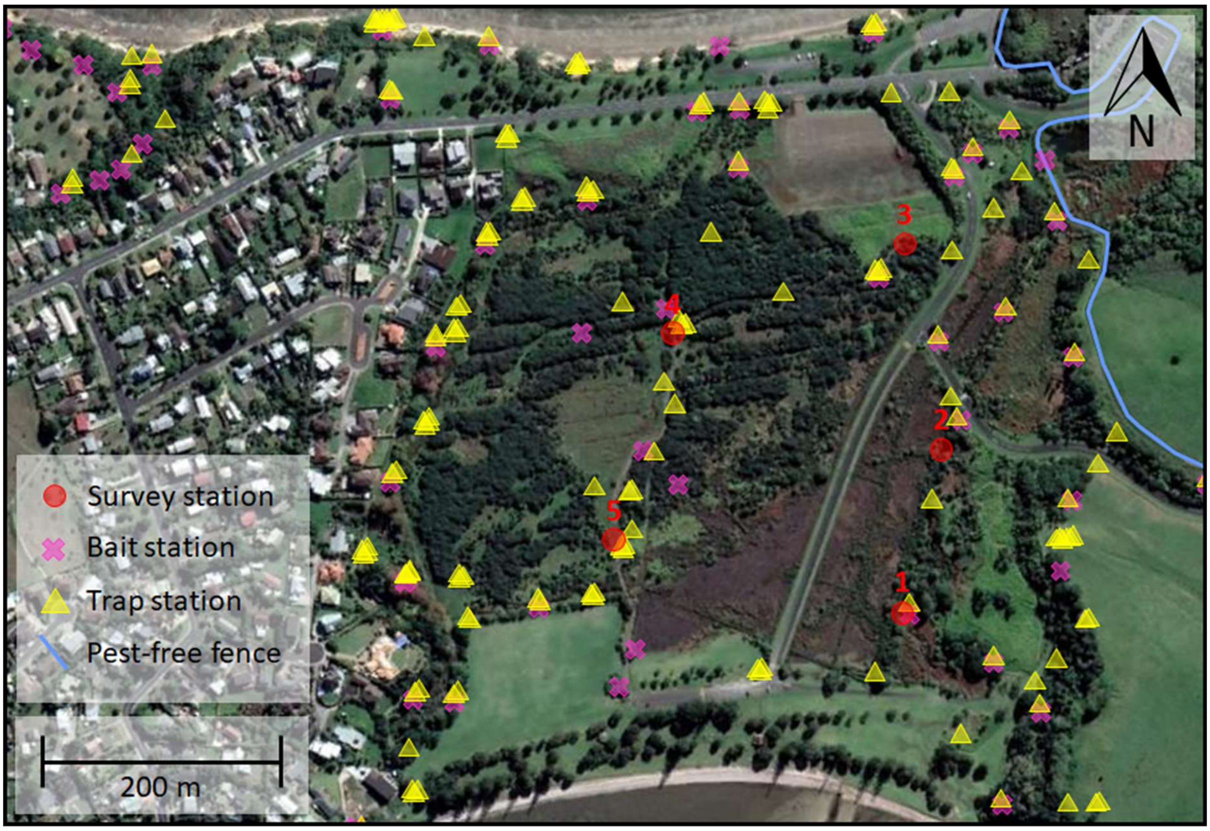

Figure A1.20: *Map of Okoromai Bay including the survey stations and known pest-management on the exterior of the predator-proof fence. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Okoromai Views Reserve – surveyed 2013 to 2016, 2020

Okoromai Views is an area of moderate ecological quality (Julian, 2008). Pōhutukawa, pines, gorse and pampas line the coast (Julian, 2008). Station one borders a wetland gully of mānuka, cabbage trees and nīkau (Julian, 2008). Kahikatea, totara and rimu (*Dacrydium cupressinum*) are unusually common in this area (Julian, 2008). Invasive species include honeysuckle (*Lonicera sp.*), jasmine (*Jasminum sp.*) and shrub balsam (*Impatiens sodenii*) (Julian, 2008). Station two borders a mānuka and māpou shrubland forest with māhoe, kānuka, karamū, cabbage trees, ponga and māpere (Julian, 2008). Invasive climbing asparagus (*Asparagus scandens)* and smilax (*Asparagus asparagoides*) are also present (Julian, 2008). Dogs are permitted under control off leash (Auckland Council, 2012, 2019a). Pest-management to the north at Okoromai Bay was installed before 2013. Pest-management from station one south was installed from April 2017 (Wilkinson, 2020).

Figure A1.21: *Map of Okoromai Views Reserve including the survey stations and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Ōrewa Lakeside Drive – surveyed 2018 to 2020

Ōrewa Lakeside Drive is located on the northern edge of the Ōrewa Estuary. The area is culturally significant and is an archaeological site of Māori origin (Auckland Council, 2019b). Station one is located behind residential homes approximately 60 m from the Ōrewa Estuary Path. Stations two to five run along the Ōrewa Estuary Path which is used for walking and cycling and is often busy (Auckland Council, 2020a). The survey locations are all on mown grass close to scattered trees, between residential homes and the estuary mangroves (Cummings, 2017). Dogs must be leashed along the walkway (Auckland Council, 2012, 2019a). The bait stations bordering the estuary were installed from June 2018 (Wilkinson, 2020). The bait line north of the stormwater drain at station five was installed from October 2019 (Wilkinson, 2020). Traps were installed in 2020.

Figure A1.22: *Map of Ōrewa Lakeside Drive including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Pacific Parade – surveyed 2015 to 2020

Pacific Parade Reserve runs along a clifftop within pest control choke line four (Forest and Bird, 2018d). The area is of significant cultural mana whenua (Auckland Council, 2019b). The reserve features a moderate quality coastal kānuka shrubland with a pōhutukawa fringe (Julian, 2008). Some gorse and pampas grass is present (Julian, 2008). The exposed coastal cliffs are threatened with instability and slipping (Auckland Council, 2019b). Stations one and three were surveyed in 2015 and 2016. All five stations have been monitored since 2017. Stations one to three are located within the reserve. The marker for station three has moved small distances but remained within its original 30 m radius between years. Stations four and five are located on the footpath by the road, surrounded by urban residential homes. Dogs are permitted under control off leash in the open grass areas (Auckland Council, 2012, 2019a). By October 2014, local volunteers were monitoring 49 traps and bait stations throughout the area (Forest and Bird, 2018d).

Figure A1.23: *Map of Pacific Parade including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Peter Snell Village – surveyed 2013 to 2020

Peter Snell Youth Village is a 109,000 m^2 section of bush and parkland that is used to host groups of school aged children (Peter Snell Youth Village, 2018). The village offers outdoor activities such as disc golf, orienteering, archery and air rifle shooting (Peter Snell Youth Village, 2018). The five stations at Peter Snell Village are located in a northern facing kānuka bush and regenerating mānuka shrubland that varies between high to low ecological quality (Julian, 2008). The vegetation is of higher quality closer to the coast in the North (Julian, 2008). Introduced vegetation includes pines, wattles, gums, gorse and pampas grass (*Cortaderia selloana*) (Julian, 2008). Six stations were surveyed between 2013 and 2016. In 2017, stations two and three were moved and station six was discontinued. Stations one to five (red and green) were surveyed from 2017 to 2019 using methodology B. All eight stations were surveyed in 2020. Trap and bait lines were installed from November 2016 (Wilkinson, 2020).

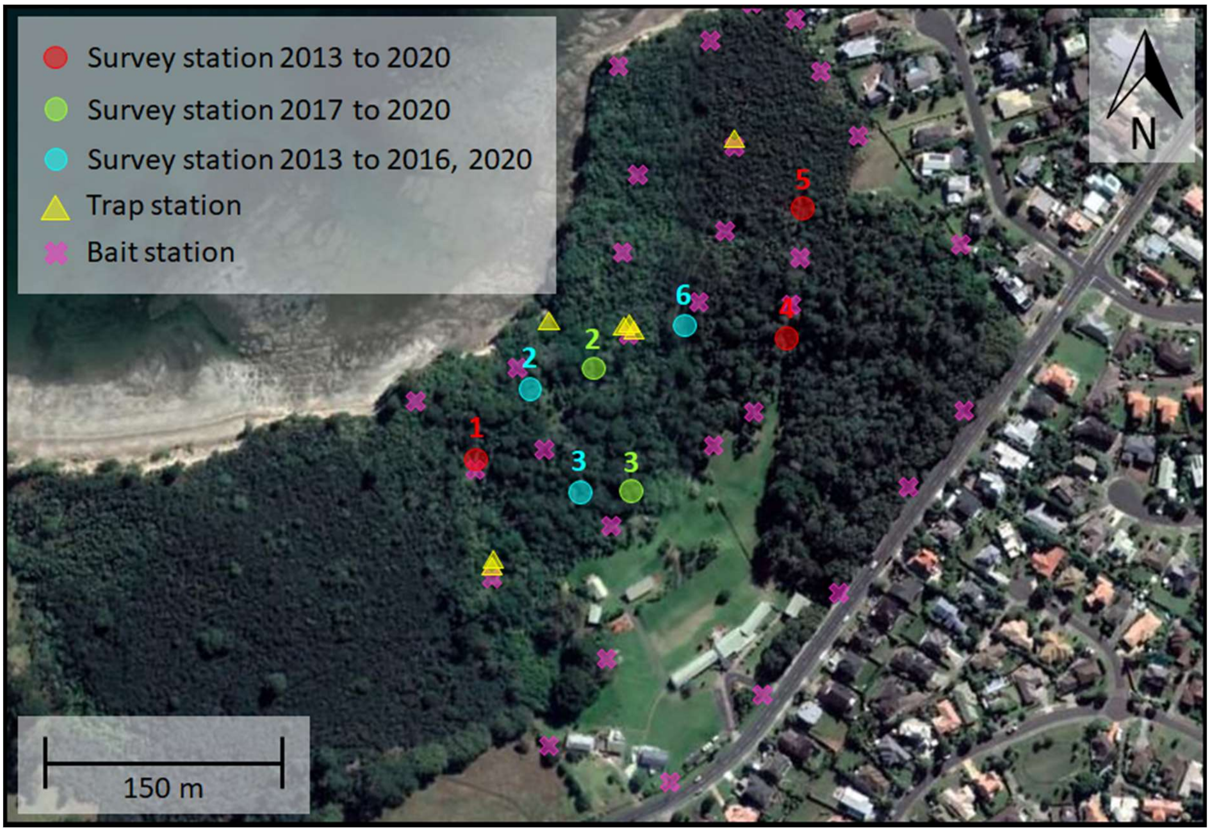

Figure A1.24: *Map of Peter Snell Village including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Raroa Bush – surveyed 2013 to 2016, 2020

Raroa Bush is a reforested native bush reserve that is located amongst residential properties. There is one survey station which was surveyed from 2013 to 2016, and again in 2020. Around 10% of the native trees on the site were planted around 40 years ago, and the bush is home to a population of ornate skinks (Forest and Bird, 2018e). The site has undergone further native replanting since 2003 (Forest and Bird, 2018e). There are few large exotic trees, and native trees have succeeded many of the weeds that previously dominated (Forest and Bird, 2018e). Raroa Bush reserve is considered an important area of refuge for native birds moving through the North-West Wildlink (Forest and Bird, 2018e). The traps within Raroa Bush Reserve were installed from November 2016 (Wilkinson, 2020). The bait and trap stations to the North-East at Garroway Reserve were installed from September 2017 (Wilkinson, 2020).

Figure A1.25: *Map of Raroa Bush including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Red Beach Recreational Reserve – surveyed 2013 to 2016, 2020

The single station is located at the Red Beach surf club in an area of significant cultural mana whenua (Auckland Council, 2019b). The reserve experiences frequent human activity (Auckland Council, 2019b). A pōhutukawa forest of moderate to high quality lies along the northern edge of the purua grass (*Bolboschoenus caldwelli*) lined marine/brackish stream that flows through the reserve (Julian, 2008). Other native vegetation includes harakeke, karo (*Pittosporum crassifolium*), houpara (*Pseudopanax lessonii*) and Astelia sp. (Julian, 2008). Weeds are few but include kahli ginger (*Hedychium gardnerianum*) (Julian, 2008). Dogs are permitted under control off leash on the grass areas from 5.00 pm to 10.00 am between Labour weekend and 1 March, and at all times from 2 March until Labour weekend (Auckland Council, 2012, 2019a). Dogs must be under control on leash at all other times (Auckland Council, 2012, 2019a). Pest-management is not present within the reserve itself. Trap and bait stations included in the map were installed in 2020.

Figure A1.26: *Map of Red Beach including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Riverhaven Drive – surveyed 2017 to 2020

The five stations along Riverhaven Drive are located along the road between steep coastal and lowland forest of low to moderate ecological quality (Julian, 2008). Native species on the hillslopes include kānuka, kōwhai, nīkau, pūriri, cabbage trees, tree ferns and broadleaf tree species such as rewarewa (*Knightia excelsa*) (Julian, 2008). The area also has a lot of exotic pampas grass (Julian, 2008). Dogs are permitted under control off leash along the road (Auckland Council, 2012, 2019a). The live cage trap and associated trap station to the south were installed in March 2017 (Wilkinson, 2020). The trap and bait stations along Fairhaven Walk were installed in September 2020.

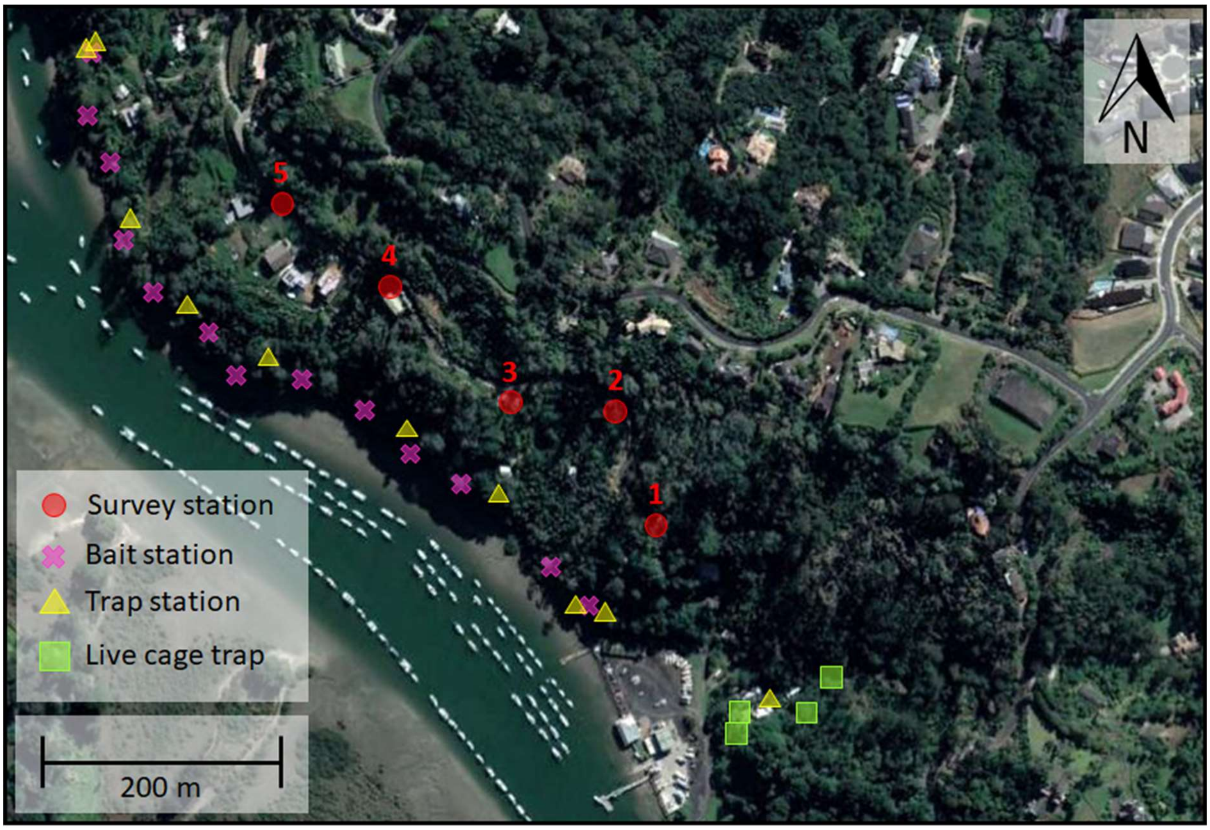

Figure A1.27: *Map of Riverhaven Drive including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Silverdale Kingsway – surveyed 2018 to 2020

Silverdale Kingsway is located on the southern edge of the Ōrewa Estuary along the Te Ara Tahuna pathway. Stations one and two are along the edge of the Laura Grace stormwater ponds. Station three is located on a small grass clearing outside of both Kingsway and Silverdale Schools and has a view of a large field and the estuary. Stations four and five are located along the edge of the estuary. Dogs are permitted but must be on a leash along the Te Ara Tahuna pathway (Auckland Council, 2012, 2019a). The three traps at Silverdale School in the south-west were installed in November 2016 (Wilkinson, 2020). The bait line east of station five was installed in January 2018 (Wilkinson, 2020). The bait line surrounding the stormwater ponds between stations one and two was installed in December 2019 (Wilkinson, 2020). Installation dates of the bait line surrounding Kingsway School and the traps along the estuary west of station five are more recent.

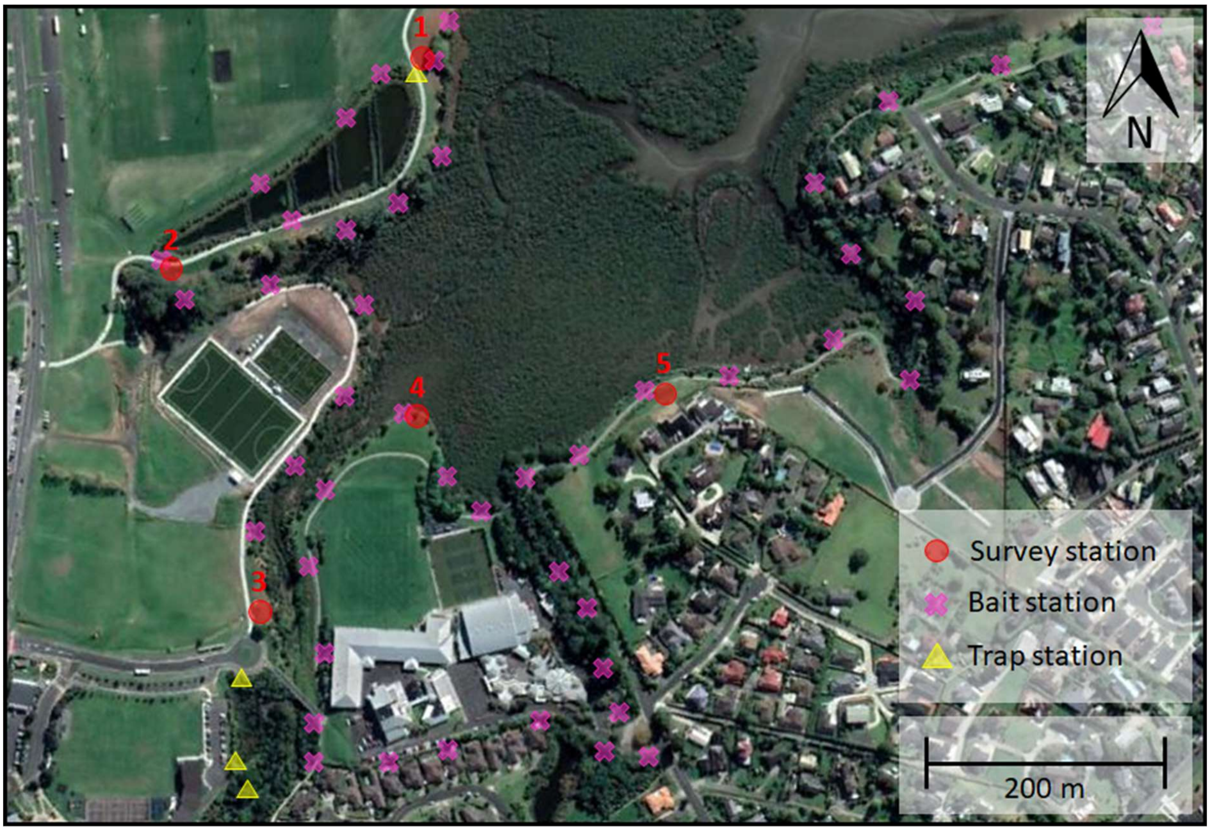

Figure A1.28: *Map of Silverdale Kingsway including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Stanmore Bay Park – surveyed 2013 to 2020

Stanmore Bay Park lies along choke line number two, installed in November 2016 (Forest and Bird, 2018d; Wilkinson, 2020). The area is of significant cultural mana whenua and is susceptible to flooding and stormwater overflow during high tides and heavy rainfall (Auckland Council, 2019b). Organised sport, recreation and educational activities occur regularly across the location (Auckland Council, 2019b). An open stormwater drainage channel runs adjacent to all stations. Station one is near the beach on a grassy bank with pōhutukawa (Julian, 2008). Station two is on a mown grass field, and stations three to five are found in or near wetland vegetation. Dogs must be under control on a leash on the large grass field between stations one and two from 10.00 am to 5.00 pm from Labour weekend to 1 March, but are permitted under control on leash in all areas of Stanmore Bay Park at any other time (Auckland Council, 2012, 2019a). Station four was monitored from 2013 to 2016, with all five stations monitored from 2017.

