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Estimating the Population Size of Two Critically Endangered South Pacific Parakeets: The Tasman Parakeet and Malherbe’s Parakeet

A thesis submitted in partial fulfilment of the requirements for the degree of

Master of Science in Conservation Biology

Massey University

New Zealand

Michael John Adam Skirrow

2018

DECLARATION

I declare that this thesis is an accurate and original account of my research and that the contents have not previously been submitted for a degree at Massey University, nor any other tertiary institution. Except where acknowledged within, the material contained in this thesis has not been written or published by any other individual and to the extent of my knowledge, does not infringe upon copyright restrictions. The information presented contributes to a broader research programme examining the ecology and conservation of South Pacific parakeet species. This programme was developed in 2013 by Luis Ortiz-Catedral and is part of a collaborative research agreement involving Massey University and the Department of the Environment Australia (Appendix A). The programme has since expanded to include research on the offshore islands of New Zealand and has been granted authority for research by the New Zealand Department of Conservation (Appendix B).

In preparation for submission to journals, several of the chapters have been prepared as manuscripts. I am the primary author of each of these manuscripts, though the first person plural 'we' and the determiner 'our' is used throughout the text in recognition of the contributions made by my supervisors. As the primary supervisor of my research, Luis Ortiz-Catedral provided advice and support that was crucial to developing various components of this thesis; and as co-supervisor, Adam Smith provided valuable assistance and feedback on statistical analysis. In acknowledgement of their contributions, they will be granted co-authorship of the manuscripts that are submitted for publication. To the best of my knowledge, the research associated with these manuscripts and the remaining thesis was conducted in accordance with the protocols of Massey University, the Department of the Environment Australia, and the New Zealand Department of Conservation.

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Michael John Adam Skirrow
2018

ACKNOWLEDGEMENTS

This thesis would not have been possible without the assistance and support of a number of key individuals and organisations. Firstly, I would like to thank my supervisors Luis Ortiz-Catedral and Adam Smith for their support and encouragement during the course of my research. I am extremely grateful to my primary supervisor Luis Ortiz-Catedral for his guidance throughout the development of this thesis. The effort he has dedicated to conservation research has allowed me the opportunity to research species of high conservation value both in New Zealand and further abroad, for which I am tremendously appreciative. I would also like to offer my sincere thanks to Adam Smith for taking on the role of co-supervisor, his statistical expertise and feedback was crucial to the development of the analyses used in this thesis.

I would also like to extend my gratitude to the many volunteers that have contributed to the collection of data: Tansy Bliss, Rebecca Hamner, Luke Martin, Serena Simmonds, John Steemson, Nat Sullivan, Matt Upton, Amy Waldmann, Daniel Waldmann, Emma Wells, and Liz Whitwell. Their efforts in the field were much appreciated. Likewise, I am thankful to the staff from the Norfolk Island National Park: Joel Christian, Ken Christian, Craig Doolan, Dids Evans, Cassandra Jones, Matt King, Rossco Quintal, Abigail Smith, and Melinda Wilson. Their hospitality has made conducting research on Norfolk Island an enjoyable experience and having access to the library catalogue at the park was tremendously helpful during the initial stages of writing this thesis.

Additionally, I would like to thank the Department of the Environment Australia for allowing me to conduct research on Norfolk Island as part of their collaborative research agreement with Massey University. Similarly, I am grateful to the New Zealand Department of Conservation for granting the authority for research on Maud Island, Blumine Island, and Chalky Island. I would also like to thank the staff from the Picton Office of the Department of Conservation for providing the landing permits and quarantine processing necessary to conduct field work on Maud Island and Blumine Island. I am equally appreciative of the assistance provided by the staff from the Te Anau Area Office of the Department of Conservation, who organised the landing permits and quarantine processing required for Chalky Island.

I am grateful to all the organisations that have provided financial support for this research including: the Mohamed bin Zayed Species Conservation Fund, Wild Mob, the Nature Conservancy, Island Conservation, the Parrot Society UK, the Parrot Trust of Australia, the World Parrot Trust, the Norfolk Island Flora and Fauna Society, Birdlife Australia, the Parrot Society of Australia, the Foundation for National Parks and Wildlife, the Auckland Zoo Conservation Fund, the Brian Mason Scientific and Technical Trust, Canon Environmental Grants, the James Sharon Watson Conservation Trust, the Royal Forest and Bird Protection Society of New Zealand, and Massey University. Their generous contributions have facilitated both the progression of this research project and the recovery of these threatened parakeet species.

Finally, I would like to thank my family and friends. I am eternally grateful to my parents who have supported me unequivocally throughout my university career. Their constant support and encouragement has allowed me to pursue scientific research and has kept me motivated during my venture into the academic world. I am also thankful to my friends for being there for me throughout this endeavour; the laughs, meals, and moments shared together never fail to make life interesting and I look forward to future adventures.

ABSTRACT

The *Cyanoramphus* parakeets are a cryptically coloured group of birds that are distributed across the islands of the South Pacific region. Due to their restricted range and island distributions, species belonging to this genus are considered vulnerable to extinction. However, the extent to which these parrot species are threatened is difficult to determine due to an absence of accurate and reliable population estimates. This research aims to contribute to the conservation of two critically endangered *Cyanoramphus* parakeets by evaluating the survey methods currently used to estimate population densities. This thesis details the precision and efficiency of distance sampling methods used for monitoring low-density parrot populations on small islands. Specifically, examining the annual variation in population size for the critically endangered Tasman Parakeet (*Cyanoramphus cookii*) and their introduced competitor, the Crimson Rosella (*Platycercus elegans*), to evaluate the effectiveness of conservation management and species control on Norfolk Island. In addition, the size of three translocated populations of the critically endangered Malherbe's Parakeet (*Cyanoramphus malherbi*) were examined to identify if this endemic New Zealand parrot requires further management.

Of the distance sampling methods used to monitor parrots, the fixed point survey method was the most suitable method for surveying Tasman Parakeets. This method yielded the highest number of parakeet detections per survey and offered the greatest count precision of the methods examined. On Norfolk Island, the Tasman Parakeet population increased by 126% over four years of intense predator management and nest provisioning. In comparison, the Crimson Rosella population remained stable, despite regular culling to control the population which competes with the Tasman Parakeet. In New Zealand, Malherbe's Parakeets were detected with varying degrees of success. On Maud Island, no parakeets were detected; however, they were detected on both Blumine Island and Chalky Island. On Blumine Island, the Malherbe's Parakeet population was moderately abundant, consisting of 202 ± 67 individuals distributed through the mature forest. In comparison, the Chalky Island population of Malherbe's Parakeet was less extensive and consisted of 84 ± 58 parakeets. This research illustrates the importance of regularly monitoring the size of threatened parrot populations for conservation.

THESIS OUTLINE

CHAPTER 1 Introduction

This chapter provides an overview of global parrot diversity, outlining the major threats faced by parrot species, with an emphasis on parrot conservation and species found on islands. The challenges of monitoring parrot populations are discussed, with consideration given to different survey techniques, and their value in assessing the success of conservation management efforts. An overview of each study site is presented, including descriptions of each study species, their conservation status, and the difficulties encountered during monitoring and management. In addition, the research rationale and main research objectives are summarised.

CHAPTER 2 Using Statistical Resampling to Identify an Efficient Method for Surveying Tasman Parakeets (*Cyanoramphus cookii*)

In this chapter, statistical resampling is used to assess the suitability of two survey methods for monitoring the critically endangered Tasman Parakeet (*Cyanoramphus cookii*) population in the Mount Pitt section of the Norfolk Island National Park, Norfolk Island. The precision of the count estimates obtained by each survey method (fixed point surveys and line transect surveys) are compared. The findings are then discussed with reference to the advantages of using this standardised survey method for monitoring the parakeet population, highlighting the need for a systematic approach to long-term monitoring of the Tasman Parakeet population on Norfolk Island.

CHAPTER 3 Interannual Estimates of Density for Tasman Parakeets (*Cyanoramphus cookii*) and Crimson Rosellas (*Platycercus elegans*) on Norfolk Island

In this chapter, fixed point surveys are used to examine temporal variation in the population size of two parrot species on Norfolk Island: The Tasman Parakeet (*Cyanoramphus cookii*), an endemic species which is critically endangered; and the Crimson Rosella (*Platycercus elegans*), an introduced competitor. The population estimates produced by this standardised survey method are used to compare the two species, which exhibit marked differences in abundance within the Mount Pitt section of the Norfolk Island National Park. The findings are discussed in relation to interannual variation in population size, the effect of conservation management efforts, and the need for regular monitoring of the Tasman Parakeet and Crimson Rosella populations.

CHAPTER 4 Estimating the Density of Malherbe's Parakeet (*Cyanoramphus malherbi*) Populations Established on Offshore Islands

This chapter investigates the density of the critically endangered Malherbe's Parakeet (*Cyanoramphus malherbi*) populations established on three offshore island sanctuaries in the South Island of New Zealand: Maud Island, Blumine Island, and Chalky Island. The estimates of population size produced for this species and other common species are used to examine the applicability and performance of the fixed point survey method across a range of island habitats. The challenges associated with monitoring the Malherbe's Parakeet populations are then discussed and recommendations are provided for future monitoring of Malherbe's Parakeet and their management on offshore islands.

CHAPTER 5 Conclusions and Recommendations

In this chapter, the key findings of the research are discussed, with reference to the estimates produced for the Tasman Parakeet population found within the Mount Pitt section of the Norfolk Island National Park and those produced for the Malherbe's Parakeet populations established on offshore island sanctuaries in New Zealand. In addition, the analysis of survey precision is discussed and an emphasis is placed on the importance of a systematic approach to monitoring these and other populations of threatened parrot species that occur in low densities. From the findings, recommendations for the future monitoring and conservation management of Tasman Parakeets and Malherbe's Parakeets are presented, with a list of the priority research needs outlined for each population surveyed during this research.

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CHAPTER 1

Introduction

DISTRIBUTION AND DIVERSITY OF PARROTS

Parrots (Psittaciformes) are a highly threatened order of birds, consisting of three superfamilies: *Psittacoidea*, true parrots; *Cacatuoidea*, cockatoos; and *Strigopoidea*, New Zealand parrots of the genera *Strigops* and *Nestor* (Joseph, Toon, Schirtzinger, Wright, & Schodde, 2012; Olah et al., 2016). Collectively parrots have a wide geographic distribution and predominantly occur across the tropical and subtropical habitats of the southern hemisphere, though some species also occupy the temperate regions of the southern hemisphere (Higgins, 1999; Juniper & Parr, 1998; Marsden & Royle, 2015; Olah et al., 2016). The regions with the greatest species richness are South America, Australasia, Asia, and Central America (Marsden & Royle, 2015; Snyder, McGowan, Gilardi, & Grajal, 2000).

All parrots are characterised by their strong curved bills, large broad heads, thick prehensile tongues, zygodactyl feet, and a general aptitude for vocal learning (Berg & Bennett, 2010; Forshaw, 1989; Juniper & Parr, 1998). The plumage of mature parrots, with the exception of cockatoos, is predominantly green; with many species also displaying plumage of red, yellow, or blue (Berg & Bennett, 2010; Higgins, 1999; Tinbergen, Wilts, & Stavenga, 2013). In contrast to other avian groups, very few parrots exhibit sexual dichromatism (Berg & Bennett, 2010; Taysom, Stuart-Fox, & Cardoso, 2011). One exception is the Eclectus Parrot (*Eclectus roratus*), which displays extreme reversed sexual dichromatism, with females displaying brilliant red and blue plumage, while males appear green with an orange bill (Heinsohn & Legge, 2003; Heinsohn, Legge, & Endler, 2005). Similarly, few parrot species display sexual dimorphism, with both sexes appearing similar in body size for the majority of species (Forshaw, 1989; Moorhouse, Sibley, Lloyd, & Greene, 1999).

Although the diagnostic characteristics of parrots remain consistent across species, body size and mass vary considerably, with a high degree of morphological diversity shown between species (Heinsohn, Buchanan, & Joseph, 2018; Juniper & Parr, 1998; Schweizer, Hertwig, & Seehausen, 2014). For example, parrots of the genus *Micropsitta*, commonly known as pygmy parrots, are among the smallest in the world, ranging from 8 – 9 cm in size and weighing as little as 10 g (Heinsohn et al., 2018; Hindwood, 1959; Juniper & Parr, 1998; Pangau-Adam, 2010). In contrast, New Zealand parrots of the genera *Strigops* and *Nestor* are considered large (Higgins, 1999; Livezey, 1992; Olah et al.,

2018). The most notable being the critically endangered Kakapo (*Strigops habroptilus*), which is the heaviest parrot species in the world at 0.9 – 4.0 kg (Cottam, Merton, & Hendriks, 2006; Eason et al., 2006; Elliott, Merton, & Jansen, 2001).

The morphological diversity present among parrots is paralleled by their wide range of ecological and behavioural characteristics (Heinsohn et al., 2018; Schweizer et al., 2014). For example, the diet of parrots predominantly consists of plant matter such as fruit, seeds, flowers, nectar, and pollen, with many species also consuming invertebrates (Forshaw, 1989; Juniper & Parr, 1998). However, there are some species that supplement their diet with vertebrate flesh, namely the Antipodes Parakeet (*Cyanoramphus unicolor*), Reischek's Parakeet (*Cyanoramphus hochstetteri*), Kea (*Nestor notabilis*), and Kaka (*Nestor meridionalis*), all of which are endemic to New Zealand and the surrounding territories (Greene, 1999; Higgins, 1999; Winn & Holdaway, 2005).

Most parrots exhibit diurnal activity patterns (Juniper & Parr, 1998), showing increased activity during the early morning and late afternoon (Gilardi & Munn, 1998; Symes & Marsden, 2007; Wirminghaus, Downs, Perrin, & Symes, 2001). The exceptions to this trend are the Night Parrot (*Pezoporus occidentalis*) and the Kakapo, both of which are nocturnal (Higgins, 1999; Kearney, Porter, & Murphy, 2016; Powlesland, Merton, & Cockrem, 2006). Other species, such as the Blue-backed Parrot (*Tanygnathus sumatranus*) and the Black-lored Parrot (*Tanygnathus gramineus*), both of Indonesia, are considered partially nocturnal with patterns of moderate activity at night related to foraging; though the latter has also been observed foraging in high foliage during the day (BirdLife International, 2001; Collar, 2006b; Riley, 2002; Robson, 2013).

Typically, parrots are arboreal, occupying forested regions and having close associations with vegetated habitat (Collar, 2000; Juniper & Parr, 1998; Legault, Chartendrault, Theuerkauf, Rouys, & Barré, 2011). However, ground-dwelling species like the Western Ground Parrot (*Pezoporus flaviventris*), Eastern Ground Parrot (*Pezoporus wallicus*), Night Parrot, Antipodes Parakeet, and Kakapo have established themselves among the heathland, tussock grassland, scrubland, and forest edge habitats at their respective localities (Davis & Metcalf, 2008; Higgins, 1999; McFarland, 1991a). These species and others, such as the Burrowing Parrot (*Cyanoliseus patagonus*) of Patagonia, form nests in natural hollows, shallow depressions, and cavities found at ground level (Eason et al., 2006;

Higgins, 1999; Masello & Quillfeldt, 2002; McFarland, 1991b). In contrast, most parrots nest in the existing cavities of mature trees (Forshaw, 1989; Snyder et al., 2000), while some others nest in cliffside cavities, crevices among rocks, and holes in arboreal or terrestrial termite nests (Brightsmith, 2000, 2004; Juniper & Parr, 1998; Snyder & Enkerlin, 1996).

Outside of the breeding season, most parrot species are gregarious and often aggregate in small flocks, family groups, or pairs (Chapman, Chapman, & Lefebvre, 1989; Gilardi & Munn, 1998; Juniper & Parr, 1998). Some species even form large communal roosts or feed in flocks that consist of multiple species (Casagrande & Beissinger, 1997; Gilardi & Munn, 1998). During foraging, most parrots exhibit secretive behaviour, often marked by a lack of vocalisation, which allows cryptically coloured species to remain undetected while feeding in the high canopy (Collar, 1991; Juniper & Parr, 1998; Marsden, 1999). However, in areas where parrots are vulnerable to predators calling behaviour can be beneficial, for instance, Red-and-green Macaws (*Ara chloropterus*) foraging at clay licks in Peru are thought to benefit from alarm calls produced by vigilant individuals perched in the surrounding vegetation (Lee, 2017).

THREATS TO PARROTS

Globally, parrots are considered the most threatened bird order, with approximately 28% of the 398 extant species classified as threatened by the International Union for the Conservation of Nature (IUCN) and BirdLife International (Heinsohn et al., 2018; Nunes & Galetti, 2007; Olah et al., 2016; Snyder et al., 2000). The main threats to parrots include overexploitation for the wildlife trade; degradation, fragmentation, and loss of key habitat; persecution as agricultural pests; competition for resources; and predation by invasive species (Berkunsky et al., 2017; Collar, 2000; Olah et al., 2016; Snyder et al., 2000). Although some of these threats occur independently, declining population sizes are often associated with multiple threats operating concurrently (Isaac & Cowlishaw, 2004; Snyder et al., 2000). These threats can vary considerably between species, populations, geographic location, and season (Berkunsky et al., 2017; Snyder et al., 2000). For example, trapping of parrots for the illegal wildlife trade is more prevalent in developing countries and threatens approximately 68% of the parrot populations in the Neotropics (Berkunsky et al., 2017; Pain et al., 2006; Pires, 2012).

As a whole, the wildlife trade has contributed to a significant global decline in wild parrot populations (Pires, 2012; Tella & Hiraldo, 2014). The vibrant plumage colouration and intelligence of parrot species make them popular as pets and therefore a valuable commodity on the international market (Pires & Clarke, 2012; Tella & Hiraldo, 2014), with rare or highly desired species fetching between $10,000 and $65,000 USD (Pires, 2012; Zimmerman, 2003). In a review of exploited birds, Beissinger (2001) estimated that 259 parrot species, representing thousands of individuals annually, had been subject to trade through regulated channels. This high demand for parrots has cultivated a thriving black market for the sale of live individuals and has contributed to significant declines in less abundant parrot species (Courchamp et al., 2006; Pires, 2012; Zimmerman, 2003). For instance, overexploitation of the Spix's Macaw (*Cyanospitta spixii*) for the live animal trade has resulted in their extinction from the riparian forests of Brazil, with only 79 individuals now remaining in captivity (Barros et al., 2012; Juniper & Yamashita, 1991; Wright et al., 2001).

Although regulation has reduced the number of parrots poached for international trade, a substantial number of birds are still poached annually for domestic wildlife markets in Neotropical countries (Pires, 2012; Tella & Hiraldo, 2014; Wright et al., 2001). The continuation of these poaching practices is concerning because the techniques used by poachers and smugglers typically result in high rates of bird mortality (Marsden et al., 2013; Moreto & Lemieux, 2015; Wright et al., 2001). For example, when González (2003) accompanied groups of poachers into the Peruvian Amazon, it was found that the harvesting of nestlings resulted in mortality rates ranging from 14.3 – 48.4% for macaw species. The highest mortality rate was observed in Blue-and-yellow Macaw (*Ara ararauna*) nestlings, which were harvested by cutting down trees containing nests; a method which contributes to progressive habitat degradation through the loss of suitable nesting locations (González, 2003; Pain et al., 2006).

For parrots, the loss of habitat suitable for nesting, roosting, and foraging poses a significant threat to survival and can be particularly detrimental for range restricted species (Juniper & Parr, 1998; Manning, Lindenmayer, & Barry, 2004; Snyder et al., 2000; Wiley, 1991). The rate of this habitat loss has increased with the expansion of human populations, especially in areas suitable for residential and commercial land development (McKinney, 2002; Seto, Güneralp, & Hutyra, 2012). In

many regions, another major threat is the destruction of habitat caused by logging and the clearance of land for agriculture (Berkunsky et al., 2017; Juniper & Parr, 1998; Olah et al., 2016). A notable example is the endangered Maroon-fronted Parrot (*Rhynchopsitta terrisi*) of northern Mexico, which has experienced population declines due to the degradation and loss of the mature coniferous forest that serves as key foraging habitat for the species (Monterrubio-Rico, Charre-Medellin, & Sáenz-Romero, 2015; Snyder & Enkerlin, 1996; Snyder et al., 2000).

In modified habitats, the loss of natural food resources can result in depredation of crops by parrot species leading to conflict with human populations (Navarro, Martella, & Chediack, 1992; Renton, Salinas-Melgoza, De Labra-Hernández, & de la Parra-Martínez, 2015). The damage or perceived damage caused by these parrots often results in their persecution and in some locations, active control through culling of large groups or colonies (Snyder et al., 2000; Warburton & Perrin, 2006). An interesting example of this is the Burrowing Parrot, which has been persecuted throughout Patagonia due to the perceived threat the species poses to agricultural produce (Failla, Seijas, Quillfeldt, & Masello, 2008; Sánchez, Ballari, Bucher, & Masello, 2016). Despite ecological evidence showing relatively low levels of crop damage caused by the Burrowing Parrot, their persecution by humans appears to have increased with agricultural expansion into the natural vegetation and as a result, the species is now in decline (Masello, Pagnossin, Sommer, & Quillfeldt, 2006; Masello et al., 2011; Sánchez et al., 2016).

Another factor that can limit productivity and threaten the survival of parrot species is competition for nest sites (Brightsmith, 2005; Snyder et al., 2000). Since most parrots are unable to excavate nests, there is often interspecific competition between species of similar sizes for pre-existing nest hollows (Bonaparte & Cockle, 2017; Dias, 2011). This is well documented in the forests of Mauritius, where the critically endangered Echo Parakeet (*Psittacula eques*) experiences significant pressure from the introduced Ring-necked Parakeet (*Psittacula krameri*) which competes strongly for access to nesting cavities (Jones, 1980; Strubbe & Matthysen, 2009). In other instances, the tree hollows used by parrots can be compromised by invertebrate competitors such as bees or wasps (Bonaparte & Cockle, 2017; Huryn, 1997; Pyke, 1999). In an assessment of Yellow-faced Parrot

(*Alipiopsitta xanthops*) nesting in central Brazil, wasps and bees were found to occupy 8% of natural cavities and 9% of nesting boxes on average each year (Dias, 2011).

The nesting success of parrots can also be limited by the predation of eggs and nestlings, with predation contributing to the extinction risk for a variety of species (Heinsohn et al., 2015; Renton & Salinas-Melgoza, 2004). During nesting, eggs and chicks are vulnerable to predation, which can be particularly detrimental to the survival of small populations of endangered birds (Brightsmith, 2005; Stojanovic, Webb, Alderman, Porfirio, & Heinsohn, 2014). This is best exemplified in parrot populations restricted to oceanic islands, many of which are now threatened due to predation by introduced species (Blackburn, Cassey, Duncan, Evans, & Gaston, 2004; Snyder et al., 2000). Two examples of this are the nests of the migratory Swift Parrot (*Lathamus discolor*) which are predated by Sugar Gliders (*Petaurus breviceps*), with up to 100% predation at some Tasmanian breeding sites (Stojanovic et al., 2014); and the nests of the endangered Kuhl's Lorikeet (*Vini kuhlii*) which are threatened by Black Rats (*Rattus rattus*) in the islands of French Polynesia (Watling, 1995; Ziembicki & Raust, 2006).

PARROT CONSERVATION

To limit the illegal export of endangered species and prevent continued exploitation of parrots, wildlife trade has been regulated in many countries through the introduction of trade laws and export bans. For most countries, this regulation occurred after the Convention on International Trade in Endangered Species (CITES) was put into effect in 1975 (Koumba Pambo et al., 2016; Zimmerman, 2003). The purpose of this international agreement is to regulate trade and prevent the extinction of endangered species across the 163 participating countries, which has since grown to include 183 parties (Koumba Pambo et al., 2016; Zimmerman, 2003). An example of the beneficial effects of this market regulation is the decline in the exportation of endemic parrots from Australia, where only 3% of transactions between 1975 and 2014 were parrots sourced from wild populations (Vall-llosera & Cassey, 2017). This decline has been attributed to successful captive breeding of parrots for the pet trade, enforcement of trapping and export bans, and the stringency of Australian biosecurity (Alacs & Georges, 2008; Vall-llosera & Cassey, 2017).

In addition to regulation of trade, the education of local communities to improve their knowledge and attitudes towards threatened species is a useful tool for parrot conservation (Beissinger & Snyder, 1992; Snyder et al., 2000; Vaughan, Gack, Solorazano, & Ray, 2003); particularly for species that are regularly poached or persecuted as pests. In the case of the Monk Parakeet (*Myiopsitta monachus*), which is persecuted due to the damage caused to crops, the use of lethal control has been shown to have a greater preference in communities with lower levels of formal education (Canavelli, Swisher, & Branch, 2013). For this reason, education and outreach programmes that outline the value of at-risk parrot populations are crucial to conservation efforts. An excellent example of the value of community outreach is from the Lesser Antilles, which in the 1980s observed marked increases in the populations of four endangered parrot species after an initiative promoting community pride in native species (Butler, 1992; Christian, Lacher, Zamore, Potts, & Burnett, 1996). Education initiatives can also encourage locals to become involved in conservation and ecotourism, which is an increasingly profitable industry that offers an excellent alternative to poaching (Briceño-Linares et al., 2011; Wirminghaus, Downs, Symes, & Perrin, 1999).

Another strategy used in parrot conservation is the protection and preservation of key habitats through the formation of reserve or national park areas (Rayner, Lindenmayer, Wood, Gibbons, & Manning, 2014; Snyder et al., 2000). These areas can be established in a number of ways, including the purchase of land containing important habitats, payment for easements through private land, designation of reserves on public land, and investment by private stakeholders and non-governmental organisations (Ferraro & Simpson, 2006; Snyder et al., 2000). In a review of parrot abundance literature, Marsden and Royle (2015) found strong links between high parrot density and areas of habitat which were protected. However, the benefits of using this strategy alone are not guaranteed (Marsden & Royle, 2015; Munks, Koch, & Wapstra, 2009; Snyder et al., 2000), as multiple threatening processes can contribute to the extinction risk of parrot species. Consequently, effective species management and conservation often requires an integrated approach, using multiple methods; including the protection of key habitats (Christian, 1993; Snyder et al., 2000).

In areas where predation has a significant impact on parrot survival, the management or eradication of predators can be extremely beneficial to species conservation and recovery (Engeman

et al., 2006; Ortiz-Catedral, Ismar, Baird, Brunton, & Haubner, 2009). The methods for controlling these predator populations can include the use of traps, poison bait stations, aerial poison drops, predator exclusion fences, predator detection dogs, contract hunters, or the modification of nest sites to prevent predator incursions (Gsell, Innes, de Monchy, & Brunton, 2010; Hill, 2002; Koenig, Wunderle, & Enkerlin-Hoeflich, 2007; Parkes & Murphy, 2003). In New Zealand, these techniques are widely used to reduce the density of introduced mammalian predators, lower predation risk, and establish predator-free sanctuaries (Parkes & Murphy, 2003; Russell, Innes, Brown, & Byrom, 2015).