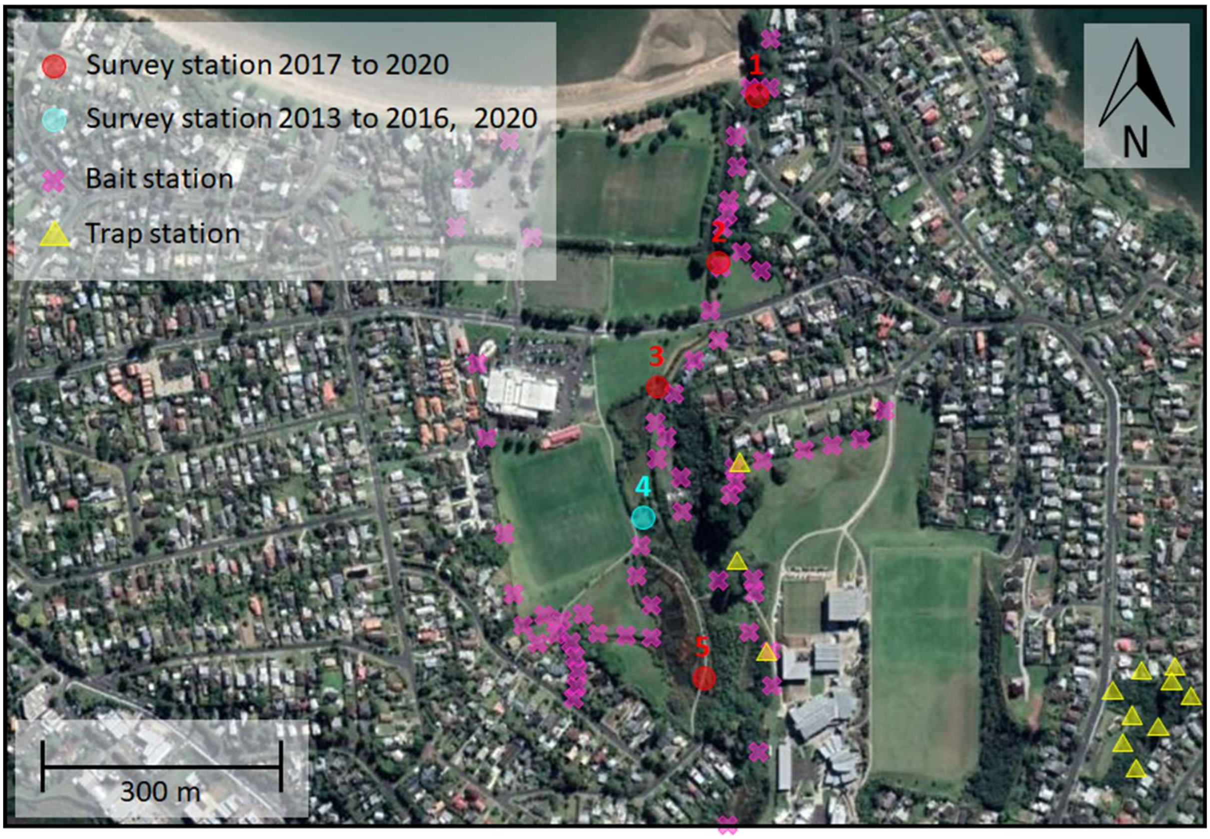

Figure A1.29: *Map of Stanmore Bay including the survey stations and known pest-management. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Sundown Reserve – surveyed 2013 to 2016, 2020

Sundown Reserve is a 6,793 m^2 grass mown reserve with scattered trees (Auckland Council, 2019b). The reserve provides walking access between the neighbouring residential streets. The single station was surveyed from 2013 to 2016, and again in 2020. There is a concrete stormwater drain that passes through the centre of the park and is within the 30 m radius of the survey station (Auckland Council, 2019b). Dogs are permitted under control off leash in the reserve (Auckland Council, 2012, 2019a). There is no pest-management in the reserve itself, but trap and bait stations were installed nearby at the Church of St. Francis by the Sea in 2020.

Figure A1.30: *Map of Sundown Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Waterfall Gully – surveyed 2013 to 2019

Waterfall Gully is a native remnant forest with a canopy primarily consisting of karaka (*Corynocarpus laevigatus*), pōhutukawa, pūriri, taraire (*Beilschmiedia tarairi*), tawaroa (*Beilschmiedia tawa*) and small patches of kauri (SOSSI, 2014b). The subcanopy consists of māhoe, pigeonwood (*Hedycarya arborea*), cabbage trees, houpara and lancewood (*Pseudopanax lessonii*) (SOSSI, 2014b). The understorey consists of hangehange, mingimingi, māpou and karamū (SOSSI, 2014b). Supplejack vines (*Ripogonum scandens*) are found throughout (SOSSI, 2014b). The few invasive weed species present are managed by contracted companies (SOSSI, 2014b). Stations one to three were monitored in 2013, station four was added in 2014 and station five was added in 2017. The multi-species predator-proof fence was installed in 2010 (SOSSI, 2014c). Trap and bait stations are also present within the sanctuary but are not included in the map.

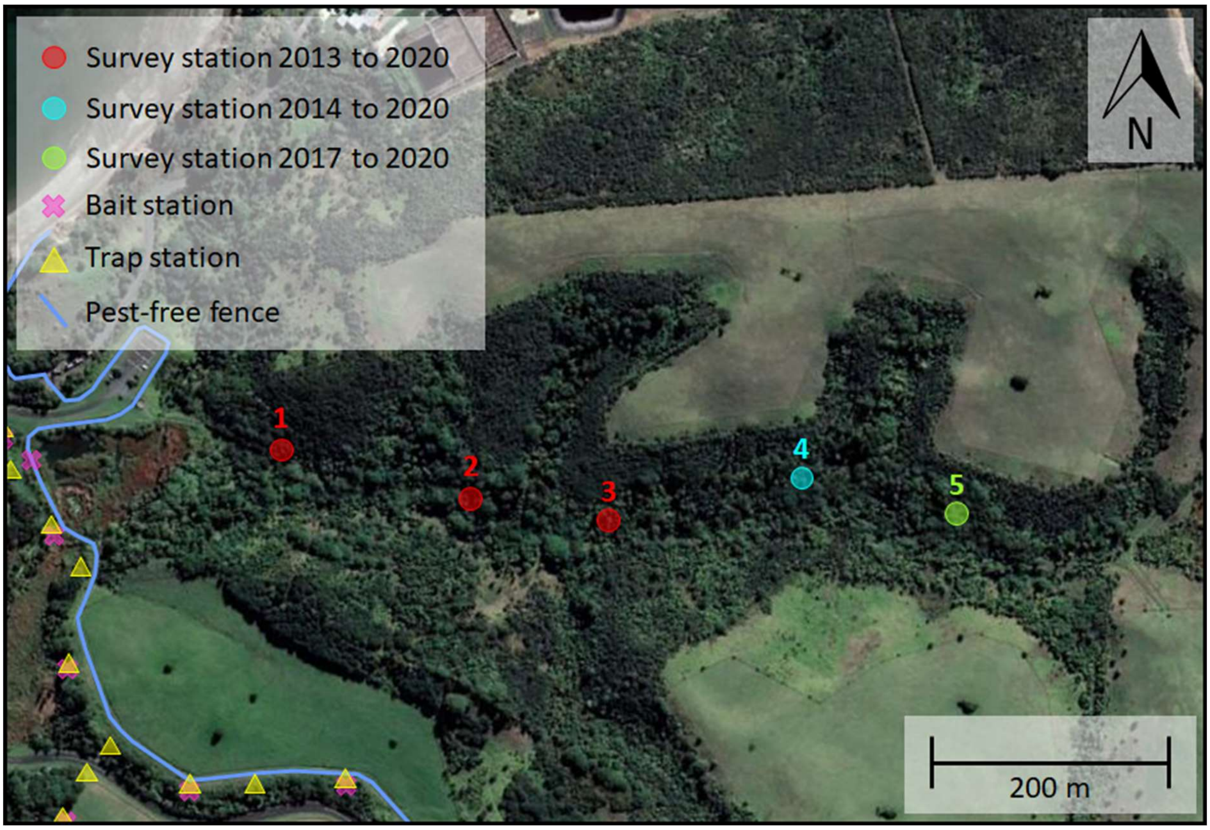

Figure A1.31: *Map of Waterfall Gully including the survey stations and known pest-management on the exterior of the predator-proof fence. Satellite image taken 29 April 2019, adapted from Google Earth Pro (2020).*

Weiti Views Reserve – surveyed 2013 to 2016, 2020

Weiti Views Reserve is a 9,208 m^2 reserve that acts as an informal recreation area, play space, and walking connection between the neighbouring residential streets (Auckland Council, 2019b). There is a small jetty and a pond within the 30 m radius of the single station, which was surveyed from 2013 to 2016, and again in 2020. A children's playground is at the southern end of the park. Dogs are permitted under control off leash in the reserve (Auckland Council, 2012, 2019a). Pest-management began in the reserve and its surrounding area in October 2020.

Figure A1.32: *Map of Weiti Views Reserve including the survey station and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Whangaparāoa Golf Course – surveyed 2013 to 2016, 2020

The two stations at Whangaparāoa Golf Course were surveyed from 2013 to 2016 and again in 2020. Both survey stations are located on the edge of small forest sections which allow for a mix of open grass and tree cover within the 30 m radius. The trees within the golf course are thought to provide an important stepping stone habitat between Shakespear Regional Park and Matakatia Glade for birds moving west across the peninsula (Cummings, 2017). 17 bait stations and one stoat trap were installed around the perimeter of the property and near the swamp in the middle of the course in May 2014 (Forest and Bird, 2018d). Additional pest-management was installed from November 2016 (Wilkinson, 2020).

Figure A1.33: *Map of Whangaparāoa Golf Course including the survey stations and known pest-management. Satellite image taken 27 July 2014, adapted from Google Earth Pro (2020).*

Appendix 2

Target bird species community

In total 45 species were targeted in surveys between 2013 and 2020. Species were added to the data sheet following translocation, or amended as their presence or absence became apparent. Targeted species were primarily terrestrial Passeriformes, though volunteers were asked to include accurate counts of all birds (excluding gulls) seen or heard. Species from 12 orders were included.

Table A2.1: *The number of target species from each group (2020).*

Order	Group	Number of species
Accipitriformes	Secretary-bird, kites, eagles, hawks and allies	1
Anseriformes	Duck-like birds	2
Charadriiformes	Waders, gulls and terns	1
Ciconiiformes	Herons, ibises and allies	1
Columbiformes	Pigeons and doves	3
Coraciiformes	Kingfishers, bee-eaters, rollers and allies	1
Cuculiformes	Cuckoos	2
Galliformes	Game birds and allies	3
Gruiformes	Rails, cranes and allies	2
Passeriformes	Passerine (perching) birds	24
Psittaciformes	Cockatoos, parrots and parakeets	3
Strigiformes	Owls	1

In 2020, the list of species was split into groups of common and uncommon birds. The common and scientific names used for bird species can vary, thus names are listed as they appear on New Zealand Birds Online (2013).

Table A2.2: *List of the target species included on the survey sheet each year.*

Common name	Scientific name	Classification	2013-16	2017	2018	2019	2020
Australian magpie	*Gymnorhina tibicen*	Common	X	X	X	X	X
Barbary dove	*Streptopelia risorii*	Common	X	X	X	X	X
Bellbird	*Anthornis melanura*	Uncommon	X	X	X	X	X
Brown quail	*Coturnix ypsilophora*	Uncommon					X
California quail	*Callipepla californica*	Common	X	X	X	X	X
Chaffinch	*Fringilla coelebs*	Common	X	X	X	X	X
Common myna	*Acridotheres tristis*	Common	X	X	X	X	X
Common pheasant	*Phasianus colchicus*	Common	X	X	X	X	X
Common redpoll	*Carduelis flammea*	N/A	X				
Common starling	*Sturnus vulgaris*	Common	X	X	X	X	X
Dunnock	*Prunella modularis*	Uncommon	X	X	X	X	X
Eastern rosella	*Platycercus eximius*	Common	X	X	X	X	X
Eurasian blackbird	*Turdus merula*	Common	X	X	X	X	X
Eurasian skylark	*Alauda arvensis*	Common	X	X	X	X	X
European goldfinch	*Carduelis carduelis*	Common	X	X	X	X	X
European greenfinch	*Carduelis chloris*	Common	X	X	X	X	X
Grey warbler	*Gerygone igata*	Common	X	X	X	X	X
House sparrow	*Passer domesticus*	Common	X	X	X	X	X
Long-tailed cuckoo	*Eudynamys taitensis*	Uncommon					X
Mallard	*Anas platyrhynchos*	Common	X	X	X	X	X
Morepork	*Ninox novaseelandiae*	Uncommon	X				X
New Zealand fantail	*Rhipidura fuliginosa*	Common	X	X	X	X	X
New Zealand pigeon	*Hemiphaga novaseelandiae*	Common	X	X	X	X	X
New Zealand pipit	*Anthus novaseelandiae*	Uncommon	X	X	X	X	X
North Island kākā	*Nestor meridionalis septentrionalis*	Uncommon	X				X
North Island robin	*Petroica longipes*	Uncommon				X	X
North Island saddleback	*Philesturnus rufusater*	Uncommon				X	X
North Island tomtit	*Petroica macrocephala toitoi*	Uncommon	X				X
Paradise shelduck	*Tadorna variegate*	Common	X	X	X	X	X
Pūkeko	*Porphyrio melanotus*	Common	X	X	X	X	X
Red-crowned parakeet	*Cyanoramphus novaezelandiae*	Uncommon	X	X	X	X	X
Sacred kingfisher	*Todiramphus sanctus*	Common	X	X	X	X	X
Shining cuckoo	*Chrysococcyx lucidus*	Common	X	X	X	X	X
Silvereye	*Zosterops lateralis*	Common	X	X	X	X	X
Song thrush	*Turdus philomelos*	Common	X	X	X	X	X
Spotless crake	*Porzana tabuensis*	Uncommon					X
Spotted dove	*Streptopelia chinensis*	Common	X	X	X	X	X
Spur-winged plover	*Vanellus miles*	Common	X	X	X	X	X
Stitchbird	*Notiomystis cincta*	Uncommon					X
Swamp harrier	*Circus approximans*	Common	X	X	X	X	X
Tūī	*Prosthemadera novaeseelandiae*	Common	X	X	X	X	X
Welcome swallow	*Hirundo neoxena neoxena*	Common	X	X	X	X	X
White-faced heron	*Egretta novahollandiae*	Common	X	X	X	X	X
Whitehead	*Mohoua albicilla*	Uncommon				X	X
Yellowhammer	*Emberiza citronella*	Common	X	X	X	X	X

Of the 45 species described, 25 (55.56%) are naturally occurring, including 15 (33.33%) endemic species, and 10 (22.22%) native species. Of these species, 1 has a conservation status of "threatened," 8 species are "at risk" and 16 species are classified as "not threatened" (Robertson et al., 2017). The remaining 20 (44.44%) bird species are introduced and naturalised following deliberate or accidental introduction by humans (Robertson et al., 2017).

Table A2.3: *Conservation status and the order of the native and endemic species targeted in 2020. Conservation statuses taken from Robertson et al. (2017).*

Common name	Scientific name	Order	Status	Conservation status
Bellbird	*Anthornis melanura*	Passeriformes	Endemic	Not threatened
Grey warbler	*Gerygone igata*	Passeriformes	Endemic	Not threatened
Long-tailed cuckoo	*Eudynamys taitensis*	Cuculiformes	Endemic	At risk, naturally uncommon
Morepork	*Ninox novaseelandiae*	Strigiformes	Native	Not threatened
New Zealand fantail	*Rhipidura fuliginosa*	Passeriformes	Endemic	Not threatened
New Zealand pigeon	*Hemiphaga novaseelandiae*	Columbiformes	Endemic	Not threatened
New Zealand pipit	*Anthus novaseelandiae*	Passeriformes	Endemic	At risk, declining – **C(1/1)**
North Island kākā	*Nestor meridionalis septentrionalis*	Psittaciformes	Endemic	At risk, recovering – **B**
North Island robin	*Petroica longipes*	Passeriformes	Endemic	At risk, declining – **B(1/1)**
North Island saddleback	*Philesturnus rufusater*	Passeriformes	Endemic	At risk, recovering – **B**
North Island tomtit	*Petroica macrocephala toitoi*	Passeriformes	Endemic	Not threatened
Paradise shelduck	*Tadorna variegate*	Anseriformes	Endemic	Not threatened
Pūkeko	*Porphyrio melanotus*	Gruiformes	Native	Not threatened
Red-crowned parakeet	*Cyanoramphus novaezelandiae*	Psittaciformes	Endemic	At risk, relict – **B**
Sacred kingfisher	*Todiramphus sanctus*	Coraciiformes	Native	Not threatened
Shining cuckoo	*Chrysococcyx lucidus*	Cuculiformes	Native	Not threatened
Silvereye	*Zosterops lateralis*	Passeriformes	Native	Not threatened
Spotless crake	*Porzana tabuensis*	Gruiformes	Native	At risk, declining – **A(1/1)**
Spur-winged plover	*Vanellus miles*	Charadriiformes	Native	Not threatened
Stitchbird	*Notiomystis cincta*	Passeriformes	Endemic	Threatened, nationally vulnerable – **B(1/1)**
Swamp harrier	*Circus approximans*	Accipitriformes	Native	Not threatened
Tūī	*Prosthemadera novaeseelandiae*	Passeriformes	Endemic	Not threatened
Welcome swallow	*Hirundo neoxena neoxena*	Passeriformes	Native	Not threatened
White-faced heron	*Egretta novahollandiae*	Ciconiiformes	Native	Not threatened
Whitehead	*Mohoua albicilla*	Passeriformes	Endemic	At risk, declining – **C(1/1)**

Table A2.4: *Explanation of conservation statuses and criteria taken from Robertson et al. (2017).*

Conservation status	Criteria	Explanation of criteria
Threatened, nationally vulnerable	B(1/1)	The species has 1,000-5,000 mature individuals with a stable population.
At risk, declining Species that do not qualify as "threatened" because populations are large and/or have a slower rate of decline than the trigger points.	A(1/1) B(1/1) C(1/1)	The species has 5,000-20,000 mature individuals with a predicted decline of 10-30%. The species has 20,000-100,000 mature individuals with a predicted decline of 10-50%. The species has > 100,000 mature individuals with a predicted decline of 10-70%.
At risk, recovering Species that have undergone a documented decline within the past 1,000 years and now have an ongoing or predicted increase of > 10% in total population or area of occupancy over the next 10 years or 3 generations (whichever is longer).	B	The species has 5,000-20,000 mature individuals or a total area occupancy of ≤ 1,000 ha and a predicted increase of > 10%.
At risk, relict Species that have undergone a documented decline over the last 1,000 years and now occupy < 10% of their former range.	B	The species has > 20,000 mature individuals with a stable population (±10%).
At risk, naturally uncommon		Species whose distribution is confined to a specific geographical area, or which occur within naturally small and widely scattered population which is not the result of human disturbance. Species with populations of < 20,000 mature individuals are not considered naturally uncommon unless they occupy an area < 1,000km^2.
Not threatened		Resident, native species that have large populations that are either stable or increasing. However, some populations may have extreme fluctuations but return to a similar long-term, large average population.

Explanation criteria is provided for native/endemic species only. Criteria from Robertson et al. (2017) that do not apply are not included. Further conservation statuses, criteria and qualifiers can be found in Robertson et al. (2017).

Table A2.5: *Introduced target species and the order of each species.*

Common name	Scientific name	Order
Australian magpie	*Gymnorhina tibicen*	Passeriformes
Barbary dove	*Streptopelia risorii*	Columbiformes
Brown quail	*Coturnix ypsilophora*	Galliformes
California quail	*Callipepla californica*	Galliformes
Chaffinch	*Fringilla coelebs*	Passeriformes
Common myna	*Acridotheres tristis*	Passeriformes
Common pheasant	*Phasianus colchicus*	Galliformes
Common redpoll	*Carduelis flammea*	Passeriformes
Common starling	*Sturnus vulgaris*	Passeriformes
Dunnock	*Prunella modularis*	Passeriformes
Eastern rosella	*Platycercus eximius*	Psittaciformes
Eurasian blackbird	*Turdus merula*	Passeriformes
Eurasian skylark	*Alauda arvensis*	Passeriformes
European goldfinch	*Carduelis carduelis*	Passeriformes
European greenfinch	*Carduelis chloris*	Passeriformes
House sparrow	*Passer domesticus*	Passeriformes
Mallard	*Anas platyrhynchos*	Anseriformes
Song thrush	*Turdus philomelos*	Passeriformes
Spotted dove	*Streptopelia chinensis*	Columbiformes
Yellowhammer	*Emberiza citrinella*	Passeriformes

Bird species excluded from surveys

A list of additional species that were recorded during annual surveys is found in Table A2.6. Further species recorded throughout the study site using eBird (2020) data for the New Zealand Bird Atlas are provided in Table A2.7. Data from four grid squares are included from 1 June 2019 to 30 November 2020. Each grid square covers 10 km^2, for a total area of 40 km^2. Three protected endemic species are exluded from this list as they are unable to disperse to the mainland from Tiritiri Matangi Island without human assistance (Heather & Robertson, 2015). These species include the flightless South Island takahē (*Porphyrio hochstetteri*), the North Island kōkako (*Callaeas wilsoni*) and the rifleman (*Acanthisitta chloris*) (eBird, 2020; Heather & Robertson, 2015). The North Island kōkako rarely flies more than 50 m at a time and the rifleman is a poor flier with limited dispersal capabilities, particularly over water (Heather & Robertson, 2015).

Table A2.6: *Additional bird species recorded during annual surveys.*

Common name	Scientific name	Order	NZ status
Australasian gannet	*Morus serrator*	Pelecaniformes	Native
Australasian shoveler	*Anas rhynchotis*	Anseriformes	Native
Black swan	*Cygnus atratus*	Anseriformes	Native
Canada goose	*Branta canadensis*	Anseriformes	Introduced
Eurasian coot	*Fulica atra*	Gruiformes	Native
Little black shag	*Phalacrocorax sulcirostris*	Pelecaniformes	Native
Little pied shag	*Phalacrocorax melanoleucos*	Pelecaniformes	Native
New Zealand dabchick	*Poliocephalus rufopectus*	Podicipediformes	Endemic
Red-billed gull	*Larus novaehollandiae*	Charadriiformes	Native
Rock pigeon	*Columba livia*	Columbiformes	Introduced
Royal spoonbill	*Platalea regia*	Ciconiiformes	Native
Southern black-backed gull	*Larus dominicanus*	Charadriiformes	Native
South Island pied oystercatcher	*Haematopus finschi*	Charadriiformes	Endemic
Variable oystercatcher	*Haeoatopus unicolor*	Charadriiformes	Endemic

Bird descriptions

The following descriptions provide a summary of relevant information about each species and are provided as a resource for volunteers associated with the Pest-Free Hibiscus Coast project. The common and scientific names are standardised as they appear on New Zealand Birds Online (2013). Māori names are dependent on iwi and may vary based on the name itself or by dialectical or spelling variants. The most widely recognised Māori name is included for each native species.

The information provided contains, but is not limited to: the species' order, its New Zealand status (introduced, endemic, native) and the year of arrival or introduction if known or applicable. "Introduced" species are those that are found in New Zealand because of anthropogenic introduction within the past 180 years. "Endemic" species are native species that evolved and are found only in New Zealand, and "native" species are those that are also found in other countries and that have naturally colonised New Zealand without the aid of humans. Information on population size, distribution, preferred habitat, and where, when and how the species is most often seen or heard is included. Diet and known behaviours such as migration, conflicts, breeding, and foraging strategies are described, as well as heterospecific and human interactions. Life history includes age at first breeding, number of offspring, and longevity. Threats for each species are provided if pertinent.

Table A2.7: *Bird species recorded in or near the study site using New Zealand Bird Atlas eBird (2020) data recorded between 1 June 2019 and 30 November 2020.*

Common name	Scientific name	Order	NZ status
Arctic skua	*Stercorarius parasiticus*	Charadriiformes	Native
Australasian little grebe	*Tachybaptus novaehollandiae*	Podicepediformes	Native
Banded dotterel	*Charadrius bicinctus*	Charadriiformes	Endemic
Bar-tailed godwit	*Limosa lapponica*	Charadriiformes	Native
Black shag	*Phalacrocorax carbo*	Pelecaniformes	Native
Black-fronted tern	*Chlidonias albostriatus*	Charadriiformes	Endemic
Brown teal	*Anas chlorotis*	Anseriformes	Endemic
Buff-banded rail	*Gallirallus philippensis*	Gruiformes	Native
Buller's shearwater	*Puffinus bulleri*	Procellariiformes	Endemic
Caspian tern	*Hydroprogne caspia*	Charadriiformes	Native
Common diving petrel	*Pelecanoides urinatrix*	Procellariiformes	Native
Cook's petrel	*Pterodroma cookii*	Procellariiformes	Endemic
Flesh-footed shearwater	*Puffinus carneipes*	Procellariiformes	Native
Fluttering shearwater	*Puffinus gavia*	Procellariiformes	Endemic
Grey duck	*Anas superciliosa*	Anseriformes	Native
Grey teal	*Anas gracilis*	Anseriformes	Native
Grey-faced petrel	*Pterodroma macroptera*	Procellariiformes	Native
Greylag goose	*Anser anser*	Anseriformes	Introduced
Indian peafowl	*Pavo cristatus*	Galliformes	Introduced
Laughing kookaburra	*Dacelo novaguineae*	Coraciiformes	Introduced
Lesser redpoll	*Acanthis cabaret*	Passeriformes	Introduced
Little penguin	*Eudyptula minor*	Sphenisciformes	Native
Little spotted kiwi	*Apteryx owenii*	Apterygiformes	Endemic
New Zealand dotterel	*Charadrius obscurus*	Charadriiformes	Endemic
New Zealand fernbird	*Bowdleria punctata*	Passeriformes	Endemic
New Zealand scaup	*Aythya novaeseelandiae*	Anseriformes	Endemic
Pacific golden-plover	*Pluvialis fulva*	Charadriiformes	Native
Pied shag	*Phalacrocorax varius*	Pelecaniformes	Native
Pied stilt	*Himantopus himantopus*	Charadriiformes	Native
Pomarine skua	*Coprotheres pomarinus*	Charadriiformes	Native
Reef heron	*Egretta sacra*	Ciconiiformes	Native
White-fronted tern	*Sterna striata*	Charadriiformes	Native
Wild turkey	*Meleagris gallopavo*	Galliformes	Introduced

Australian magpie (*Gymnorhina tibicen*)

The Australian magpie is a Passeriform that was introduced to New Zealand by Acclimatisation societies between 1864 and 1874 (Heather & Robertson, 2015). Introductions were intended to control agricultural pests and the species was protected until 1951 (Heather & Robertson, 2015). The 1,000+ introduced magpies successfully propagated and became widespread, aided by the extensive clearance of forests across New Zealand (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006). Today, they are common in urban gardens, parks, golf courses, roadsides, and in open farmland with tall, scattered trees (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). Although rare within forests, magpies forage around fringe habitats, primarily feeding on invertebrates pecked from the ground (Chambers, 2009; Higgins et al., 2006). Diet is supplemented with seeds, grain, nestlings, eggs, lizards, mice, sick sheep and carrion (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996).

Figure A2.1: *Photograph of the Australian magpie (Gymnorhina tibicen). Photo credit: Hayden Pye.*

Magpies have complex social organisations and may be found alone, in pairs, or in groups (Higgins et al., 2006). Sub-adults and yearlings may form flocks of up to 80 non-territorial birds, whilst adults form pairs or small groups of 2-10 (Heather & Robertson, 2015). Adult magpies defend territories year round with distinctive undulating flute-like calls that are made from high perches, usually around dawn and dusk (Heather & Robertson, 2015; Moon, 1996; Moon, 2006). Although magpies may protect crops by eating insects, they are considered pests as they pull seedlings from the ground and show aggression towards humans, dogs, and other animals over the breeding season (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006). They also raid the nests of tūī and skylarks and may attack and kill large native birds such as swamp harriers and white-faced herons (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). Despite this aggression, magpies can be tame, playful and bold, especially in urban areas (Higgins et al., 2006; Moon, 2006).

Magpie flocks usually have one breeding pair, sometimes two (Heather & Robertson, 2015). Nests are built in tall trees, hedges, or on power poles in June, and one clutch of 2-5 eggs (average 3-4) is laid between July and November (Heather & Robertson, 2015; Moon, 1996). Later clutches are typically replacements of a failed first clutch, however occasionally a second clutch may be laid (Heather & Robertson, 2015). The eggs are incubated by the female for 20-21 days and both parents feed the chicks which fledge at 21 days (Heather & Robertson, 2015). Magpies usually breed from age three, though females can breed after one year (Heather & Robertson, 2015). Longevity is 25-30 years (Angus, 2017).

Barbary dove (*Streptopelia risorii*)

The barbary dove is a domesticated African Columbiform that was first introduced to New Zealand in 1867 (Gill et al., 2010). Today, feral populations are mostly the descendants of aviary escapees or birds that were liberated by pigeon enthusiasts in the 1970s (Chambers, 2009; Higgins & Davies, 1996; Moon, 1996). The species is thus relatively tame (Stidolph, 1974). Although locally common across Ōrewa, there are less than 2,000 barbary doves in isolated but increasing populations (Chambers, 2009; Heather & Robertson, 2015). They are typically found alone or in pairs in urban gardens, parks and orchards with tall trees (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). Small flocks feed at ground level on grain, fruit, seeds, invertebrates and food scraps provided by humans (Heather & Robertson, 2015; Higgins & Davies, 1996). Their call is a soft but conspicuous two syllable “coo-crroo” (Chambers, 2009; Heather & Robertson, 2015).

Figure A2.2: *Photograph of the barbary dove (Streptopelia risorii). Photo credit: JJ Harrison via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

Barbary doves form monogamous pairs and re-nest multiple times each season (Frost, 2013; Heather & Robertson, 2015). Breeding is most prolific during spring and summer but occurs year-round if food is abundant (Heather & Robertson, 2015). Clutches of two eggs are laid on a flimsy platform nest in the forks of trees, shrubs or hedges (Chambers, 2009; Heather & Robertson, 2015). The eggs are incubated for around 15 days by both parents, who also brood the chicks for the first week (Heather & Robertson, 2015). Young fledge at 15 days and quickly become independent (Heather & Robertson, 2015). The age of first breeding is one year old (Frost, 2013). Maximum longevity in the wild is unknown, but barbary doves can live up to 12 years in captivity (Frost, 2013).

Bellbird (korimako) (*Anthornis melanura*)

The bellbird is a protected endemic Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Bellbirds are found in patchy distributions in and around native and exotic forest, scrub, farm shelterbelts, gardens, and parks – especially where vegetation is dense or diverse (Department of Conservation, 2020a; Heather & Robertson, 2015). Bellbirds are widespread and are present in most of New Zealand's regions, though they are absent from parts of Canterbury, almost all of Northland, and from mainland Auckland since the 1860s (Gill et al., 2010; Heather & Robertson, 2015). Their absence in these areas is thought to be a result of deforestation, food competition with possums, and possibly avian disease (Department of Conservation, 2020a; Moon, 2006). Bellbirds have recently established at Shakespear Regional Park (from Tiritiri Matangi Island) and are breeding on the Whangaparāoa Peninsula (Chambers, 2009; Heather & Robertson, 2015).

Bellbirds are relatively tame and are easily noticed (Higgins, Peter, & Steele, 2001). They produce a 3-5 bell note song at dawn and dusk, and a loud, far-travelling liquid call during the day (Heather & Robertson, 2015; Moon, 1996). Their wings also make a conspicuous whirring sound in flight (Chambers, 2009). Outside of the breeding season bellbirds can be nomadic and solitary, but they may associate with other bellbirds, tūī, silvereyes and kererū at food sources (Heather & Robertson, 2015; Higgins et al., 2001). Diet is primarily nectar along with fruit, and insects hawked or gleaned off vegetation (Heather & Robertson, 2015; Higgins et al., 2001). Bellbirds are valuable in supporting native forest regeneration through pollination and the dispersion of fruit seeds (Moon, 2006).

Bellbirds are territorial and are often seen in pairs or family groups over the breeding season (Heather & Robertson, 2015; Higgins et al., 2001). On the mainland, females build a cup nest in a tree fork (Heather & Robertson, 2015). They breed in the same territory each year, typically raising two broods of 3-5 eggs (average 4) between September and January (Heather & Robertson, 2015; Moon, 1996). The female incubates the eggs for about 15 days and both parents feed the chicks which fledge around 19 days (Heather & Robertson, 2015). Bellbirds breed after one year and can live over eight years (Heather & Robertson, 2015). Populations are limited by predation from rats and stoats (*Mustela* *erminea*), but they do persist in areas with predators (Department of Conservation, 2020a; Heather & Robertson, 2015).

Figure A2.3: *Photographs of the male (left) and female (right) bellbird (Anthornis melanura). The female has a flax pollen crown. Photo credit: Sid Mosdell (CC BY 2.0) and Glen Fergus (CC BY-SA 2.5) via Wikimedia Commons. Images cropped.*

Brown quail (*Coturnix ypsilophora*)

The brown quail is a Galliform that was widely introduced to New Zealand from Australia in the 1860s and 1870s (Chambers, 2009; Heather & Robertson, 2015). Today, they persist only in scattered populations across the northern half of the North Island and on some northern offshore islands (Gill et al., 2010; Moon, 1996). Brown quail are sedentary in New Zealand and occupy swamp margins, salt marshes, the edges of dusty country roads and rough open grassland with scrub cover (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993). They are generally seen at ground level where they forage on fallen seeds, weeds, leaves, shoots, flowers, insects and small reptiles (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Shakespear Open Sanctuary is considered one of the best places to find brown quail in New Zealand (Heather & Robertson, 2015; Seabrook-Davison, 2013).

Brown quail are small and have inconspicuous, cryptic plumage (Heather & Robertson, 2015). Their call is a whistling “ker-wee” with a rising inflection on the second syllable (Heather & Robertson, 2015). Brown quail are reluctant flyers and will rapidly scuttle and bound to cover in the undergrowth if disturbed (Heather & Robertson, 2015; Marchant & Higgins, 1993). If flushed, they noisily burst from cover with a fast whirring flight (Heather & Robertson, 2015; Marchant & Higgins, 1993).

Figure A2.4: *Photograph of the brown quail (Coturnix ypsilophora). Photo credit: JJ Harrison via Wikimedia Commons (CC BY-SA 4.0). Image cropped.*

Brown quail may be seen alone but they are most commonly found in pairs or family groups of up to 30 birds over the September to January breeding season (Heather & Robertson, 2015; Marchant & Higgins, 1993; Seabrook-Davison, 2013). Monogamous pairs lay one clutch of 7-12 eggs in a nest built at ground level under thick vegetation (Heather & Robertson, 2015; Marchant & Higgins, 1993). The female incubates the eggs for around 21 days and chicks leave the nest and form family groups soon after hatching (Heather & Robertson, 2015). Brown quail reach adult size by six weeks and are sexually mature by 100 days (Marchant & Higgins, 1993). Longevity is unknown.

California quail (*Callipepla californica*)

The California quail is a Galliform that was introduced widely to New Zealand from 1865 to 1875 (Gill et al., 2010; Heather & Robertson, 2015). Subsequent liberations of New Zealand bred stock have supplemented populations which are now distributed broadly across tussockland, rough pasture, roadside verges and less intensely developed areas that have low, dense scrub (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Moon, 1996). California quail are typically sedentary but they do may make some local movements (Marchant & Higgins, 1993). They are commonly seen on the ground or perched on fenceposts, bushes or low trees, and may be found in pairs, family groups or large coveys (Marchant & Higgins, 1993). California quail forage at ground level near dense cover, particularly in the early morning and before dusk (Heather & Robertson, 2015; Marchant & Higgins, 1993). Diet consists of fallen seeds, fruit, leaves, grasses and insects (Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996).

California quail have conspicuous behaviours. Males often produce a loud tri-syllabic “chi-ca-go!” call for an extended period of time from a perch (Chambers, 2009; Heather & Robertson, 2015). Lost chicks make loud distress whistles and adults respond to them with crowing calls (Marchant & Higgins, 1993). They may freeze and crouch when disturbed, and sound a variety of loud calls when alarmed (Chambers, 2009; Marchant & Higgins, 1993). Their wings create a prominent whirring sound as they escape by running and then flying away (Chambers, 2009; Marchant & Higgins, 1993).

Coveys disband near the end of winter and monogamous pairs form in late August (Heather & Robertson, 2015; Marchant & Higgins, 1993). From late September to early February, one brood of 8-24 eggs (average 13) is laid in a depression in long grass that is close to or under thick vegetation (Heather & Robertson, 2015; Marchant & Higgins, 1993). The female incubates the eggs for 22-23 days and the chicks leave the nest soon after hatching (Heather & Robertson, 2015). Young can fly by 10 days old and breeding can begin at age one (Heather & Robertson, 2015; Marchant & Higgins, 1993). The oldest known New Zealand bird lived 11 years (Heather & Robertson, 2015). California quail are subject to predation from stoats, ferrets, cats (*Felis catus*) and hedgehogs (*Erinaceus europaeus* *occidentalis*) (Marchant & Higgins, 1993). Nests are often destroyed by gardening or cultivation, and disturbed nests may be abandoned (Moon, 2006).

Figure A2.5: *Photograph of the male (left) and female (right) California quail (Callipepla californica). Photo credits: Hayden Pye.*

Chaffinch (*Fringilla coelebs*)

The chaffinch is a Passeriform that was introduced to New Zealand from Europe by Acclimatisation societies between 1862 and 1880 (Heather & Robertson, 2015). Chaffinches were slow to establish but have since become the second most widely distributed bird species in New Zealand (Gill et al., 2010; Heather & Robertson, 2015; Watola, 2011). Large populations can be found in pine forests and they are common around native forest fringes, scrubland, suburban gardens, parks, farmland, tussockland, coasts, beaches and mudflats (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006). They are resident in Auckland but are thought to make some local seasonal movements from settled and wooded habitats to open areas over winter (Higgins et al., 2006).