The beneficial effect of predator control is exemplified by the recovery of the Kaka, which has shown increased breeding and fledging success in regions of New Zealand where predator populations are actively managed (Dilks, Willans, Pryde, & Fraser, 2003; Moorhouse et al., 2003). In addition, the cost of this type of predator management is generally offset by the value or perceived value gained by the protection or conservation of rare and endemic species (Bodenchuk, Mason, & Pitt, 2000; Engeman et al., 2006). For instance, a cost-benefit analysis of the predator management required to protect Puerto Rican Parrots (*Amazona vittata*), found the expenses related to predator control were cost-effective; even if only one parrot was protected over a 12 year period (Engeman, Constantin, Gruver, & Ross, 2009; Engeman, Shwiff, Cano, & Constantin, 2003).

Another approach to protecting at-risk parrot populations is the translocation of individuals to areas where predators are absent or occur in low densities. This technique can involve the introduction of a species outside its natural range, the reintroduction of a species into an area it historically occupied, or supplementation of an existing population using captive-bred or wild-caught individuals (IUCN, 1998; IUCN/SSC, 2013; White et al., 2012). In New Zealand, species translocations have been widely adopted as a conservation tool, with many taxa, including parrots, released to sanctuaries free of mammalian predators; usually offshore islands (Armstrong & McClean, 1995; Miskelly & Powlesland, 2013; Ortiz-Catedral & Brunton, 2009a, 2010). Of the 65 endemic bird taxa translocated throughout New Zealand between 1863 and 2012, seven of the eight extant parrot species have been the subject of translocation efforts (Miskelly & Powlesland, 2013).

In addition to their prevalent use in New Zealand conservation, species translocations are frequently used elsewhere for parrot conservation; with varying degrees of success (Salinas-Melgoza,

Salinas-Melgoza, & Wright, 2013; White et al., 2012). For example, a soft-release of Blue-and-yellow Macaws in the Nariva Swamp of Trinidad resulted in a successful reintroduction, where the species is now well established within its historic range (Oehler et al., 2001; Plair, Lal, Ramadhar, & Ramsubage, 2013). In contrast, a soft-release of Ultramarine Lorikeets (*Vini ultramarina*) on Fatu Iva, French Polynesia failed after initial establishment of the species, due to the presence of Black Rats on the island (Collar, 2006a; Ziembicki, Raust, & Blanvillain, 2003).

Although reintroductions are frequently used in parrot conservation, the parameters of success are poorly defined in most reintroduction and translocation literature (White et al., 2012). Seddon and Cade (1999) indicate the importance of long-term post-release monitoring for assessing the success of reintroductions and conservation management. For monitoring threatened populations, the estimation of abundance, density, and population size can provide crucial information regarding population trends, extinction risk, the impact of threats, the viability of a population, and the effectiveness of conservation management (Collen et al., 2011; Dénes, Tella, & Beissinger, 2018; Marsden & Royle, 2015). These estimates can also be used to assess the current conservation status of a population or species and can assist in further development of conservation management plans (Dénes et al., 2018; Harding et al., 2001; IUCN, 2001). In the case of parrot species, there are a wide variety of survey methods for estimating population size, though they can be difficult for conservation biologists to implement due to the differences between species (Casagrande & Beissinger, 1997; Snyder et al., 2000).

SURVEY METHODS

The diverse behavioural and ecological characteristics of parrots make them a challenging group to survey (Casagrande & Beissinger, 1997; Dénes et al., 2018; Saunders, 2011). Most parrots are highly mobile and form large multispecies flocks that travel between areas of dense forest, making it difficult for researchers to detect, count, or capture birds (Chapman et al., 1989; Dénes et al., 2018). For example, species belonging to the genera *Ara* and *Amazona* tend to occupy the high, dense, inaccessible expanses of rainforest of the Neotropics (Forshaw, 1989; Gilardi & Munn, 1998). Consequently, researchers often have to use motorised boats or dugout canoes to conduct surveys

along rivers adjacent to the foraging or roosting sites of Neotropical species (de Moura, Vielliard, & da Silva, 2010; Renton, 2002).

Furthermore, the efficacy of some survey methods can be limited by the distribution of parrots, which can vary considerably with seasonal changes in food availability, the onset of breeding, or the relocation of roosting sites (Dénes et al., 2018; Renton, 2002; Wirminghaus et al., 2001). Additionally, many parrot species exhibit secretive behaviour while perched, which can reduce their detectability in dense foliage, especially if the species is cryptically coloured (Casagrande & Beissinger, 1997; Legault et al., 2013; Marsden, 1999). Although these factors make monitoring parrot populations a difficult task, a range of approaches have been successfully used to estimate parrot abundance including roost counts, mark recapture, and distance sampling.

ROOST COUNTS

This method of estimating parrot abundance involves locating roost sites prior to sampling (Dénes et al., 2018; Saunders, 2011). Once these roost sites are located, observers position themselves nearby and record birds as they leave and enter the site at dawn or dusk (Dénes et al., 2018; Saunders, 2011). The population size is then estimated using the number of parrots encountered at each roost site (Marsden et al., 2013; Pithon & Dytham, 1999). In some instances, demographic information about the population can also be obtained by identifying pairs or family groups as they arrive or leave the roost site (Dénes et al., 2018; Matuzak & Brightsmith, 2007; Saunders, 2011). For example, parrots belonging to the genera *Amazona* and *Ara* typically form strong pair bonds or family flocks (of three or more birds), which allows breeding individuals and juveniles to be identified at the roost site (Berg & Angel, 2006; Gilardi & Munn, 1998; Matuzak & Brightsmith, 2007).

When using roost counts to estimate parrot abundance, a key consideration is the ease of locating and sampling all roost sites in an area (Casagrande & Beissinger, 1997; Dénes et al., 2018; Saunders, 2011). If every roost site is sampled simultaneously, the variation caused by parrots moving between roost locations is reduced, thus providing reasonable estimates of bird abundance (Dénes et al., 2018; Pithon & Dytham, 1999). However, seasonal changes in bird behaviour and food distribution can cause variation in the size, number, and location of active roost sites, making

concurrent sampling difficult (Casagrande & Beissinger, 1997; Cougill & Marsden, 2004; Matuzak & Brightsmith, 2007). This is exemplified in Casagrande and Beissinger (1997), where the roost sites of a Green-rumped Parrotlet (*Forpus passerinus*) population changed so rapidly throughout the study period that data pooling was required to complete the analysis. To avoid these complications, Cougill and Marsden (2004) recommend that roost counts be completed during periods of the year when parrots are sedentary and roost sites are stable.

To produce robust estimates using the roost count method, researchers must consider additional factors that limit the accuracy of estimates including visibility at the roost site, local weather conditions, size of the flock, and differences in flight behaviours (Dénes et al., 2018; Saunders, 2011; Snyder, Wiley, & Kepler, 1987). For example, repeated movement of parrots within the roost area can lead to double counting, but careful recording of individual movements or using designated buffer zones around the roost site can reduce the likelihood of counting errors (Cougill & Marsden, 2004; Dénes et al., 2018). Similarly, species knowledge is crucial to establishing suitable sampling regimes; surveys of the *Amazona* genus have shown differences in roosting activity between species, with some species equally active at both dawn and dusk (de Moura et al., 2010), while other species were varied in their use of the roost sites (Cougill & Marsden, 2004; Gilardi & Munn, 1998; Matuzak & Brightsmith, 2007).

Although the roost count method can provide reasonable estimates of abundance (Casagrande & Beissinger, 1997; Pithon & Dytham, 1999), the applicability of the technique is limited to species that roost communally. Furthermore, the technique is ineffective when sampling during the breeding season, as mature birds typically abandon communal roost sites in search of nesting hollows (Berg & Angel, 2006; de Moura et al., 2010; Martuscelli, 1995). In addition, roost count sampling often requires a large time investment relative to other methods, as all roosting locations must be found and multiple observers are required to record birds as they enter and leave each roosting site (Casagrande & Beissinger, 1997). Despite these disadvantages, the roost count technique provides estimates that closely correspond to those produced by other survey types and yields relatively low values for the coefficient of variation (Casagrande & Beissinger, 1997). In addition, the method offers a useful

alternative to direct nest monitoring and can be used to infer recruitment in wild populations that exhibit predictable patterns of breeding pair formation (Berg & Angel, 2006).

MARK RECAPTURE

The basic method of mark recapture involves capturing and marking a sample (n_1) of the study population and then releasing the marked individuals back into the population (Arnason, Schwarz, & Gerrard, 1991; Nichols, 1992; Otis, Burnham, White, & Anderson, 1978). After the captured individuals have been given time to disperse through the study site, the population is resampled (Nichols, 1992; Petit & Valiere, 2006). The number of marked individuals (m_2) in the second sample and the total number of individuals captured (n_2) during this resampling are then recorded (Arnason et al., 1991; Nichols, 1992; Otis et al., 1978). Provided the population remains closed during the study and experiences no fluctuations due to recruitment, mortality, immigration, or emigration, then the estimated population size ($\widehat{N}$) can be determined (McClintock et al., 2014; Nichols, 1992). This relies on the principle that the proportion of marked individuals that are recaptured is equivalent to the proportion of marked individuals within the population (McClintock et al., 2014; Nichols, 1992; Pollock, Nichols, Brownie, & Hines, 1990), as defined by the Lincoln-Petersen estimator:

$$\widehat{N} = n_1 n_2 / m_2$$

The development of software programs that use this basic mark recapture principle to analyse data has made producing density estimates a straightforward process for biologists (Arnason & Schwarz, 1999; White & Burnham, 1999). Furthermore, methods of greater complexity are increasingly being used to account for parameters such as survival, recruitment, and dispersal (Dénes et al., 2018; McClintock & White, 2012; Pollock et al., 1990). Whether using basic or complex mark recapture methods, it is assumed all individuals in the population have an equal probability of capture (Arnason et al., 1991; Otis et al., 1978; Petit & Valiere, 2006). However, heterogeneity within populations and differences in trap responses can result in different capture probabilities between individuals (Pollock, 1982; Pollock et al., 1990). For example, lek behaviour in subtropical bird species may cause differences between capture rates, with males remaining at display sites while

females actively move through the habitat (Sandercock, Beissinger, Stoleson, Melland, & Hughes, 2000). Additionally, the mark recapture method assumes that the marked individuals have an equal probability of being accurately and independently identified, with no loss of marks between surveys (Casagrande & Beissinger, 1997; McClintock et al., 2014; Petit & Valiere, 2006).

When using mark recapture to sample bird populations, captured individuals are usually marked with a unique combination of coloured leg bands (Lettink & Armstrong, 2003; Olah, Heinsohn, Brightsmith, & Peakall, 2017). However, this technique is not always suitable for parrots, as they have powerful bills and sharp claws, which can easily remove, manipulate, or destroy identification markers (Dénes et al., 2018; Meyers, 1995; Rowley & Saunders, 1980). Furthermore, parrots generally have short tarsi, which can limit the application of multiple bands and makes identification of individuals difficult in resighting surveys, especially when birds are perched in the upper canopy (Dénes et al., 2018; Senar, Carrillo-Ortiz, & Arroyo, 2012). Increasingly, researchers are using novel techniques to mark parrot populations. For example, Senar et al. (2012) successfully used neck collars to mark populations of Monk Parakeets and Ring-necked Parakeets, with no detrimental effect on behaviour, body condition, or survival. Additionally, rigid wing tags have been successfully used to mark cockatoo species such as Galahs (*Cacatua roseicapilla*), Long-billed Black Cockatoos (*Calyptorhynchus baudinii*), and Sulphur-crested Cockatoos (*Cacatua galerita*), offering a reliable alternative to leg banding (Davis, Major, Taylor, & Martin, 2017; Rowley & Saunders, 1980).

Although mark recapture has been used to monitor some parrot species, the difficulty of capturing parrots for marking has limited the widespread adoption of the method (Casagrande & Beissinger, 1997; Dénes et al., 2018). In addition, the standard methods of applying markers involve handling animals, which is not always feasible for endangered species, particularly if capture and handling could have detrimental effects on the marked individuals (MacKenzie, Nichols, Sutton, Kawanishi, & Bailey, 2005). Furthermore, the mark recapture method requires relatively large sample sizes to reduce variance and generate reliable density estimates (Lettink & Armstrong, 2003; MacKenzie et al., 2005). For populations of rare or cryptic species, obtaining these large sample sizes is not always possible (MacKenzie et al., 2005; Riley, 2002). However, mark recapture methods are continuing to improve, with the inclusion of additional parameters and the introduction of less

invasive sampling increasing the suitability of this technique for parrot surveys (Dénes et al., 2018; Olah et al., 2017). This is exemplified in Olah et al. (2017), where feather samples collected from a Red-and-green Macaw clay lick were genetically analysed and then modelled using a mark recapture approach to estimate the size of the macaw population.

DISTANCE SAMPLING

Distance sampling is frequently used for estimating the abundance of birds and has been widely used among parrot species (Buckland, Marsden, & Green, 2008; Dénes et al., 2018; Marsden & Royle, 2015). In a recent review of the parrot abundance literature, Marsden and Royle (2015) found 84% of the density estimates in the publications they examined were derived using distance sampling. This method of sampling requires the distance to each bird (or group of birds) detected to be measured by an observer while they walk along a transect line or stand at a survey point (Buckland, Anderson, Burnham, & Laake, 1993; Buckland et al., 2001; Thomas et al., 2010). The detection probability of the species is then modelled as a function of distance from the transect line or survey point (Legault et al., 2013; Pollock et al., 1990; Thomas et al., 2010). This probability function is then used alongside the mean group size to model the number of individuals within the survey area and provide estimates of density (Dénes et al., 2018; Pollock et al., 1990).

The distance sampling method relies on three main assumptions: birds are detected with certainty on the line or point, birds are detected at their original location, and all distances are measured precisely (Buckland et al., 1993; Buckland et al., 2001; Thomas et al., 2010). Additionally, it is assumed that group sizes are recorded accurately and that bird detections occur independently of each other (Buckland et al., 1993; Buckland et al., 2008). Furthermore, to obtain representative and independent samples, the distance sampling method requires that transect lines or survey points are distributed throughout the survey area using a stochastic sampling design (Buckland et al., 2008; Thomas et al., 2010). When the assumptions of the method are violated, the estimates produced can be subject to bias and are likely unreliable (Bächler & Liechti, 2007; Buckland et al., 2001). For example, if a parrot flies towards or away from the observer prior to being detected, the recorded

distance can be drastically different and cause error in the density estimates (Bibby, Burgess, Hill, & Mustoe, 2000; Buckland et al., 2008; Legault et al., 2013).

When surveying parrot species, their behavioural and ecological characteristics can contribute to further violations of the distance sampling assumptions (Casagrande & Beissinger, 1997; Marsden, 1999). For example, a fixed point survey of a Red-cheeked Parrot (*Geoffroyus geoffroyi*) population in Indonesia found parrots were rarely detected near the observer, resulting in a negative bias of approximately 5% in the density estimates (Marsden, 1999). This has been attributed to the cryptic colouration and secretive behaviours of parrot species, which allows them to remain relatively undetected in dense foliage and high canopies (Casagrande & Beissinger, 1997; Legault et al., 2013; Marsden, 1999). However, recent advances in software and survey techniques have allowed some assumptions to be relaxed to help accommodate sampling difficulties (Buckland et al., 2008). For instance, the fixed point method of distance sampling can be adjusted to account for detection failure by allowing observers to search near the point and locate birds after an initial sampling period (Buckland et al., 2008; Marsden, 1999). Alternatively, survey data can be truncated *post hoc* to reduce the errors caused by failure to detect individuals on the line or at the survey point (Marsden, 1999).

Although the detection of individuals can be difficult when surveying parrots, adequate training of observers, robust sampling design, and use of equipment such as laser rangefinders can improve the accuracy of detections and make sampling easier (Buckland et al., 2008; Lee & Marsden, 2008; Thomas et al., 2010). In comparison to mark recapture, distance sampling is considerably less invasive, as it requires the detection of individuals rather than direct capture (Dénes et al., 2018; Legault et al., 2013; Whitman, Hagan, & Brokaw, 1997). Furthermore, distance sampling is more efficient compared to other methods, especially in large survey areas, as sampling of the entire population is not required to generate density estimates (Buckland et al., 2008; Lee & Marsden, 2008; Whitman et al., 1997). Similarly to mark recapture, the development of specialised software for analysing distance sampling data has simplified the production of density estimates and made the method more accessible to biologists (Buckland et al., 2008; Thomas et al., 2010).

RESEARCH RATIONALE

As the most threatened avian order, parrots are the focus of conservation management throughout the world and despite regularly serving as flagship species for conservation initiatives, community outreach, and ecological restoration projects, there remains an absence of published literature surrounding many species and their biology (Guedes, 2004; Marsden & Royle, 2015; Snyder et al., 2000). In a recent editorial, Heinsohn et al. (2018) indicated that the number of scientific publications relating to parrots has been increasing, with organisations like the Working Group on Psittaciformes encouraging evaluation of the threats faced by parrot species. Nonetheless, parrots remain a challenging group to study, with Marsden and Royle (2015) finding robust density estimates for less than a quarter of all extant parrot species in their review of parrot abundance literature. The proportion of these density estimates was relatively even across geographic regions (Marsden & Royle, 2015), though there are a number of threatened parrot species that require the attention of conservation research in the South Pacific region of Oceania (Olah et al., 2018).

This thesis investigates the suitability of survey techniques for two critically endangered parrot species, which are found across a diverse range of island habitats within the South Pacific region, and aims to produce updated estimates of population size to evaluate the conservation needs of these two parrot species. Following the specific research objectives, detailed descriptions of the study sites and study species are provided. In addition, descriptions of the other species encountered during this research are provided in recognition of the impact that they have on both the principal study species and the monitoring of these species for conservation management.

The first study species examined was the Tasman Parakeet (*Cyanoramphus cookii*), which is endemic to Norfolk Island (Director of National Parks, 2010; Forshaw, 2002; Higgins, 1999). Prior to the current research, no attempts have been made to assess the efficiency of the two survey methods used to detect and estimate the size of the Tasman Parakeet population on Norfolk Island, despite over four decades of management. In addition, the most recent estimate of population size published for the Tasman Parakeet population was from a multispecies survey completed in late 2009 (Dutson, 2013). The second and third chapters of this thesis address each respective issue: Chapter 2 offering a

comparison of the precision of counts provided by the fixed point survey and line transect survey methods; while Chapter 3 examines interannual variation in population size for the endemic Tasman Parakeet and their invasive competitor, the Crimson Rosella (*Platycercus elegans*).

The second study species examined was Malherbe's Parakeet (*Cyanoramphus malherbi*), which is endemic to New Zealand. This species occurs in the central South Island and on four island sanctuaries: Mayor Island, Maud Island, Blumine Island, and Chalky Island (Miskelly & Powlesland, 2013; Ortiz-Catedral & Brunton, 2009b). Of the four offshore populations of Malherbe's Parakeet established via translocation, the only published estimates of population size are of the Maud Island population, which experienced an increase between 2007 and 2009 (Ortiz-Catedral, Kearvell, & Brunton, 2012). Chapter 4 of this thesis addresses the absence of information, providing density estimates for the populations established on Maud Island, Blumine Island, and Chalky Island; however, the Mayor Island population was unable to be assessed due to logistical constraints.

RESEARCH OBJECTIVES

Chapter 1: General Introduction

- Provide background information about the distribution and diversity of parrot species and describe the principal threats that they encounter.
- Outline the various conservation strategies used to protect parrots against these threats and highlight the importance of biodiversity monitoring.
- Discuss the challenges associated with monitoring parrot populations and examine the main methods used to estimate the size and density of parrot populations.
- Provide a research rationale for this thesis and outline the main research objectives.
- Give a description of the study sites, study species, and non-target species encountered.

Chapter 2: Using Statistical Resampling to Identify an Efficient Method for Surveying Tasman Parakeets (*Cyanoramphus cookii*)

- Generate estimates of the mean number of Tasman Parakeets detected per day using statistical resampling of data collected by the fixed point survey and line transect survey methods.

- Compare the precision of the count estimates obtained by the two survey methods used to estimate the size of the Tasman Parakeet population.
- Provide recommendations regarding the most efficient survey method for detecting Tasman Parakeets considering count precision, survey effort, and applicability in the field.

Chapter 3: Interannual Estimates of Density for Tasman Parakeets (*Cyanoramphus cookii*) and Crimson Rosellas (*Platycercus elegans*) on Norfolk Island

- Provide annual estimates of population size for Tasman Parakeets and Crimson Rosellas using the fixed point survey method.
- Determine whether there is a significant difference between the estimated density of the Tasman Parakeet population and the Crimson Rosella population.
- Evaluate the interannual population trends of Tasman Parakeets and Crimson Rosellas in relation to conservation management on Norfolk Island.

Chapter 4: Estimating the Density of Malherbe's Parakeet (*Cyanoramphus malherbi*) Populations Established on Offshore Islands

- Determine the detectability of Malherbe's Parakeet at each study site.
- Provide estimates of population size for the Malherbe's Parakeet populations established on Maud Island, Blumine Island, and Chalky Island.
- Provide recommendations for future monitoring of the Malherbe's Parakeet populations established on the offshore island sanctuaries of New Zealand.

Chapter 5: Conclusions and Recommendations

- Outline the benefits of using a standardised survey method for monitoring threatened parrot populations that occur in low densities.
- Discuss the estimates of population size generated for each population surveyed and the implications for current and future conservation management.
- Provide a list of priority conservation actions for both the Tasman Parakeet and Malherbe's Parakeet populations.

STUDY SITES

NORFOLK ISLAND

Norfolk Island (29.0408° S, 167.9547° E) is located in the southwest Pacific Ocean, approximately 1100 km northwest of Auckland, New Zealand (Director of National Parks, 2008, 2010). The main island (Figure 1.1) has an area of approximately 34.6 km^2, with several groups of rocky islets scattered along the coastline (Abell & Falkland, 1991; Director of National Parks, 2010). To the south, lie two smaller islands: Nepean Island and Phillip Island (Abell & Falkland, 1991; Director of National Parks, 2008; Hill, 2002). Collectively, these remote islands and islets form the offshore territory of Norfolk Island, which is considered part of the Australian Commonwealth (Abell & Falkland, 1991).

The main island is comprised of an elevated plateau, featuring deep valleys that extend towards the coast (Abell & Falkland, 1991; Bird, 2010; Director of National Parks, 2010). To the northwest of the island, the terrain becomes more extreme, reaching elevations of 318 m and 316 m at the highest points: the summit of Mount Bates and Mount Pitt (Abell & Falkland, 1991; Director of National Parks, 2010). To the south, the plateau gradually subsides, transitioning from rolling hills to coastal lowlands, where the elevation falls below 20 m above sea level (Abell & Falkland, 1991). The remaining coastline is predominated by sheer cliffs, reaching heights of approximately 100 m on the northwest of the island (Abell & Falkland, 1991; Director of National Parks, 2010; Wakelin, 1968).

Since human settlement in 1788, the endemic species of Norfolk Island have suffered severely, with the extensive clearing of vegetation and the introduction of invasive species causing devastation to the endemic flora and fauna (Director of National Parks, 2008, 2010; Dutson, 2013; Smithers & Disney, 1969). The main island, previously covered by native rainforest and pine forest, now consists of areas predominated by farmland, urban settlements, orchards, and forestry plantations (Smithers & Disney, 1969). The remaining native vegetation is now represented within the 4.6 km^2 area, which forms the Mount Pitt Section of the Norfolk Island National Park (Figure 1.1), with approximately 25% of the 182 native plant species classified as threatened by the Environmental Protection and Biodiversity Conservation Act of Australia (Director of National Parks, 2008, 2010).

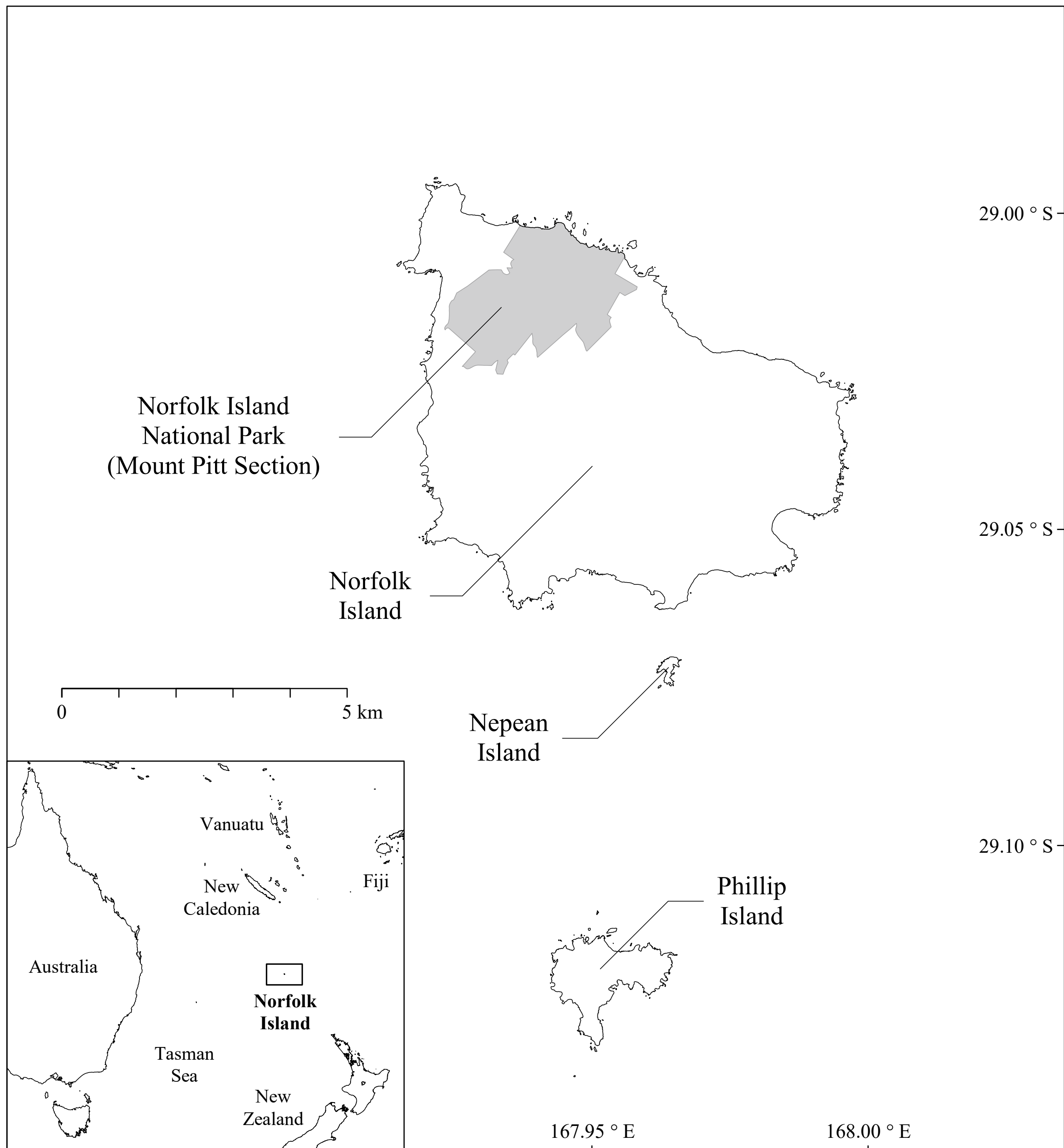

Figure 1.1: Map showing the location of Norfolk Island and the study site (grey).