Chaffinches are commonly found alone or in twos and are often heard before they are seen over the breeding season (Heather & Robertson, 2015; Higgins & Davies, 1996). The male’s territorial song is repeated from a high perch and generally comprises seven short sharp notes followed by a varied flourish (Higgins & Davies, 1996; Moon, 1996). Over autumn, winter and early spring they may form large feeding flocks with other finches, house sparrows and native insectivorous passerines (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). Chaffinches primarily feed at ground level on cereal, weed and pine seeds, but also consume fruit, glean invertebrates and hawk flying insects

(Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They may cause minor damage to cereal crops and fruit buds, though damage to commercial fruit is rare (Heather & Robertson, 2015; Higgins & Davies, 1996). Chaffinches can be tame and will beg for food crumbs from humans, flying up to cover if disturbed or threatened (Chambers, 2009).

Figure A2.6: *Photographs of the male (left) and female (right) chaffinch (Fringilla coelebs). Photo credit: Andreas Trepte (CC BY-SA 2.5) and Diego Delso (CC BY-SA 4.0) via Wikimedia Commons. Images cropped.*

Flocks break up in late July and pairs form for the breeding season (Heather & Robertson, 2015). Females build a nest in trees or shrubs and typically lay a single clutch of 3-6 eggs (average 4) between mid-September and late-January, peaking over October-November (Heather & Robertson, 2015; Higgins et al., 2006). The female incubates the eggs for 11-15 days (average 13) and the chicks hatch over a period of 1-3 days (average 13) (Heather & Robertson, 2015; Higgins et al., 2006). The young fledge after 10-16 days but continue to be fed by both parents for another three weeks (Heather & Robertson, 2015). Chaffinches can breed at age one and can live almost 10 years in New Zealand (Heather & Robertson, 2015; Higgins & Davies, 1996).

Common myna (*Acridotheres tristis*)

The common myna is a Passeriform that was primarily introduced to the South Island between 1870 and 1877 to control crop pest invertebrates (Heather & Robertson, 2015; Watola, 2011). Populations reached Auckland by 1947 but mynas are now absent from the South Island, presumably as they prefer warmer climates (Heather & Robertson, 2015; Moon, 1996; Watola, 2011). Today, Mynas are locally abundant across North Island farmlands, orchards, and suburbs (Chambers, 2009; Heather & Robertson, 2015). They are common around forest fringes, but rare within (Chambers, 2009). Mynas are sedentary and may be seen alone, in pairs, or in flocks (Heather & Robertson, 2015; Higgins et al., 2006). Large flocks may travel 10 km+ to communal roosting spots in the evening (Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.7: *Photograph of the common myna (Acridotheres tristis). Photo credit: Erik Karits via Pixabay. Image cropped.*

Mynas typically feed at ground level on invertebrates, fruit, food scraps, lizards, insects, carrion, small birds, chicks and bird's eggs (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). Although they may benefit farmers by consuming crop-eating invertebrates, mynas are considered pests due to the damage they cause to commercial fruit crops and their aggressive nature towards native species (Chambers, 2009; Heather & Robertson, 2015; Tiritiri Matangi Open Sanctuary, 2010a). Mynas can be tame around humans, but they evict saddlebacks from their nest boxes, starlings from their nests, and may attack other birds for no discernible reason (Higgins et al., 2006; Moon, 1996; Tiritiri Matangi Open Sanctuary, 2010a). During the breeding season, territorial fights also break out between neighbouring pairs (Heather & Robertson, 2015).

Early morning territorial calls are a loud raucous medley of gurgling and chattering sounds produced by both sexes for up to 15 minutes (Heather & Robertson, 2015). Nests are built in holes in trees, buildings, cliffs, or thick tangled vegetation (Heather & Robertson, 2015). Monogamous, lifelong pairs typically raise two broods of 1-6 eggs (average 3-4) each breeding season (Heather & Robertson, 2015; Higgins et al., 2006). Eggs are laid from mid-October to early March (peaking in November and January) and are primarily incubated by the female for two weeks (Heather & Robertson, 2015; Moon, 1996). Young take 20-32 days to fledge and continue to be fed by both parents for around three weeks after leaving the nest (Heather & Robertson, 2015). Breeding pairs may form at nine months of age, though few attempt breeding in their first year (Heather & Robertson, 2015). Mynas can live up to 12 years in New Zealand (Heather & Robertson, 2015).

Common pheasant (*Phasianus colchicus*)

The common pheasant is a Galliform that was repeatedly introduced to New Zealand as a game bird from 1842 (Chambers, 2009; Gill et al., 2010). The New Zealand stock consists of multiple interbreeding subspecies; the most prominent being the Chinese ring-necked pheasant (Gill et al., 2010; Heather & Robertson, 2015). Today, the population of around 250,000 is constantly reinforced with the release of captive-bred birds (Gill et al., 2010; Heather & Robertson, 2015; Watola, 2011). Pheasants are a sedentary species and are found across shrubland, vegetated sand dunes, riverbanks, open country and farmland that has plenty of cover (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Although sparse in the South Island, they are common throughout the North Island, particularly in the north (Gill et al., 2010; Heather & Robertson, 2015; Moon, 1996).

Pheasants may be seen alone, in pairs or groups of 2-3, or in flocks of up to 20 birds (Marchant & Higgins, 1993). They are most active during the morning and late afternoon (Marchant & Higgins, 1993). Pheasants are omnivorous and primarily forage at ground level on seeds, leaves, green shoots, grain, fruit, invertebrates and small vertebrates (Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Males make abrupt, territorial "kok-kok" calls that can be heard over long distances (Heather & Robertson, 2015). They have highly conspicuous colouration, whilst the plumage of females, chicks and juveniles make them cryptic when motionless (Marchant & Higgins, 1993). If disturbed, pheasants will freeze, or burst loudly from the undergrowth to escape (Heather & Robertson, 2015; Marchant & Higgins, 1993).

Figure A2.8: *Photographs of the male (left) and female (right) common pheasant (Phasianus colchicus). Photo credit: Lukasz Lukasik and Thermos via Wikimedia Commons (CC BY-SA 3.0). Images cropped.*

Pheasants are polygamous (Moon, 1996). In New Zealand, breeding occurs from late-July to late-March (Heather & Robertson, 2015). Nests are built in thick vegetation under bracken or blackberry on roadsides or countryside (Heather & Robertson, 2015). 7-15 eggs (average 9) are laid and incubated by the female alone for 23-28 days (Heather & Robertson, 2015; Marchant & Higgins, 1993). Chicks leave the nest after a few hours and are able to fly around two weeks (Heather & Robertson, 2015). The age that pheasants begin breeding in New Zealand is unknown. The oldest known wild New Zealand bird lived 15+ years (Heather & Robertson, 2015). Females are protected but around 50,000 males are shot each hunting season (Heather & Robertson, 2015).

Common starling (*Sturnus vulgaris*)

The common starling is a Passeriform that was introduced to New Zealand from 1862 until 1883 to control invertebrate pests (Chambers, 2009; Heather & Robertson, 2015). Today, they are one of New Zealand's most widespread and abundant bird species (Gill et al., 2010; Heather & Robertson, 2015). Starlings are social and are often seen in pairs or large flocks around forest margins, farmland, orchards, beaches, city parks, gardens and streets (Heather & Robertson, 2015; Higgins et al., 2006;

Moon, 2006). Flocks are highly vocal and individuals can be good mimics of blackbirds, pūkeko, California quails and shining cuckoos (Chambers, 2009; Heather & Robertson, 2015; Moon, 2006).

Figure A2.9: *Photograph of common starlings (Sturnus vulgaris). Photo credit: Hayden Pye.*

Starlings are primarily insectivorous and forage on invertebrates at ground level, or by hawking (Moon, 2006). They also consume fruit and supplement with nectar from flowering flax which may deprive kererū, bellbirds and tūī of food over winter (Heather & Robertson, 2015; Moon, 1996). Although starlings may benefit farmers by reducing invertebrate pests, they do cause damage to commercial fruit and they are typically wary of humans (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006). Starlings are thought to be sedentary or resident but can fly 30 km+ daily between feeding sites and roosts (Heather & Robertson, 2015; Higgins et al., 2006). Some also make local seasonal movements between farmland and built up areas where they breed from August to January (Higgins et al., 2006).

Starlings nest in tree hollows or crevices on cliffs or buildings, aggressively displacing other species if required (Higgins et al., 2006; Moon, 2006). Each morning from August/September to December/January, males visit their nest site and defend it all day with a territorial song comprised of clicks, warbles and whistles (Heather & Robertson, 2015; Moon, 2006). Females lay a clutch of 1-9 eggs (average 4-5) around mid to late October (Heather & Robertson, 2015). 30-50% of successful breeders lay a second clutch in the first week of November, and a second/third clutch is laid late November/early December (Heather & Robertson, 2015). Both parents incubate the eggs for 11-13 days (Heather & Robertson, 2015). Chicks fledge after 18-25 days and continue to be fed by both parents for 1-2 weeks (Heather & Robertson, 2015). Females begin breeding at 1-2 years and males at 2-3 years (Heather & Robertson, 2015). The average life expectancy is just over three years, though the oldest known New Zealand bird lived 14 years (Heather & Robertson, 2015).

Dunnock (*Prunella modularis*)

The dunnock is a Passeriform that was introduced to New Zealand from England by Acclimatization societies and individuals between 1867 and 1882 (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015). Several hundred birds were liberated and although they are now widespread and locally common, the species is rare throughout Auckland (Chambers, 2009; Heather & Robertson, 2015). Dunnocks have taken advantage of widespread native forest deforestation and the resulting dense regrowth (Chambers, 2009; Higgins et al., 2006). They are typically found around thick vegetation in pine forests, orchards, well established suburban parks and gardens, open farmland with scattered hedges, and native forest fringes (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996).

Dunnocks are typically found alone or in pairs, though occasionally in small flocks or associating with house sparrows on lawns (Chambers, 2009; Higgins et al., 2006). They are highly active and restlessly produce a melodious warbled whistling song from a high perch on top of vegetation, as well as a sharp, high pitched "tseep" call (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). Despite this behaviour, they are typically secretive and often remain unseen (Moon, 1996). Dunnocks primarily forage alone close to or within low vegetation at ground level, feeding on invertebrates with some seeds and small fruit (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996).

In New Zealand, dunnocks are sedentary and remain in the same territory year round (Heather & Robertson, 2015; Higgins et al., 2006). Here, they appear to commonly form monogamous pairs, but they exhibit polygyny, polyandry and polygynandry elsewhere (Heather & Robertson, 2015). Nests are built within a hedge or bush at a low height and 2-3 broods of 2-5 eggs (average 4) are laid between August to January (Heather & Robertson, 2015). The female incubates the eggs for 11-14 days (average 12) and both parents feed the chicks until fledging at 10-14 days (average 12) (Heather & Robertson, 2015; Higgins et al., 2006). Dunnocks begin breeding at age one with the oldest known New Zealand bird living for six years (Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.10: *Photograph of the dunnock (Prunella modularis). Photo credit: Charles J Sharp via Wikimedia Commons (CC BY-SA 4.0). Image cropped.*

Eastern rosella (*Platycercus eximius*)

The eastern rosella is a Psittaciform that was introduced to New Zealand from Australia through liberations and aviary escapes (Gill et al., 2010; Heather & Robertson, 2015). Populations became established in Auckland by 1920 (Heather & Robertson, 2015; Watola, 2011). Eastern rosellas are now locally common in the parks and gardens of settled regions, open country, native forests, exotic forests, and forest remnants across most of the North Island and the Otago region (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Higgins, 1999). They are social and are typically seen in pairs or small flocks of 5-25 birds (Heather & Robertson, 2015; Higgins, 1999). Eastern rosellas are sedentary and monogamous pairs persist year round, from year to year (Higgins, 1999).

Figure A2.11: *Photograph of eastern rosellas (Platycercus eximius). Photo credit: Hayden Pye.*

Eastern rosellas have conspicuous colouration and are the most brightly coloured bird in New Zealand (Chambers, 2009; Heather & Robertson, 2015). However, they can be cryptic when moving amongst branches (Chambers, 2009). Eastern rosellas are wary and will flee from humans unless in the safety of a tree (Higgins, 1999; Moon, 2006). They produce a loud ringing bell-like call when in flight, and a chattery muted babbling sound when eating or approaching feeding sites (Heather & Robertson, 2015; Moon, 1996; Moon, 2006). Diet consists of a wide range of fruits, flowers, nectar, buds, shoots, insects and seeds (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). Eastern rosellas are primarily arboreal feeders, though they do consume seeds at ground level (Higgins, 1999). They occasionally cause damage to citrus fruit, kiwifruit, tomatoes and apples (Heather & Robertson, 2015).

Between October and February, a clutch of 4-7 eggs (average 5-6) is laid in a nest in a tree cavity or the crown of a tree fern (Heather & Robertson, 2015). A second clutch may be laid if conditions are good (Galbraith, 2017). The female incubates the eggs for 18-22 days (Heather & Robertson, 2015). Over this time she is fed by the male, who continues to feed her during brooding (Heather & Robertson, 2015; Higgins, 1999). Females in turn feed the young whilst brooding, and both parents feed older chicks which fledge at 28-36 days (Heather & Robertson, 2015). Offspring remain around their parents for several months (Heather & Robertson, 2015; Moon, 2006). In New Zealand, the age of first breeding is unknown, however, Australian birds can breed from age one, but typically begin at age three (Higgins, 1999). Maximum longevity in New Zealand is also unknown, though eastern rosellas can live 8.8 years in Australia (Galbraith, 2017).

Eurasian blackbird (*Turdus merula*)

The Eurasian blackbird is a Passeriform that was introduced to New Zealand between 1862 and 1875 for sentimental reasons (Gill et al., 2010; Heather & Robertson, 2015). Blackbirds have successfully taken advantage of modified habitats and are today the most widespread avian species in New Zealand, common across almost all terrestrial environments that have a mixture of dense cover and open space (Heather & Robertson, 2015; Higgins et al., 2006; Robertson et al., 2017). Blackbirds are sedentary in New Zealand and are generally observed either alone or in pairs, though occasionally in small groups (Higgins et al., 2006). They are often found foraging near vegetation cover at ground level where they consume invertebrates, seeds and fruit (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006). Blackbirds facilitate the dispersal of native seeds, but also spread the seeds of weed species and cause considerable damage to commercial fruit crops (Heather & Robertson, 2015; Moon, 1996).

Blackbirds are highly vocal, particularly at dawn and dusk (Chambers, 2009). Their soft warbling subsong is typically produced from under vegetation cover (Heather & Robertson, 2015). Blackbirds are shy and wary of humans and will produce a loud, sharp and repeated alarm call when threatened, or if a predator is near (Heather & Robertson, 2015; Higgins et al., 2006). From April to

January, males defend their breeding territory with a loud territorial song that consists of a variety of clattering and clucking notes, ending with a trill (Heather & Robertson, 2015; Moon, 2006).

Blackbirds are monogamous and nest in the forks of trees, typically at the same site each year (Armitage, 2017; Moon, 2006). Between August and late December 2-3 broods of 2-6 eggs (average 3-4) are laid and incubated by the female for about two weeks (Heather & Robertson, 2015). Nests are quickly replaced if they fail (Heather & Robertson, 2015). Both parents feed the chicks which fledge after 13-15 days, and the young remain near their parents who continue to feed them for weeks (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). Blackbirds can breed after nine months and the oldest known New Zealand bird lived 15 years (Heather & Robertson, 2015).

Figure A2.12: *Photographs of the male (left) and female (right) Eurasian blackbird (Turdus merula). Photo credit: Zeynel Cebeci (CC BY-SA 4.0) and Tim Sträter (CC BY 2.0) via Wikimedia Commons, and Images cropped.*

Eurasian skylark (*Alauda arvensis*)

The Eurasian skylark is a Passeriform that was introduced to New Zealand by Acclimatisation societies between 1864 and 1875 (Gill et al., 2010; Heather & Robertson, 2015). 1,000+ birds were introduced for sentimental reasons (Heather & Robertson, 2015). Skylarks quickly established and are now widespread and common across open country, farmland, sand dunes, tussock grasslands and subalpine herb fields (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are absent from forests and thick vegetation and are commonly observed perched on the ground, rocks, low shrubbery or on fenceposts (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006). Skylarks are mostly sedentary in New Zealand and are usually seen alone or in pairs, however, some birds make local movements to flock at good food sources over autumn and winter (Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.13: *Photograph of the Eurasian skylark (Alauda arvensis). Photo credit: Alun Williams via Wikimedia Commons (CC BY-SA 4.0). Image cropped.*

Skylarks feed at ground level on the seeds of grasses, cereals and weeds, and occasionally invertebrates (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They can cause considerable economic loss by eating the sown grains of commercial crops and by pulling out or stripping the leaves from tomatoes, wheat, cabbages and peas (Heather & Robertson, 2015; Higgins et al., 2006). If threatened, skylarks crouch and remain stationary, taking panicked flight if approached or flushed (Chambers, 2009; Higgins et al., 2006). Males produce a conspicuous territorial trilling song for up to five-minutes whilst hovering up to 100 m in the air (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). This song is also sometimes produced when perched (Chambers, 2009).

Skylarks are monogamous and breed in the same territory year after year (Heather & Robertson, 2015). Females build a nest in a ground depression and lay 2-3 clutches of 2-5 eggs (average 3-4) between September to January (Heather & Robertson, 2015). The female incubates the eggs for around 11 days and both parents feed the chicks (Heather & Robertson, 2015; Moon, 1996). The young leave the nest after 9-10 days and begin flying at around 20 days old (Heather & Robertson, 2015). Skylarks can breed at age one (Heather & Robertson, 2015). Longevity in New Zealand is unknown, but skylarks can live to eight years old in Europe (Heather & Robertson, 2015). Predators include Australian magpies, and hedgehogs (*Erinaceus europaeus*) which eat eggs (Higgins et al., 2006).

European goldfinch (*Carduelis carduelis*)

The European goldfinch is a Passeriform that was introduced to New Zealand by Acclimatisation societies between 1862 and 1883 (Gill et al., 2010; Heather & Robertson, 2015). The 500 or so liberated British birds established quickly and the species was widespread by 1900 (Heather & Robertson, 2015; Watola, 2011). Today, goldfinches are more common in New Zealand than in Britain and are found nationwide across urban parks and gardens, orchards, farmland, open country, exotic forests, beaches and surrounding habitats (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are absent from tall indigenous forests (Chambers, 2009). Goldfinches are sedentary and are most commonly found in flocks of 3 or more (Higgins et al., 2006). Over autumn and winter they may move locally to form flocks of over 1,000, often with other finch species (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996).

Goldfinches usually forage at or near ground level on the seeds of grasses, weeds and thistles, the occasional invertebrate, and very rarely, nectar (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). Although goldfinches may benefit commercial agriculture by eating the seeds of weeds and thistles, they also cause minimal damage to ripening strawberries (Heather & Robertson, 2015; Higgins et al., 2006). Goldfinches can be approachable, but flocks will flee from disturbance (Higgins et al., 2006). In flight they produce a soft "tswitt-witt-witt" and the distinctive gold bars on their black wings are easily recognisable (Chambers, 2009; Heather & Robertson, 2015).

In late-September, flocks break up, monogamous pairs form, and the male begins singing a canary-like liquid twittering song until early-February (Heather & Robertson, 2015). The female builds a nest in gorse, shrubs, a conifer, or peach or apple tree (Heather & Robertson, 2015; Moon, 2006).

Two broods of 2-6 eggs (average 4-5) are laid between mid-October to mid-February and are incubated by the female for 11-13 days (average 12) (Heather & Robertson, 2015; Higgins et al., 2006). The male feeds the female while she is incubating and brooding, and the female feeds the chicks for the first week (Heather & Robertson, 2015). Young fledge at 12-17 days (average 14) and continue to be fed by both parents for a further 2-3 weeks (Heather & Robertson, 2015). In New Zealand, goldfinches can breed at just under one year old and may live up to eight years (Heather & Robertson, 2015).