In addition to the relatively high proportion of threatened flora, there are a variety of native birds, reptiles, and invertebrates on Norfolk Island that are threatened by extinction (Director of National Parks, 2010). Two native reptile species, the Lord Howe Island Skink (*Oligosoma lichenigera*) and the Lord Howe Island Gecko (*Christinus guentheri*), are now restricted to Phillip Island as a consequence of predator-induced extinction on mainland Norfolk Island, with the latter species also occurring on Nepean Island and the offshore islets of Moo-oo Stone, Green Pool Stone,

and Bird Rock (Cogger, Muir, & Shea, 2006; Director of National Parks, 2008, 2010). Similarly, the introduction of non-native species and the clearance of vegetation has impacted Norfolk Island invertebrates, particularly the endemic land snails, with five of these terrestrial molluscs now classified as critically endangered and a further six species considered extinct (Director of National Parks, 2010; Ponder, 1997).

Of the bird species which are endemic to Norfolk Island, six terrestrial birds have been listed as extinct and a further four species are now threatened by reduced resource availability, increased predation, and amplified interspecific competition associated with occupying the modified habitat of the Norfolk Island National Park (Director of National Parks, 2008, 2010). The threatened terrestrial birds which are endemic to Norfolk Island include the Norfolk Island Scarlet Robin (*Petroica multicolor multicolor*), the Norfolk Island Morepork (*Ninox novaeseelandiae undulata*), the Golden Whistler (*Pachycephala pectoralis xanthoprocta*), and the Tasman Parakeet (Director of National Parks, 2008, 2010). The identification of these threatened terrestrial bird species, combined with the high number of migratory seabirds which use the island and surrounding islets for nesting and roosting, resulted in Norfolk Island being classified as an Important Bird Area (Director of National Parks, 2008; Dutson, Garnett, & Gole, 2009).

MAUD ISLAND

Maud Island (41.0261° S, 173.8871° E) is a sheltered offshore island located in the Pelorus Sound of Marlborough, South Island, New Zealand (Department of Conservation, 2006a). The island (Figure 1.2) has an area of approximately 3.09 km^2 and is a designated scientific reserve managed by the Department of Conservation (Sheldon-Sayer, 2006; Whitaker, Hitchmough, & Chappell, 1999). The terrain consists of relatively steep hills, reaching an elevation of 368 m at the highest point (Bell & Pledger, 2010).

Historically, Maud Island was covered entirely by native forest, with the exception of the steep cliff sides, which remained relatively bare (Sheldon-Sayer, 2006). During the late 1800s, a substantial area of this native vegetation was cleared for pasture, with heavy grazing occurring for decades (Department of Conservation, 2006b; Sheldon-Sayer, 2006). This grazing ended in the 1970s,

following the reacquisition of Maud Island by the crown, with the native vegetation making a gradual recovery from the extensive modification caused by agriculture (Department of Conservation, 2006b; Sheldon-Sayer, 2006). The habitat of Maud Island is now classified into four major categories: remnant native broadleaf forest, regenerating scrub, introduced Radiata Pine (*Pinus radiata*) forest, and grassland (Ortiz-Catedral & Brunton, 2009b; Ortiz-Catedral et al., 2012; Ortiz-Catedral, Kearvell, Hauber, & Brunton, 2009).

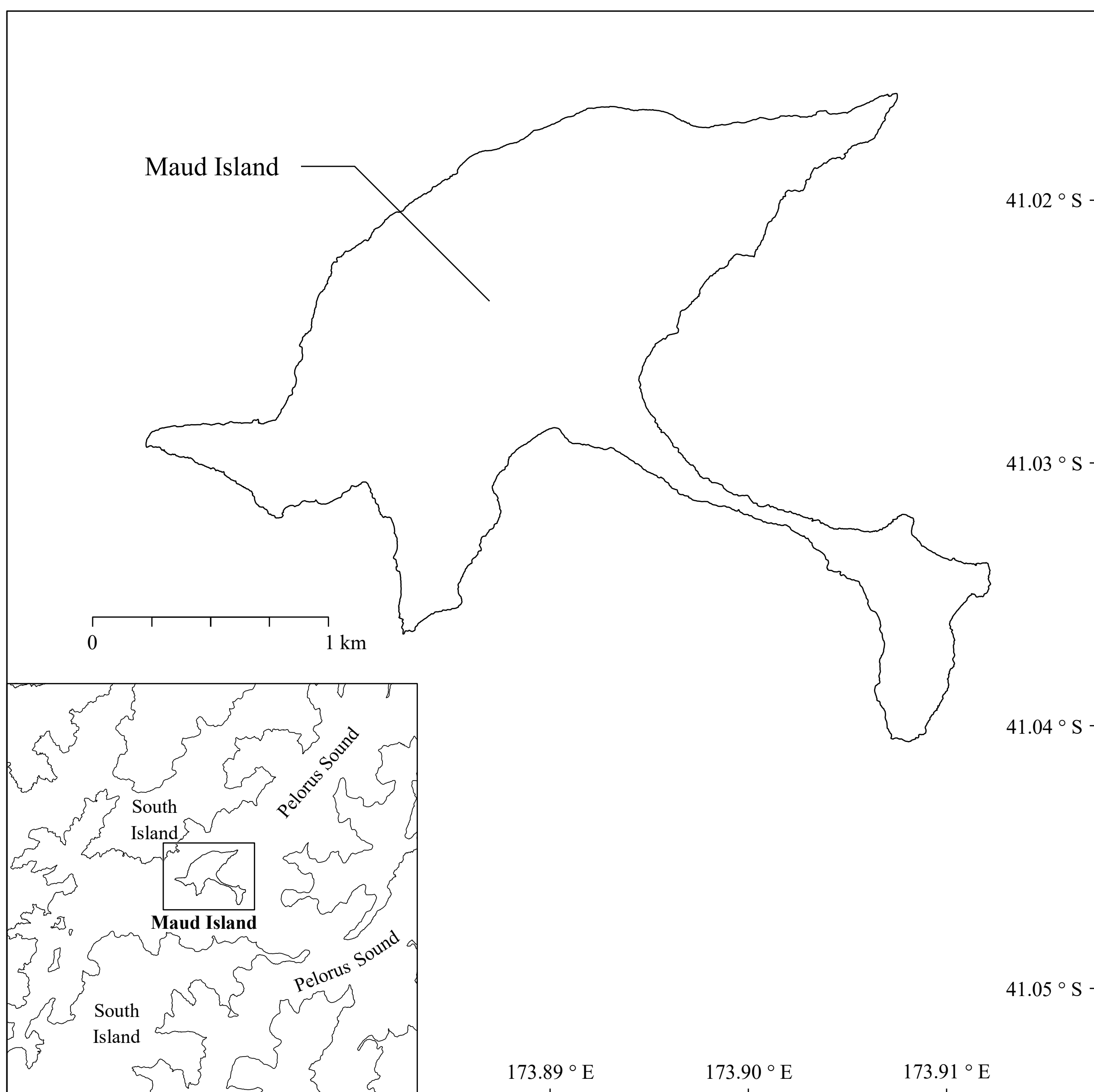

Figure 1.2: Map showing the location of Maud Island.

Historically, Maud Island had not suffered from any invasions by rodent species and was considered predator-free (Department of Conservation, 2006a, 2006b). This changed in 2013, with an incursion of mice (*Mus musculus*) on the island (Department of Conservation, 2013b). This discovery led to targeted poison bait drops and the subsequent eradication of mice in late 2014, with the predator-free status of the island reinstated in 2016 (Department of Conservation, 2016).

Previous to this, Maud Island had suffered similar incursions by stoats (*Mustela erminea*), with the relatively short distance between the island and the mainland suggested as a contributing factor in the invasions which occurred during the 1980s (Elliott, Willans, Edmonds, & Crouchley, 2010; Veale, Hannaford, Russell, & Clout, 2012). These incursions prompted intensive pest management, resulting in the eradication of stoats from the island in the early 1990s, with ongoing trapping and management currently in place to prevent further reinvasions (Clout & Russell, 2006; Elliott et al., 2010).

As a predator-free scientific reserve, Maud Island has been important in the conservation of threatened endemic species (Department of Conservation, 2006a, 2006b). The large stand of remnant native forest on the island supports a population of the Maud Island Frog (*Leiopelma pakeka*), a range restricted and conservation dependent species that is classified as vulnerable (Bell, Pledger, & Dewhurst, 2004; Newman et al., 2013). The island is also inhabited by a population of Stephens Island Striped Gecko (*Hoplodactylus stephensi*), a vulnerable species only found at two other sites in New Zealand (Hitchmough et al., 2016; Whitaker et al., 1999).

In addition, Maud Island has been the site of numerous translocations, with the release of 43 Cook Strait Giant Weta (*Deinacrida rugosa*) in 1977, and 40 Speckled Skinks (*Oligosoma infrapunctatum*) in early 2004 (Gaze & Cash, 2008). The island has also been the release site of eight different bird taxa including Kakapo, Little Spotted Kiwi (*Apteryx owenii*), South Island Saddleback (*Philesturnus carunculatus*), South Island Robin (*Petroica australis australis*), Takahe (*Porphyrio hochstetteri*), Fluttering Shearwater (*Puffinus gavia*), South Island Tomtit (*Petroica macrocephala macrocephala*), and Malherbe's Parakeet, all of which were released on the island between 1974 and 2008 (Gaze & Cash, 2008; Miskelly & Powlesland, 2013).

BLUMINE ISLAND

Blumine Island (41.1748° S, 174.2411° E) is located in the Queen Charlotte Sound of Marlborough, South Island, New Zealand. The island (Figure 1.3) is approximately 3.37 km^2 in area and is the largest reserve in the Marlborough Sounds (Department of Conservation, 2006b). The island consists of relatively steep hills, climbing to a central ridge (Conner & Conner, 1981), which reaches an elevation of 298 m at the highest point. The coastline consists of rocky bays, with many of the sloped hillsides ending near the coast (Conner & Conner, 1981; Conner, Powlesland, & Conner, 1981).

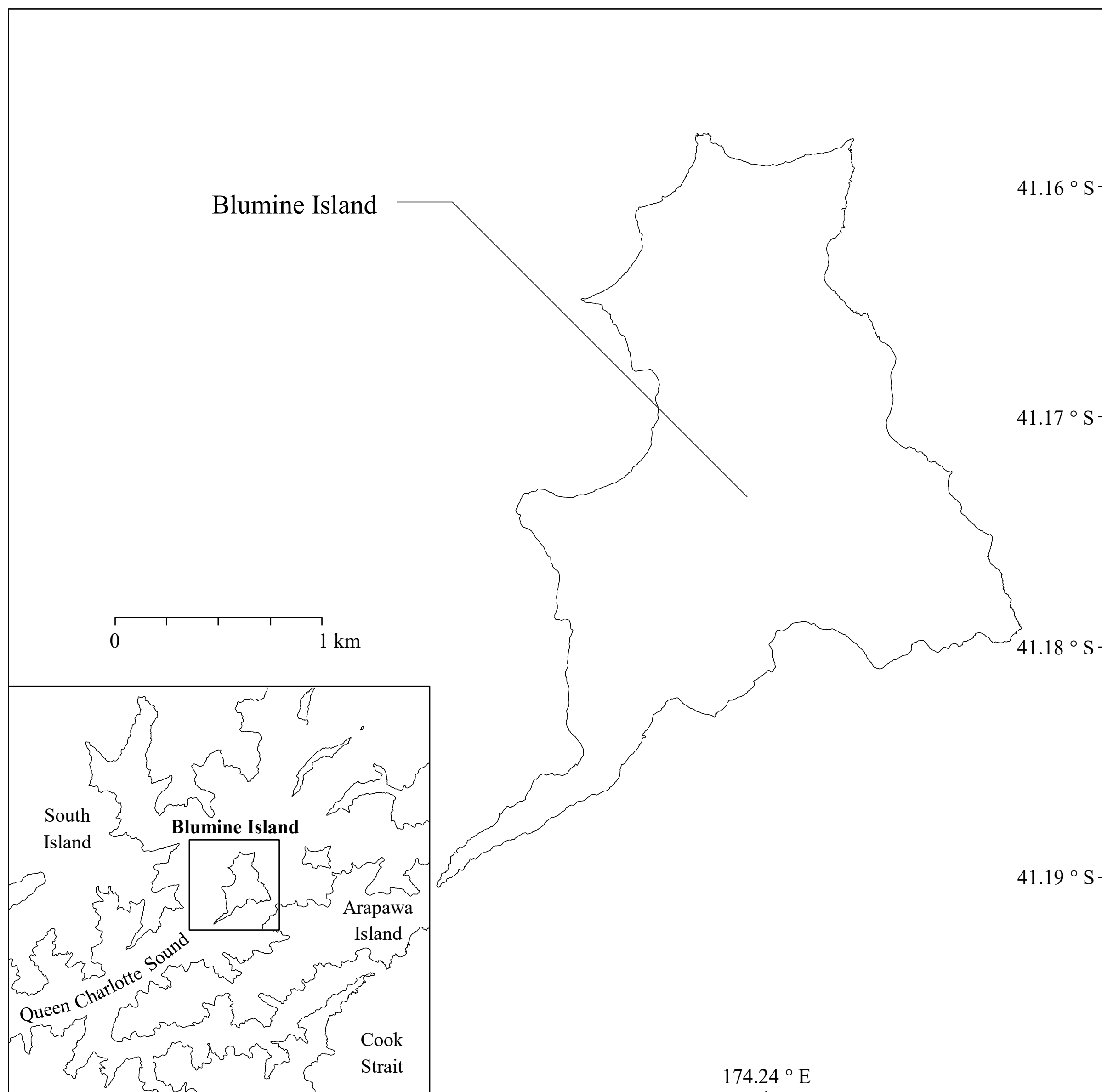

Figure 1.3: Map showing the location of Blumine Island.

Historically, Blumine Island was predominated by hardwood and podocarp forest (Conner & Conner, 1981). However, in the late 1880s, the majority of the island was cleared for grazing (Conner & Conner, 1981; Conner et al., 1981; Department of Conservation, 2013a). After this clearance, a moderate sized area of mature vegetation remained on the southern side of the island (Conner & Conner, 1981; Conner et al., 1981; Department of Conservation, 2013a). This vegetated area was later designated as a scenic reserve, followed by the entire island, which is now managed by the Department of Conservation (Conner & Conner, 1981; Department of Conservation, 2013a).

Following designation as a scenic reserve, seeding and planting efforts resulted in the regeneration of native vegetation on Blumine Island (Conner & Conner, 1981; Conner et al., 1981). In an assessment by Conner et al. (1981), this habitat was classified into three categories: mature forest, consisting of Tawa (*Beilschmiedia tawa*), Kohekohe (*Dysoxylum spectabile*), Matai (*Prumnopitys taxifolia*), Totara (*Podocarpus totora*), and Beech (*Nothofagus* spp.); regenerating forest, comprised of Mahoe (*Melicytus ramiflorus*), Five-finger (*Pseudopanax arboreus*), and Kawakawa (*Marcopiper excelsum*); and regenerating scrub predominated by Manuka (*Leptospermum scoparium*). These areas are inhabited by a variety of native bird and invertebrate species (Powlesland, 1981).

In addition to supporting native species, Blumine Island has a history of invasive mammal incursions (Powlesland, 1981). The island is separated from the nearest landmass of Arapawa Island by only 400 m, which has likely contributed to the presence of stoats, pigs (*Sus scrofa domesticus*), and other non-natives on the island in previous decades (Taylor & Tilley, 1984; Veale et al., 2012). Active pest management has since resulted in the eradication of these species, with pigs removed in 1989, stoats and rodents in 2005, and ongoing management in place to prevent further incursions (Clout & Russell, 2006; Department of Conservation, 2006b; Gaze & Cash, 2008; Veale et al., 2012).

In 2008, the Conservation Minister of New Zealand declared Blumine Island a predator-free sanctuary (New Zealand Government, 2008). The absence of mammalian predators on the island is likely to benefit a multitude of endemic species, including the giant land snail (*Powelliphanta hochstetteri bicolour*) and the resident birds. From 2009 to 2012, three native bird species have been translocated to Blumine Island including South Island Saddleback, Okarito Brown Kiwi (*Apteryx rowi*), and Malherbe's Parakeet (Miskelly & Powlesland, 2013).

CHALKY ISLAND

Chalky Island (46.0487° S, 166.5272° E) is an offshore island located at the entrance to the Chalky Inlet in southern Fiordland, South Island, New Zealand (Department of Conservation, 2017). The 5.14 km^2 island (Figure 1.4) is a predator-free sanctuary, which is part of the Fiordland National Park (Department of Conservation, 2017). The majority of the coastline is bordered by steep cliffs (Benson, Bartrum, & King, 1935), with the forested slopes reaching an elevation of 151 m at the highest point.

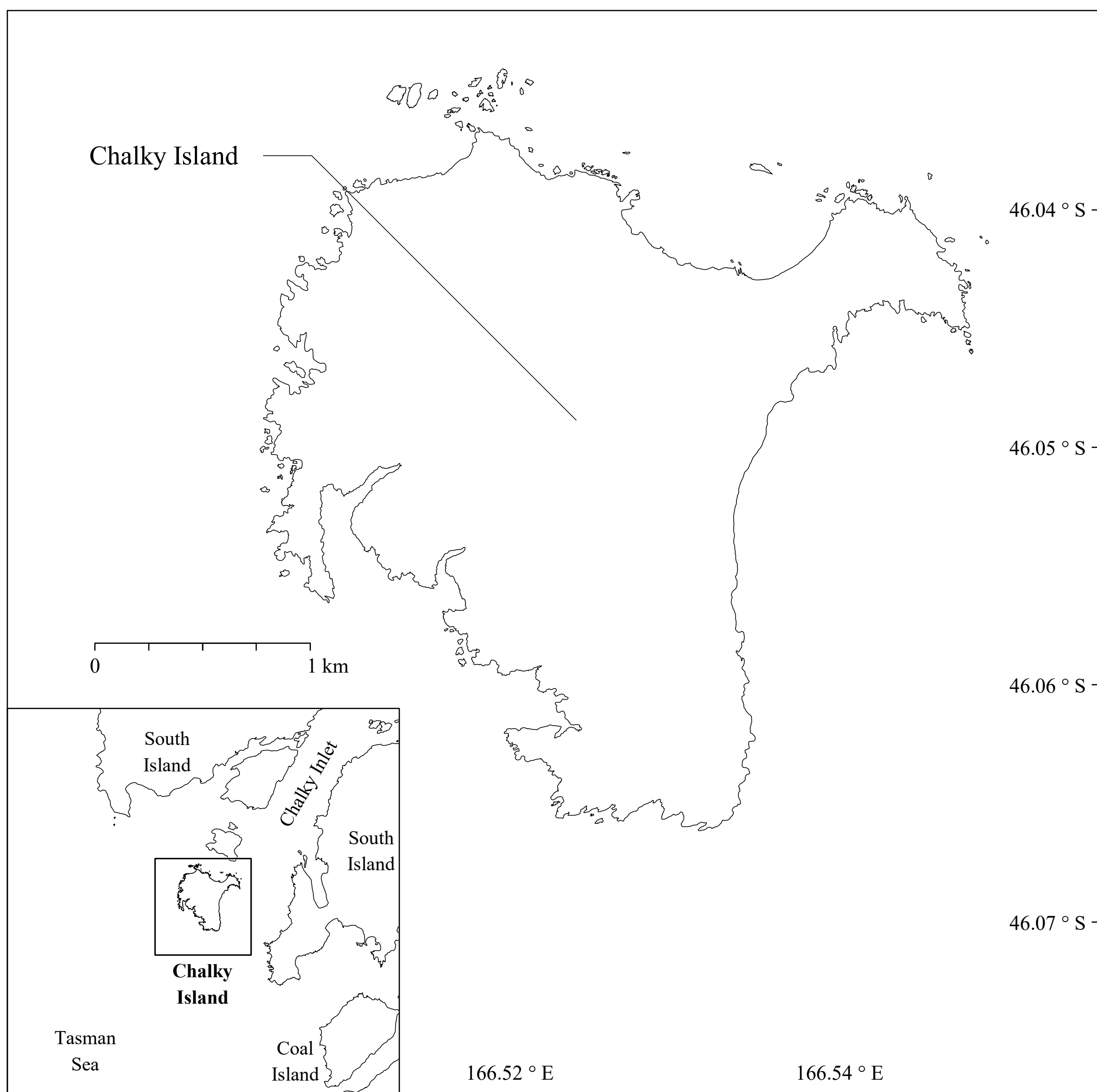

Figure 1.4: Map showing the location of Chalky Island.

Prior to the implementation of a stoat eradication programme, the close proximity of the Passage Islands and Great Island, which lie near the mainland, allowed stoats to become established on Chalky Island (Elliott et al., 2010). This has been attributed to the swimming ability of stoats, which are able to cross stretches of up to 1.5 km with relative ease compared to other predatory species (Elliott et al., 2010; Russell, Towns, & Clout, 2008; Veale et al., 2012). However, since the intensive trapping of stoats in the winter of 1999, Chalky Island has been predator-free, with systematic trapping of the Passage Islands and Great Island preventing further immigration of stoats to Chalky Island (Edge, Crouchley, McMurtrie, Willans, & Byrom, 2011; Elliott et al., 2010).

Similarly to other predator-free islands, Chalky Island has proved an ideal location for the conservation of threatened New Zealand endemics. The island currently supports a population of Chalky Island Skink (*Oligosoma tekakahu*), a critically endangered lizard endemic only to Chalky Island (Chapple et al., 2011; Hitchmough et al., 2016). In addition, this island has been useed as the translocation site for six endemic bird taxa including Yellowhead (*Mohoua ochrocephala*), Kakapo, Malherbe's Parakeet, South Island Saddleback, Little Spotted Kiwi, and South Island Robin (Department of Conservation, 2017; Miskelly & Powlesland, 2013).

STUDY SPECIES

TASMAN PARAKEET – *CYANORAMPHUS COOKII*

Endemic to Norfolk Island, the Tasman Parakeet (Figure 1.5) is a relatively large parrot (30 cm) with a long (14 – 18 cm) gradated tail (Forshaw, 1989, 2002; Higgins, 1999). The plumage is predominantly green, with striking violet-blue on the outermost edge of the primaries, and crimson patches on both sides of the rump (Forshaw, 1989; Higgins, 1999). The underparts are a paler green, with an olive-grey tinge to the underside of the tail (Forshaw, 2002). Extending from crown to forehead is a patch of crimson feathers, which taper into a thin band ending near the eyes, with distinct red patches on the ear coverts (Forshaw, 2002; Juniper & Parr, 1998). The bill is blue-grey becoming black towards the tip, the irises are orange-red, and the legs are a muddy grey colour (Forshaw, 1989, 2002; Higgins, 1999). Females have similar plumage to males, though they show a smaller patch of red feathers on the ear coverts and are typically smaller in size, with a narrower bill

(Forshaw, 2002; Higgins, 1999). Juvenile parakeets resemble adult birds in appearance, but exhibit less extensive crimson colouring on the head and rump, with light brown irises, pale pink bills, and shorter tails (Forshaw, 2002; Higgins, 1999).

Figure 1.5: Photograph of the Tasman Parakeet (*Cyanoramphus cookii*). Photo credit: Luis Ortiz-Catedral

The species was formerly widespread, occurring throughout the densely vegetated regions of Norfolk Island, but the extensive clearing of forested habitats, competition with invasive species, and predation by rodents and feral cats (*Felis catus*) has caused significant decreases in population size (Forshaw, 2002; Taylor, 1985). During the late 1970s, the population was estimated at a maximum of 30 individuals (Forshaw, 2002; Hicks & Greenwood, 1989; Hill, 2002). Later surveys, conducted from 1981 to 1982, revealed further declines, suggesting fewer than 30 individuals remained (Forshaw, 2002; Hill, 2002). In response, the Australian National Parks and Wildlife Service established a recovery programme, which aimed to mitigate further decreases in the Tasman Parakeet population by managing known nesting sites, trapping and eradicating mammalian predators, and forming a captive breeding population (Forshaw, 2002; Hicks & Greenwood, 1989; Hill, 2002). These

management initiatives resulted in gradual increases during the 1990s and by 2001, the parakeet population comprised of approximately 160 individuals (Hill, 2002). In 2009, a study using fixed point surveys estimated the population at 240 parakeets, though the estimate precision was limited by a small sample size (Dutson, 2013).

The remaining population is restricted to a small area of remnant forest within the 4.6 km^2 Mount Pitt section of the Norfolk Island National Park (Hill, 2002; Taylor, 1985). This area consists of a mixture of vegetation types, including native palm forest, native hardwood forest, native subtropical rainforest, native forest infested with invasive weeds, and exotic forest (Director of National Parks, 2008, 2010; Hill, 2002). Described as preferring native vegetation, Tasman Parakeets generally inhabit the areas predominated by tall dense native trees, though they can be observed foraging throughout the Mount Pitt area and are occasionally seen feeding in gardens and orchards beyond the national park (Forshaw, 2002; Smithers & Disney, 1969; Taylor, 1985). The species feeds on a combination of native and exotic plants, with a diet consisting of seeds, fruit, flowers, young leaf shoots, and occasionally bark (Forshaw, 2002; Garnett, Szabo, & Dutson, 2011; Hill, 2002; Taylor, 1985). This species of parakeet typically feeds among the foliage of the middle to upper storey, though they can also be observed foraging for fallen seeds at ground level (Forshaw, 2002; Garnett et al., 2011; Hill, 2002; Taylor, 1985). While feeding, they occasionally emit subdued notes of *kek-kik ... kek-kik or kek-kik-kek ... kek-kik-kek* and can usually be located by the consistent clicking of their mandibles and plant debris falling to the ground (Forshaw, 2002).

Tasman Parakeets establish nests in the hollow trunks and limbs of trees, preferentially nesting in areas of native forest (Hill, 2002). Nesting occurs throughout the year, during which the parakeets produce relatively large clutches of up to eight eggs (Forshaw, 2002; Hicks & Greenwood, 1989; Hill, 2002). The success of this nesting is limited by a number of factors, including competition for nesting hollows; availability of suitable tree cavities; and most significantly, predation by mammalian predators (Forshaw, 2002; Hill, 2002). Despite active management of known nest sites, low nesting and fledging success continue to limit the recovery of the Tasman Parakeet population (Hill, 2002). A recent assessment of population size that mapped the locations breeding pairs placed the remaining number of parakeets between 46 and 92 individuals in 2009 (Ortiz-Catedral, 2013).

Currently, the IUCN and BirdLife International list the Tasman Parakeet as a subspecies of the Red-crowned Parakeet (*Cyanoramphus novaezelandiae*), despite molecular evidence presented by Boon, Daugherty, and Chambers (2001) which validates the classification of the Tasman Parakeet as a distinct species. The subspecies grouping has resulted in the Tasman Parakeet being classified as least concern by both the IUCN and BirdLife International, a category that indicates no immediate need for conservation intervention. This classification is contrary to a recent evaluation provided by Garnett et al. (2011) that identified the Tasman Parakeet as a critically endangered species on the basis of their persistently small population size, low number of mature individuals, and small area of occurrence within the Norfolk Island National Park. In this thesis, the Tasman Parakeet is considered a distinct species in accordance with the findings of Boon et al. (2001) and is categorised as a critically endangered species following the conservation status reported by Garnett et al. (2011).

MALHERBE'S PARAKEET – *CYANORAMPHUS MALHERBI*

Malherbe's Parakeet (Figure 1.6) is a small (20 cm) parrot with a relatively long (10 – 12 cm) tail (Forshaw, 1989; Higgins, 1999). The plumage is a cold green, with a violet-blue tinge along the outer webs of the primary feathers, and a patch of orange feathers on either side of the rump (Higgins, 1999). The green colouration of the underparts is slightly paler, with the grey underside of the tail exhibiting a blue-green tinge (Higgins, 1999). A patch of pale yellow feathers continues from the crown to the forehead, meeting a thin orange frontal band, which becomes lighter as it extends towards the eye (Forshaw, 1989; Higgins, 1999; Kearvell, Connor, & Farley, 2014). The colouration of this frontal band and the rump patches distinguishes this species from Yellow-crowned Parakeets (*Cyanoramphus auriceps*), which display a bright yellow crown, a wide crimson frontal band, and red patches on both sides of the rump (Higgins, 1999; Kearvell et al., 2014). The bill is dark grey near the tip becoming a lighter blue-grey towards the nares, the irises are orange-red, and the legs are grey-brown (Forshaw, 1989; Kearvell et al., 2014). Males and females exhibit little difference in plumage colouration and appearance, though males have slightly longer and wider bills (Higgins, 1999; Young & Kearvell, 2001). Juveniles resemble adults, though the frontal band and forecrown are less distinct, with pale red-brown irises, pastel pink bills, and shorter tails (Higgins, 1999; Kearvell et al., 2014).

Figure 1.6: Photograph of Malherbe's Parakeet (*Cyanoramphus malherbi*). Photo credit: Luis Ortiz-Catedral

This species is endemic to New Zealand, historically occurring throughout the forested areas of the South Island (Forshaw, 1989; Grant & Kearvell, 2003; Taylor, 1985). However, having experienced substantial population declines as a result of habitat modification, competition for resources, and predation by introduced mammalian predators, the remaining population of Malherbe's Parakeet is currently restricted to three locations in the Canterbury region of the South Island (Andrews, Hale, & Steeves, 2013; Elliott & Suggate, 2007; Ortiz-Catedral & Brunton, 2009b): the South Branch of the Hurunui River valley, Lake Sumner Forest; the Hawdon River valley, Arthur's Pass National Park; and the Poulter River valley, Arthur's Pass National Park (Higgins, 1999; Kearvell et al., 2014; Kearvell & Farley, 2016). These mainland populations were originally estimated to total less than 500 parakeets (Higgins, 1999; Kearvell & Briskie, 2003; Kearvell, Grant, & Boon, 2003), but recent estimates indicate further declines, placing the mainland population between 150 and 300 individuals (Elliott & Suggate, 2007; Kearvell, 2016; Ortiz-Catedral, Kearvell, et al., 2009).

Due to the severity of the population declines experienced by this species, the Department of Conservation, in partnership with the Isaac Conservation and Wildlife Trust, has made efforts to establish populations of Malherbe's Parakeet on protected offshore islands free of predators (Elliott &

Suggate, 2007; Ortiz-Catedral & Brunton, 2009b; Ortiz-Catedral, Kearvell, et al., 2009). This led to the translocation and introduction of Malherbe's Parakeet to four offshore islands: Mayor Island, Maud Island, Blumine Island, and Chalky Island (Miskelly & Powlesland, 2013; Ortiz-Catedral et al., 2012). Of these translocated populations, there is one published account of population size, with an estimated 96 to 126 individuals occurring on Maud Island in 2009 (Ortiz-Catedral et al., 2012).

On both, offshore islands and the mainland, Malherbe's Parakeet consumes a range of dietary components including seeds, fruit, leaves, flower and leaf buds, flowers, and invertebrates (Higgins, 1999; Kearvell, Young, & Grant, 2002; Ortiz-Catedral & Brunton, 2009b). Compared to the closely related Yellow-crowned Parakeet, invertebrates constitute a slightly larger proportion of the diet (Higgins, 1999; Kearvell et al., 2002). The species has also been observed consuming non-dietary items such as the bark and sticks of native and introduced trees, and in one instance grit from a sand bed (Ortiz-Catedral & Brunton, 2009b). The vocalisations of Malherbe's Parakeet are similar to those of other *Cyanoramphus* parakeets, producing chatter calls of *ki-ki-ki-ki*, which do not differ significantly in structure from the chatter calls of the Yellow-crowned Parakeet, aside from their syllabic frequency (Kearvell & Briskie, 2003).

Similarly to other *Cyanoramphus* parakeets, Malherbe's Parakeet is a cavity nester (Kearvell, 2002, 2013; Kearvell & van Hal, 2016; Ortiz-Catedral, Kearvell, et al., 2009). On the mainland, the species predominantly establishes nests in the cavities and hollows formed in the trunks and branches of mature beech trees (Kearvell, 2002; Kearvell & van Hal, 2016). However, Ortiz-Catedral, Kearvell, et al. (2009) indicate parakeets translocated to Maud Island seemed to exhibit flexibility in nest site selection, observing nest hollows in the trunks of dead Black Tree Ferns (*Cyathea medullaris*), the branch of a dead Kohekohe, and even the vacant nesting holes formed in soil banks by Sacred Kingfishers (*Todiramphus sanctus*). Following nest site selection and breeding, Malherbe's Parakeets can produce clutches of five to eight eggs for incubation (Duncan & van Hal, 2004). During nesting and incubation, these parakeets are vulnerable to mammalian predators, with nest accessibility contributing to the population declines associated with predation (Duncan & van Hal, 2004; Elliott & Suggate, 2007; Hansford, 2017).

Historically, the taxonomy of Malherbe's Parakeet has been a contentious issue, with the recognition of Malherbe's Parakeet as a distinct species only occurring within the last 20 years (Kearvell et al., 2003). Prior to this recognition, Malherbe's Parakeet was often debated to be a colour morph of the Yellow-crowned Parakeet (Nixon, 1981; Taylor, 1998). However, molecular evidence provided by Boon, Kearvell, Daugherty, and Chambers (2000), combined with the ecological and behavioural evidence reviewed by Kearvell et al. (2003) has contributed to the acceptance of Malherbe's Parakeet as a distinct species. The species is now identified as critically endangered by the Department of Conservation, with the range restricted and conservation dependent populations experiencing fluctuations in population size at both mainland and offshore sites (Robertson et al., 2017). In this thesis, Malherbe's Parakeet is recognised as a distinct species following the evidence presented by Kearvell et al. (2003) and is considered to be critically endangered as per listings by the Department of Conservation, BirdLife International, and the IUCN (Robertson et al., 2017).

NON-TARGET SPECIES

CRIMSON ROSELLA – *PLATYCERCUS ELEGANS*

The Crimson Rosella (Figure 1.7) is a large parrot (36 cm) with a long (18 – 20 cm) tail (Forshaw, 1989, 2002). In contrast to the brilliant green feathers of *Cyanoramphus* parakeets, the Crimson Rosella has red plumage (Forshaw, 1989, 2002); with rich crimson feathers covering the head, neck, and body regions (Higgins, 1999). The head region also comprises of prominent violet-blue cheek patches, dark brown irises, and a pearl-grey bill with a dark grey cere (Forshaw, 1989, 2002; Higgins, 1999). The nape is covered with black feathers widely fringed with a rich red, which extends to the mantle, upper back, and tertials (Forshaw, 1989, 2002; Higgins, 1999). The leading edge of the wing appears violet-blue, continuing from the mauve-grey outer secondary coverts to the dark violet-blue primary coverts (Forshaw, 2002; Higgins, 1999). The primaries and outermost secondary feathers are grey-black, becoming a dark violet-blue towards the outer webs (Forshaw, 2002; Higgins, 1999). The remaining wing feathers are black, with all except the lesser secondary coverts margined with crimson (Forshaw, 2002; Higgins, 1999). The central tail feathers are dark blue nearing black, with lateral tail feathers transitioning from dark blue near the base to pale blue near the tip (Forshaw, 2002; Higgins,

1999). The underside of the central tail feathers are dark grey, contrasted by the lateral tail feathers which appear a light blue-violet, tipped with white (Forshaw, 1989; Higgins, 1999).

Females generally resemble males, though typically have smaller bills and duller feathers suffused with green-blue elements (Forshaw, 2002). Juveniles appear distinct from adult individuals, mostly displaying bright olive-green plumage, rather than the rich crimson of mature birds (Higgins, 1999). The crown and forehead are red, bordering the distinct violet-blue cheek patches to join the crimson throat and breast feathers (Forshaw, 2002; Higgins, 1999). In addition, crimson feathers can be observed on the thighs, undertail coverts, and occasionally the uppertail coverts, with most other feathers an olive-green (Forshaw, 1989, 2002; Higgins, 1999). Both mature and juvenile individuals have grey legs, though they appear lighter in juveniles (Higgins, 1999).

Figure 1.7: Photograph of the Crimson Rosella (*Platycercus elegans*). Photo credit: New Zealand Birds Online

The Crimson Rosella is a native of the eastern and southern reaches of Australia, with an isolated population occurring on Norfolk Island (Forshaw, 1989, 2002; Higgins, 1999). The species was introduced to Norfolk Island in the 1800s, establishing a wild population from escaped individuals that were originally kept as cage birds (Higgins, 1999). They are now widespread

throughout the different habitat types of mainland Norfolk Island, occurring in the vegetation scattered across farmland, remnant stands of native rainforest, regenerating bush, forestry plantations, and household gardens (Forshaw, 2002; Higgins, 1999; Smithers & Disney, 1969; Wakelin, 1968). In these areas, the Crimson Rosella can be easily identified by their bright red plumage and distinctive screeching call, which is described as loud and harsh, with guttural qualities (Higgins, 1999).

Within the confines of the Mount Pitt section of the Norfolk Island National Park, the species is particularly abundant and can be observed feeding in the upper storey, as well as on the forest floor (Forshaw, 1989; Higgins, 1999; Smithers & Disney, 1969). The Norfolk Island population of Crimson Rosella feed upon a variety of seeds, fruit, flowers, and emergent shoots (Forshaw, 1989; Higgins, 1999; Wakelin, 1968). This dietary profile is similar to that of the critically endangered Tasman Parakeet, which has resulted in competitive interactions between the two species, often favouring the abundant and more aggressive Crimson Rosella population (Director of National Parks, 2008; Hicks & Greenwood, 1989; Smithers & Disney, 1969).

Similarly to the Tasman Parakeet, the Crimson Rosella is a cavity nester that establishes nests in the hollow trunks, limbs, or stumps of large trees (Higgins, 1999; Smithers & Disney, 1969; Wakelin, 1968). Consequently, the Crimson Rosella population imposes a significant threat to the Tasman Parakeet population, with both species competing for the limited number of suitable nesting hollows that remain in the Mount Pitt section of the national park (Director of National Parks, 2010; Hill, 2002; Smithers & Disney, 1969).

YELLOW-CROWNED PARAKEET – *CYANORAMPHUS AURICEPS*

The Yellow-crowned Parakeet (Figure 1.8) is a small parrot (23 cm) with a relatively long (11 – 12 cm) tail (Forshaw, 1989; Higgins, 1999). The plumage is bright green, with blue shown along the leading edge of the primaries, and small patches of dark red on both sides of the rump (Forshaw, 1989; Higgins, 1999). The underparts are a paler yellow-green, with feathers on the underside of the tail showing a dark grey washed with yellow-green (Higgins, 1999; Juniper & Parr, 1998). Similarly to Malherbe’s Parakeet, the Yellow-crowned Parakeet exhibits a golden-yellow patch of feathers, which extends from the crown to forehead, though this species is distinguished by a frontal band

consisting of red feathers (Forshaw, 1989; Higgins, 1999). The legs are commonly black-brown, varying through to pink-brown; the bill is a pale blue-grey, tipped with black; and the irises are orange-red (Forshaw, 1989; Higgins, 1999). Similarly to other *Cyanoramphus* parakeets, there is little difference in plumage colouration between the sexes, though females can generally be distinguished by short narrow bills and smaller body size (Higgins, 1999; Young & Kearvell, 2001). The juveniles of this species resemble adults, though the distinctive plumage of the head region tends to be diffusely coloured, with shorter tails, and bare parts that appear lighter in colouration during fledging (Forshaw, 1989; Higgins, 1999).

Figure 1.8: Photograph of the Yellow-crowned Parakeet (*Cyanoramphus auriceps*). Photo credit: Jake Osborne

This species is endemic to New Zealand and is predominantly distributed across the large forested areas of the South Island and southern reaches of the country, with some isolated records occurring in the North Island (Higgins, 1999; Taylor, 1985). In these regions, the Yellow-crowned Parakeet favours tall, dense areas of native podocarp and beech forest (Higgins, 1999; Taylor, 1985), habitat which is also frequented by the less abundant Malherbe's Parakeet in areas where sympatric populations of the two species occur (Kearvell et al., 2002). Examination of the diet, habitat use, and

nest site selection of these two species indicates similarities in their ecology (Kearvell & van Hal, 2016; Kearvell et al., 2002), though it is suggested interspecific competition between these species occurs as a result of the limited resources provided by the modified habitat in which they occur (Kearvell & van Hal, 2016). In these areas, Malherbe's Parakeet is reported to frequent the lower forest canopy while foraging (Kearvell et al., 2002). This may be indicative of their historical niche as middle canopy and understorey feeders, which has since been limited by the introduction of predators and herbivorous browsing species (Hansford, 2017).

At both mainland and offshore sites where sympatric populations of the Yellow-crowned Parakeet and Malherbe's Parakeet occur, the morphological similarities between the two species can cause difficulties for field identification, especially in areas with high canopies or dense foliage cover (Kearvell et al., 2014). Similarly, the chattering *ki-ki-ki-ki* vocalisations of the Yellow-crowned Parakeet can be difficult to distinguish from those of Malherbe's Parakeet, only differing significantly from the latter by their syllabic frequency, though this alone is not sufficient to differentiate one species from the other (Kearvell & Briskie, 2003). The most reliable method of distinguishing between these species in the field is to identify the distinctive colouration of the frons and rump patches (Higgins, 1999; Kearvell et al., 2014).

In contrast to Malherbe's Parakeet, the Yellow-crowned Parakeet is classified as not threatened by the Department of Conservation (Robertson et al., 2017). This species usually breeds during summer, though breeding can occur throughout the year during mast seeding events. During these masting events, beech trees produce copious quantities of seeds increasing food availability and consequently increasing breeding among birds, particularly parakeets (Elliott, Dilks, & O'Donnell, 1996a; Higgins, 1999; Kearvell & van Hal, 2016). The Yellow-crowned Parakeet can produce clutches of two to nine eggs (Elliott et al., 1996a) and is a secondary cavity nester, which exhibits a preference for mature beech trees (Elliott, Dilks, & O'Donnell, 1996b; Kearvell, 2002; Kearvell & van Hal, 2016).

BELLBIRD – *ANTHORNIS MELANURA*

The Bellbird (Figure 1.9) is a medium-sized (17 – 20 cm) passerine with a relatively long tail (Higgins, Peter, & Steele, 2001). The species is endemic to New Zealand, occurring through much of the central North Island, South Island, and Stewart Island (Higgins et al., 2001). The males of this species are predominantly olive-green, displaying darker feathers around the head and neck regions, with outer primaries and uppertail feathers, which appear black-brown (Higgins et al., 2001). In contrast, the feathers of the females are a drab olive-brown, offset near the bill by a thin white-yellow moustachial stripe (Higgins et al., 2001). Juveniles resemble females most closely, appearing a dull olive-grey compared to adults, though sharing the crimson iris colour and grey legs (Higgins et al., 2001). The short black decurved bill of the Bellbird is used during foraging to obtain nectar, fruit, insects and insect products (Craig, Stewart, & Douglas, 1981; Higgins et al., 2001; O'Donnell & Dilks, 1994).

SILVEREYE – *ZOSTEROPS LATERALIS*

The Silvereye (Figure 1.9) is a small (12 cm) passerine with a short tail (Higgins, Peter, & Cowling, 2006). The species is widespread, occurring throughout the countries and islands of the South Pacific region including Australia, New Zealand, New Caledonia, Vanuatu, Fiji, Lord Howe Island, Norfolk Island, the Kermadec Islands, and the Chatham Islands (Higgins et al., 2006). The species exhibits a distinctive white eye-ring, which appears narrower in juvenile birds (Higgins et al., 2006). The plumage of the head, nape, rump, and uppertail are olive-grey, disrupted by the feathers of the hind neck, mantle, and scapulars, which form a grey saddle (Higgins et al., 2006). The underparts are lighter, with the pale yellow feathers of the throat transitioning from grey across the breast to white along the belly, vent, and thighs (Higgins et al., 2006). The plumage of male and female birds is similar, though the brown feathers of the flanks appear paler in females (Higgins et al., 2006). The Silvereye consumes a large range of seeds, flowers, fruit, and invertebrates, foraging from the ground to the upper canopy and while flying (Higgins et al., 2006; Moeed, 1979; O'Donnell & Dilks, 1994).

Figure 1.9: Photographs of the non-target species observed during fixed point surveys in New Zealand: Yellowhead (*Mohoua ochrocephala*), a species which often form mixed flocks with *Cyanoramphus* parakeets (top); Silvereye (*Zosterops lateralis*), a species of small songbird (middle left); Bellbird (*Anthornis melanura*), a species renowned for its bell-like call (middle right); and Tui (*Prosthemadera novaeseelandiae*), a large nectar eating songbird (bottom). Photo credit: Luis Ortiz-Catedral, Yani Dubin, Jake Osborne, and Tony Whitehead

TUI – *PROSTHEMADERA NOVAESEELANDIAE*

The Tui (Figure 1.9) is a large (27 – 32 cm) passerine, which is endemic to New Zealand (Higgins et al., 2001). The species occurs throughout the North Island and Stewart Island, with the South Island population mainly distributed along the western coast (Higgins et al., 2001). The plumage is predominantly black, though feathers exhibit strong iridescence and typically appear to have a dark blue, blue-green, or purple sheen (Higgins et al., 2001). The dark feathers of the body are contrasted by a tuft of white feathers on the throat and a filamentous collar of white feathers on the hindneck (Higgins et al., 2001). This species generally feeds upon nectar, though consumes insects and fruit when nectar is unavailable (Craig et al., 1981; Higgins et al., 2001; O'Donnell & Dilks, 1994).

YELLOWHEAD – *MOHOUA OCHROCEPHALA*

The Yellowhead (Figure 1.9) is a small (15 cm) passerine with a medium-sized tail (Higgins & Peter, 2002). Endemic to the South Island and southern reaches of New Zealand, the Yellowhead is easily distinguished by the bright yellow plumage of the head, neck, and underparts (Higgins & Peter, 2002). The remaining plumage is olive-brown, with strong yellow suffusion around the edge of the upper tail feathers (Higgins & Peter, 2002). The species exhibits a preference for native beech forest, where they predominantly feed on invertebrates (Higgins & Peter, 2002; O'Donnell & Dilks, 1994). Higgins and Peter (2002) also report that Yellowheads will occasionally feed on the nectar of Scarlet Mistletoe (*Peraxilla colensoi*) and the fruit of New Zealand Broadleaf (*Griselinia littoralis*). When Yellowhead forage, they form flocks consisting of up to 40 birds, which can be comprised of a mixture of species including *Cyanoramphus* parakeets (Higgins & Peter, 2002).

CHAPTER 2

Using Statistical Resampling to Identify an Efficient Method for Surveying Tasman Parakeets (*Cyanoramphus cookii*)

ABSTRACT

Generating precise estimates of population size is an important aspect of wildlife monitoring and can facilitate effective management for the conservation of threatened species. For parrots, obtaining precise estimates can be challenging, particularly for threatened species that occur in low densities across fragmented habitats. In this study, we used a statistical resampling approach to compare the reliability and precision of two survey methods (fixed point surveys and line transect surveys), which are used to monitor the critically endangered Tasman Parakeet (*Cyanoramphus cookii*) on Norfolk Island. The counts obtained from these fixed point surveys had an estimated precision (standard error/mean) of 0.274 which compared to an estimated precision of 0.476 for line transect surveys indicates that estimates from fixed point surveys are more precise. Additionally, the fixed point survey method was more efficient, yielding 1.338 parakeet detections per survey compared to the 0.642 parakeet detections per survey obtained by line transect surveys. Our research demonstrates that although both of these survey methods are capable of detecting Tasman Parakeets, fixed point surveys are more efficient and yield more precise estimates. To generate reliable estimates of the Tasman Parakeet population and continue monitoring the recovery of the species long-term, we suggest future surveys are conducted using the fixed point survey method.

INTRODUCTION

Determining population size is a crucial component of species conservation and wildlife management research (Kellner & Swihart, 2014; Silveira, Jacomo, & Diniz-Filho, 2003). Estimates of population size offer insight into population trends, extinction risk, species conservation status, population viability, the impact of different threats, and the effectiveness of species management (Dénes et al., 2018; Kéry et al., 2009; Marsden & Royle, 2015). Typically obtaining these estimates requires counts of individuals observed or detected in the field (Boulinier, Nichols, Sauer, Hines, & Pollock, 1998; Williams, Nichols, & Conroy, 2002). These counts are then analysed to infer the relative density of the species of interest (Kellner & Swihart, 2014; MacKenzie et al., 2005; Pollock et al., 2002). However, there are multiple factors that can influence the precision of these estimates, including the behavioural characteristics of the species of interest, the complexity of the habitat, the size and

colouration of the survey species, the experience of the observers conducting surveys, and the season in which sampling occurs (Ahrestani, Hebblewhite, & Post, 2013; Anderson, 2001).

Increasingly, advances in technology and survey methods are allowing scientists to estimate these population parameters with greater precision. Novel approaches to surveying, such as the use of drones fitted with high definition cameras, enable biologists to rapidly assess populations while reducing the error associated with ground-based survey methods (Hodgson, Baylis, Mott, Herrod, & Clarke, 2016; Hodgson et al., 2018). Similarly, diver operated stereo-video systems used in the assessment of marine biomass can overcome observer biases such as the inaccurate estimation of distances, misidentification of species, and underestimation or overestimation of abundance (Harvey, Fletcher, Shortis, & Kendrick, 2004; Salinas-de-León et al., 2016). In a recent study, Hodgson et al. (2018) found survey data collected using drones was up to 96% more accurate than data obtained using traditional survey methods. However, these techniques are often limited to use with large or easily detected species that occur across small geographic areas of low habitat complexity (Anderson & Gaston, 2013; Linchant, Lisein, Semeki, Lejeune, & Vermeulen, 2015).

Quantifying populations of species that occupy more complex habitats, presents an additional challenge to scientists attempting to estimate population size, particularly for species found on remote islands. One example is the monitoring of the Kermadec Red-crowned Parakeet (*Cyanoramphus novaezelandiae cyanurus*) population, which occurs on an isolated group of islands to the northeast of New Zealand (Higgins, 1999; Juniper & Parr, 1998). Due to high research costs, time constraints, and a complex island topography, the species is unable to be surveyed regularly (Greene, Scofield, & Dilks, 2004). Consequently, the population estimates generated for this species were highly variable and lacked precision, with estimates produced for the Macauley Island population ranging between 1000 and 20000 individuals (Greene et al., 2004; Taylor, 1985). However, a recent assessment by Greene et al. (2014) placed an emphasis on increasing accuracy through habitat-specific sampling and produced a refined estimate, indicating the parakeet population consisted of 3484 individuals.

Another species that requires additional research to provide precision estimates of abundance is the critically endangered Tasman Parakeet (*Cyanoramphus cookii*). This species is a cryptically coloured parrot, which is restricted to a small patch of remnant forest on Norfolk Island (Forshaw,

2002; Hill, 2002; Taylor, 1985). As an island endemic, the Tasman Parakeet has suffered significant declines due to habitat loss, predation, and competition with introduced species (Director of National Parks, 2010; Taylor, 1985). After a severe population collapse in the early 1980s, a recovery programme was established to prevent the extinction of the species (Forshaw, 2002; Hicks & Greenwood, 1989; Hill, 2002).

Figure 2.1: Photograph showing the cryptic plumage of a Tasman Parakeet (*Cyanoramphus cookii*) foraging on the fruit of Red Guava (*Psidium cattleianum*) in the Mount Pitt section of the Norfolk Island National Park. Photo credit: Luis Ortiz-Catedral

Since then, the recovery of this managed population has been monitored sporadically using a variety of survey methods. This unstructured approach to monitoring limits the ability to compare estimates and reduces the confidence with which population trends can be inferred (Legault et al., 2013). In addition, the low density of the population and cryptic colouration of the species (Figure 2.1), has limited the precision of estimates produced by past assessments (Dutson, 2013; Hicks & Greenwood, 1989). Therefore identifying an efficient method that provides reasonable precision is critical to establishing effective long-term monitoring and is considered a key priority for the Tasman Parakeet recovery programme (Ortiz-Catedral, Nias, Fitzsimons, Vine, & Christian, 2018).