Figure A2.14: *Photograph of the European goldfinch (Carduelis carduelis). Photo credit: Francis C. Franklin via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

European greenfinch (*Carduelis chloris*)

The European greenfinch is a Passeriform that was introduced to New Zealand by Acclimatization societies between 1862 and 1868 (Gill et al., 2010; Heather & Robertson, 2015). Less than 100 British birds were liberated but greenfinches quickly propagated and are today locally common across farmlands, exotic plantations, shelterbelts, scrub fringes, large suburban parks, gardens and any modified habitat with introduced vegetation (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006). They are uncommon in native forest and are absent from dense forest (Chambers, 2009; Heather & Robertson, 2015). Greenfinches are sedentary and are usually found in small flocks (Higgins et al., 2006). Over autumn and winter they may make local movements to form large flocks and forage with goldfinches, yellowhammers and house sparrows in open farmland and areas with coastal vegetation (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006).

Figure A2.15: *Photographs of the male (left) and female (right) European greenfinch (Carduelis chloris). Photo credit: Kev Chapman (CC BY 2.0) and Estormiz via Wikimedia Commons. Images cropped.*

Greenfinches usually forage at or near ground level on the seeds of grasses, weeds, cereals and pines, supplementing with invertebrates and small fruit (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are considered a minor commercial pest as they damage cereal grains and consume the buds of some fruit crops (Heather & Robertson, 2015). In settled areas greenfinches may be approachable and use garden bird tables, though they are more wary in open areas (Higgins et al., 2006; Moon, 2006). In September, flocks break up, monogamous pairs form, and the male begins fluttering between high perches and producing a harsh repeated “dzwee” call (Angus, 2013a; Chambers, 2009; Heather & Robertson, 2015). This call is repeated until February and is the most commonly reported bird vocalisation across New Zealand (Higgins et al., 2006). Resultingly, greenfinches are heard more often than they are seen (Higgins et al., 2006).

Nests are built in forks or outer branches near the top of trees, gorse bushes or shrubs (Heather & Robertson, 2015; Higgins et al., 2006). 2-3 clutches of 3-6 eggs (average 5) are laid and incubated by the female for 11-15 days (average 13) between mid-October and early February, with peaks in late-October and early January (Heather & Robertson, 2015). The male feeds the female while she is on the nest and both parents feed the chicks (Heather & Robertson, 2015). The young fledge at 13-17 days (average 16) and continue to be fed for another 2-3 weeks (Heather & Robertson, 2015). Greenfinches begin breeding at just under one year old and can live at least seven years in New Zealand (Heather & Robertson, 2015).

Grey warbler (riroriro) (*Gerygone igata*)

The grey warbler is a protected endemic Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Grey warblers are New Zealand's second smallest bird and they have become the most widely distributed endemic bird species following widespread anthropogenic landscape modification (Anderson, 2013; Higgins & Peter, 2002; Robertson et al., 2007). They are common and abundant in the middle and upper canopy wherever vegetation is present (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). Grey warblers may be found alone, in pairs, or in small flocks over winter, occasionally with silvereyes, whiteheads, fantails and chaffinches (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). They produce a loud and lengthy wavering trill song and are often heard before they are seen (Anderson, 2013; Heather & Robertson, 2015).

Grey warblers primarily consume invertebrates and occasionally eat seeds or small fruit (Heather & Robertson, 2015; Higgins & Peter, 2002; Moon, 1996). Prey is usually gleaned from leaves or caught whilst hovering near the end of branches, using their wings to stir up prey (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). Adult grey warblers are vulnerable to predation from cats, and eggs are sometimes eaten by mustelids and rodents (Higgins & Peter, 2002). It appears that populations are large enough to remain unthreatened by predators (Department of Conservation, 2020d; Higgins & Peter, 2002).

Figure A2.16: *Photograph of the grey warbler (Gerygone igata). Photo credit: Francesco Veronesi via Wikimedia Commons (CC BY-SA 2.0). Image cropped.*

Grey warbler pairs are sedentary and monogamous, remaining together year round and breeding from late-July to early August in the same territory year after year (Heather & Robertson, 2015; Higgins & Peter, 2002). Domed nests are built by the female and 1-2 broods of 2-5 eggs (average 4) are raised between August and December, with peaks in September and November (Heather & Robertson, 2015; Higgins & Peter, 2002). For 17-21 days (average 17.5) the eggs are incubated by the female, who also broods the young for the first 10 days (Heather & Robertson, 2015). Chicks fledge at 15-19 days (average 17) and are fed frequently by both parents during this time, as well as for an additional 35 days after leaving the nest (Heather & Robertson, 2015; Higgins & Peter, 2002). Independent young disperse several kilometres from their natal territory and begin breeding at around one year old (Heather & Robertson, 2015). The average life expectancy is around five years, though some grey warblers may live over 10 years (Heather & Robertson, 2015).

Grey warblers are also hosts of the migratory parasitic shining cuckoo (Heather & Robertson, 2015). Although first clutches are typically laid before their arrival, shining cuckoos often remove and replace an egg in the grey warbler's second clutch (Heather & Robertson, 2015; Moon, 1996). Once hatched, the shining cuckoo chick expels the grey warbler's eggs or chicks from the nest and the young cuckoo is raised alone by the grey warbler hosts (Heather & Robertson, 2015).

House sparrow (*Passer domesticus*)

The house sparrow is a sociable Passeriform that was introduced to New Zealand between 1866 and 1871 to control crop pest invertebrates (Chambers, 2009; Heather & Robertson, 2015). Today, house sparrows are widely distributed and are abundant around arable farm land, forest fringes and areas with high anthropogenic activity such as cities, suburban parks and gardens (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are uncommon within forests (Moon, 2006). House sparrows are primarily sedentary and are typically seen in pairs or flocks, rarely alone (Dawson, 2013; Heather & Robertson, 2015; Higgins et al., 2006). Over summer they are commonly found taking dust baths on dirt paths and along road edges (Moon, 2006). House sparrows sing with an unmusical variety of chirps, and flocks produce a collective cacophony from their roosts at dawn and dusk over autumn and winter (Chambers, 2009; Heather & Robertson, 2015).


Figure A2.17: *Photographs of the male (left) and female (right) house sparrow (Passer domesticus). Photo credit: Mathias Appel (CC0 1.0) and Lip Kee Yap (CC BY-SA 2.0) via Wikimedia Commons. Images cropped.*

House sparrows are opportunistic feeders who often forage in large flocks at ground level (Heather & Robertson, 2015; Higgins et al., 2006). Their diet primarily consists of cereal grains, grass and weed seeds, food scraps, and is supplemented with nectar, fruit and invertebrates (Heather &

Robertson, 2015; Higgins et al., 2006). Although wary, house sparrows can be tame and will approach humans for food (Higgins et al., 2006). They may show aggression towards other birds around anthropogenic food sources (Moon, 2006). Today, house sparrows are considered a pest as they cause considerable damage to cereal grains and fruit crops, spread the seeds of weeds, and foul city infrastructure (Heather & Robertson, 2015; Higgins et al., 2006).

Monogamous pairs typically remain together for life and re-use the same nesting sites year after year (Higgins et al., 2006). Males build a domed nest in the side of a tree, building or cliff in September, defending the territory with loud calls until January (Heather & Robertson, 2015). 3-4 broods of 1-6 eggs (average 4) are incubated by both parents for 10-15 days (average 12) (Heather & Robertson, 2015). Both parents feed the chicks which fledge after 11-19 days (average 15) (Heather & Robertson, 2015; Higgins et al., 2006). Mortality of eggs and nestlings in New Zealand is high with only 1.6 to 1.9 individuals from each clutch typically surviving to fledge (Dawson, 2013). House sparrows begin breeding at just under one year and may live up to 15 years (Heather & Robertson, 2015).

Kākā (North Island kākā) (*Nestor meridionalis septentrionalis*)

The kākā is a protected endemic Psittaciform that has a conservation status of "recovering" (Heather & Robertson, 2015; Robertson et al., 2017). Kākā were abundant when Europeans arrived in New Zealand but widespread deforestation, predation, and feeding competition from introduced mammals reduced populations to localised flocks by 1930 (Department of Conservation, 2020e; Heather & Robertson, 2015). As a direct result of successful conservation management, kākā are now locally common and have a population of around 10,000 (Heather & Robertson, 2015; Robertson et al., 2017). Most kākā are resident on predator-free offshore islands but they also occupy or infrequently visit old and remnant mainland native forests, predator-free habitats, orchards, city parks and suburban gardens (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999). Kākā occasionally visit Shakespear Open Sanctuary, likely from Tāwharanui Regional Park or Little Barrier Island (SOSSI, 2014a; Tiritiri Matangi Open Sanctuary, 2010b).

Kākā are usually seen alone or in noisy flocks of up to 10 in the early morning and late evening (Department of Conservation, 2020e; Higgins, 1999). They can be vocally conspicuous and produce a variety of calls ranging from soft melodious whistling notes to harsh guttural sounds (Heather & Robertson, 2015; Higgins, 1999). Softer calls are usually produced around the nest whilst harsher calls are made when disturbed, flying, or in flocks (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). Kākā may be cryptic and vocally silent when feeding in trees on fruit, nectar, seeds, sap, flowers, foliage and shoots, though the sound of bark being ripped from dead trees to find invertebrates can give their presence away (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). They are also conspicuous as they loudly jump between branches in the forest canopy (Heather & Robertson, 2015; Higgins, 1999).

Figure A2.18: *Photograph of the North Island kākā (Nestor meridionalis septentrionalis). Photo credit: Rosino via Wikimedia Commons (CC BY-SA 2.0). Image cropped.*

Kākā nest in tree cavities and nest boxes (Heather & Robertson, 2015). Food availability dictates the timing and extent of breeding, and few pairs breed in years that food is limited (Heather & Robertson, 2015). Monogamous pairs lay 1-2 clutches of 1-8 eggs (average 4-5) between October and March (Heather & Robertson, 2015). Females incubate the eggs for 23-25 days and are fed by the male every 90 minutes (Heather & Robertson, 2015; Moon, 1996). Young are brooded for 15-20 days and both parents feed the chicks which fledge around 70 days (Heather & Robertson, 2015). Some chicks may leave the nest before they can fly and will spend a few days hidden in low shrubbery (Department of Conservation, 2020e; Higgins, 1999). Kākā can begin breeding at age four and the oldest known individual lived more than 27 years (Heather & Robertson, 2015; Higgins, 1999). Nesting females and eggs are particularly vulnerable to predation from stoats and rats as they are unable to escape from nest cavities (Department of Conservation, 2020e; Heather & Robertson, 2015). Sex ratios are thus skewed, and pest control targeting possums, rats, stoats and wasps likely benefits mainland populations (Department of Conservation, 2020e; Heather & Robertson, 2015).

Long-tailed cuckoo (koekoeā) (*Eudynamys taitensis*)

The long-tailed cuckoo is a protected endemic Cuculiform that has a conservation status of "naturally uncommon," though data is poor (Heather & Robertson, 2015; Robertson et al., 2017). It is a migratory brood parasite that breeds in New Zealand between October and March and overwinters in the Pacific Islands (Gill et al., 2010; Heather & Robertson, 2015; Higgins, 1999). Long-tailed cuckoos maybe be found anywhere in New Zealand during their migration, but they are most commonly found in native and exotic forests where their hosts are present (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Higgins, 1999). Hosts include whiteheads in the North Island, and yellowheads (*Mohoua ochrocephala*) and brown creepers (*Mohoua novaeseelandiae*) in the South Island (Heather & Robertson, 2015).

Long-tailed cuckoos forage in the crowns of trees and dense shrubs, feeding on large invertebrates, lizards, nestlings, small birds, bird's eggs, mice and occasionally berries and fruit (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). They are one of New Zealand's larger forest birds – in flight its tail feathers are as long as its body (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). However, long-tailed cuckoos are well camouflaged, cryptic and are often only detected by their harsh shrieking "zzwheesht" call produced from a high perch or whilst in flight (Heather & Robertson, 2015; Higgins, 1999). Although rarely seen, they usually occur alone or in twos, though up to five birds (likely males) may line up to perform perched displays for other groups (likely females) whilst calling (Heather & Robertson, 2015; Higgins, 1999). Long-tailed cuckoos do not form pairs and are thought to have a lek-mating system (Higgins, 1999).

Figure A2.19: *Photograph of the long-tailed cuckoo (Eudynamys taitensis) mounted specimen. Photo credit: Te Papa birds collection (CC BY 4.0).*

Between mid-November and mid-December the long-tailed cuckoo lays a single egg in its host's nest (Moon, 1996). The egg is larger than the host's eggs but it is usually accepted and incubated for 16 days (Heather & Robertson, 2015). Upon hatching, the young cuckoo ejects the host's eggs and chicks from the nest and is raised alone (Heather & Robertson, 2015). The chick fledges after 21 days and continuously begs for food for about 4 weeks (Heather & Robertson, 2015). Once independent, young cuckoos migrate to the Pacific Islands where they remain for at least two years (Heather & Robertson, 2015; Higgins, 1999). Adults return to the same nesting sites each year, and although some may overwinter in New Zealand, these birds remain inconspicuous (Heather & Robertson, 2015). Longevity is unknown and it is thought that populations may be declining due to declines in host species' populations and the clearance of sub-tropical Pacific Island forests (Heather & Robertson, 2015). Long-tailed cuckoos are predated by cats and they are often killed by window-strike during migration (Heather & Robertson, 2015; Higgins, 1999).

Mallard (*Anas platyrhynchos*)

The mallard is a partially protected Anseriform that was introduced to New Zealand for game purposes (Heather & Robertson, 2015). British stock from Australia was liberated between 1867 and 1918 but populations were not particularly successful until the introduction of North American stock in 1937 (Gill et al., 2010; Heather & Robertson, 2015). Mallards were intensively bred throughout the 1930s and 1940s and liberations continued until 1974 (Heather & Robertson, 2015). Today, mallard populations make up around 80% of New Zealand's dabbling ducks and they are the most widespread waterfowl species in the country (Gill et al., 2010; Moon, 1996). Around 500,000 mallards are legally shot each year during game season and populations are declining (Heather & Robertson, 2015).

Mallards are found nationwide in pairs or flocks across freshwater and saltwater environments such as shallow ponds, lakes, rivers, estuaries, beaches, wetlands, farm drains, mudflats and lagoons (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990; Moon, 1996). They primarily feed on aquatic vegetation, invertebrates and seeds (Heather & Robertson, 2015; Marchant & Higgins, 1990; Moon, 1996). When in water they feed on the surface, or upend to feed below (Heather & Robertson, 2015; Marchant & Higgins, 1990). On land they graze on grasses, peas, grains and clover, and they will readily approach and take food from humans (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990). Mallards sometimes cause considerable damage to standing crops by trampling plants whilst feeding (Heather & Robertson, 2015).

Seasonally monogamous breeding pairs form by the end of July and nests are built near water at ground level in dense vegetation (Heather & Robertson, 2015; Williams, 2013). Between July and October a clutch of 10-16 eggs (average 13) is laid and incubated by the female for 26-28 days (Heather & Robertson, 2015; Marchant & Higgins, 1990). Males stand guard during breeding and laying but leave to seek additional mating opportunities during incubation (Heather & Robertson, 2015). The female leads the ducklings to water soon after hatching, and the young disperse widely after fledging at 50-65 days (Heather & Robertson, 2015). A second brood is sometimes raised in urban areas, with renesting until the end of December (Heather & Robertson, 2015; Williams, 2013). New Zealand mallards also breed and hybridise with grey ducks (*Anas superciliosa*) (Heather & Robertson, 2015).

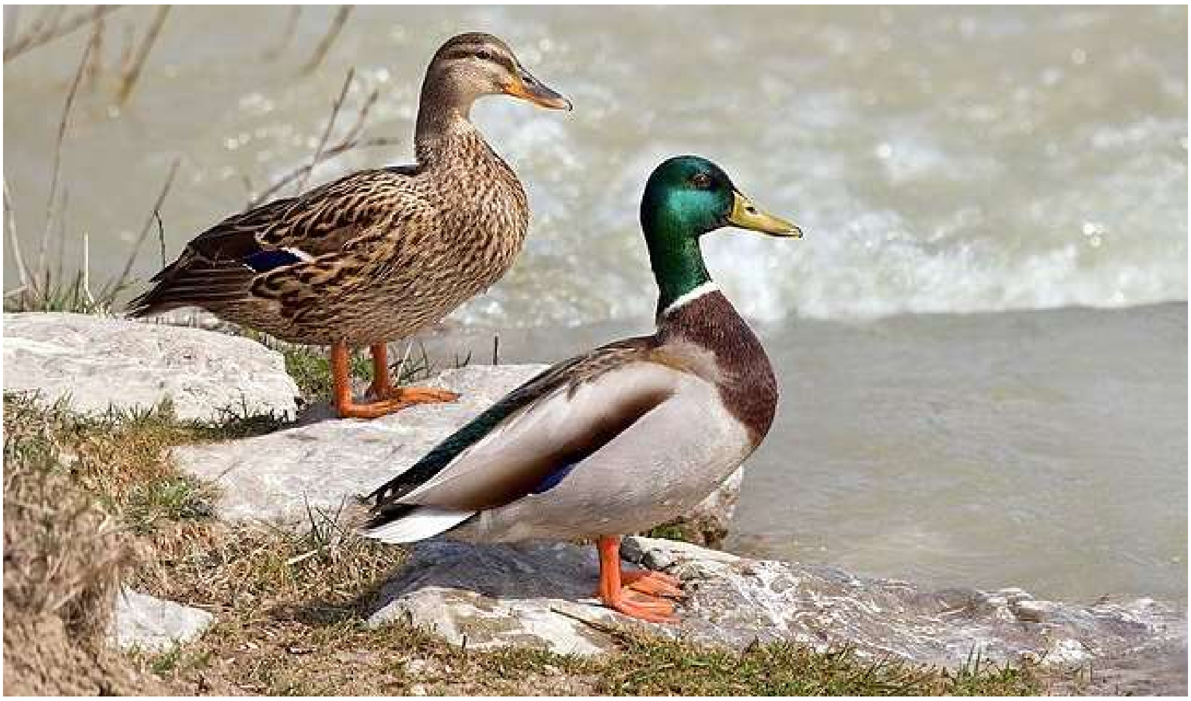

Figure A2.20: *Photograph of the female (left) and male (right) mallard duck (Anas platyrhynchos). Photo credit: Richard Bartz via Wikimedia Commons (CC BY-SA 2.5). Image cropped.*

Mallards may begin breeding at age one, but only half typically survive to breeding age (Heather & Robertson, 2015; Marchant & Higgins, 1990). Average longevity in New Zealand is 2.5 years, though the oldest known bird was at least 26 (Heather & Robertson, 2015). Eggs are vulnerable to predation or destruction from ferrets (*Mustela sp.*), brown rats (*Rattus norvegicus*) and pigs (*Sus sp.*) (Marchant & Higgins, 1990).

Morepork (ruru) (*Ninox novaseelandiae novaseelandiae*)

The morepork is a protected, native, nocturnal Strigiform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Morepork are moderately common and widespread across New Zealand having adapted well to anthropogenic modification (Gill et al., 2010; Heather & Robertson, 2015). They are found across native, modified and exotic forests, well-vegetated urban gardens and parks, and open country with mature trees (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). During the day, morepork roost in thick vegetation with overhead protection (Department of Conservation, 2020f; Heather & Robertson, 2015). They may be found alone, in pairs, or in family groups which consist of an adult pair and up to three young (Higgins, 1999). Morepork can be approachable, but will flee if threatened, unless tending to young (Higgins, 1999).

Figure A2.21: *Photograph of the morepork (Ninox novaseelandiae novaseelandiae). Photo credit: Toby Jackson via Wikimedia Commons (CC0 1.0). Image cropped.*

Morepork are silent in flight, but are conspicuously vocal (Chambers, 2009; Heather & Robertson, 2015). Calls include a common and repeated "more-pork," a harsh rising "cree," and a repeated "more" (Heather & Robertson, 2015). Morepork are carnivorous and feed in the dark by observing from a perch and pouncing on invertebrates, small birds, mice, rats and geckos (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). They take advantage of anthropogenic lights which attract flying invertebrates after dark, and the introduction of small mammals has benefitted the species by providing increased prey opportunities (Chambers, 2009; Heather & Robertson, 2015). However, morepork may also be at risk to accumulated toxins that have been ingested by mammalian prey (Department of Conservation, 2020f). Females, chicks and eggs are also vulnerable to predation from stoats, rats, possums and cats, as well as hedgehogs and pigs when nesting at ground level (Department of Conservation, 2020f; Seaton & Hyde, 2013).

Morepork build nests in tree hollows, tree forks, or near ground level under fern fronds, in petrel burrows or between pōhutukawa (*Metrosideros excelsa*) roots (Heather & Robertson, 2015). Monogamous pairs lay a clutch of 1-3 eggs (average 2) between September to February (usually between October to November) and the female incubates the eggs for 25-30 days (Department of Conservation, 2020f; Heather & Robertson, 2015; Higgins, 1999). The male calls the female from the nest to feed her, and both parents feed the young which fledge at 35-40 days (Heather & Robertson, 2015). Morepork begin breeding after one year and can live for around six years (Seaton & Hyde, 2013). Despite their relative commonality, populations may be in decline due to predation and loss of habitat (Department of Conservation, 2020f; Higgins, 1999).

New Zealand fantail (pīwakawaka) (*Rhipidura fuliginosa*)

The fantail is a protected endemic Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Fantails are widespread, common, and are one of the few native forest birds to benefit from the clearance of indigenous forest and the subsequent creation of regenerating and fringe environments (Department of Conservation, 2020c; Heather & Robertson, 2015). As such, fantails are found across a wide variety of vegetated habitats including urban parks, gardens, native and exotic forests, wetlands, river margins and farmland with scattered vegetation (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are often fearless and will approach humans whilst producing conspicuous saw-like calls and penetrating "cheet" vocalisations (Heather & Robertson, 2015; Higgins et al., 2006).

Fantails are usually sedentary and are typically seen alone or in monogamous pairs, though some adults disperse and form loose foraging flocks of 10-20 birds over autumn to early spring (Heather & Robertson, 2015; Higgins et al., 2006). They have a varied insectivorous diet and use their fanned tail to disturb prey that they glean from vegetation or hawk using erratic, acrobatic flight across all levels of the forest (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). Diet is supplemented with fruit and they are sometimes observed feeding on invertebrates disturbed by silvereyes, whiteheads, saddlebacks and parakeets (Heather & Robertson, 2015).

Figure A2.22: *Photograph of the fantail (Rhipidura fuliginosa). Photo credit: Jon-Paul Hansen.*

Pairs defend their territories throughout the breeding season by using song to advertise territory ownership (Heather & Robertson, 2015; Higgins et al., 2006). In the North Island, the female alone builds a sheltered nest in the fork of an understorey shrub or fern (Heather & Robertson, 2015). 2-5 broods of 2-5 eggs (average 3-4) are laid between late-August to February (Heather & Robertson, 2015). The eggs are incubated for 13-16 days (average 14) by both parents, who also feed the nestlings which fledge after 11-16 days (average 13) (Heather & Robertson, 2015; Higgins et al., 2006). After leaving the nest, the young continue to be fed by the parents until they become independent and disperse (Heather & Robertson, 2015). Fantails may begin breeding at two months old, though most begin at nine months (Heather & Robertson, 2015). The oldest known fantail lived for three years (Heather & Robertson, 2015).

Mortality rates are high for juveniles and adults (Heather & Robertson, 2015). Severe winter and spring storms can cause populations to fluctuate dramatically and even cause local extinctions (Heather & Robertson, 2015). However, areas are often quickly recolonised due to high annual productivity and juvenile dispersal (Heather & Robertson, 2015). Fantails are considered an important indicator species for monitoring predation rates and the effects of predator control as they are vulnerable to direct predation and the consumption of their eggs by cats, possums, rats, stoats and mynas (Department of Conservation, 2020c; Higgins et al., 2006; Stirnemann, 2008).

New Zealand pigeon (kererū) (*Hemiphaga novaseelandiae*)

The New Zealand pigeon (henceforth kererū) is a protected endemic Columbiform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Kererū are found throughout New Zealand in native lowland forest, remnant forest patches in cities and suburbs, and open country with nearby fruiting trees (Gill et al., 2010; Heather & Robertson, 2015; Moon, 2006). They are commonly observed alone or in pairs but will form loose flocks if food is abundant (Higgins & Davies, 1996). Although sedentary, they may move over 100 km to reach good food sources (Heather & Robertson, 2015; Mander et al., 1998). Kererū are herbivorous and eat a wide range of fruit and seeds as well as supplementing with foliage, young shoots, flowers and buds (Heather & Robertson, 2015; Higgins & Davies, 1996; Moon, 1996). They typically eat directly from the tree and play an important ecological role as the only species large enough to swallow and disperse many of New Zealand's larger native seeds (Heather & Robertson, 2015; Moon, 2006).

Kererū can be tame and may allow humans to approach closely (Higgins & Davies, 1996). Their calls are a low "kuu kuu" that are produced when feeding, resting, or when they are disturbed (Moon, 2006). In flight, kererū produce a prominent whistling wingbeat (Moon, 1996). They are vulnerable to predation from cats and stoats, who along with rats and possums also eat their eggs and compete for food resources (Department of Conservation, 2020i; Moon, 2006). Kererū respond positively to intensive predator control and populations are mostly increasing, though decreases occur in areas lacking predator control and where illegal hunting occurs (Department of Conservation, 2020i; Heather & Robertson, 2015).

Figure A2.23: *Photograph of the kererū (Hemiphaga novaseelandiae). Photo credit: Manu Bird via Pixabay.*

Both sexes exhibit conspicuous courtship flight and perched displays (Chambers, 2009; Heather & Robertson, 2015). Breeding occurs year round but is closely related to food availability and is thus most common between September and March (Heather & Robertson, 2015). Nests are built in a tangle of vines or a horizontal tree fork (Heather & Robertson, 2015). Monogamous pairs lay 2-3 clutches of a single egg and both adults incubate and brood the chick which fledges after 35-45 days (Heather & Robertson, 2015; Higgins & Davies, 1996; Moon, 1996). The chick continues to be fed for weeks after fledging and is evicted when the parents re-nest (Heather & Robertson, 2015). Clutches may overlap with a second egg which is incubated in a new nest whilst the first chick is being raised (Heather & Robertson, 2015; Moon, 1996). Breeding begins around one to two years of age and the oldest known wild kererū lived to 23 (Heather & Robertson, 2015).

New Zealand pipit (pīhoihoi) (*Anthus novaseelandiae*)

The New Zealand pipit is a protected endemic Passeriform that has a conservation status of "at risk declining" (Heather & Robertson, 2015; Robertson et al., 2017). Pipits have wide, patchy distributions and are rare in Auckland (Heather & Robertson, 2015; Robertson et al., 2007). They have likely benefitted from forest clearance as populations are found across unmaintained open countryside, rocky terrain, sand dunes, beaches, riverbeds, roadsides, forest margins and in exotic forest clearings, (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996; Moon, 2006). They are highly terrestrial and are often observed walking whilst bobbing and flicking their tails, or perched on tree stumps, rocks, fence posts and low bushes (Higgins et al., 2006; Moon, 2006). Pipits are mostly sedentary and are typically seen alone and rarely in pairs, however, they occasionally make local movements to form flocks outside of the breeding season (Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.24: *Photograph of the New Zealand pipit (Anthus novaseelandiae). Photo credit: Sabine's Sunbird via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

Pipits are omnivorous and feed at ground level on invertebrates and occasionally the seeds of grasses and weeds (Heather & Robertson, 2015; Moon, 1996). They can be cryptic but are relatively tame, landing near humans and allowing them to approach (Chambers, 2009; Higgins et al., 2006).

Their common calls are a shrill "scree" or high-pitched "pee-pit" (Heather & Robertson, 2015; Moon, 2006). Although nationwide populations exceed 100,000, they do have a predicted decline of 10-70% (Robertson et al., 2017). Introduced mammalian predators (particularly rats), magpies, and habitat degradation from intensified farming combined with the increased use of pesticides has contributed to local declines and extirpation from some regions (Heather & Robertson, 2015; Higgins et al., 2006).

Monogamous pairs are highly territorial, directing aggressive song towards conspecifics over the August to February breeding season (Heather & Robertson, 2015; Higgins et al., 2006). Females build a nest close to the ground in tall grass, the base of a bush, or small hollows in banks or under logs (Chambers, 2009; Heather & Robertson, 2015). 2-5 eggs (average 3-4) are incubated for 14-15 days and both parents feed the chicks which fledge after 14-16 days (Heather & Robertson, 2015; Moon, 1996). Nests are sometimes predated by magpies (Moon, 2006). The age of first breeding and maximum longevity is unknown.

North Island robin (toutouwai) (*Petroica longipes*)

The North Island robin is a protected endemic Passeriform that has a conservation status of "at risk, declining" (Heather & Robertson, 2015; Robertson et al., 2017). Robins were widespread at the time of European settlement but populations were heavily reduced by the early 1900s due to deforestation and predation from introduced predators (Heather & Robertson, 2015; Higgins & Peter, 2002). Today, robins are uncommon and are found in patchy distributions across the North Island in some large native forests, exotic forests, and shrublands (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). They have been re-introduced to many mainland and offshore pest-free sanctuaries including Shakespear Open Sanctuary, where 40 robins were translocated in April 2016 (Gill et al., 2010; Heather & Robertson, 2015; SOSSI, 2017).

Robins are typically sedentary and may be seen alone or in pairs close to or on the ground (Higgins & Peter, 2002). Although silent in flight, robins are particularly vocal in the mid-morning and produce a loud ringing song without pause for up to an hour (Chambers, 2009; Moon, 1996). They are active and alert with a confiding inquisitive nature, and will approach humans to feed on the insects that they disturb (Higgins & Peter, 2002; Moon, 1996). Robins feed on invertebrates using a number of methods such as gleaning, hawking and encouraging prey to surface by hopping about, scratching and trembling on the forest floor (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). They also perch on low vegetation and watch for prey which they fly down to and pick from the ground (Heather & Robertson, 2015; Moon, 1996). Diet may be supplemented with small fruit over summer and autumn (Heather & Robertson, 2015).

Figure A2.25: *Photograph of the North Island robin (Petroica longipes). Photo credit: Tony Wills via Wikimedia Commons (CC BY 2.5). Image cropped.*

Robins are territorial year-round, especially during the breeding season (Heather & Robertson, 2015). Courtship feeding begins in July and the male starts singing his full territorial song from August (Heather & Robertson, 2015). The female builds a nest in a well-hidden notch or fork in a tree or fern (Heather & Robertson, 2015; Higgins & Peter, 2002). Monogamous pairs typically mate for life, laying 2-3 clutches (up to five if nests fail) of 1-3 eggs (average 2) between September to January (Heather & Robertson, 2015; Higgins & Peter, 2002). The eggs are incubated for 17-21 days by the female who leaves only to be fed by the male, who calls her from 20-50 m away (Heather & Robertson, 2015). Both parents feed the chicks which fledge around 17-22 days (Heather & Robertson, 2015; Moon, 1996). Young begin feeding themselves about two weeks later but continue to be fed for 4-7 weeks until they are ousted from their natal territory at 7-10 weeks old (Heather & Robertson, 2015). Breeding begins at age one and the oldest known robin lived for 17 years (Heather & Robertson, 2015).

Robin populations and eggs are limited by introduced predators, namely ship rats (*Rattus rattus*), cats, possums, mice and stoats (Department of Conservation, 2020j; Heather & Robertson, 2015; Higgins & Peter, 2002). Females are particularly susceptible to predation during incubation and brooding (Department of Conservation, 2020j). Pest control and 1080 operations have benefitted populations by reducing predators which has improved nesting success (Department of Conservation, 2020j; Heather & Robertson, 2015).

North Island saddleback (tīeke) (*Philesturnus rufusater*)

The North Island saddleback is a protected endemic Passeriform that has a conservation status of "recovering" and a population of around 10,000 birds (Heather & Robertson, 2015; Robertson et al., 2017). At the time of European settlement saddlebacks were found in forests across the entire North Island and on many offshore islands (Gill et al., 2010; Heather & Robertson, 2015). Populations declined throughout the 1800s due to deforestation and the spread of Norway rats (*Rattus norvegicus*) and feral cats, with local extinctions accelerated by the introduction of mustelids and ship rats (Department of Conservation, 2020m; Heather & Robertson, 2015). The species was extinct on the mainland by 1900, and by 1950 the only surviving population was 500 birds on Hen Island (Gill et al., 2010; Heather & Robertson, 2015). Since 1964, an intensive management programme has successfully translocated North Island saddlebacks to at least 19 predator-free offshore islands and multiple mainland sanctuaries where they have become locally abundant in old and secondary growth forests and remnant forest patches (Chambers, 2009; Department of Conservation, 2020m; Gill et al., 2010; Heather & Robertson, 2015; Moon, 1996). 50 saddlebacks were introduced to Shakespear Open Sanctuary in 2018 (Auckland Council, 2018b).

Saddlebacks are highly active, inquisitive, and conspicuous amongst vegetation (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). They are sedentary and territorial, producing far-carrying, rhythmic calls throughout the day (Chambers, 2009; Higgins et al., 2006). Saddlebacks are weak, noisy fliers and rarely sustain flight for more than 50 m (Heather & Robertson, 2015; Higgins et al., 2006). Instead, they prefer to bound between branches and are often seen close to or on the forest floor, foraging in pairs or family groups (Chambers, 2009; Heather & Robertson, 2015; Hooson & Jamieson, 2003). Diet primarily consists of invertebrates gleaned from foliage, dug up from the forest floor, or prised from underneath bark (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). This method of feeding often attracts fantails and whiteheads which also feed on the disturbed insects (Heather & Robertson, 2015; Higgins et al., 2006). When in season, saddlebacks also consume nectar and fruit (Heather & Robertson, 2015; Moon, 1996).

Figure A2.26: *Photograph of the North Island saddleback (Philesturnus rufusater). Photo credit: Judi Lapsley Miller via Wikimedia Commons (CC BY 4.0). Image cropped.*

Monogamous pairs hold their territory year round (Higgins et al., 2006). They will challenge humans but are easily approachable (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). Nests are built around 2-3 m from the ground in tree or rock holes (Heather & Robertson, 2015). A single brood of 1-4 eggs (average 2-3) is typically raised between October and January, though up to four broods may be raised between August and May if resources are not limited (Heather & Robertson, 2015). Females incubate the eggs for around 18 days and both adults feed the young which fledge after 26 days (Heather & Robertson, 2015). Saddlebacks can breed at age one and live up to 21 years (Auckland Council, 2018b; Higgins et al., 2006).

Paradise shelduck (pūtangitangi) (*Tadorna variegata*)

The paradise shelduck is a partially protected endemic Anseriform that has a conservation status of "not threatened," and a population of around 620,000 (Heather & Robertson, 2015; Robertson et al., 2017). The conversion of native forest to pasture, the construction of farm ponds, harvest laws introduced in 1868, and the early 1900s liberation of South Island stock to the North Island have all contributed to nationwide range expansion and population increases (Department of Conservation, 2020k; Heather & Robertson, 2015; Marchant & Higgins, 1990). Paradise shelducks are commonly seen in monogamous life pairs or family parties around lakes, ponds, rivers, tussockland, wetlands and farmland (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990). Although adults are typically sedentary, they also form large flocks over freshwater habitats during their annual December to March moult (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990).

Figure A2.27: *Photographs of the male (left) and female (right) paradise shelduck (Tadorna variegata). Photo credits: Hayden Pye.*

The paradise shelduck is a nervous and alert species (Chambers, 2009). If disturbed, they take flight and circle, with males producing a deep "zonk zonk" call, and females a shrill "zeek zeek" (Chambers, 2009; Heather & Robertson, 2015). They are primarily herbivorous pasture grazers, feeding on grass, seeds, clovers, peas, grain and the occasional invertebrate (Heather & Robertson, 2015; Marchant & Higgins, 1990; Moon, 1996). When in water, they consume lakeweeds either from the surface or by upending (Heather & Robertson, 2015; Moon, 1996). Paradise shelducks are sometimes considered pests as flocks can damage young hay and grain crops (Department of Conservation, 2020k; Heather & Robertson, 2015).

Males aggressively defend their territory and are constantly on the lookout for predators over the breeding season (Heather & Robertson, 2015). The female lays a single clutch of 5-15 eggs (average 9) in a ground depression nest between August and September (though occasionally in November), and incubates for 30-35 days (Department of Conservation, 2020k; Heather & Robertson, 2015; Marchant & Higgins, 1990). Upon hatching, the female leads the chicks to water (Heather & Robertson, 2015). Eggs that hatch late may be abandoned (Heather & Robertson, 2015). Young are cared for by both parents and fledge at 55-65 days (Heather & Robertson, 2015). Following their annual moult, juvenile females typically return to their natal area, though juvenile males may disperse up to 100 km (Heather & Robertson, 2015). Paradise shelduck may breed at age two, but some females only begin at three (Department of Conservation, 2020k; Heather & Robertson, 2015). Average longevity is around 2.3 years, though many live older, with the oldest known bird living to 23 (Department of Conservation, 2020k; Heather & Robertson, 2015).

Each year around 200,000 paradise shelducks (around 35% of breeding adults) are legally shot over the game season, with some areas experiencing local declines from over-hunting (Department of Conservation, 2020k; Heather & Robertson, 2015). Paradise shelducks are also vulnerable to introduced mammalian predators and losses to wetland habitat, though the ability to persist across a wide range of habitats appears to outweigh these threats (Department of Conservation, 2020k).

Pūkeko (*Porphyrio melanotus*)

The pūkeko is a partially protected native Gruiform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Pūkeko are thought to have established in New Zealand around 500 years ago (Heather & Robertson, 2015). They became common and abundant following widespread deforestation and the creation of rough damp pastures over the last few hundred years (Department of Conservation, 2020l; Heather & Robertson, 2015). Pūkeko may be found alone, in pairs or in territorial groups with extended family members across open country, wetlands, swamps, lake edges, estuaries, parks and roadsides (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Although pūkeko are tamer in urban areas, they still run to cover, dive into water, or clumsily fly short distances to escape if disturbed (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Pūkeko are primarily sedentary, though some dispersive movements may occur, particularly by juveniles (Marchant & Higgins, 1993).

Figure A2.28: *Photograph of the pūkeko (Porphyrio melanotus). Photo credit: Hayden Pye.*

Pūkeko produce loud screeches, and softer clucking sounds when feeding (Heather & Robertson, 2015; Marchant & Higgins, 1993). They are primarily herbivorous ground feeders, but also consume invertebrates, frogs, small mammals, eggs, and small or young birds (Department of Conservation, 2020l; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). Pūkeko may graze and damage grain and vegetable crops and are thus often considered agricultural pests (Heather & Robertson, 2015). They can also be aggressive, particularly over the breeding season when neighbouring territorial groups noisily challenge and fight each other (Chambers, 2009; Marchant & Higgins, 1993). It is legal to shoot pūkeko over the duck hunting season and they are sometimes culled to protect threatened species (Department of Conservation, 2020l; Heather & Robertson, 2015).

Pūkeko mating systems include long-term monogamy, polygamy and promiscuity (Marchant & Higgins, 1993). There are usually two laying females and at least two breeding males in each community (Heather & Robertson, 2015). Nests are built above or near water on clumps of bulrush (*Typha orientalis*) or tussock grass, and several nests may be shared by multiple females at the same time (Heather & Robertson, 2015). Each laying female lays 2-7 eggs (average 5) between August and February (peaking between October and November), and up to 15 eggs in one nest are incubated for 23-29 days (average 25) by all breeding females and males (Heather & Robertson, 2015; Marchant & Higgins, 1993). Chicks may leave the nest within hours, though they usually wait 4-5 days (Heather & Robertson, 2015). Young can feed themselves after two days but continue to be fed by adults and non-breeding helpers for about two months (Heather & Robertson, 2015; Marchant & Higgins, 1993). Pūkeko can begin breeding at the end of their first year, though they usually begin at age two (Heather & Robertson, 2015). Longevity depends on the environment; in Auckland it is around 5-6 years, though the oldest known New Zealand bird lived for nine years (Heather & Robertson, 2015).