The primary aim of this research was to identify a reliable and repeatable survey method for monitoring the critically endangered Tasman Parakeet population. Using statistical resampling, we examined the precision of the count estimates obtained by two survey methods used for monitoring the parakeet population: fixed point surveys and line transect surveys. The theoretical performance of each method was then compared, allowing us to identify the best approach to sampling this cryptically coloured species and providing essential information for establishing an effective long-term monitoring strategy for a critically endangered parrot population that occurs in low densities.

METHODS

STUDY SITE

Our research was conducted in the Norfolk Island National Park, Norfolk Island (29.0408° S, 167.9547° E). Established in 1984, this protected region consists of two main areas of habitat: the Mount Pitt section on mainland Norfolk Island, and the nearby Phillip Island (Director of National Parks, 2008). Currently, the 4.6 km^2 Mount Pitt region is the only area of the national park which supports a naturally occurring population of the critically endangered Tasman Parakeet (Hill, 2002). Considering this, we confined our sampling to the Mount Pitt section of the national park and excluded the 1.9 km^2 Phillip Island from our surveys.

DATA COLLECTION

We conducted seasonal sampling of the Tasman Parakeet population in the autumn, winter, and spring of 2014 and 2015. To obtain counts of individual birds we used two distinct methods: fixed point surveys and line transect surveys. In both cases, surveys were conducted from 6:30 am to 12:00 pm, a period of heightened activity established for *Cyanoramphus* parakeets (Legault, Theuerkauf, Rouys, Chartendrault, & Barré, 2012). To increase the probability of detecting parakeets during this time, we only collected data in conditions which registered from zero to two on the Beaufort scale. All surveys were conducted by experienced observers to ensure the accuracy of species identification.

FIXED POINT SURVEY METHOD

To conduct fixed point surveys, we selected a random subset of survey points from an existing grid of rodent bait stations (Figure 2.2) which are distributed across the Mount Pitt section of the Norfolk Island National Park. These survey points cover a variety of habitat types within the occurrence area of the Tasman Parakeet. Consequently, the distance, terrain, and habitat separating each of these randomly selected points varied, which limited the number of surveys conducted each day.

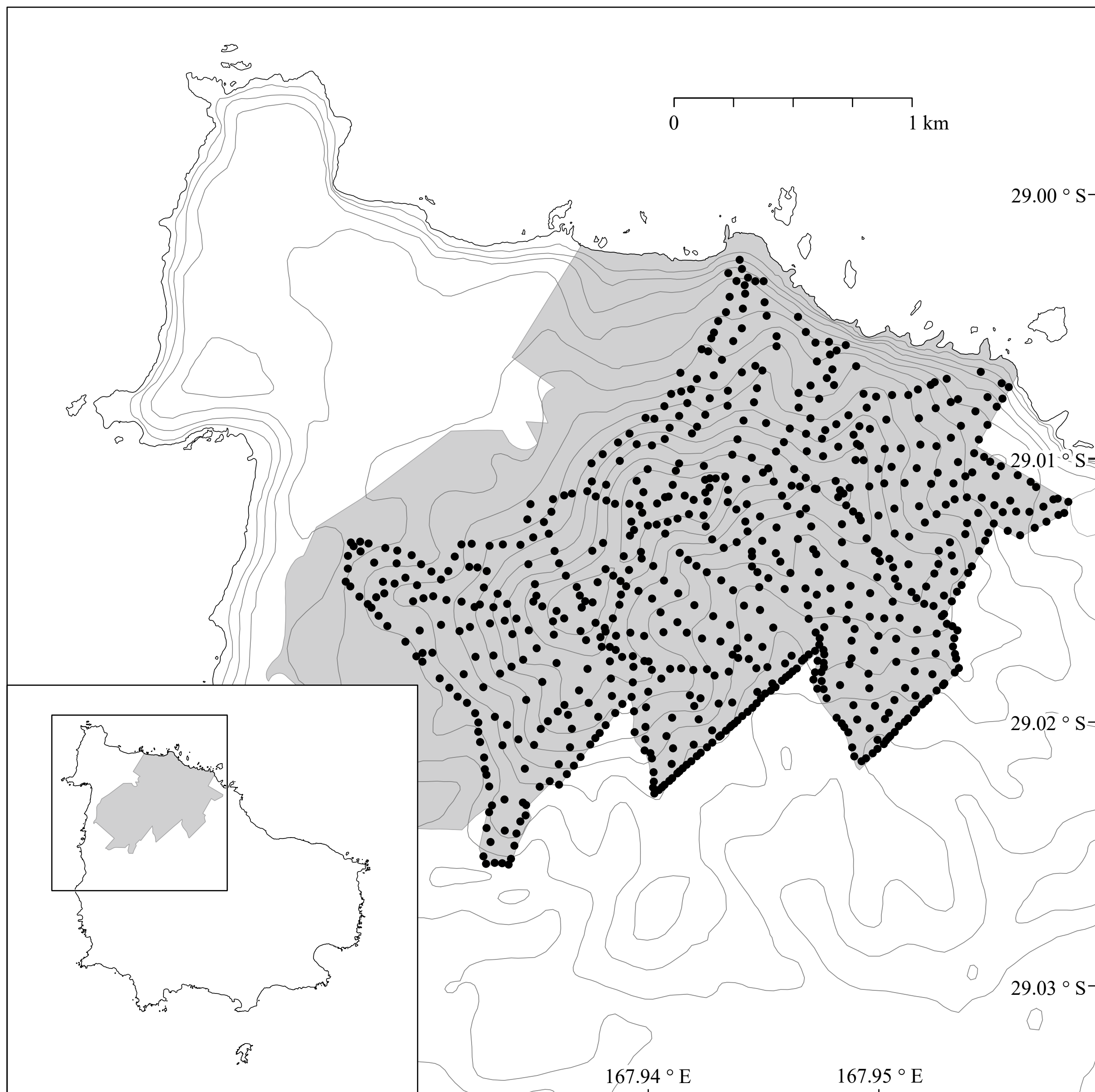

Figure 2.2: Map showing the distribution of rodent bait stations (black circles) across the Mount Pitt section of the Norfolk Island National Park (shaded grey), with contour lines (dark grey lines) showing the increase in elevation at 20 m intervals.

To increase the likelihood of detecting parakeets and minimise disturbance to birds during sampling, we approached each survey point as quietly as possible. After arriving at each point, a five minute rest period was observed before beginning the survey, further mitigating the effects of any disturbance caused by the approaching observer. During each survey, we observed for ten minutes recording any acoustic or visual parakeet detections for later analysis. Acoustic records consisted of any unique Tasman Parakeet vocalisation heard near the survey point. During surveys, all indistinct or repeated calls were disregarded to reduce the likelihood of counting the same individual, pair, or group more than once. Visual records consisted of any positively identified individual, pair, or group of Tasman Parakeets observed near the survey point.

LINE TRANSECT SURVEY METHOD

Line transect surveys were conducted along the accessible walking paths, tracks, and roads distributed across the Mount Pitt section of the Norfolk Island National Park (Figure 2.3). Similarly to the survey points used for the fixed point survey method, these tracks and roads covered a variety of habitat types within the occurrence area of the Tasman Parakeet. Despite each of these transects varying in length, they were selected in favour of those with randomly selected start points and a standardised sampling length, as they better reflect the line transect surveys conducted in previous assessments of the Tasman Parakeet population. To accurately represent the surveys conducted in these previous assessments, we alternated our starting location and direction of travel each sampling day.

In any one sampling period, we attempted to cover the entire network of tracks to achieve a representative sample; though this was occasionally limited by the availability of observers. When carrying out each survey, we walked quietly and at a relatively slow pace (2.0 – 3.5 km/h) to maximise our chance of detecting parakeets. While walking, any acoustic or visual parakeet detections were recorded, along with GPS coordinates for later analysis. An acoustic record was any distinct Tasman Parakeet call heard near the transect line. To reduce the possibility of double counting, we excluded all vocalisations from individuals, pairs, or groups of parakeets that had previously been recorded. Only unique individuals, pairs, or groups of Tasman Parakeets that were clearly identified along the transect line were included as visual records.

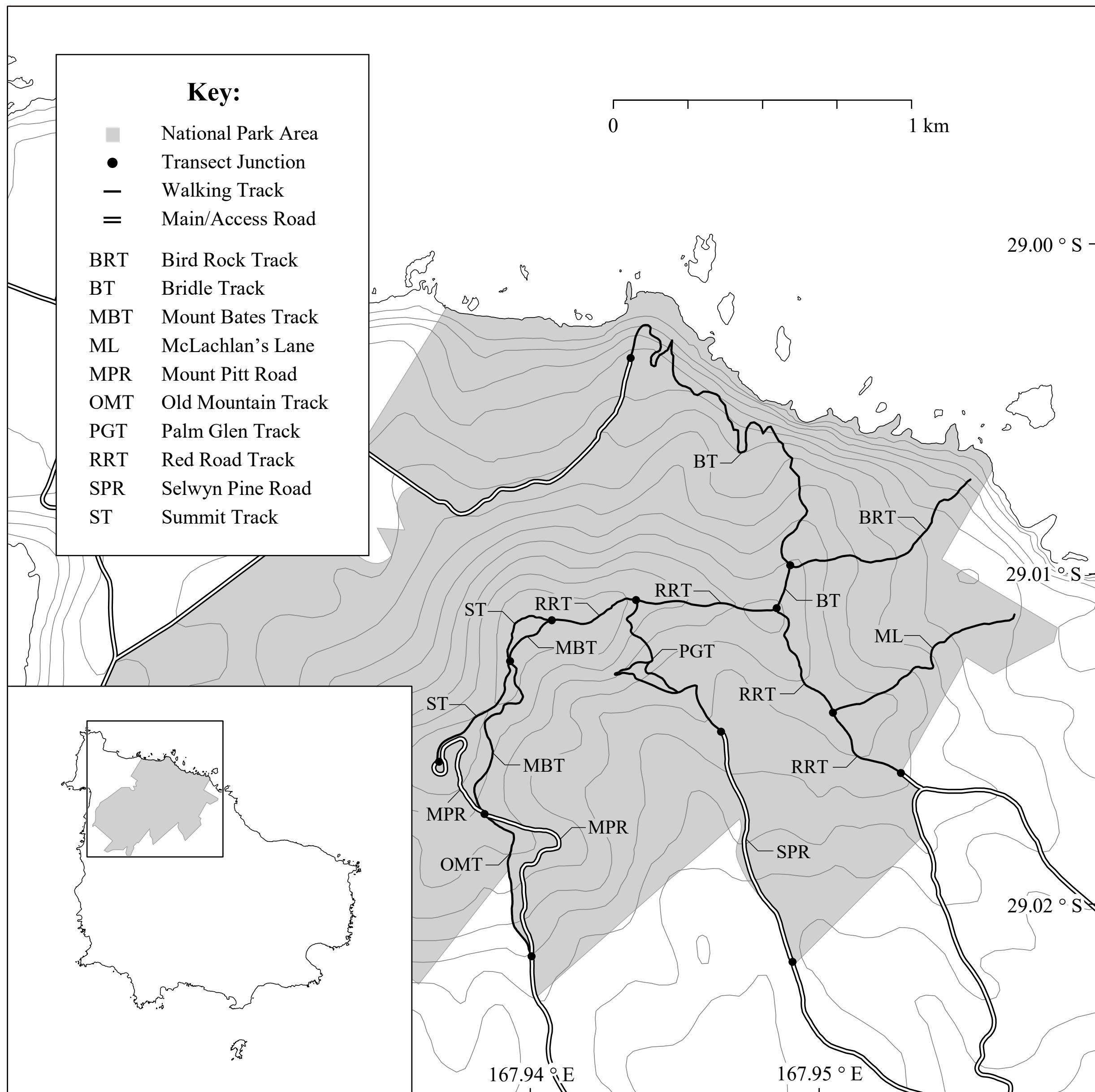

Figure 2.3: Map showing the distribution of walking tracks and roads across the Mount Pitt section of the Norfolk Island National Park, with contour lines (dark grey lines) showing the increase in elevation at 20 m intervals.

ANALYSIS

We used R version 3.3.3 (R Core Team, 2017) to examine and compare the count data collected during this research. In our preliminary analysis of the data (Appendix C), we fit generalised linear mixed models to produce posterior predictions of survey efficiency, which we then compared between the two survey methods. Each model was fitted using a Poisson error distribution. When fitting both models, we used the year and season of sampling as fixed effects variables to account for any

temporal variation in the count data. We also incorporated random effects variables to account for any variation arising from the survey points and transect lines being nested within a broader sampling space. In both models, the logarithm of time in hours was used as an offset to allow comparison between the two survey methods. The findings of this preliminary analysis were consistent with those of our final analysis (see Appendix C).

In our final analysis, we used a bootstrap resampling approach to produce many comparable, replicate data sets from the original fixed point survey and line transect survey data sets. The sample sizes in these original data sets were unbalanced between the two methods. However, our resampling approach allowed us to standardise the sample sizes between the two methods, so they could be compared with equivalence across a range of different sample sizes. We chose to resample the data obtained during the winter of 2015 because the sample sizes for each survey method during this period were relatively even compared to other combinations of season and year: $n = 73$ for fixed point surveys and $n = 105$ for line transect surveys. The replicate data sets produced were then compared in terms of estimates of the mean and the precision of estimates of the mean.

The resampling algorithm was designed to simulate count data collected during a typical research trip. The number of surveys per day was standardised to ten for both methods, whereas the number of surveys per day varied from four to 15 surveys in the original data sets; with a mean of 9 and 11 surveys conducted per day for fixed point and line transect surveys respectively. We simulated surveys for one, two, three, four, five, six, and seven days. The data was structured as a set of Tasman Parakeet counts nested within days. The simulation algorithm proceeded first by randomly selecting from the list of days without replacement and then randomly sampled with replacement the counts within each of the selected days. This process was repeated numerous times ($m = 1000000$) for each simulated day of sampling, with sample size $n =$ 10, 20, 30, 40, 50, 60, and 70 for each respective day. Let x_{ij} represent the jth count from the ith simulated sample, where $i = 1, \ldots, m$ and $j = 1, \ldots, n$. The mean of each sample was calculated as:

$$\bar{x}_i = \frac{1}{n}\sum_{j=1}^{n} x_{ij}$$

The mean and standard error of the sample means were given by:

$$\bar{\bar{x}} = \frac{1}{m}\sum_{i=1}^{m} \bar{x}_i$$

$$SE = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(\bar{x}_i - \bar{\bar{x}})^2}$$

The precision was calculated as:

$$p = SE/\bar{\bar{x}}$$

In addition to modelling survey precision, we used the replicate data sets to examine the cumulative parakeet detections obtained using each survey method. In this instance, the sum of the parakeet counts in each random sample was taken and used to calculate the mean number of cumulative detections across each data set. The means were then plotted to visualise the relative efficiency of the two survey methods. Similarly, we plotted the estimated precision of the counts to demonstrate the difference in precision between fixed point and line transect surveys. The mean number of parakeets detected per survey across each theoretical data set was also used to infer the relative efficiency of these survey methods for detecting Tasman Parakeets.

RESULTS

During the winter of 2015, a total of 88 hours was spent in the Mount Pitt section of the Norfolk Island National Park, this included 18.25 hours of fixed point surveys and 46.15 hours of line transect surveys. The duration of fixed point surveys was standardised, consisting of five minutes rest and a ten minute survey to total 15 minutes, while line transect surveys varied from five to 70 minutes. Collectively, these surveys yielded a total of 163 parakeet detections, 62% of which were visual observations. The fixed point surveys accounted for 59% of all recorded detections. The number of surveys that yielded detections varied between survey type, with 46 and 23 successful surveys for the fixed point survey method and line transect survey method respectively. This is equivalent to a 63% success rate for fixed point surveys and a success rate of 22% for the line transect surveys.

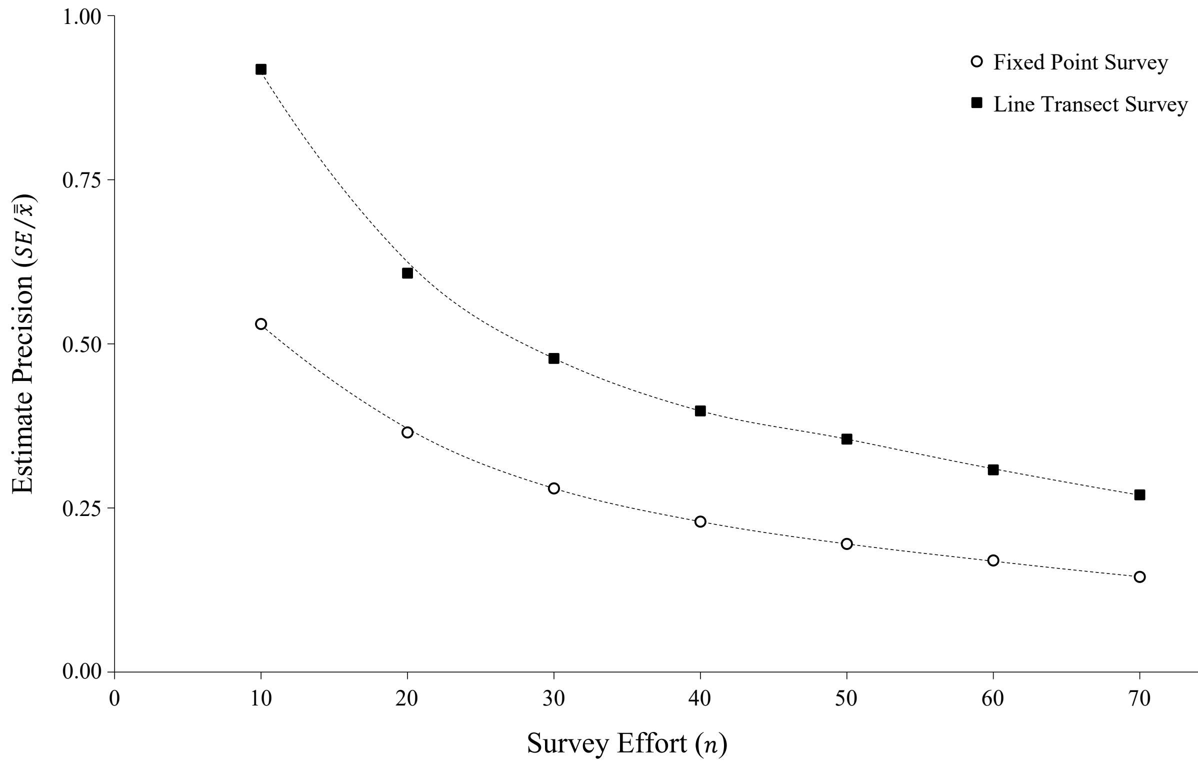

Figure 2.4: Precision of estimates obtained by two survey methods used to monitor the Tasman Parakeet (*Cyanoramphus cookii*) population in the Mount Pitt section of the Norfolk Island National Park.

Although both survey methods allowed the successful detection of Tasman Parakeets in the field, the precision of the estimates varied with survey type and survey effort (Figure 2.4). The results of the bootstrap resampling analysis indicate the line transect survey method was less precise than the fixed point survey method, with a mean estimated precision of 0.476 and 0.274 for the respective survey types. It is also evident that an increase in the survey effort improved the precision of the estimates produced by both survey types (Figure 2.4).

Following an initial sample of ten surveys, the precision of line transect surveys was equivalent to 0.918 and for fixed point surveys was 0.530. Following a further 60 surveys, the precision of estimates improved and a precision of 0.270 and 0.145 was registered for line transect surveys and fixed point surveys respectively. Despite these improvements, it is clear that the fixed point survey method produces greater precision per unit of effort, as the precision achieved following 70 line transect surveys was approximately equivalent to the precision obtained after 30 fixed point surveys.

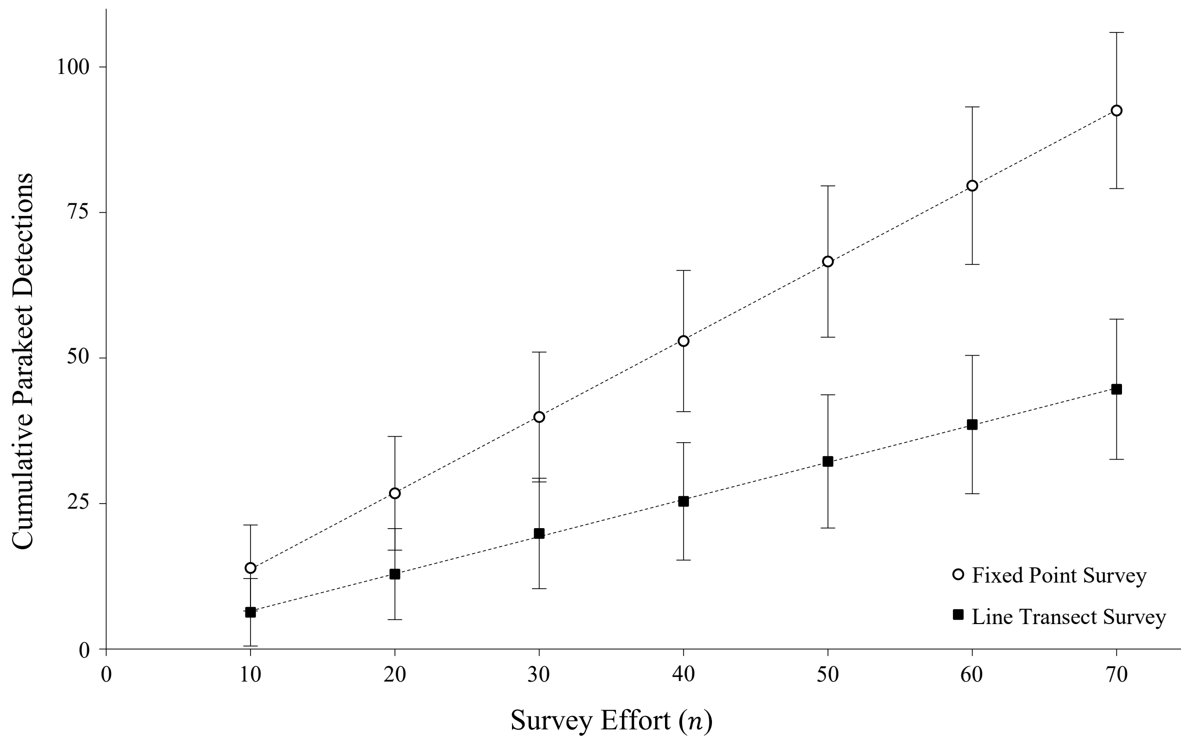

Figure 2.5: Cumulative detections obtained by two survey methods used to monitor the Tasman Parakeet (*Cyanoramphus cookii*) population in the Mount Pitt section of the Norfolk Island National Park.

In addition to generating greater estimate precision, the fixed point survey method appeared to be more efficient than the line transect survey method (Figure 2.5), obtaining a higher number of parakeet detections per unit of effort. Assuming that the number of Tasman Parakeet detections was proportional to survey effort, the fixed point survey method was estimated to produce a mean of 1.338 parakeet detections per survey (95% CI: 0.649, 2.048). In contrast, the line transect survey method only produced a mean of 0.642 parakeet detections per survey (95% CI: 0.174, 1.370). These results indicate that fixed point surveys can obtain the same number of parakeet detections as 70 line transects in as few as 34 surveys.

DISCUSSION

For monitoring the Tasman Parakeet population on Norfolk Island, we determined that fixed point surveys were the most suitable method of sampling. Our findings indicate that fixed point surveys yielded a higher number of detections per unit of effort compared to line transect surveys (Figure 2.5). This is interesting, as the fixed point survey method can result in the loss of data when birds are

detected while travelling between points (Buckland et al., 2008; Thomas et al., 2002). Despite the potential loss of data, the fixed point survey method was able to outperform the line transect method and accounted for 59% of Tasman Parakeet detections recorded in the winter of 2015. One possible explanation for the poor performance of line transect surveys on Norfolk Island is the use of paths, roads, and tracks, rather than randomly selected transect lines. In New Caledonia, Legault et al. (2012) noted that most parrot species exhibited a preference for forests and generally avoided forest edge areas. When conducting surveys, these preferences may contribute to a decreased number of detections, particularly if there is a lack of vegetation near the transect line (Legault et al., 2013).

When sampling on Norfolk Island, the fixed point surveys were found to be more precise than line transect surveys. Our results indicate that to achieve a similar level of precision to these fixed point surveys, a far larger sampling effort was required for line transect surveys (Figure 2.4). Other studies suggest that fixed point surveys can result in biased estimates (Buckland et al., 2001; Casagrande & Beissinger, 1997; Cassey, Craig, McArdle, & Barraclough, 2007). However, compared to line transect surveys, accurately recording multiple detections is considered straightforward for observers conducting fixed point surveys (Buckland et al., 2008). Furthermore, differences in the walking speed of observers may contribute to detection bias between sampling events, particularly when attempting to detect a cryptically coloured species such as the Tasman Parakeet.

In an examination of the sampling methods used to monitor the parrots of New Caledonia, Legault et al. (2013) determined that the line transect survey method was more efficient than the fixed point survey method. Their assessment involved monitoring a variety of cryptic parrot species, including the New Caledonian Parakeet (*Cyanoramphus saisseti*), a medium-sized parrot which is closely related to the Tasman Parakeet (Boon et al., 2001). Their findings provide insight into the value of line transect surveys for monitoring parrots across large areas of habitat, where scalability is an issue for fixed point surveys. However, when compared to the 4.6 km^2 area of remnant habitat that the Tasman Parakeet occupies on Norfolk Island, the areas surveyed by Legault et al. (2013) were considerably larger, ranging between 45 km^2 and 130 km^2. Due to this, the benefit of conducting rapid line transect surveys through habitat of low complexity is likely to be negligible for monitoring parrots on Norfolk Island. Additionally, the limitation of scalability is minimised on Norfolk Island,

as the area of remnant forest is relatively small and consists of a mixture of habitat types; many of which can be accessed with minimal effort.

In conclusion, we encourage the use of the fixed point survey method for monitoring the Tasman Parakeet population on Norfolk Island, as it offers greater precision and efficiency per unit of effort. By using this standardised method of sampling, future estimates of population size can be interpreted and compared with greater confidence than those obtained during the sporadic sampling conducted over the past four decades of species management. The findings of this study also give an indication of the suitability of this method for monitoring other cryptic species that occupy small areas of habitat and may be useful for other researchers investigating species with restricted distributions.

CHAPTER 3

Interannual Estimates of Density for Tasman Parakeets (*Cyanoramphus cookii*)

and Crimson Rosellas (*Platycercus elegans*) on Norfolk Island

ABSTRACT

Globally, the introduction of invasive species has contributed to the decline and extinction of numerous endemic species. These introductions are generally associated with increased competition, predation, and disease transmission, which can significantly impact threatened endemic species that have restricted distributions. To reduce the impact of these pressures and facilitate the recovery of threatened endemics, introduced species are often controlled as part of conservation management. A useful approach to quantifying the effectiveness of these management efforts is to monitor both the endemic and introduced populations. In this study, we aimed to examine whether conservation management on Norfolk Island is having a measurable effect on the recovery of the critically endangered Tasman Parakeet (*Cyanoramphus cookii*). In addition, we aimed to evaluate the effect of population control on introduced Crimson Rosellas (*Platycercus elegans*), which compete with the Tasman Parakeets. From 2014 to 2017, we conducted annual surveys of Tasman Parakeets and Crimson Rosellas in the Norfolk Island National Park using the fixed point survey method. According to our estimates, the Tasman Parakeet population increased by 126%, expanding from 194 to 438 parakeets in the 310 ha area. In comparison, the Crimson Rosella population remained stable, with a mean of 1250 individuals in the same 310 ha area, showing a maximum difference of 12% between years. These findings indicate that management is having a positive effect on the recovery of the Tasman Parakeet. However, we maintain the persistence of the Crimson Rosella population is limiting further increases in the parakeet population through competitive exclusion.

INTRODUCTION

Island ecosystems are regions of high biodiversity that are key to species conservation and wildlife research (Kier et al., 2009; Tershy, Shen, Newton, Holmes, & Croll, 2015). The species restricted to these island habitats are often vulnerable to extinction as they occur in small populations, exhibit low reproductive rates, and are either partially or entirely naïve to predatory species (Blumstein & Daniel, 2005; Spatz et al., 2017). Of the taxonomic groups, avian species are particularly at risk, with 59% of all critically endangered bird species occurring on islands (Tershy et al., 2015). The decline of these island bird species is largely attributed to predation by introduced species, which are a significant

threat to the survival of many island endemics (Blackburn et al., 2004; Doherty, Glen, Nimmo, Ritchie, & Dickman, 2016). However, the role of competitive displacement by invasive species is an increasingly recognised factor in the decline of endemic species.

On Norfolk Island, there are numerous endemic species that are threatened with extinction (Director of National Parks, 2010; Dutson, 2013). The Tasman Parakeet (*Cyanoramphus cookii*) is a critically endangered parrot which is confined to a small vegetated region in the Mount Pitt section of the Norfolk Island National Park (Hill, 2002; Taylor, 1985). The presence of introduced mammalian predators in this area has contributed to declines in the Tasman Parakeet population and is recognised as a threat to the continued survival of this endemic parrot species (Director of National Parks, 2010; Hill, 2002). To reduce predation by feral cats (*Felis catus*) and rats (*Rattus* spp.), Parks Australia established a predator control programme in the late 1980s, which involved predator trapping, poison baiting for rodents, and protection of parakeet nest sites (Hicks & Greenwood, 1989; Ortiz-Catedral et al., 2018). Following these initiatives, Innes (1995) reported increases in breeding attempts by Tasman Parakeets and subsequent increases in population size.

In 2009, the Tasman Parakeet population in the Mount Pitt section of the Norfolk Island National Park was estimated to consist of 240 individuals (Dutson, 2013). However, a deterioration of the limited nesting sites and a reduction in the intensity of predator management was connected to the population declining to between 46 and 92 parakeets by 2013 (Ortiz-Catedral, 2013; Ortiz-Catedral et al., 2018). Following this decline, predator control within the Mount Pitt section of the Norfolk Island National Park was intensified and numerous nest sites were modified to prevent incursions by mammalian predators (Ortiz-Catedral et al., 2018). The extent of population recovery associated with these management strategies has yet to be quantified, though the Tasman Parakeet population may have experienced a limited expansion due to competitive displacement by introduced avian species.

In an early assessment of the birds of Norfolk Island, Smithers and Disney (1969) identified the introduced Crimson Rosella (*Platycercus elegans*) as an aggressive competitor of the Tasman Parakeet. Similarly to other cavity-nesting species, the Crimson Rosella experiences high levels of competition for nesting hollows within their natural range in Australia (Krebs, 1998). On Norfolk Island, the introduced Crimson Rosella population competes strongly with the Tasman Parakeet

population for access to the limited nesting cavities available within the forests of the national park (Director of National Parks, 2010; Hicks & Greenwood, 1989; Hill, 2002). In addition to displacing parakeets from their territories (Hicks & Preece, 1991), the Crimson Rosellas have been observed entering active Tasman Parakeet nests (Figure 3.1), and regularly attempt to nest in hollows that management staff have modified for parakeets (Hill, 2002; Ortiz-Catedral, 2013).

Figure 3.1: Photograph of a Crimson Rosella (*Platycercus elegans*) attempting to enter an active Tasman Parakeet (*Cyanoramphus cookii*) nest. Photo credit: Luis Ortiz-Catedral

In the Mount Pitt section of the Norfolk Island National Park, the Crimson Rosella is reported to consume a range of dietary items (Forshaw, 1989; Higgins, 1999; Wakelin, 1968); some of which represent significant components in the diet of the Tasman Parakeet (Waldmann, 2016). Although the overlap in the dietary profile of these species has yet to be formally quantified, evidence suggests that there is at least minor competition between the Crimson Rosellas and Tasman Parakeets foraging within the forests of Norfolk Island. During an investigation into the foraging ecology of Tasman Parakeets, Waldmann (2016) observed an aggressive interaction between a Crimson Rosella and a Tasman Parakeet feeding on African Olive (*Olea europea cuspidata*), which resulted in the parakeet falling from the tree. Similarly, Hicks and Greenwood (1989) report Crimson Rosellas harassing Tasman Parakeets as they forage.

On Norfolk Island, the Crimson Rosella population is considered a significant threat to the recovery of the Tasman Parakeet due to nest displacement, competition for foraging resources, and the potential transmission of disease (Hill, 2002; Taylor, 1985; Yorkston, 1995). In recognition of this threat, Parks Australia has attempted to control the Crimson Rosella population through the removal of active nests and the culling of rosellas occupying the Mount Pitt section of the Norfolk Island National Park (Director of National Parks, 2010; Hicks & Greenwood, 1989; Hill, 2002). Since 2014, approximately 1020 Crimson Rosellas have been culled within the boundaries of the national park (Parks Australia, personal communication, 2018). However, the effect of this control is currently unknown, as the only density estimates for the Crimson Rosella population are from 2009, which found approximately 1200 individuals occupied the Mount Pitt section of the Norfolk Island National Park (Dutson, 2013).

The aim of our investigation was to assess the recovery of the critically endangered Tasman Parakeet population and examine the effectiveness of continued management in the presence of an introduced competitor. Additionally, we aimed to evaluate whether population control was having a measurable effect on the introduced Crimson Rosella population. We produced interannual estimates of population size for both species using the fixed point survey method, offering insight into the value of a standardised approach to long-term monitoring and providing information that can be used to refine management of the Tasman Parakeet and Crimson Rosella populations.

METHODS

STUDY SITE

We conducted our research throughout the Mount Pitt section of the Norfolk Island National Park, Norfolk Island (29.0408° S, 167.9547° E). This site (Figure 3.2) represents 4.6 km^2 of the 6.5 km^2 national park area and consists of a variety of habitat types, including the last remnants of the native subtropical rainforest found on Norfolk Island (Director of National Parks, 2008). Currently, this area of mixed habitat is the only location where the critically endangered Tasman Parakeet occurs naturally (Hill, 2002). However, the area also supports a population of the Crimson Rosella (Hill, 2002; Taylor, 1985).

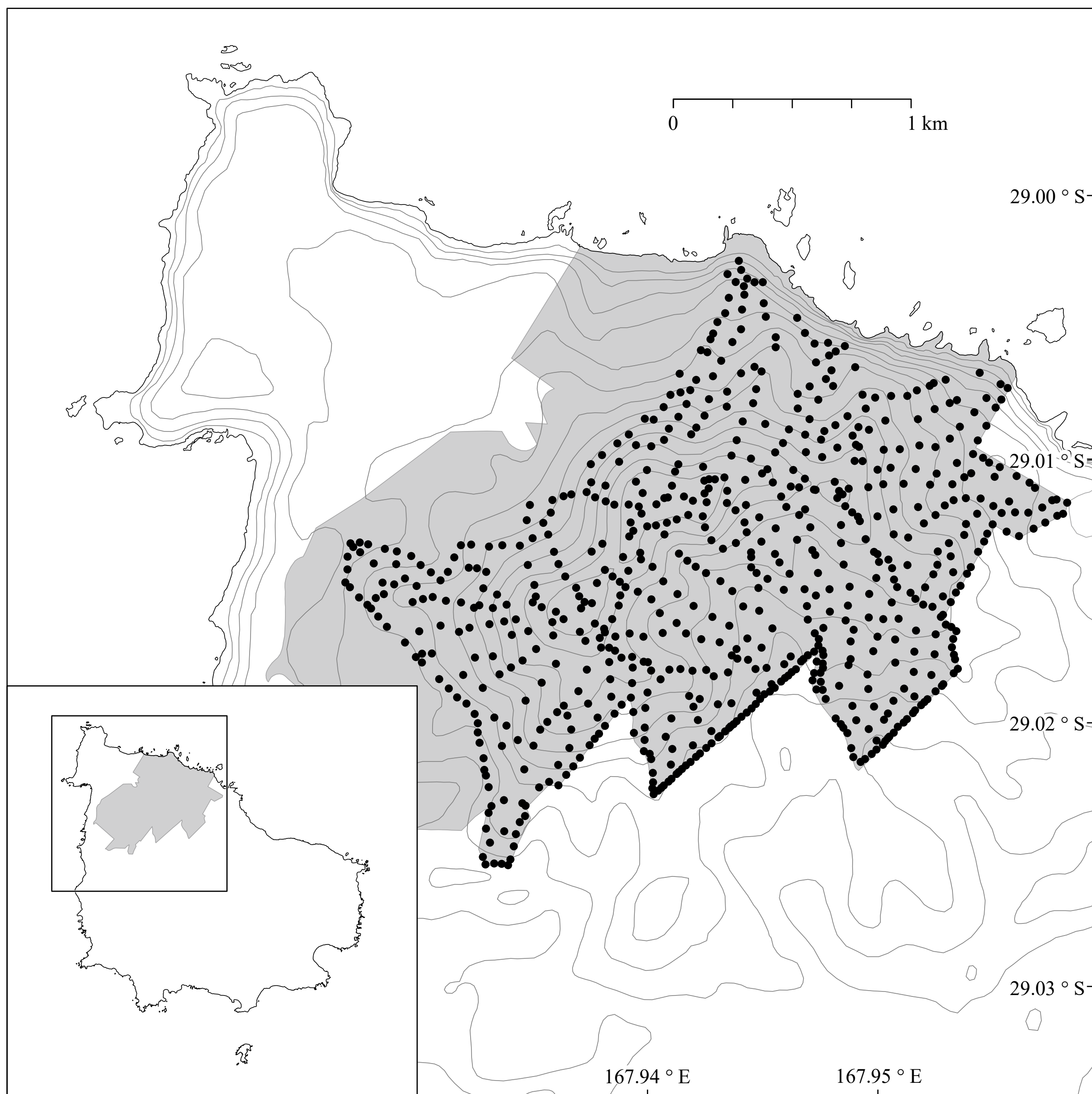

Figure 3.2: Map showing the distribution of rodent bait stations (black circles) across the Mount Pitt section of the Norfolk Island National Park (shaded grey), with contour lines (dark grey lines) showing the increase in elevation at 20 m intervals.

DATA COLLECTION

From 2014 to 2017, we performed annual surveys of the parrot populations in the Mount Pitt section of the Norfolk Island National Park. These surveys were conducted using the fixed point survey method and were completed during the spring of each year. We used the grid of predator bait stations (Figure 3.2) distributed throughout the Mount Pitt section of the national park as the source of our survey points. Since each point was selected at random from the collection of bait station coordinates,

the number of surveys we completed each day was determined by the habitat, terrain, and distance separating each survey location. At each survey point, we recorded both acoustic and visual detections during a ten minute observation period, using the distinctive vocalisation patterns and morphology to distinguish between our two focal species.

To enhance the likelihood of detecting birds near each survey point, we sampled during the peak activity period for local avifauna, performing surveys between 6:30 am and 12:00 pm each day. During this period, we only completed surveys at points with conditions measuring from zero to two on the Beaufort scale in an attempt to maintain fair conditions. Survey points adhering to our assessment criteria were approached quietly to reduce disturbance to nearby birds and to maximise the probability of detection. Prior to each survey, five minutes of rest was observed to further minimise disturbance. Additionally, we had experienced individuals conduct the surveys to ensure that each species was correctly identified.

Whenever a Tasman Parakeet or Crimson Rosella was positively identified near the survey point, we recorded the species, number of birds, detection type (acoustic or visual), and the perpendicular distance from the observer to the initial bird location. A visual detection was any individual, pair, or group of birds observed near the point, while acoustic detections consisted of calls heard nearby. When measuring perpendicular distance for visual detections, we used a laser rangefinder (Bushnell Pro Sport 450) to precisely gauge the distance between the bird and the observer. When we recorded distances for acoustic detections, we accounted for the difficulties in perceiving distance by categorising the detections into groups: very near, 0 – 25 m; near, 26 – 50 m; far, 51 – 75 m; and very far, 76 – 100 m.

ANALYSIS

We analysed the fixed point survey data using Distance version 7.1 release 1 (Thomas et al., 2010). During this analysis, we used the conventional distance sampling engine to model the data and generate estimates of population density. To produce these estimates, we used different combinations of the default key functions (uniform, half-normal, hazard-rate, or negative exponential) and series expansions (cosine, simple polynomial, or Hermite polynomial) offered by the software, evaluating

the fit of each model using the Akaike Information Criterion (AIC). The suitability of each model was then assessed based on visual examination of the detection probability histograms, the goodness of fit tests, and coefficient of variation. Population size was estimated for both species by extrapolating the estimated density to the 310 ha area covered during surveys in the Mount Pitt Section of the Norfolk Island National Park. The estimates produced are presented as the mean density $\pm$ standard error, with the 95% confidence interval presented in parentheses.

RESULTS

TASMAN PARAKEET

A total of 56 visual detections of Tasman Parakeets were recorded during the fixed point surveys conducted in the Mount Pitt Section of the Norfolk Island National Park. Of these visual detections, 80% were recorded within 25 m of the survey point, with only 7% of parakeets detected further than 50 m away. The small number of parakeet detections obtained each year limited the precision of the density estimates (Table 3.1), with a relatively high coefficient of variation calculated for each estimate.

Table 3.1: Annual density estimates of the Tasman Parakeet population from fixed point surveys conducted in the Mount Pitt section of the Norfolk Island National Park.

Year	D	SE	LCI	UCI	CV	n	EDR
2014	0.625	0.388	0.168	2.332	0.620	8	23
2015	0.816	0.625	0.209	3.179	0.766	8	23
2016	1.258	0.452	0.624	2.537	0.360	21	32
2017	1.413	0.541	0.676	2.955	0.383	16	24

D estimated density (birds/ha), SE standard error (birds/ha), LCI lower bound of the 95% confidence interval (birds/ha), UCI upper bound of the 95% confidence interval (birds/ha), CV coefficient of variation, n number of visual detections, EDR effective detection radius (m).

The model using a uniform key function with a simple polynomial series expansion ranked second best of the models used to analyse the 2014 data set, with the top model generating unreasonably high density estimates from the small number of observations. The selected model produced a reasonable goodness of fit on visual inspection (Figure 3.3) and gave a realistic estimate of the parakeet density. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.434,\ p > 0.05$), indicating a good fit to the data. This model included flying birds (an additional three observations) and offered a more conservative density estimate than the model excluding flying birds, which showed a 21% higher estimate of parakeet density and a 33% higher coefficient of variation. Based on the density estimates generated (Table 3.1), the size of the Tasman Parakeet population in 2014 was 194 $\pm$ 120 parakeets (95% CI: 52, 723).

Of the models used to analyse the 2015 data set, the model using a uniform key function with a cosine series expansion was ranked the best of the models fitted. All models used to analyse this data set produced a poor fit (Figure 3.3) due to the small number of observations, 75% of which were clustered at a single distance. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.750,\ p < 0.05$), corroborating the poor fit produced for this clustered data set. The selected model excluded flying birds (one less observation) to produce a more conservative density estimate, showing an 11% decrease in the density estimate relative to the model including flying birds, though there was a slight decrease in estimate precision. From the density estimates produced (Table 3.1), the population of Tasman Parakeets in 2015 consisted of 253 $\pm$ 194 individuals (95% CI: 65, 986).

A half-normal key function with a simple polynomial series expansion was used to model the 2016 data. This model had the fourth lowest AIC score of the models used to analyse the data and was selected in favour of higher ranked models which produced unreasonable density estimates, each with a relatively high coefficient of variation. The selected model fit the data reasonably well on visual inspection (Figure 3.3), producing a realistic estimate of parakeet density, and a relatively low coefficient of variation. The difference between the observed and expected distribution of distances,

though smaller than other models fitted, was significant (Kolmogorov-Smirnov test: $D_n = 0.367$, $p < 0.05$), indicating the data deviated from the fitted model slightly. This model excluded flying birds (two less observations), generating a 12% lower density estimate than the less conservative model which included flying birds. The density estimates generated by the selected model (Table 3.1) indicate the 2016 Tasman Parakeet population comprised of 390 $\pm$ 140 birds (95% CI: 193, 787).

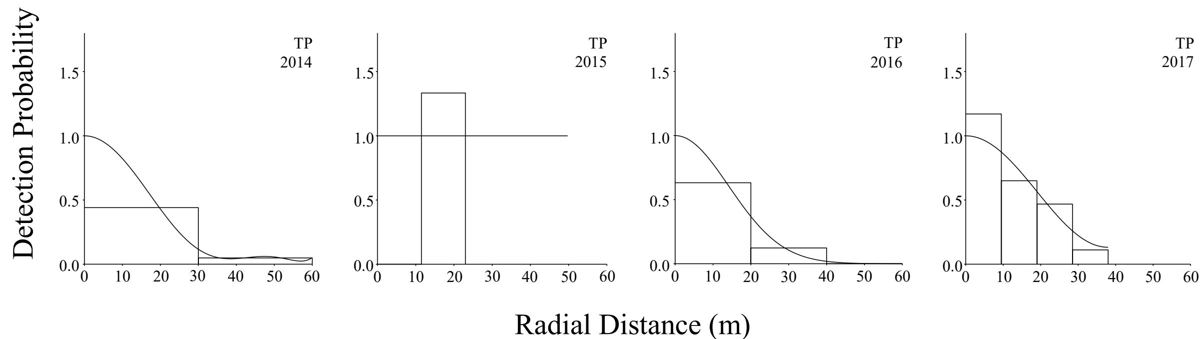

Figure 3.3: Detection functions for Tasman Parakeets (*Cyanoramphus cookii*) obtained during annual fixed point surveys conducted in the Mount Pitt Section of the Norfolk Island National Park.

The data recorded in 2017 was modelled using a uniform key function with a cosine series expansion. This model was ranked third among the models used to analyse the data, returning no error warnings, and reasonable density estimates relative to the models with lower AIC scores. The selected model included flying birds (an additional two observations) and presented an excellent fit to the data on visual inspection (Figure 3.3), with a lower coefficient of variation than the model that omitted flying birds. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.148$, $p > 0.05$), indicating the data followed the distribution of the selected model. The size of the 2017 Tasman Parakeet population based on these estimates (Table 3.1) was 438 $\pm$ 168 parakeets (95% CI: 210, 916).

CRIMSON ROSELLA

A total of 218 visual detections of Crimson Rosellas were recorded during fixed point surveys in the Mount Pitt Section of the Norfolk Island National Park. Of the detections, 83% occurred within 25 m of the point, while 0.9% occurred further than 50 m. The large number of detections, relative to those of Tasman Parakeets, resulted in a greater estimate precision for the Crimson Rosellas (Table 3.2).

Table 3.2: Annual density estimates of the Crimson Rosella population from fixed point surveys conducted in the Mount Pitt section of the Norfolk Island National Park.

Year	D	SE	LCI	UCI	CV	n	EDR
2014	4.204	1.009	2.629	6.722	0.240	42	20
2015	4.200	1.417	2.183	8.081	0.337	24	18
2016	3.720	1.194	1.995	6.937	0.321	31	23
2017	4.011	0.998	2.468	6.518	0.249	55	26

D estimated density (birds/ha), SE standard error (birds/ha), LCI lower bound of the 95% confidence interval (birds/ha), UCI upper bound of the 95% confidence interval (birds/ha), CV coefficient of variation, n number of visual detections, EDR effective detection radius.

The data recorded in 2014 was modelled using a half-normal key function and a Hermite polynomial series expansion. This model ranked eighth among the models used to analyse the data, providing a reasonable fit on visual inspection (Figure 3.4), sensible density estimates, and a relatively low coefficient of variation compared to the higher ranked models. However, the largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.301, p < 0.05$), indicating that the data deviated from the distribution of the selected model. This model included flying individuals (an additional seven observations), producing more conservative estimates, with a 43% lower coefficient of variation than the model which excluded flying birds. These estimates of Crimson Rosella density (Table 3.2) indicate the 2014 population comprised of 1303 $\pm$ 313 birds (95% CI: 815, 2084).

A uniform key function with a simple polynomial series expansion was used to analyse the data collected in 2015. This model ranked the best of the models used to analyse the data, providing a good visual fit (Figure 3.4), reasonable estimates of Crimson Rosella density, and a low coefficient of variation relative to the other models used to analyse the data. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.164, p > 0.05$), indicating the data followed the distribution of the selected model. This model

excluded flying birds (seven less observations) from the analysis, producing a density estimate 39% lower than the model including flying birds, with a marginal loss of precision. Based on the density estimates (Table 3.2), the 2015 Crimson Rosella population size was 1302 $\pm$ 439 individuals (95% CI: 677, 2505).

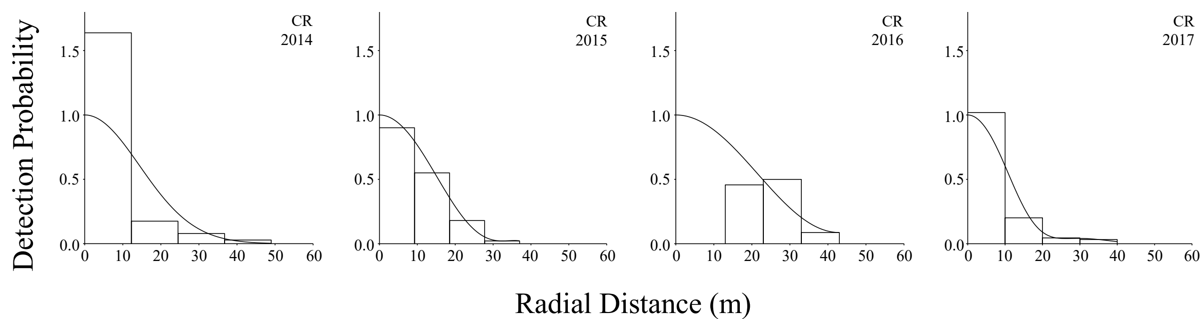

Figure 3.4: Detection functions for Crimson Rosellas (*Platycercus elegans*) obtained during annual fixed point surveys conducted in the Mount Pitt Section of the Norfolk Island National Park.

Of the models used to analyse the 2016 data, the model using a uniform key function with a cosine series expansion ranked third best. This model was selected in favour of higher ranked models, which generated unreasonable density estimates and large coefficient of variation values. The selected model excluded the large number observations within 13 m of the survey point, this truncation allowed the remaining data to be reliably modelled, producing a reasonable visual fit to the data (Figure 3.4), sensible estimates, and a low coefficient of variation. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.184,\ p > 0.05$), indicating a good fit. Due to the truncation of nearby observations flying individuals were excluded from both analyses. The 2016 density estimates (Table 3.2) produced by the selected model indicate a population size of 1153 $\pm$ 370 Crimson Rosellas (95% CI: 618, 2150).

The model using a uniform key function and simple polynomial series expansion was ranked third among the models used to analyse the 2017 data. This model was selected in favour of the higher ranked models, which produced extremely high density estimates and similarly high coefficient of variation values. The selected model offered a sensible estimate of density, with a reasonable fit to the data on visual inspection (Figure 3.4), and a relatively low coefficient of variation. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-

Smirnov test: $D_n = 0.405, p < 0.05$), indicating the data deviated from the fitted model. This model included flying birds (an additional 16 observations) generating more conservative estimates than the model excluding flying birds which had 18% higher density estimates and produced a 15% higher coefficient of variation. In addition to including flying individuals, the five most distant observations were excluded to allow more reliable modelling of the data. From the density estimates (Table 3.2), the 2017 population was calculated at 1243 ± 309 rosellas (95% CI: 765, 2021).

POPULATION TRENDS

The results indicate an overall increase in population size for the Tasman Parakeet population present within the Mount Pitt section of the Norfolk Island National Park (Figure 3.5). Between 2014 and 2017 the population is estimated to have increased by 126%, expanding from 194 to 438 parakeets. In contrast, the Crimson Rosella population within the national park area has remained relatively stable, though it appears to have declined slightly (Figure 3.5). During the four year sampling period, the mean population size was estimated at 1250 individuals, with a maximum difference of 12% between sampling years. Throughout the sampling period, the Crimson Rosella population was larger than the Tasman Parakeet population, with a minimum difference of 96% recorded in 2017.