Red-crowned parakeet (kākāriki) (*Cyanoramphus novaezelandiae*)

The red-crowned parakeet (henceforth kākāriki) is a protected endemic Psittaciform that has a conservation status of “relict” (Heather & Robertson, 2015; Robertson et al., 2017). Captive breeding programmes have contributed to species preservation and today kākāriki have a stable population of > 20,000 mature individuals with populations increasing at > 10% (Department of Conservation, 2020h; Robertson et al., 2017). Kākāriki are common on predator-free offshore islands where they occur across a variety of habitats (Gill et al., 2010; Higgins, 1999). They are rare on the mainland, favouring lowland forests in and around the predator-free sanctuaries to which they have been re-introduced (Gill et al., 2010; Heather & Robertson, 2015; Higgins, 1999). Kākāriki can be tame and approachable and may be found alone, in pairs, family parties or small groups (Heather & Robertson, 2015; Higgins, 1999). They have dispersed to and are breeding at Shakespear Open Sanctuary following their introduction to Tiritiri Matangi Island (Chambers, 2009; SOSSI, 2014a).

Kākāriki are typically sedentary but they may fly long distances to reach good food sources or fresh water (Heather & Robertson, 2015). They forage at ground level or low in the forest canopy on a seasonally varied diet of seeds, flowers, buds, shoots, fruit, nectar, invertebrates and carrion (Heather & Robertson, 2015; Moon, 1996). Kākāriki camouflage well but are more often seen than heard (Higgins, 1999). They may be silent or produce a babbling chatter whilst feeding, and make a loud repeated "ke ke ke" whilst flying (Heather & Robertson, 2015; Moon, 1996).

Figure A2.29: *Photograph of the red-crowned parakeet (Cyanoramphus novaezelandiae). Photo credit: Craig Nash via Wikimedia Commons (CC BY 2.0). Image cropped.*

Kākāriki are monogamous and nest in the holes of trees, cliffs, rocks, or ground burrows (Heather & Robertson, 2015; Higgins, 1999). Breeding occurs between October and December, though re-laying can occur until March (Heather & Robertson, 2015). 4-9 eggs (average 7) are laid and incubated for 23-25 days (average 24) (Heather & Robertson, 2015). Egg laying can occur at intervals of up to 3-4 days thus hatching is asynchronous and the age and size of chicks varies (Heather & Robertson, 2015). The male calls the female from the nest to feed her during incubation and over the first 14 days after hatching (Heather & Robertson, 2015). Both parents then feed the chicks which fledge after 36-49 days (average 41) (Heather & Robertson, 2015). Kākāriki can breed at age one (Heather & Robertson, 2015). Maximum longevity is unknown. Populations are threatened by ship rats, stoats and cats due to their hole nesting and ground feeding habits (Chambers, 2009; Heather & Robertson, 2015). Chicks also occasionally leave the nest before they can fly and are vulnerable whilst at ground level (Heather & Robertson, 2015).

Sacred kingfisher (kōtare) (*Todiramphus sanctus*)

The sacred kingfisher is a protected native Coraciiform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Kingfishers are widespread and are common near water throughout New Zealand forests, open country, wetlands, mangroves, rivers, estuaries, lakes and rocky coastlines (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). They may be found alone or in pairs and are commonly observed perched on high posts, powerlines, fence wires, branches and foreshore rocks (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999). Kingfishers are easily identified from a distance by their repeated and monotonous staccato call which consists of 4 or 5 "kek" sounds (Higgins, 1999; Moon, 1996).

Deforestation has benefitted kingfishers by creating fringe habitats in which the species hunts (Heather & Robertson, 2015; Higgins, 1999). Prey items include earthworms, large insects, mice, skinks, crustaceans, fish and small birds, particularly silvereyes (*Zosterops lateralis*) (Heather & Robertson, 2015; Higgins, 1999; Moon, 1996). Prey is regularly taken from the ground by darting in a descending flight from a perch and then immediately returning to the perch to wait and repeat the process (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999). Kingfishers can be partly migratory depending on food availability and seasonality (Moon, 2006). Individuals that occupy inland high country often migrate to coasts and lowland farmland over winter (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015). Birds that move return to the same breeding sites and non-breeding areas each year (Higgins, 1999).

Figure A2.30: *Photograph of the sacred kingfisher (Todiramphus sanctus). Photo credit: Hayden Pye.*

Kingfishers are thought to be monogamous (Higgins, 1999). Nests are built in rotting tree trunks, tree cavities, or tunnels in clay banks along rivers, roadsides or coastal cliffs (Heather & Robertson, 2015; Moon, 1996). They are sometimes evicted from their nests by house sparrows, starlings and mynas, but pairs aggressively defend their breeding site from birds that approach or nest nearby (Higgins, 1999). Between October and January, a clutch of 3-7 eggs (average 5) is laid and is mainly incubated by the female for around 3 weeks (Heather & Robertson, 2015). Chicks fledge around 26-27 days but continue to be fed by both parents for around 7-10 days after leaving the nest (Heather & Robertson, 2015; Moon, 1996). The age of first breeding and longevity are unknown.

Shining cuckoo (pīpīwharauroa) (*Chrysococcyx lucidus*)

The shining cuckoo is a protected native Cuculiform that has a conservation status of "not threatened", though data is poor (Heather & Robertson, 2015; Robertson et al., 2017). They are a widespread and locally common parasitic species that migrate from the Solomon Islands, New Guinea, west Indonesia and the Bismarck Archipelago to breed in New Zealand between September and March (Gill et al., 2010; Heather & Robertson, 2015). Shining cuckoos occupy native forest, pine forest, scrubland, and vegetated parks and gardens across New Zealand, particularly around areas in which their host species the grey warbler is found (Chambers, 2009; Heather & Robertson, 2015; Moon, 2006). Populations appear to be stable due to their prolific hosts, though the continued clearance of subtropical rainforest in the countries that shining cuckoos overwinter in may have great negative consequences on their populations (Heather & Robertson, 2015). Shining cuckoos are also common casualties of window strike during migration, and are predated by cats (Heather & Robertson, 2015; Higgins, 1999).

The shining cuckoo feeds on invertebrates found in the forest understorey, canopy, on the ground, and hawked while flying (Higgins, 1999; Moon, 1996). Although usually solitary, pairs form over spring and mating birds gather communally in tall trees for noisy feeding and courtship displays (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999). They are well camouflaged and are heard more often than they are seen (Moon, 1996; Moon, 2006). Their song is a distinctive series of high-pitched upwards inflecting whistles followed by 1 or 2 descending notes, used to define territory and attract a mate (Chambers, 2009; Heather & Robertson, 2015; Higgins, 1999).

Between mid-October and mid-January the adult cuckoo removes a single egg from the host's nest and replaces it with one of their own (Heather & Robertson, 2015). The adult cuckoo may also remove grey warbler chicks, possibly so the host re-nests and the shining cuckoo can parasitise the new clutch (Heather & Robertson, 2015). The egg is incubated by the host and hatches after 14-17 days (average 15), around four days faster than the grey warbler's eggs (Heather & Robertson, 2015). At 3-7 days old (average 4) the cuckoo chick evicts the grey warbler's eggs or chicks from the nest and is raised alone (Heather & Robertson, 2015). Shining cuckoos fledge at 19-21 days but are fed by both grey warbler parents for at least four weeks (Heather & Robertson, 2015). Young cuckoos instinctively migrate to the tropics and return to New Zealand when they are two years old (Heather & Robertson, 2015; Moon, 2006). Adults return to the same breeding site each year (Heather & Robertson, 2015; Moon, 1996). The age of first breeding and maximum longevity is unknown.

Figure A2.31: *Photograph of the shining cuckoo (Chrysococcyx lucidus). Photo credit: JJ Harrison via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

Silvereye (tauhou) (*Zosterops lateralis*)

The silvereye is a protected native Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Silvereyes self-introduced from Australia and were first recorded in small flocks around Southland and Stewart Island in 1832 (Heather & Robertson, 2015; Moon, 1996; Watola, 2011). By 1856 large numbers had arrived and the species had permanently colonised (Heather & Robertson, 2015). Today, they are widespread across native forests and scrub, exotic plantations, orchards, vineyards, mangroves, and suburban parks and gardens (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006). Silvereyes are one of New Zealand's most common native birds; in some forests their biomass outweighs that of any other bird species (Heather & Robertson, 2015). It is thought that they have significantly impacted native forest communities through food competition and altering the patterns of seed dispersal, thereby creating new native habitat for endemic bird species (Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.32: *Photograph of the silvereye (Zosterops lateralis). Photo credit: Hayden Pye.*

Silvereyes are mostly sedentary, though they may make considerable local movements to visit the same food sources each year during winter (Heather & Robertson, 2015; Higgins et al., 2006). They may be found alone or in pairs, but they are typically seen feeding and moving quickly through the canopy in small flocks, occasionally with grey warblers, fantails, whiteheads, goldfinches, greenfinches and kākāriki (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). Their song is a mix of melodious warbles, slurs and trills, and flocks produce a "cli-cli-cli" in flight (Heather & Robertson, 2015). Diet is a variation of fruit, invertebrates and nectar, as well as sugar water, bread and cooked meat from bird tables in suburban areas (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006). They are often excluded from feeding sites by bellbirds and tūī (Heather & Robertson, 2015). Although silvereyes can cause serious commercial damage to crops, they also consume invertebrate pests and typically feed from fruit that has already been damaged by other species (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996).

Silvereyes form monogamous lifelong pairs that defend territories with vocalisations and displays over the breeding season (Heather & Robertson, 2015; Higgins et al., 2006). Suspended cup nests are built near the outer ends of branches, ferns or shrubs (Heather & Robertson, 2015). 2-3 clutches of 2-5 eggs (average 3) are laid between September and February (Heather & Robertson, 2015). Both parents incubate the eggs for 10-12 days (average 11) and feed the young which fledge at 9-11 days (average 10) (Heather & Robertson, 2015; Moon, 1996). The family remains together for 2-3 weeks before the young become independent (Heather & Robertson, 2015). Silvereyes may begin breeding after nine months and live at least 11.5 years (Heather & Robertson, 2015). They are preyed upon by rats, cats and stoats, and are sometimes victims of window strike and vehicles (Department of Conservation, 2020n; Higgins et al., 2006).

Song thrush (*Turdus philomelos*)

The song thrush is a Passeriform that was introduced to New Zealand between 1862 and 1878 for sentimental reasons (Heather & Robertson, 2015). They are now are widespread and common in modified habitats such as suburban gardens, parks, orchards, exotic forests and scrub (Chambers, 2009; Gill et al., 2010; Higgins et al., 2006; Moon, 1996). Song thrushes are rare in native forests where the original forest bird communities persist (Heather & Robertson, 2015). They are thought to be sedentary and may be found alone, in pairs, or in small family groups, and are also commonly seen foraging with blackbirds, starlings and house sparrows (Higgins et al., 2006).

Song thrushes are often seen at ground level, hopping and running in short spurts, remaining motionless between movements as they search for invertebrate prey (Moon, 1996; Moon, 2006). They also eat fruit and may cause damage to commercial crops and spread the seeds of weed species (Heather & Robertson, 2015). Song thrushes may be heard singing, often from high perches in the late afternoon (Heather & Robertson, 2015). They produce a conspicuous string of musical phrases that are repeated twice and then separated by a brief pause (Heather & Robertson, 2015; Moon, 2006). Song thrushes also produce a repeated "chuk chuk" alarm call when disturbed (Moon, 2006). They are inconspicuous and often remain hidden and quiet outside of the breeding season (Heather & Robertson, 2015).

New Zealand mating systems are unknown, but song thrushes are thought to be extralimital monogamous breeders that likely form new pairs each year (Higgins et al., 2006). Males loudly defend their breeding territories with song between April and January, and the female builds a cup nest in the fork of a hedge or shrub (Chambers, 2009; Heather & Robertson, 2015). 2-3 broods of 2-6 eggs (average 3-4) are raised between early-August and late-December (Heather & Robertson, 2015). The female incubates the eggs for 12-13 days and the chicks are fed by both adults (Heather & Robertson, 2015; Moon, 1996). The young fledge at 13-15 days and remain around their parents, who occasionally feed them (Heather & Robertson, 2015). They can breed at nine months old and the oldest known New Zealand bird lived for 10.5 years (Heather & Robertson, 2015). Song thrushes are commonly predated by cats and may fall victim to poison from slug baits that prey has consumed (Moon, 2006).

Figure A2.33: *Photograph of the song thrush (Turdus philomelos). Photo credit: Hayden Pye.*

Spotless crake (pūweto) (*Porzana tabuensis*)

The spotless crake is a protected native Gruiform that has a conservation status of "at risk, declining," though data is poor and population numbers are unknown (Department of Conservation, 2020o; Heather & Robertson, 2015; Robertson et al., 2017). Spotless crakes are thought to be recent colonisers and are today locally common in the North Island and found in scattered populations in the northern South Island (Heather & Robertson, 2015). They are cryptic and occur alone, in pairs, and in loose groups across wetlands, swamps, saltmarshes and lake verges, particularly in environments with sedge, bulrush and an overstorey of mānuka (*Leptospermum scoparium*) (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Watola, 2011). Spotless crakes are a mobile species, but pairs remain on territory year round (Heather & Robertson, 2015). Their presence is a good indicator of wetland health as they require an ecologically diverse habitat with rich food sources (Department of Conservation, 2020o). Spotless crakes are present in the Okoromai Bay wetlands (SOSSI, 2014a).

Figure A2.34: *Photograph of the spotless crake (Porzana tabuensis). Photo credit: Frankzed via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

Spotless crakes forage in shallow water and in dense vegetation at ground level (Heather & Robertson, 2015). Diet is a mix of insects, larvae, earthworms, molluscs, crustaceans, tadpoles, fallen fruit and the seeds of aquatic plants (Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). They are primarily active at dawn and dusk, but rarely venture into the open (Heather & Robertson, 2015; Moon, 1996). Their presence is often only realised after hearing calls, which include a sharp “pip,” a repeated “book,” and a trilling machine-gun like purr (Heather & Robertson, 2015). If disturbed, spotless crakes quickly run to cover if exposed, or fly up from cover to escape (Chambers, 2009; Heather & Robertson, 2015).

Monogamous pairs nest in sedge around 30-50 cm above water (Heather & Robertson, 2015). Clutches of 2-5 eggs (average 3-4) are laid between late-August and January (peaking over September and October) and are incubated by both parents for 20-22 days (Chambers, 2009; Department of Conservation, 2020o; Heather & Robertson, 2015). Egg and clutch sizes increase over the breeding season (Heather & Robertson, 2015; Marchant & Higgins, 1993). The young leave the nest within four days but continue to be looked after by both parents until they reach adult size after 4-5 months (Heather & Robertson, 2015; Moon, 1996). The age of first breeding and maximum longevity is unknown. The draining and degradation of wetlands combined with the introduction of mammalian predators has negatively impacted populations (Heather & Robertson, 2015; Marchant & Higgins, 1993). They are vulnerable to predation from cats, dogs, rats and mustelids, and are also victims of roadkill, flying into powerlines, and duck shooters (Department of Conservation, 2020o; Heather & Robertson, 2015).

Spotted dove (*Streptopelia chinensis*)

The spotted dove is an introduced Asian Columbiform that is common around Auckland orchards and suburban parks and gardens that have lots of trees (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). The steadily increasing population likely consists of the descendants of escaped caged birds and a sizeable liberation from Mt Eden in the 1920s (Heather & Robertson, 2015). Spotted doves are typically tame and approachable and are common across the Whangaparāoa Peninsula (Higgins & Davies, 1996; Tiritiri Matangi Open Sanctuary, 2010c). They are thought to be sedentary and may occur alone or in pairs, sometimes forming small flocks in areas where food is abundant (Higgins & Davies, 1996).

Spotted doves are heard more often than they are seen (Heather & Robertson, 2015). Their calls are a mellow “coo” or “croo” of up to 4 notes produced from high trees, chimneys and rooftops (Heather & Robertson, 2015). They forage on lawns or paths, feeding on grains, seeds, snails and bread scraps provided by humans (Chambers, 2009; Heather & Robertson, 2015; Higgins & Davies, 1996). Males also perform conspicuous display flights around dusk (Chambers, 2009). These displays involve fast, noisy, steep swooping and stalling movements with their wings spread (Chambers, 2009; Higgins & Davies, 1996).

Spotted doves are solitary breeders that re-nest multiple times each season (Heather & Robertson, 2015). They can breed year round if food is abundant and the weather is favourable, though breeding is most prolific during spring and summer (Heather & Robertson, 2015). The nest is a flimsy twig platform that is hidden high in a tree, shrub or hedge (Heather & Robertson, 2015). Two eggs are incubated by both adults for around 16 days (Heather & Robertson, 2015). Both adults feed the chicks who fledge and become independent after 15 days (Heather & Robertson, 2015; Moon, 1996). Spotted doves can begin breeding at age one and maximum longevity is 10 years (Frost, 2020).

Figure A2.35: *Photograph of the spotted dove (Streptopelia chinensis). Photo credit: Hayden Pye.*

Spur-winged plover (*Vanellus miles*)

The spur-winged plover is a native Charadriiform that has a conservation status of "not threatened" (Gill et al., 2010; Heather & Robertson, 2015; Robertson et al., 2017). Spur-winged plovers self-introduced from Australia in 1932 and populations began to rapidly spread from the 1960s (Gill et al., 2010; Heather & Robertson, 2015). The clearance of native forest has benefitted the species which are now found nationwide across open country, rough grasslands, sports-fields, golf courses, wetlands and the shorelines of rivers, estuaries and lakes (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 1996). They are common on almost any grassy urban surface, even around disruptions such as heavy traffic (Marchant & Higgins, 1993). Spur-winged plovers are sedentary and may occur in pairs, family groups, and occasionally in large flocks outside of the breeding season (Heather & Robertson, 2015; Marchant & Higgins, 1993).

Figure A2.36: *Photograph of the spur-winged plover (Vanellus miles). Photo credit: Hayden Pye.*

Spur-winged plovers are wary and alert (Moon, 2006). When threatened they produce a loud, extended and far travelling staccato "kerr-kick-ki-ki-ki" alarm call (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1993). They also dive-bomb human intruders and attack other birds if they fly nearby, especially in defence of their nest and chicks (Heather & Robertson, 2015; Marchant & Higgins, 1993). Spur-winged plovers are ground feeders and have a varied diet of insects, larvae, earthworms, seeds, leaves and marine crustaceans (Heather & Robertson, 2015; Moon, 1996). Although they may benefit commercial farmers by eating invertebrate pests, spur-winged plovers also damage leafy green crops and are generally disliked due to their aggressive and noisy presence (Heather & Robertson, 2015; Woodley, 2013). They were fully protected from 1946 but this status was revoked in 2010 due to their negative impact on agriculture, increased bird strike by aeroplanes, and their aggressive nature towards other native species (Woodley, 2013).

Spur-winged plovers are monogamous and typically mate for life (Marchant & Higgins, 1993). Clutches of 1-4 eggs are laid in a ground depression nest between June and late-November (peaking in August) (Heather & Robertson, 2015; Marchant & Higgins, 1993). Both parents incubate the eggs for 30-31 days (Heather & Robertson, 2015; Moon, 1996). Chicks leave the nest and can feed themselves within hours but remain close to their parents (Heather & Robertson, 2015; Moon, 2006). The young fledge around 7-8 weeks (Heather & Robertson, 2015). Although breeding can begin at age one, life mates are typically found during their first year and breeding usually begins at age two (Heather & Robertson, 2015). Maximum longevity in New Zealand is 16 years, and populations are increasing (Gill et al., 2010; Heather & Robertson, 2015).