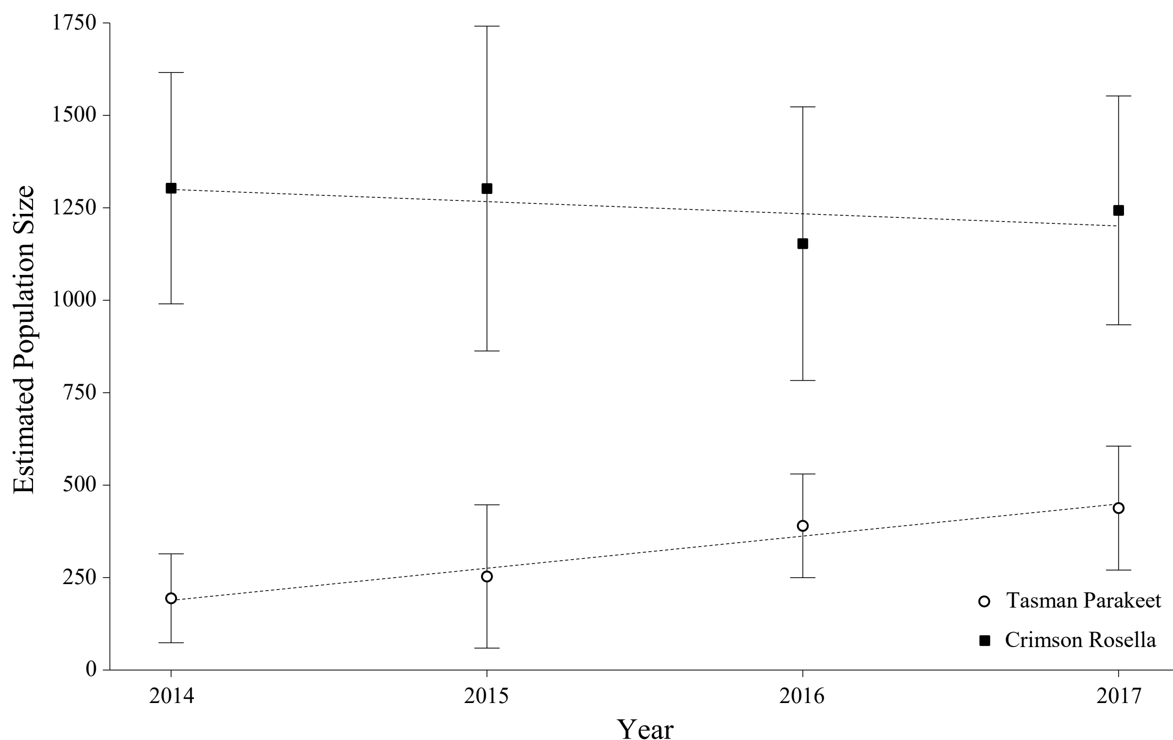

Figure 3.5: Interannual population trends for Tasman Parakeets (*Cyanoramphus cookii*) and Crimson Rosellas (*Platycercus elegans*) within the Mount Pitt section of the Norfolk Island National Park.

DISCUSSION

In 2013, the Tasman Parakeet population on Norfolk Island was estimated to consist of as few as 46 individuals (Ortiz-Catedral, 2013). This prompted an immediate conservation intervention, with management staff intensifying predator control and provisioning nest sites to prevent further declines in population size (Ortiz-Catedral et al., 2018). The results presented here provide evidence of the positive effect that this type of targeted management can have on the recovery of threatened species. The density estimates generated between 2014 and 2017 (Table 3.1) show a gradual increase in the number of Tasman Parakeets present within the national park area, with clear evidence of population recovery during the four year sampling period (Figure 3.5). This is partially attributed to the active management of nesting sites, which as indicated by Ortiz-Catedral et al. (2018) resulted in the nesting success of Tasman Parakeets increasing to an average of 70% by 2016. Despite these increases, we suggest the continued presence of the Crimson Rosella population is limiting further expansion of the Tasman Parakeet population present within the national park.

The Crimson Rosella population in the Mount Pitt section of the Norfolk Island National Park has remained relatively stable despite efforts to reduce their numbers. Estimates produced by Dutson (2013) indicate that the Crimson Rosella population present in this area consisted of 1200 individuals in 2009. The density estimates generated between 2014 and 2017 were slightly higher (Table 3.2), though it appears there was little fluctuation in the number of Crimson Rosellas during the four years of sampling (Figure 3.5). Collectively, these results indicate that although population control has limited further expansion of the introduced Crimson Rosella population, there has been little reduction in the number of individuals present within the Mount Pitt region.

One explanation for the persistence of Crimson Rosellas within this area is the high nesting productivity exhibited by this species. A field study conducted in the Black Mountain Reserve in Canberra documented a mean fledging success of 75.3% for Crimson Rosellas despite intense competition for nest sites (Krebs, 1998). Although the nesting productivity of Crimson Rosellas has not been formally quantified for the Norfolk Island population, at least three active nests containing five to seven chicks have been destroyed since 2013 (L. Ortiz-Catedral, personal communication,

2018). In addition to exhibiting high nesting productivity in adverse conditions, Crimson Rosellas reach sexual maturity after approximately 15 months (Juniper & Parr, 1998). Therefore, the efficacy of sporadic population control is limited, as the high nesting success and relatively rapid maturation of individuals allows the population to recover from partial reductions in the breeding population.

A further factor contributing to the persistence of the Mount Pitt population of Crimson Rosellas is the presence of a population outside the national park area. In addition to occupying the regenerating bush and native rainforest within the park, Crimson Rosellas also occur throughout the other habitats of Norfolk Island including farmland, orchards, forestry plantations, and household gardens (Forshaw, 2002; Higgins, 1999). The individuals, pairs, and groups that occur in these areas are currently subject to less control than the population within the park and collectively represent a source population that could supplement the Mount Pitt rosella population. Considering that removing Crimson Rosellas from within the Mount Pitt region reduces intraspecific competition for resources, a gradual influx of individuals from outside of the park has likely maintained the actively managed population within the park, thus limiting the effects of population control.

Although the current population control efforts have restricted the expansion of the Crimson Rosella population, the continued presence of this competitor is likely to limit further recovery of the Tasman Parakeet population. In the 4.6 km^2 area of the national park, the introduced Crimson Rosella occurs in far greater densities than the Tasman Parakeet, with a ratio of 2.8:1.0 recorded in the spring of 2017. Given the abundance of Crimson Rosellas, increased competition for nesting and feeding resources is likely to limit the productivity of the Tasman Parakeet population. Furthermore, Crimson Rosellas exhibit flexibility in nest site selection (Higgins, 1999; Wakelin, 1968), which allows them to utilise a variety of nest sites, in addition to displacing parakeets from the cavities within the Mount Pitt area. As a solution to these ongoing competitive pressures, Dutson (2013) suggested the complete eradication of Crimson Rosellas from Norfolk Island may benefit the Tasman Parakeet population.

Given that the Crimson Rosella population remains a significant threat to the recovery of the Tasman Parakeet, the practicality of a broad-scale approach to competitor management should be investigated. This type of approach has been successfully implemented to control the proliferation of introduced populations on other islands. One example is the targeted control of introduced Ring-

necked Parakeets (*Psittacula krameri*) on the island of Mahé in the Seychelles archipelago. The extensive competitor eradication programme on Mahé has resulted in a 90% reduction in the invasive parakeet population (Seychelles Islands Foundation, 2014) and significantly reduced the threat to the endemic Seychelles Black Parrot (*Coracopsis barklyi*) population. To implement a similar programme for the eradication of Crimson Rosellas on Norfolk Island would require a significant investment of time, planning, and resources; though it is achievable considering what was accomplished on the island of Mahé, which represents a far larger management area at 157.3 km^2.

When interpreting the results of our study, it is important to consider the relative densities and biological characteristics of the focal species. Similarly to the population assessment conducted by Dutson (2013), the low density of the Tasman Parakeet population and cryptic colouration of the species contributed to small sample sizes (Table 3.1), which may have limited the accuracy of our estimates. To ensure the accuracy of future estimates and determine whether the Tasman Parakeet population is continuing to respond positively to management, we advocate regular population monitoring within the Mount Pitt section of the park. Similarly, we encourage regular monitoring of the Crimson Rosella population to ensure that control efforts are preventing the expansion of the population. To further limit competition between Crimson Rosellas and Tasman Parakeets, we also suggest that efforts are made to intensify the management of rosellas within the national park by establishing a regular schedule for the removal of invasive competitors.

Our research demonstrates that intensive predator management and provisioning of nest sites has contributed to the recovery of the Tasman Parakeet population on Norfolk Island. During the four year sampling period, the parakeet population increased by 126%, which is indicative of the positive effects of ongoing conservation management. In contrast, we found that the attempts to reduce the Crimson Rosella population have been largely unsuccessful, though management has limited the expansion of the population within the Mount Pitt section of the national park. To ensure the recovery of the critically endangered Tasman Parakeet, we encourage continued monitoring of population size and sustained conservation management within the national park.

CHAPTER 4

Estimating the Density of Malherbe's Parakeet (*Cyanoramphus malherbi*)

Populations Established on Offshore Islands

ABSTRACT

In New Zealand, the translocation of threatened species to predator-free areas has proven an effective tool for conservation. However, for most species, there is a lack of published literature following the release and establishment of these translocated populations. Determining the size of these populations is essential to assessing management requirements, though generating estimates can be constrained by the accessibility of sites, particularly for species released on remote islands. In this study, we aimed to produce estimates of population size for three translocated populations of the critically endangered Malherbe's Parakeet (*Cyanoramphus malherbi*), after a mean establishment period of 6.3 years. Using fixed point surveys, we assessed the populations established on Maud Island, Blumine Island, and Chalky Island. On Blumine Island, our estimates indicate there are 202 $\pm$ 67 parakeets distributed through the mature forest of the 3.37 km^2 island. In comparison, the Chalky Island population was estimated at 84 $\pm$ 58 parakeets in an area of 5.14 km^2. The Maud Island population was unable to be evaluated, as no parakeets were detected. Our findings indicate that Blumine Island sustains the largest offshore population of Malherbe's Parakeet. We suggest this is due to differences in habitat composition between islands. Additionally, we propose the endemic Yellow-crowned Parakeet (*Cyanoramphus auriceps*) is limiting the expansion of the Malherbe's Parakeet population on Chalky Island through competition for resources. To assess the long-term trends of these populations and identify if further management is required, we advocate regular monitoring at each island site.

INTRODUCTION

In a recent review of the parrot species which inhabit the South Pacific region, Olah et al. (2018) identified Malherbe's Parakeet (*Cyanoramphus malherbi*) as one of nine critically endangered parrots requiring further conservation research. Historically, this species was considered a variant of the Yellow-crowned Parakeet (*Cyanoramphus auriceps*), due to the morphological similarities between the two species (Nixon, 1981; Taylor, 1998). However, research examining bill morphology (Young & Kearvell, 2001), assortative pairing (Kearvell & Steeves, 2015), vocal patterns (Kearvell & Briskie, 2003), comparative ecology (Kearvell et al., 2002), and molecular systematics (Boon et al., 2000; Rawlence et al., 2015) has provided sufficient evidence for the classification of Malherbe's Parakeet

as a phylogenetically distinct species (Kearvell et al., 2003). Despite their recent recognition as a distinct species, the historical uncertainty surrounding the taxonomy of Malherbe's Parakeet has hindered conservation efforts and likely contributed to the unchecked decline of this species at mainland sites (Kearvell et al., 2003).

Currently restricted to three valleys in the South Canterbury region, the remnant mainland population of Malherbe's Parakeet was recently estimated to total between 150 and 300 individuals (Kearvell, 2016; Kearvell & Farley, 2016). The decline of this species at mainland sites has been attributed to a combination of habitat loss, competition for resources, and predation by introduced mammalian predators (Andrews et al., 2013; Kearvell, 2016). Of these threats, predation by mustelids (*Mustela* spp.) and rats (*Rattus* spp.) is particularly significant (Higgins, 1999; Kearvell, 2016; O'Donnell, 1996), as Malherbe's Parakeets appear to frequent the ground and low-level vegetation of mainland sites, increasing their susceptibility to predation (Forshaw, 2017; Kearvell et al., 2002). To reduce predation pressure and facilitate the recovery of the Malherbe's Parakeet population, the New Zealand Department of Conservation has coordinated the translocation of captive-bred parakeets to four predator-free offshore islands: Mayor Island, Maud Island, Blumine Island, and Chalky Island (Hansford, 2017; Miskelly & Powlesland, 2013).

Table 4.1: Summary of the Malherbe's Parakeet translocations undertaken between 2005 and 2013 by the New Zealand Department of Conservation and Isaac Wildlife Trust.

Translocation Site	Translocation Period	Number of Individuals Released
Mayor Island (37.2862° S, 176.2514° E)	2009 – 2013	95
Maud Island (41.0261° S, 173.8871° E)	2007 – 2009	68
Blumine Island (41.1748° S, 174.2411° E)	2011 – 2012	61
Chalky Island (46.0487° S, 166.5272° E)	2005 – 2007	45

The information presented in this table was provided by the following sources: Elliott and Suggate (2007); Forshaw (2017); Gaze and Cash (2008); Miskelly and Powlesland (2013); Ortiz-Catedral et al. (2012).

Figure 4.1: Photograph showing the cryptic plumage of a Malherbe's Parakeet (*Cyanoramphus malherbi*) perched among the foliage of a Beech tree (*Nothofagus* spp.). Photo credit: David Boyle

Of the Malherbe's Parakeet populations established by translocation, only the Maud Island population has been formally assessed. Using a mark resighting approach, Ortiz-Catedral et al. (2012) estimated that the population had increased from the 68 individuals released, to between 96 and 126 individuals by early 2009. Aside from this assessment, there has been little subsequent monitoring of these translocated populations since the initial release of parakeets on each island (Forshaw, 2017). The only additional data available for these four populations is the total number of parakeets released at each site (Table 4.1). Due to the lack of published data for the remaining offshore sites, determining population trends is a difficult task and continued management of the Malherbe's Parakeet population is limited because the extent of population recovery is unable to be accurately determined.

In a recovery plan developed by the Department of Conservation, accurate determination of population size was listed as a key priority for the recovery and continued management of the Malherbe's Parakeet population (Grant & Kearvell, 2003). However, due to the cryptic colouration of their plumage (Figure 4.1) and seasonal fluctuations in numbers, monitoring of *Cyanoramphus* parakeet populations is a difficult process (Elliott, 1998; Forshaw, 2017; Rawlence, 2009). In the past,

a variety of approaches have been used for estimating the density of New Zealand parakeet species, including mist net catch rates, line transect surveys, five-minute bird counts, mark resighting, and fixed point surveys (Elliott, 1998; Graham & Veitch, 2002; Greene, 2000; Ortiz-Catedral et al., 2012). However, to compare populations of parrots that occur across a large geographic range, a structured approach to surveying is crucial to improving the confidence with which the data can be compared and interpreted (Legault et al., 2013), particularly when examining multiple populations of a single species. Therefore, using a robust and repeatable method of surveying that produces precise count estimates is critical to current and future monitoring of the managed populations of Malherbe's Parakeets (Grant & Kearvell, 2003).

In this study, we aimed to produce estimates of population size for the Malherbe's Parakeets established on Maud Island, Blumine Island, and Chalky Island after a mean establishment period of 6.3 years. Using a standardised fixed point survey method, we were able to produce estimates for two populations of Malherbe's Parakeets, while the other was unable to be calculated due to an absence of detections during the survey period. In addition, we examined the applicability and performance of the fixed point survey method across each island site by generating estimates of other species including Bellbirds (*Anthornis melanura*), Silvereyes (*Zosterops lateralis*), Tui (*Prosthemadera novaeseelandiae*), Yellow-crowned Parakeets, *(Cyanoramphus auriceps*), and Yellowheads (*Mohoua ochrocephala*). Our research offers a critical insight into the status of each translocated population of Malherbe's Parakeet and represents the first published estimates of the Malherbe's Parakeet populations established on Blumine Island and Chalky Island.

METHODS

STUDY SITES

Our study sites (Figure 4.2) consisted of three offshore island locations in the South Island of New Zealand: Maud Island (41.0261° S, 173.8871° E), Blumine Island (41.1748° S, 174.2411° E), and Chalky Island (46.0487° S, 166.5272° E). All three of these islands have been used as translocation release sites for the Malherbe's Parakeet (Miskelly & Powlesland, 2013). During our investigation, we visited each offshore site to conduct fixed point surveys of the Malherbe's Parakeet populations

and local bird communities. The surveys conducted at these sites occurred at least four years after the last release of captive-bred individuals, with a mean establishment period of 6.3 years for the Malherbe's Parakeets translocated across the three islands.

Maud Island is a 3.09 km^2 predator-free reserve located in the Pelorus Sound of Marlborough, South Island, New Zealand. The island has been the release site for 68 captive-bred Malherbe's Parakeets, which were translocated between 2007 and 2009 (Ortiz-Catedral et al., 2012). When conducting surveys on Maud Island, we were required to exclude 0.1 km^2 of bush, to minimise disturbance to the Maud Island Frog (*Leiopelma pakeka*) population, which is classified as nationally vulnerable (Newman et al., 2013). In addition, we excluded an area of 0.2 km^2 on the western peninsula, where the Department of Conservation had implemented an eradication scheme targeting the invasive Radiata Pine (*Pinus radiata*) forest. This area of habitat was excluded from sampling, due to the hazards presented by unstable ground and deteriorating trees.

Blumine Island is a 3.37 km^2 reserve located in the Queen Charlotte Sound of Marlborough, South Island, New Zealand. Open to the public, this predator-free island is covered by a variety of hardwood and podocarp forest, with remnant stands of mature beech (*Nothofagus* spp.) forest on the southern side of the island (Conner & Conner, 1981; Conner et al., 1981; Department of Conservation, 2013a). From 2011 to 2012, a total of 61 captive-bred Malherbe's Parakeets were translocated to the island (Forshaw, 2017). When conducting surveys on Blumine Island, we were not required to exclude any area from our sampling, though care was taken to avoid hazardous areas.

Chalky Island is a 5.14 km^2 island located at the entrance to the Chalky Inlet in southern Fiordland, South Island, New Zealand. After the successful eradication of predators in 1999, Chalky Island became an offshore sanctuary and has been the release site for a variety of native species (Edge et al., 2011; Elliott et al., 2010; Miskelly & Powlesland, 2013). Between 2005 and 2007, a total of 45 captive-bred Malherbe's Parakeets were released to the island (Forshaw, 2017) and towards the end of this period, a population of Yellow-crowned Parakeets is also reported to have dispersed to Chalky Island from the South Island (Department of Conservation, 2017). The vegetation on the island is a mixture of native scrub and forest (Johnson, 1997). Similarly to Blumine Island, we were not required to exclude any area of Chalky Island from sampling, though hazardous areas were avoided.

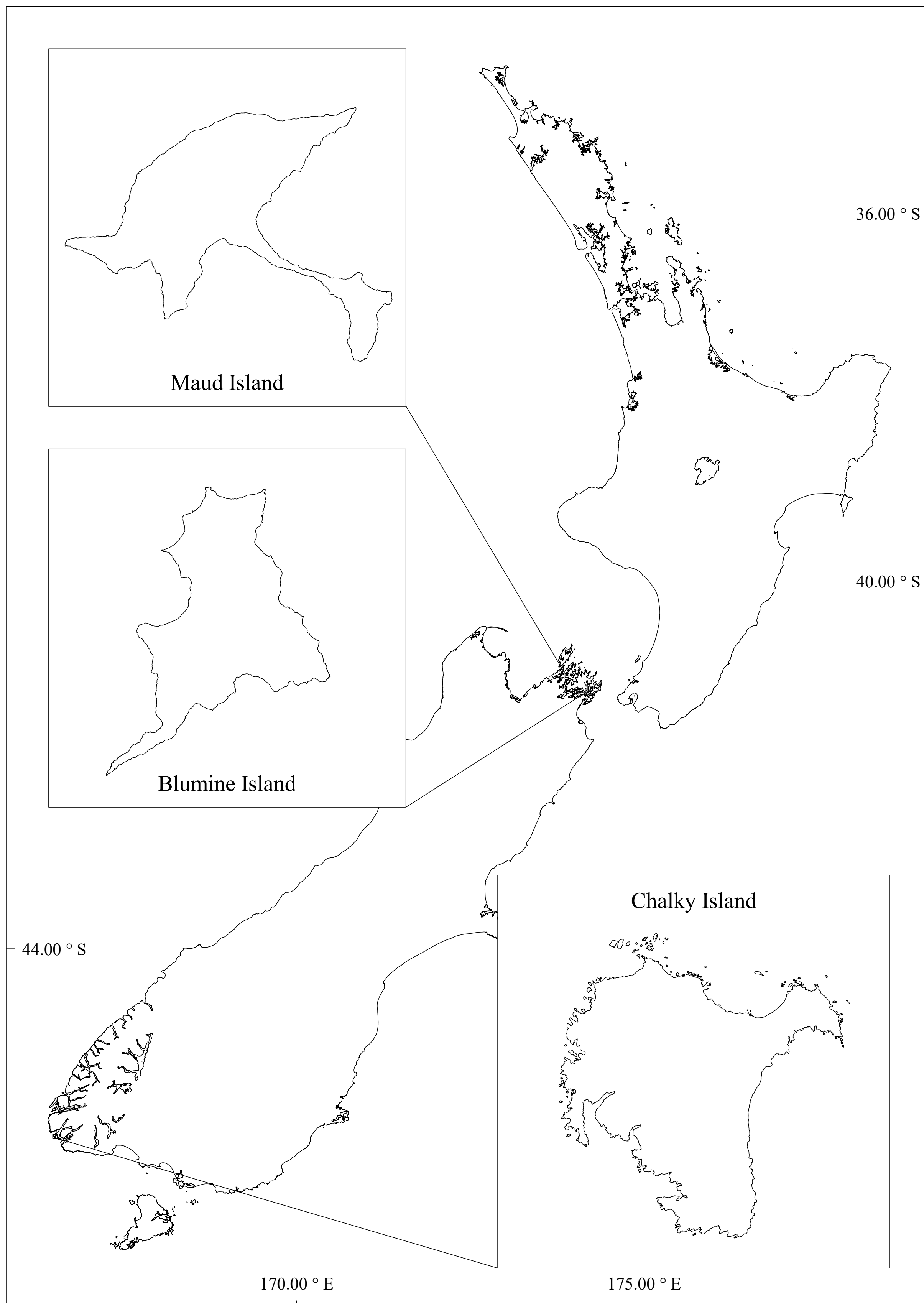

Figure 4.2: Map of New Zealand showing the location of the Malherbe's Parakeet release sites visited: Maud Island (top left), Blumine Island (middle left), and Chalky Island (bottom right).

DATA COLLECTION

Between 2015 and 2016, we conducted fixed point surveys of Malherbe’s Parakeets and other bird species at each research site. The purpose of this sampling was to provide data to calculate density estimates for the Malherbe’s Parakeets and bird communities of each site. In April 2015, a total of 27 fixed point surveys were carried out by two observers on Chalky Island. Another pair of observers conducted a total of 34 fixed point surveys on Maud Island in April 2016. A further two observers collectively completed 47 fixed point surveys on Blumine Island in August 2016.

The survey points we visited were randomly selected from a collection of GPS coordinates generated for each research site. The number of survey points covered each day was limited by the terrain and distance separating points, with hazardous areas excluded from sampling. At each viable survey point, we spent ten minutes sampling, attempting to detect parakeets and other endemic bird species. Any detection was categorised as either visual or acoustic, with distinctive song patterns and morphological characteristics used to identify different species. To minimise the risk of incorrect identifications, we engaged experienced observers to assist with data collection.

As we conducted each survey, efforts were made to maximise the likelihood of detecting parakeets and birds near the survey point. We collected data over a 5.5 hour period each day (7:00 am – 12:30 pm), allowing observations during the peak activity period for *Cyanoramphus* species; as established by Legault et al. (2012). Sampling was only conducted at survey points registering zero to two on the Beaufort scale to maintain fair conditions. All survey points that did not meet these requirements were abandoned. The viable survey points were approached quietly to minimise disturbance to any birds present, with a five minute rest period observed prior to sampling.

When we encountered Malherbe’s Parakeets or endemic birds near the survey points, the following information was recorded: species, size of the flock, detection type (acoustic or visual), and the perpendicular distance from the initial bird location to the observer. For visual detections, we used a laser rangefinder (Bushnell Pro Sport 450) to accurately measure the distance from the bird to the observer. To reconcile the difficulties of accurately estimating distances for acoustic detections, we categorised these records into four groups: very near, 0 – 25 m; near, 26 – 50 m; far, 51 – 75 m; and very far, 76 – 100 m.

ANALYSIS

We used Distance version 7.1 release 1 (Thomas et al., 2010) to analyse the fixed point survey data collected. When analysing each data set, we generated estimates of population density using the conventional distance sampling engine. After using various combinations of the key functions (uniform, half-normal, hazard-rate, or negative exponential) and series expansions (cosine, simple polynomial, or Hermite polynomial), the Akaike Information Criterion (AIC) was used to evaluate each model and its suitability for producing estimates. Following this, we selected the most appropriate model by examining the detection probability histograms, the goodness of fit tests, and coefficient of variation values for the models with the lowest AIC scores. Population size was estimated for each species using the estimated density across the area of each island: 309 ha, 337 ha, and 514 ha for Maud Island, Blumine Island, and Chalky Island respectively. These population estimates are presented as the mean density ± standard error, with the 95% confidence interval in parentheses.

RESULTS

MAUD ISLAND

On Maud Island, a total of 8.5 hours was spent conducting fixed point surveys and a further 13.5 hours was spent in the field. The fixed point surveys yielded a total of 280 bird detections, 67% of which consisted of visual records (Table 4.2). Acoustic records were excluded from the analysis, as their inclusion provided little improvement to the estimates generated. Similarly, observations of flying birds were excluded to produce a better fit by the selected models. Of the visual records, 74% of birds were detected within 20 m of the survey point and only 2% were observed further than 50 m away. During the time spent on Maud Island, no Malherbe’s Parakeets were detected. Accordingly, the density of the Malherbe’s Parakeet population was unable to be estimated. Similarly, no estimates were produced for Yellow-crowned Parakeets or Yellowheads, as neither species occurs on Maud Island.

Table 4.2: Density estimates of the Malherbe's Parakeet, Bellbird, Silvereye, and Tui populations from fixed point surveys conducted on Maud Island

Species	D	SE	LCI	UCI	CV	n	EDR
Malherbe's Parakeet (*Cyanoramphus malherbi*)	–	–	–	–	–	–	–
Bellbird (*Anthornis melanura*)	3.000	0.541	2.086	4.314	0.180	60	22
Silvereye (*Zosterops lateralis*)	3.680	1.234	1.908	7.097	0.335	92	24
Tui (*Prosthemadera novaeseelandiae*)	1.089	0.371	0.562	2.109	0.340	36	28

D density (birds/ha), SE standard error (birds/ha), LCI lower bound of the 95% confidence interval (birds/ha), UCI upper bound of the 95% confidence interval (birds/ha), CV coefficient of variation, n number of visual detections, EDR effective detection radius (m).

A model fitted with a uniform key function and simple polynomial series expansion was selected to generate estimates of Bellbird population size on Maud Island. This model produced a reasonable goodness of fit on visual inspection (Figure 4.3) and had the lowest coefficient of variation of the models fitted. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.372$, $p < 0.05$), indicating some nonconformity between the observed data and the fitted distribution. Based on the density estimates produced (Table 4.2), the Bellbird population on Maud Island consisted of 927 $\pm$ 167 individuals (95% CI: 645, 1333).