Stitchbird (hihi) (*Notiomystis cincta*)

The stitchbird (henceforth hihi) is a protected endemic Passeriform that has a conservation status of "nationally vulnerable," but with stable populations (Heather & Robertson, 2015; Robertson et al., 2017). Hihi were relatively common in scattered populations across the lower North Island and some of its offshore islands until 1870 (Gill et al., 2010). Populations rapidly declined and by 1885 just a single group persisted on Little Barrier Island (Gill et al., 2010; Heather & Robertson, 2015). Population decline is likely attributed to a combination of introduced mammalian predators, habitat loss and possibly avian disease (Department of Conservation, 2020p; Heather & Robertson, 2015). Translocations to predator-free islands and mainland sanctuaries since 1980 have insured the species from extinction and raised populations to 4,000-5,000 mature individuals, though populations are range restricted and are still reliant on conservation programmes (Department of Conservation, 2020p; Heather & Robertson, 2015; Higgins et al., 2001; Robertson et al., 2017). Hihi were translocated to Tiritiri Matangi Island between 1995 and 2010, and 40 of the Tiritiri stock were translocated to

Shakespear Open Sanctuary on 3 July 2020 (Auckland Council, 2020c; Gill et al., 2010; Heather & Robertson, 2015).

Hihi are often found in pairs in the forest canopy of secondary and mature native forests (Chambers, 2009; Heather & Robertson, 2015; Moon, 1996). Young hihi may form loose flocks with an adult male and the species commonly associates with tūī, bellbirds, whiteheads, saddlebacks and other passerines (Chambers, 2009; Heather & Robertson, 2015). Although relatively tame and approachable, hihi produce a resonant "tik-tik-tik" call to warn of intruders (Heather & Robertson, 2015; Higgins et al., 2001). Males also make a high pitched territorial whistling "see-si-ip" call when near the nest or while feeding (Heather & Robertson, 2015). Hihi are arboreal feeders that consume nectar, berries, fruit, and insects gleaned from vegetation (Heather & Robertson, 2015; Higgins et al., 2001; Moon, 1996; Watola, 2011). Populations often rely on supplementary nectar feeders due to limited natural resources and feeding competition with dominant tūī and bellbirds (Heather & Robertson, 2015). Although sedentary within their home range, hihi will travel several kilometres a day between good food sources (Heather & Robertson, 2015).

Figure A2.37: *Photographs of the male (left) and female (right) stitchbird (Notiomystis cincta). Photo credit: Judi Lapsley Miller (CC BY 4.0) and Pseudopanax via Wikimedia Commons. Images cropped.*

Hihi are monogamous on Little Barrier Island but are polygynandrous at all other sites, possibly due to a lack of food sources and tree holes to nest in (Chambers, 2009; Heather & Robertson, 2015). Artificial nest boxes are thus often installed (Higgins et al., 2001). Hihi lay two broods of 1-6 eggs (average 4) between September and March (Heather & Robertson, 2015). Females incubate the eggs for 14-20 days (average 16) and both parents feed the chicks which fledge after 21-34 days (average 27) (Heather & Robertson, 2015; Moon, 1996). Hihi may begin breeding at six months old (Castro, 2013). Maximum longevity may exceed nine years (Heather & Robertson, 2015). Populations are particularly susceptible to avian diseases which can be introduced by domestic bird species (Department of Conservation, 2020p). Populations have responded positively to the eradication of mammalian predators (Heather & Robertson, 2015).

Swamp harrier (kāhu) (*Circus approximans*)

The swamp harrier is a partially protected native Accipitriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Swamp harriers colonised and flourished in New Zealand following widespread forest clearance and the introduction of small mammals and birds (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015). They are now New Zealand's most common raptor and are found near open countryside, tall crops, forest edges, wetlands, lakes, coastal areas, and occasionally cities and suburbs (Heather & Robertson, 2015; Marchant & Higgins, 1993). They are primarily found alone, soaring silently through the air or perched on fenceposts, tree stumps or low vegetation (Heather & Robertson, 2015; Marchant & Higgins, 1993). New Zealand birds are typically sedentary, though pairs may travel hundreds of kilometres to breed in the same territories each year (Heather & Robertson, 2015; Marchant & Higgins, 1993).

Swamp harriers hunt in open country and along the edges of forests and roads (Heather & Robertson, 2015; Moon, 1996). They primarily scavenge sheep and possum roadkill but also catch live rats, mice, rabbits, hares, hedgehogs, birds, fish, reptiles, frogs, tadpoles and large insects at ground level (Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 2006; Watola, 2011). Swamp harriers also occasionally take new-born lambs, free-range chickens, and endangered species from managed areas (Chambers, 2009; Heather & Robertson, 2015; Watola, 2011). As a result, populations are controlled in some areas and farmers may shoot them (Heather & Robertson, 2015). Populations are strong but have declined since the 1950s as rabbit prey has become less common due to pest control (Heather & Robertson, 2015).

Figure A2.38: *Photograph of the swamp harrier (Circus approximans). Photo credit: JJ Harrison via Wikimedia Commons (CC BY-SA 3.0). Image cropped.*

Pairs begin courtship diving and producing high pitched, long carrying "kee-a" and "kee-o" calls between June and October (Heather & Robertson, 2015; Marchant & Higgins, 1993; Moon, 2006). Although mostly monogamous, males occasionally mate with two females (Heather & Robertson, 2015; Marchant & Higgins, 1993). Females build nests at ground level and lay broods of 2-7 eggs (average 3-5) between September and December (Heather & Robertson, 2015; Marchant & Higgins, 1993). The female incubates the eggs for 31-34 days and is fed by the male, who also leaves food nearby for the female to feed the chicks once they hatch (Heather & Robertson, 2015). Hatching is asynchronous and eggs may be abandoned after the first two hatch (Heather & Robertson, 2015; Moon, 2006). Chicks fledge after 43-46 days but remain with their parents for about a week, slowly venturing further away until dispersing around seven weeks later (Heather & Robertson, 2015; Marchant & Higgins, 1993). Females may breed after one year, and males typically breed at age two or three (Heather & Robertson, 2015). Plumage gets paler with age, and the oldest known New Zealand bird lived to 18 (Heather & Robertson, 2015).

Tomtit (North Island tomtit) (miromiro) (*Petroica macrocephala toitoi*)

The North Island tomtit is a protected endemic Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Tomtits are widespread across the North Island, though populations are sparse between Whangārei and southern Waikato (Heather & Robertson, 2015). Numbers have declined due to large-scale forest clearance, but the species has adapted and populations today are stable and locally common across old and secondary native forests, exotic pine forests with native understorey, forest fringes, and tall native scrub (Chambers, 2009; Department of Conservation, 2020q; Gill et al., 2010; Heather & Robertson, 2015; Higgins & Peter, 2002). Tomtits are often seen perched on the side of tree trunks and may occur alone, in pairs, family groups, or associating with heterospecific species (Chambers, 2009; Higgins & Peter, 2002). Although susceptible to introduced mammalian predators, they still persist in areas that lack predator-management (Department of Conservation, 2020q; Heather & Robertson, 2015).

Figure A2.39: *Photographs of the male (left) and female (right) North Island tomtit (Petroica macrocephala toitoi). Photo credit: Jon-Paul Hansen and Christopher Stephens (CC BY-SA 4.0) via Wikimedia Commons. Images cropped.*

Males are seen more frequently than females (Moon, 1996). Males produce a conspicuous warbling "ti-oly oly oly oh" call, whilst females produce a softer version, as well as a short high-pitched "swee" (Heather & Robertson, 2015). Diet is insectivorous and is caught by gleaning from the forest understorey, or by scanning from a low perch and flying down to grab prey from the ground (Heather

& Robertson, 2015; Higgins & Peter, 2002; Moon, 1996). Small fruit is also consumed over autumn and winter (Heather & Robertson, 2015; Higgins & Peter, 2002).

Adult tomtits remain in the same territory year round (Heather & Robertson, 2015). Males increase their vocalisations for territory defence from July, and the female builds a nest in a tree cavity (Heather & Robertson, 2015; Higgins & Peter, 2002). Monogamous life pairs raise up to three broods of 3-6 eggs (average 4) between September to January (Heather & Robertson, 2015; Higgins & Peter, 2002). Females incubate the eggs for 15-17 days (average 16), leaving the nest only to be fed by the male (Heather & Robertson, 2015). Chicks are fed by both parents and fledge after 17-20 days (average 18), but continue to be fed until 35 days old (Heather & Robertson, 2015; Moon, 1996). Once independent, young tomtits disperse from their natal territory and can breed at age one (Heather & Robertson, 2015). The oldest known tomtit lived to three, though it is thought that some live up to 10 years (Heather & Robertson, 2015).

Tūī (*Prosthemadera novaseelandiae*)

The tūī is an endemic Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Tūī have adapted well to anthropogenic change and are locally common and widespread throughout native and exotic forests, forest remnants, gardens and vegetated areas in towns and suburbs across New Zealand (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Moon, 1996). They are primarily found alone but may occur in pairs, family groups, or in large numbers around good food sources (Heather & Robertson, 2015; Higgins et al., 2001; Moon, 1996). Diet consists of a wide variety of nectar and fruit, as well as the occasional insect caught by hawking (Department of Conservation, 2020r; Heather & Robertson, 2015; Moon, 1996). Tūī play an important ecological role in pollinating many native tree species and are one of the main dispersers of medium sized seeds (Heather & Robertson, 2015). They are a resident species but can fly 20 km+ a day between feeding sites and may make some seasonal movements to reach good food sources (Heather & Robertson, 2015; Higgins et al., 2001).

Tūī are often heard before they are seen (Department of Conservation, 2020r). Their wings produce a loud whirring noise in flight, and they call from high tree perches with melodious and guttural sounds, particularly in the early morning and late afternoon (Chambers, 2009; Heather & Robertson, 2015). Tūī are aggressive to one another and will noisily chase silvereyes, kererū and bellbirds from their feeding and breeding territories (Heather & Robertson, 2015; Higgins et al., 2001). They also defend themselves from magpies and mob together against harriers (Department of Conservation, 2020r). The greatest threats to tūī are habitat loss and predation from cats, rats, possums, stoats and ferrets (Department of Conservation, 2020r). Populations often have a dramatic positive increase in response to effective predator-management (Department of Conservation, 2020r).

Figure A2.40: *Photograph of the tūī (Prosthemadera novaseelandiae). Photo credit: Hayden Pye.*

Tūī are monogamous and establish their breeding territories around September and October (Heather & Robertson, 2015; Higgins et al., 2001). The female builds the nest in a tree fork or on an outer branch (Heather & Robertson, 2015). Broods of 2-4 eggs (average 3) are laid between September and January (peaking over November and December) and incubated by the female for two weeks (Heather & Robertson, 2015). The female initially feeds the chicks alone but both adults feed the young as they get older (Heather & Robertson, 2015). The young fledge after 21 days and females may begin breeding at age one (Heather & Robertson, 2015; Higgins et al., 2001). Maximum longevity is 12+ years (Heather & Robertson, 2015).

Welcome swallow (warou) (*Hirundo neoxena neoxena*)

The welcome swallow is a protected native Passeriform that has a conservation status of "not threatened" (Heather & Robertson, 2015; Robertson et al., 2017). Welcome swallows colonised from Australia and were first reported in New Zealand in 1920 (Chambers, 2009; Gill et al., 2010). A breeding colony established in 1958 and quickly took advantage of forest clearance, artificial water sources and anthropogenic structures (Heather & Robertson, 2015; Higgins et al., 2006). The species rapidly spread and today they are common with large stable populations around open farmland, mudflats, swamps, coasts, stormwater drains, sewerage ponds, lakes, rivers and estuaries (Chambers, 2009; Gill et al., 2010; Heather & Robertson, 2015; Moon, 1996). Welcome swallows are common near human settlements and can be easily approachable (Higgins et al., 2006). North Island populations are thought to be non-migratory (Higgins et al., 2006).

Figure A2.41: *Photograph of welcome swallows (Hirundo neoxena neoxena). Photo credit: Hayden Pye.*

Welcome swallows may be found alone or in pairs, but are typically seen in flocks perched on fences or telephone wires, or flying in swift, agile circles over water or open country (Chambers, 2009;

Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are strictly insectivorous and feed by hawking, catching prey from the water surface, or gleaning from vegetation (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 2006). Welcome swallows produce high-pitched "zwitt" calls as well as trills and warbles (Moon, 2006).

Monogamous pairs construct their nest on a cliff, bank or part of a man-made structure in August (Chambers, 2009; Higgins et al., 2006; Moon, 2006). They are sometimes considered a nuisance as they foul the anthropogenic surfaces around their nests (Heather & Robertson, 2015). Up to 3 broods of 2-7 eggs (average 4) are laid between August and February (Heather & Robertson, 2015). The second brood is typically the largest (Heather & Robertson, 2015). The female incubates the eggs for 15-19 days (average 17) but leaves the nest to feed regularly (Heather & Robertson, 2015). The young fledge at 18-23 days (average 21) but continue to be fed by both parents for up to three weeks (Heather & Robertson, 2015; Moon, 1996). Welcome swallows may breed at age one and the oldest known New Zealand bird lived for six years (Heather & Robertson, 2015).

White-faced heron (matuku moana) (*Egretta novahollandiae*)

The white-faced heron is a protected native Ciconiiform that has a conservation status of "not threatened" with stable or slightly declining populations (Heather & Robertson, 2015; Robertson et al., 2017). White-faced herons colonised from Australia and were first recorded in Auckland in 1865 (Heather & Robertson, 2015; Watola, 2011). Occasional sightings of the species continued until the 1930s and the first confirmed breeding occurred in 1941 (Chambers, 2009; Heather & Robertson, 2015). White-faced herons were widespread and abundant by the 1960s and are now common nationwide across sheltered coasts, harbours, wetlands, estuaries, swamps, public gardens, golf courses, lakes and open wet countryside (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990; Moon, 1996). They are commonly seen at ground level and perched on fenceposts or the edges of water troughs (Heather & Robertson, 2015; Marchant & Higgins, 1990).

White-faced herons are typically solitary though they may occur in large flocks over winter, occasionally with southern black-backed gulls (*Larus dominicanus*) and cattle egrets (*Ardea ibis*) (Chambers, 2009; Heather & Robertson, 2015; Marchant & Higgins, 1990). They are likely locally nomadic, making regular short and few long distance movements between feeding grounds (Marchant & Higgins, 1990; Moon, 2006). In flight, they produce a mournful croaking call (Moon, 2006). White-faced herons often forage by wading slowly through water, stalking their target and using their feet to disturb prey (Marchant & Higgins, 1990; Moon, 1996; Moon, 2006). Diet is a varied mix of small fish, frogs, tadpoles, crustaceans, insects, earthworms and mice (Heather & Robertson, 2015; Moon, 1996).

Figure A2.42: *Photograph of the white-faced heron (Egretta novahollandiae). Photo credit: Hayden Pye.*

White-faced herons nest in old, tall trees (Heather & Robertson, 2015; Marchant & Higgins, 1990). Mating systems are unknown. Broods of 3-5 eggs (average 4) are laid between June and February (peaking in October) and are incubated by both parents for around 26 days (Heather & Robertson, 2015). Adults typically only raise two of the chicks (Heather & Robertson, 2015). Both parents feed the young which remain close to the nest until they can fly, around six weeks later (Heather & Robertson, 2015). The age of first breeding and maximum longevity in New Zealand is unknown.

Whitehead (pōpokatea) (*Mohoua albicilla*)

The whitehead is a protected endemic Passeriform that has a conservation status of "at risk, declining" (Heather & Robertson, 2015; Robertson et al., 2017). Populations were widespread across the North Island at the time of European settlement but deforestation saw the species locally extinct from the northern North Island by 1880 (Heather & Robertson, 2015). Today, whiteheads are locally common from the Central Volcanic Plateau south, and on some offshore islands (Heather & Robertson, 2015). They occur in dense scrub, tall native forests, and in pine forests that have native understorey (Gill et al., 2010; Heather & Robertson, 2015; Higgins & Peter, 2002). Populations are currently > 100,000 but the species is reliant on conservation programmes, with a predicted decline of 10-70% (Robertson et al., 2017). In July 2015, 60 whiteheads were translocated to Shakespear Open Sanctuary from Tiritiri Matangi Island and Tāwharanui Regional Park (Heather & Robertson, 2015; SOSSI, 2015).

Whiteheads are sedentary but may make small local seasonal movements (Higgins & Peter, 2002). They may be found alone or in pairs, but are commonly seen in small noisy flocks in the forest canopy (Heather & Robertson, 2015; Higgins & Peter, 2002; Moon, 1996). Whiteheads produce a variety of calls including a single note contact call, loud alarm calls, and a wavering, harsh chattery song while feeding (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002). Diet is primarily invertebrates picked from vegetation, with some fruit and seeds (Heather & Robertson, 2015; Higgins & Peter, 2002; Moon, 1996). Food is taken from all levels of the forest, but rarely from the ground (Heather & Robertson, 2015; Higgins & Peter, 2002). Whiteheads also associate with saddlebacks, silvereyes, fantails and parakeets, feeding on the insects that they disturb (Heather & Robertson, 2015; Higgins & Peter, 2002).

Whiteheads are commonly polygamous co-operative breeders (Higgins & Peter, 2002). Family groups are territorial and generally comprise of a breeding pair or two breeding females, and 0-6 young helpers (Heather & Robertson, 2015). The main breeding female builds a nest in the forest canopy or a low shrub in early-September (Heather & Robertson, 2015). Broods of 2-4 eggs (average 3) are laid between late-September and late-December (Heather & Robertson, 2015). Later clutches are typically replacements, though a second clutch is sometimes laid (Heather & Robertson, 2015). The main female incubates the eggs for 17-19 days (average 18) and the family group feeds the chicks which fledge at 16-19 days (average 17) (Heather & Robertson, 2015). Whiteheads begin breeding after one year in low density populations, but they delay breeding and act as helpers for a few years in high density populations (Heather & Robertson, 2015). Maximum longevity exceeds 16 years (Heather & Robertson, 2015). Whiteheads are also the host species of the long-tailed cuckoo, and their eggs and young are often predated by rats (Chambers, 2009; Heather & Robertson, 2015; Higgins & Peter, 2002).

Figure A2.43: *Photograph of the whitehead (Mohoua albicilla). Photo credit: Hayden Pye.*

Yellowhammer (*Emberiza citrinella*)

The yellowhammer is a Passeriform that was introduced to New Zealand by Acclimatisation societies between 1862 and the early 1870s (Heather & Robertson, 2015). Yellowhammers have benefitted from widespread deforestation and are today widespread and locally common across open areas such as sports fields, parks, gardens, farmland, tussockland, coastal sand dunes and orchards (Chambers, 2009; Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They may occur alone or in twos, but they are most commonly found at ground level in small feeding flocks, occasionally with chaffinches, goldfinches, greenfinches and house sparrows (Higgins et al., 2006).Yellowhammers are a resident species in Auckland though some may make local movements to gather at good feeding grounds over autumn and winter (Gill et al., 2010; Heather & Robertson, 2015; Higgins et al., 2006).

Figure A2.44: *Photographs of the male (left) and female (right) yellowhammer (Emberiza citrinella). Photo credit: Andreas Trepte (CC BY-SA 2.5) and Estormiz (CC0 1.0) via Wikimedia Commons. Images cropped.*

Yellowhammers feed on grains and seeds, supplementing with invertebrates (Heather & Robertson, 2015; Higgins et al., 2006; Moon, 1996). They are considered a minor pest as they can cause some damage to crops, haystacks and newly sown seeds (Higgins et al., 2006). Their calls include a metallic "tink," and the male's territorial song follows the syllable pattern of "little bit of bread and no cheese!" (Heather & Robertson, 2015).

Nests are built close to the ground in long grass, brambles, gorse or thick vegetation on a bank or un-grazed area (Chambers, 2009; Heather & Robertson, 2015). Males begin territorial singing in late August (Heather & Robertson, 2015). Two broods of 3-5 eggs (average 4) are laid between October and mid-February (Heather & Robertson, 2015). Eggs are incubated for 12-13 days, primarily by the female (Heather & Robertson, 2015; Higgins et al., 2006). The young fledge at 12-13 days old and are fed by both adults (Heather & Robertson, 2015; Higgins et al., 2006). Yellowhammers can begin breeding after one year (Angus, 2013b). Maximum longevity in New Zealand is 9+ years (Heather & Robertson, 2015).