Of the models fitted to the Silvereye data, the model with a uniform key function and simple polynomial series expansion was selected to generate estimates of the Maud Island population. This model returned a low coefficient of variation and fit the data reasonably well (Figure 4.3). The largest difference between the observed and expected distribution of distances, though smaller than other models, was significant (Kolmogorov-Smirnov test: $D_n = 0.326$, $p < 0.05$), indicating some deviation from the distribution of the selected model. The density estimates generated by the selected model (Table 4.2) indicate the Maud Island population of Silvereyes comprised of 1137 $\pm$ 381 birds (95% CI: 590, 2193).

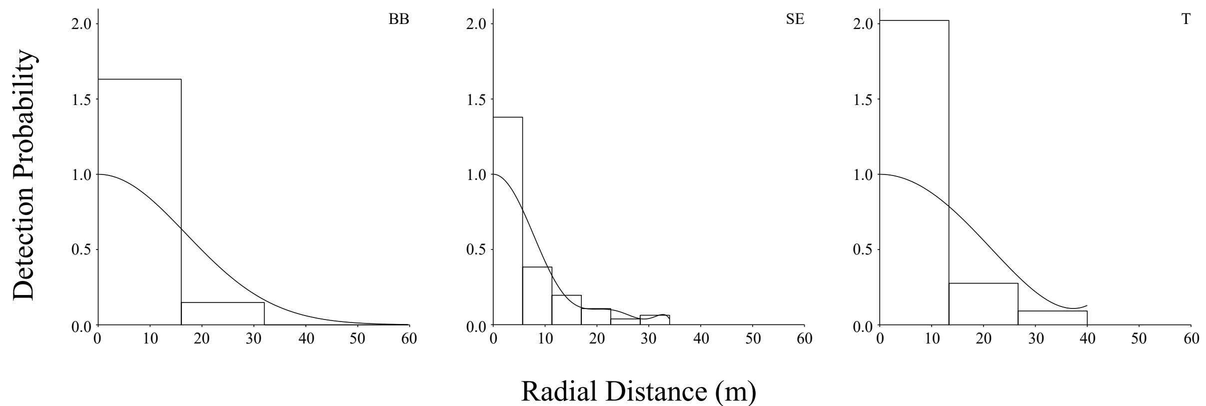

Figure 4.3: Detection functions for Bellbirds (*Anthornis melanura*), Silvereyes (*Zosterops lateralis*), and Tui (*Prosthemadera novaeseelandiae*) obtained during fixed point surveys conducted on Maud Island.

The data for the Maud Island population of Tui was fitted with a uniform key function and simple polynomial series expansion to produce density estimates. This model, though providing an average visual fit to the data (Figure 4.3), had a relatively low coefficient of variation and generated sensible estimates of population size. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.459, p < 0.05$), which is an indication that the data deviated from the fitted distribution. The size of the Tui population on Maud Island, based on the density estimates produced (Table 4.2), was 337 ± 115 individuals (95% CI: 174, 652).

BLUMINE ISLAND

On Blumine Island, a total of 11.75 hours was spent conducting fixed point surveys and a further 10.25 hours was spent in the field. During surveys, a total of 306 birds were detected, with visual records accounting for 69% of the detections (Table 4.3). The final analyses included 17 records of flying birds and excluded acoustic records, improving the fit produced by the selected models and producing conservative estimates of density. Of the detections used in the analysis, 91% were within 15 m of the observer and only 3% of observations were further than 20 m away. Density estimates were unable to be produced for Yellow-crowned Parakeets because although the species occurs in the northern regions of the South Island, there is no population present on Blumine Island.

Table 4.3: Density estimates of the Malherbe's Parakeet, Bellbird, Silvereye, Tui, and Yellowhead populations from fixed point surveys conducted on Blumine Island.

Species	D	SE	LCI	UCI	CV	n	EDR
Malherbe's Parakeet (*Cyanoramphus malherbi*)	0.599	0.200	0.311	1.152	0.334	27	32
Bellbird (*Anthornis melanura*)	4.696	0.534	3.739	5.898	0.114	107	23
Silvereye (*Zosterops lateralis*)	3.536	1.202	1.831	6.830	0.340	44	17
Tui (*Prosthemadera novaeseelandiae*)	1.849	0.575	1.003	3.406	0.311	23	17
Yellowhead (*Mohoua ochrocephala*)	1.419	0.920	0.431	4.673	0.648	9	12

D density (birds/ha), SE standard error (birds/ha), LCI lower bound of the 95% confidence interval (birds/ha), UCI upper bound of the 95% confidence interval (birds/ha), CV coefficient of variation, n number of visual detections, EDR effective detection radius (m).

The data for Malherbe's Parakeets on Blumine Island was fitted using a uniform key function and Hermite polynomial series expansion. This model produced a good visual fit to the data (Figure 4.4) and had the lowest coefficient of variation of the models fitted. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.650$, $p < 0.05$), indicating some deviation from the fitted distribution. The population of Malherbe's Parakeets on Blumine Island, based on the density estimates generated by the fitted model (Table 4.3), comprised of 202 ± 67 individuals (95% CI: 105, 388).

A model fitted using a uniform key function and Hermite polynomial series expansion was selected to estimate the density of Bellbirds on Blumine Island. Of the models fitted, this model returned the lowest coefficient of variation, generating reasonable estimates of density, and fitting the data reasonably well on visual inspection (Figure 4.4). The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.572$, $p < 0.05$), indicating that the observed data deviated slightly from the selected model. The density estimates generated by the fitted model (Table 4.3), indicate that the Blumine Island population of Bellbirds consisted of 1583 ± 180 individuals (95% CI: 1260, 1988).

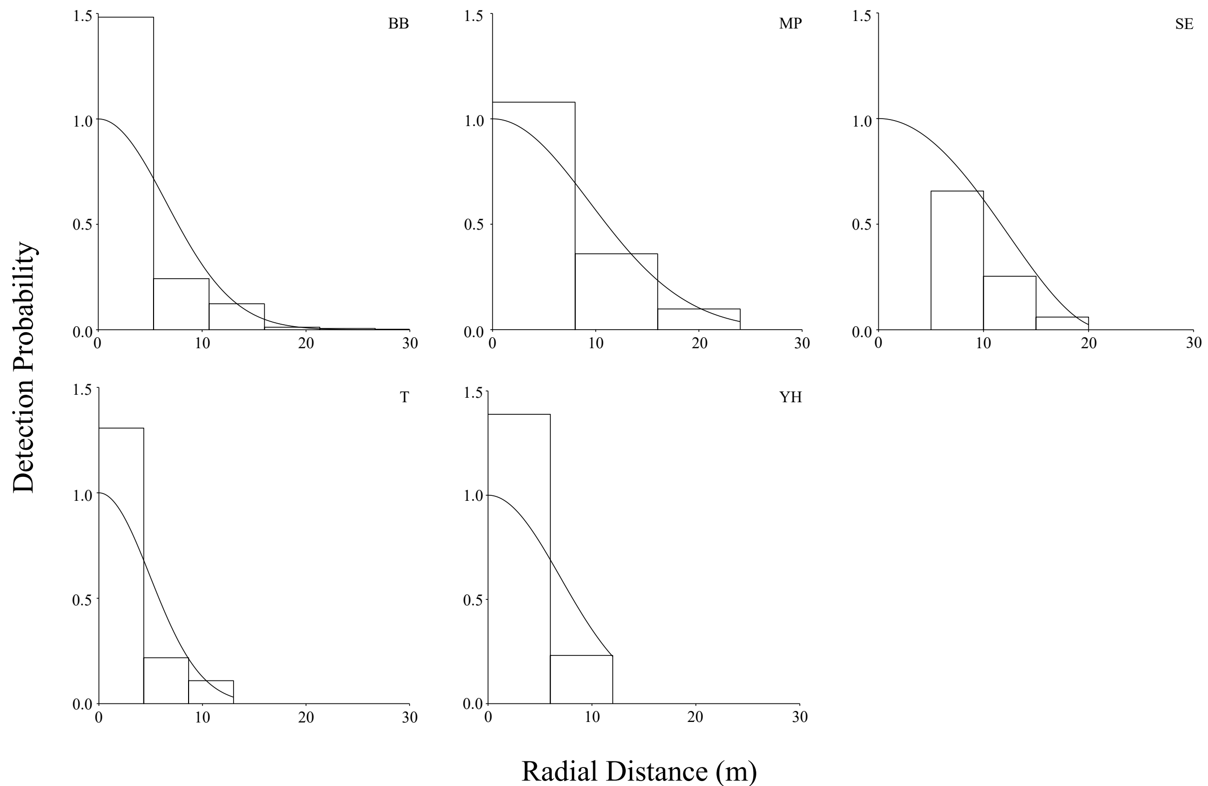

Figure 4.4: Detection functions for Bellbirds (*Anthornis melanura*), Malherbe's Parakeets (*Cyanoramphus malherbi*), Silvereyes (*Zosterops lateralis*), Tui (*Prosthemadera novaeseelandiae*), and Yellowheads (*Mohoua ochrocephala*) obtained during fixed point surveys conducted on Blumine Island.

Of the models fitted to the Silvereye data, the model with a uniform key function and Hermite polynomial series expansion was selected to produce density estimates of the Blumine Island population. Providing a good visual fit to the data (Figure 4.4), this model had a relatively low coefficient of variation compared to the other models fitted and generated reasonable estimates of density. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.449, p < 0.05$), indicating some nonconformity between the data and the fitted distribution. Based on the density estimates produced by the selected model (Table 4.3), the Silvereye population on Blumine Island comprised of 1192 ± 405 birds (95% CI: 617, 2302).

To generate density estimates for the Tui population on Blumine Island, a model fitted with a uniform key function and Hermite polynomial series expansion was selected. This model provided a reasonable goodness of fit on visual inspection (Figure 4.4) and generated a relatively low coefficient of variation. The largest difference between the observed and expected distribution of distances was

significant (Kolmogorov-Smirnov test: $D_n = 0.609$, $p < 0.05$), indicating some deviation of data from the distribution of the fitted model. Based on the density estimates (Table 4.3), the population of Tui on Blumine Island comprised of 623 $\pm$ 194 individuals (95% CI: 338, 1148).

A model fitted using the uniform key function with a simple polynomial series expansion was selected to estimate the density of Yellowheads on Blumine Island. The fit appeared reasonable on visual inspection (Figure 4.4), producing a sensible estimate of density, and returning the lowest coefficient of variation of the models fitted. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.556$, $p < 0.05$), which is an indication that there was some deviation between the observed data and the fitted distribution. From the density estimates produced (Table 4.3), the Yellowhead population on Blumine Island comprised of 478 $\pm$ 310 birds (95% CI: 145, 1575).

CHALKY ISLAND

On Chalky Island, a total of 6.75 hours was spent conducting fixed point surveys and a further 9.75 hours was spent in the field. A total of 200 birds were detected during the fixed point surveys, of these detections 28% were visual records. During the analysis, the nine observations of flying birds were excluded to improve model fitting. The acoustic records from Chalky Island were unable to be fitted as estimates of distance were not recorded. The detections largely consisted of nearby observations, where 77% of visual records were within 10 m and only 6% were further than 15 m away.

A composite model, fitted using a uniform key function and cosine series expansion, was selected to model the density of both Malherbe's Parakeets and Yellow-crowned Parakeets. Once post-stratified, this model provided sensible density estimates for the two species, despite the small sample size. In a visual examination of the detection function fitted to the Malherbe's Parakeet data, the fit appeared reasonable (Figure 4.5). Additionally, the coefficient of variation generated by this post-stratified model was the lowest of all models fitted. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.585$, $p > 0.05$), indicating the data followed the distribution. Based on the density estimates (Table 4.4), this population of Malherbe's Parakeet, consisted of 84 $\pm$ 58 individuals (95% CI: 23, 303).

Table 4.4 Density estimates of the Malherbe's Parakeet, Yellow-crowned Parakeet, Bellbird, Silvereye, Tui, and Yellowhead populations from fixed point surveys conducted on Chalky Island.

Species	D	SE	LCI	UCI	CV	n	EDR
Malherbe's Parakeet (*Cyanoramphus malherbi*)	0.163	0.113	0.045	0.590	0.693	2	17
Bellbird (*Anthornis melanura*)	3.048	2.281	0.723	12.860	0.748	9	8
Silvereye (*Zosterops lateralis*)	1.175	0.815	0.324	4.261	0.693	2	20
Tui (*Prosthemadera novaeseelandiae*)	1.102	0.809	0.286	4.247	0.734	3	8
Yellow-crowned Parakeet (*Cyanoramphus auriceps*)	0.244	0.179	0.063	0.940	0.734	3	17
Yellowhead (*Mohoua ochrocephala*)	2.571	1.286	0.973	6.793	0.500	28	16

D density (birds/ha), SE standard error (birds/ha), LCI lower bound of the 95% confidence interval (birds/ha), UCI upper bound of the 95% confidence interval (birds/ha), CV coefficient of variation, n number of visual detections, EDR effective detection radius (m).

To generate estimates of Bellbird density on Chalky Island, a model fitted with a negative exponential key function and simple polynomial series expansion was selected. This model provided a good fit to the data on visual inspection (Figure 4.5), had a relatively low coefficient of variation, and provided a conservative estimate of population density. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.131$, $p > 0.05$), indicating a good fit to the data. Based on the density estimates provided (Table 4.4), the Bellbird population comprised of 1567 ± 1172 birds (95% CI: 371, 6610).

A model fitted using a hazard-rate key function and cosine series expansion was selected to generate estimates of density for the Chalky Island population of Silvereye. In addition to producing the lowest coefficient of variation of the fitted models, the goodness of fit for this model appeared reasonable (Figure 4.5), and produced realistic estimates of density. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.500$, $p > 0.05$), indicating the data fitted the selected distribution. Based on the density estimates (Table 4.4), the Silvereye population consisted of 604 ± 419 birds (95% CI: 167, 2190).

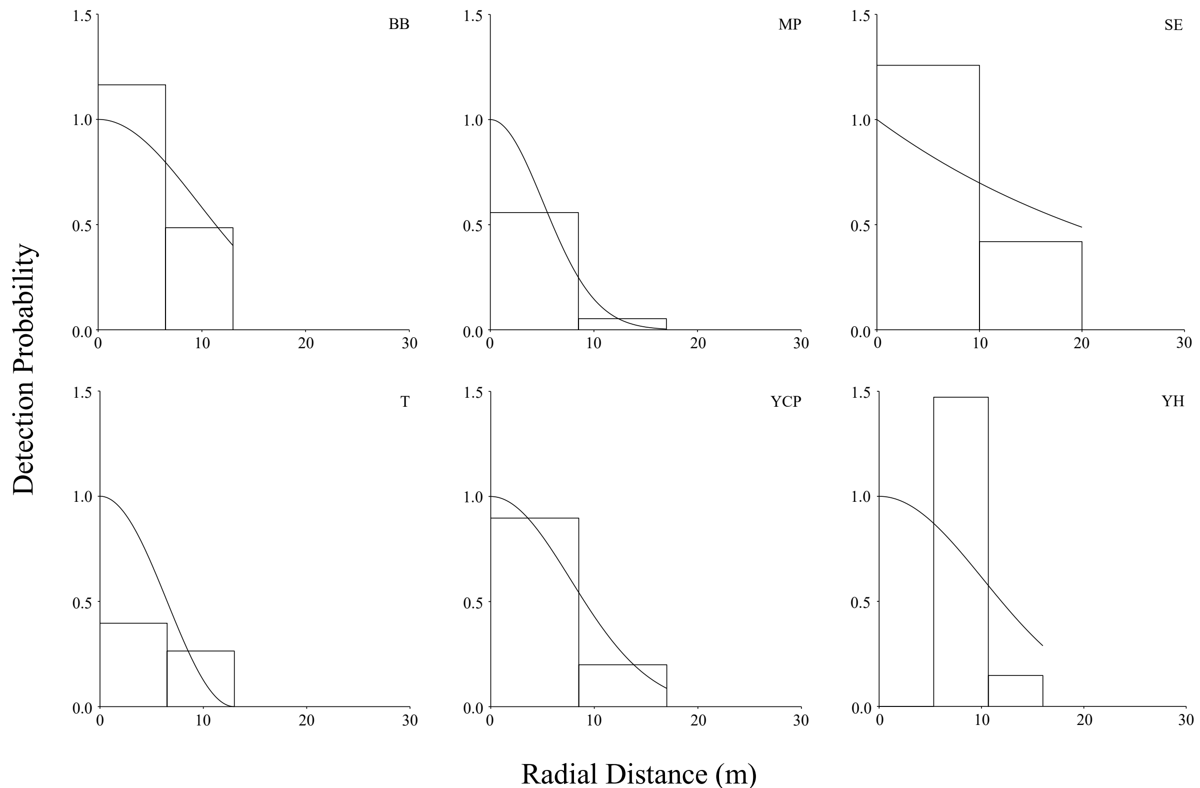

Figure 4.5: Detection functions for Bellbirds (*Anthornis melanura*), Malherbe's Parakeets (*Cyanoramphus malherbi*), Silvereyes (*Zosterops lateralis*), Tui (*Prosthemadera novaeseelandiae*), Yellow-crowned Parakeets, (*Cyanoramphus auriceps*), and Yellowheads (*Mohoua ochrocephala*) obtained during fixed point surveys conducted on Chalky Island.

Of the models fitted to the Chalky Island Tui data, the uniform key function and cosine series expansion was selected to produce estimates of density. The goodness of fit on visual inspection appeared reasonable (Figure 4.5) and the model provided the lowest coefficient of variation of all models fitted. The largest difference between the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.667,\ p > 0.05$), indicating the distribution of the selected model provided a good fit. The density estimates produced (Table 4.4) indicate that the Tui population on Chalky Island comprised of 566 $\pm$ 416 individuals (95% CI: 147, 2183).

The Yellow-crowned Parakeet data was fitted using a composite model with a uniform key function and cosine series expansion. This composite model was selected to generate estimates of both the Malherbe's Parakeet and Yellow-crowned Parakeet populations on Chalky Island. After post-stratification, the model produced a good visual fit to the data (Figure 4.5), despite the small sample sizes. Additionally, the model returned a relatively low coefficient of variation and produced conservative estimates of density compared to the other models fitted. The largest difference between

the observed and expected distribution of distances was not significant (Kolmogorov-Smirnov test: $D_n = 0.445, p > 0.05$), indicating the data followed the distribution of the selected model. From the density estimates (Table 4.4), the Chalky Island population of Yellow-crowned Parakeets was calculated to consist of 125 ± 92 individuals (95% CI: 33, 483).

A model using a uniform key function and cosine series expansion was selected to fit the Yellowhead data and generate estimates for the Chalky Island population. Due to the clustering of observations, all models provided an average fit on visual examination (Figure 4.5). However, the selected model returned the lowest coefficient of variation and produced the most sensible estimates of the models fitted. The largest difference between the observed and expected distribution of distances was significant (Kolmogorov-Smirnov test: $D_n = 0.467, p < 0.05$), indicating the data deviated from the distribution of the selected model. Based on the density estimates (Table 4.4), the Chalky Island population of Yellowhead comprised of 1322 ± 661 individuals (95% CI: 500, 3491).

DISCUSSION

Attempting to detect and monitor low-density populations of the cryptically coloured *Cyanoramphus* parakeets is a recognised challenge for conservation management in New Zealand and across the wider South Pacific region (Elliott, 1998; Hicks & Greenwood, 1989; Legault et al., 2013; Rawlence, 2009). Examples include the Tasman Parakeet (*Cyanoramphus cookii*) and the New Caledonian Parakeet (*Cyanoramphus saisseti*), both of which have been the subject of survey-based studies (see Chapter 2, Chapter 3, and Legault, 2012).

On Maud Island, Malherbe's Parakeets were not detected during the 8.5 hours of surveys conducted by experienced observers, nor during a further 13.5 hours spent in the field. These findings indicate that the species either occurs in extremely low densities or is no longer present on the island. The absence of detections during our fixed point surveys is interesting in the context of the conservation and recovery of Malherbe's Parakeet, as following their initial translocation, the population on Maud Island had increased; with Ortiz-Catedral et al. (2012) estimating a maximum population size of 126 parakeets following mark resighting surveys conducted in 2009.

Establishing the reason for the decline and disappearance of Malherbe's Parakeet from Maud Island is difficult. However, the surveys completed in 2016 indicate the population no longer occurs in the relatively high densities reported by Ortiz-Catedral et al. (2012). One explanation for this decline is the loss of key nesting habitat. The area of invasive Radiata Pine forest and mixed shrub, which had been utilised as the preferred nesting habitat of the parakeet population (Ortiz-Catedral, Kearvell, et al., 2009), has recently been targeted as part of efforts to restore the island, resulting in a severe degradation and loss of habitat on the western peninsula (Figure 4.6). Although the remaining habitat (Figure 4.7) consists largely of regenerating scrub and native broadleaf forest (Ortiz-Catedral & Brunton, 2009b; Ortiz-Catedral, Kearvell, et al., 2009), the availability of suitable nesting cavities has likely been diminished.

Figure 4.6: Photograph showing the extent of Radiata Pine (*Pinus radiata*) forest loss and habitat deterioration on the western peninsula of Maud Island. Photo credit: Michael Skirrow

Evidence from studies examining the nesting behaviour of mainland and offshore populations of Red-crowned Parakeets (*Cyanoramphus novaezelandiae*) indicate that breeding pairs regularly select nest sites used in previous nesting attempts (Greene, 2003; Higgins, 1999; Taylor, 1985). When nest failure occurs in these preferred cavities, the breeding pair will often seek an alternative site for subsequent nesting attempts (Higgins, 1999). This pattern of nesting may also be a characteristic behaviour exhibited by other *Cyanoramphus* parakeet species (Elliott et al., 1996b; Greene, 2003;

Taylor, 1985) and could explain the absence of Malherbe's Parakeets on Maud Island. Provided Malherbe's Parakeets exhibit a preference for reusing nest sites, the deterioration or loss of cavities on the western peninsula of Maud Island may have caused the dispersal of parakeets to areas with sufficient nesting resources. The nearest landmass is only 900 m from Maud Island and represents a potential dispersal site for parakeets attempting to find suitable nesting sites.

The Chalky Island population of Malherbe's Parakeet occurred in low densities relative to the Yellow-crowned Parakeets present on the island (Table 4.4). This sympatric population of Yellow-crowned Parakeets is reported to have established following dispersal to Chalky Island in 2007 (Department of Conservation, 2017) and has likely limited the expansion of the translocated Malherbe's Parakeet population through competitive displacement. At mainland sites, there is evidence of interspecific competition between Yellow-crowned Parakeets and Malherbe's Parakeets for both dietary and nesting resources (Kearvell, 2002; Kearvell & van Hal, 2016; Kearvell et al., 2002). In locations where suitable nesting sites are limited, Kearvell (2002) suggested that similarities in the nesting requirements of the two species may result in one species gaining a competitive advantage.

Studies examining the nest site selection of mainland *Cyanoramphus* parakeet populations indicate that most cavities utilised by parakeets occur in mature trees with a diameter at breast height of approximately 70 cm or more (Elliott et al., 1996b; Kearvell, 2002; Kearvell & van Hal, 2016). On Chalky Island, the habitat is largely composed of Manuka (*Leptospermum scoparium*) and Kanuka (*Kunzea ericoides*) scrub (Figure 4.7), with some stands of mature Beech forest. Given that suitable nesting sites for parrots only represent a subset of the available cavities present in the landscape (Renton et al., 2015; Stojanovic, Webb, Roshier, Saunders, & Heinsohn, 2012), the relative scarcity of mature forest on Chalky Island could limit the availability of suitable nest sites and contribute to interspecific competition between these parakeet species.

On other offshore islands where suitable nesting sites are limited, *Cyanoramphus* parakeets have been observed utilising novel nesting cavities, to varying degrees of success (Greene, 2003; Ortiz-Catedral & Brunton, 2009a; Ortiz-Catedral, Kearvell, et al., 2009). For Red-crowned Parakeets on Little Barrier Island, Greene (2003) indicated that interspecific competition with Yellow-crowned

Parakeets, combined with a scarcity of suitable nests, resulted in the use of suboptimal nesting cavities by Red-crowned Parakeets and likely limited population size. Conversely, the use of alternative nest sites by Malherbe's Parakeets on Maud Island did not appear to impact upon nesting success (Ortiz-Catedral, Kearvell, et al., 2009), though the limited data available for this small population of translocated parakeets prevented a comparison with the remnant mainland populations that utilise the nesting cavities of mature trees.

Of the islands surveyed, Blumine Island had the highest density of Malherbe's Parakeets (Table 4.3). This island is similar to Maud Island and Chalky Island, in that invasive predators have been successfully eradicated (Department of Conservation, 2006b). However, the composition and structure of the habitat varies from the other island locations (Figure 4.7), with a significant area of mature bush on the southern face of the island and large stands of regenerating forest distributed throughout the remaining habitat (Conner & Conner, 1981; Conner et al., 1981). This core area of vegetation contains stands of mature Beech forest and appears to be favoured by the Malherbe's Parakeets established on the island (M. Skirrow, personal observation, 2016). Since few suitable nesting cavities are available in younger trees (Spurr, 1987), the presence of this mature forest has likely contributed to the success of Malherbe's Parakeets on Blumine Island.

In addition to an abundance of mature forest, the Malherbe's Parakeet population on Blumine Island likely benefits from the absence of large sympatric competitors. The island supports a small population of Yellowheads, though it is unlikely that competition for nesting cavities is limiting either species on Blumine Island. Evidence from mainland sites indicates that when nest sites are abundant, there is sufficient separation in nest site selection between Yellowheads and *Cyanoramphus* parakeets to reduce the effects of competition for individual nest sites (Elliott et al., 1996b). Given that Blumine Island shares features with the other translocation release sites, the relative success of the Malherbe's Parakeet population established on the island is likely due to a combination of factors including an abundance of mature habitat, availability of suitable nesting cavities, reduced levels of interspecific competition for resources, and a relatively large founder population.

Figure 4.7: Photographs showing the difference in habitat composition between Maud Island (top), Blumine Island (middle), and Chalky Island (bottom). Photo credit: Michael Skirrow, Michael Skirrow, and Luis Ortiz-Catedral.

In contrast to the Malherbe's Parakeet populations, the differences in the habitat composition of the three islands did not appear to influence the density of the wider bird community. At each site, the fixed point survey method appeared to produce consistent estimates of density for the non-target species examined. However, comparisons of population size were limited to species which occurred on at least two of the island study sites. For example, the Yellow-crowned Parakeet does not currently occur on Maud Island or Blumine Island, which restricted the comparison to the sympatric Malherbe's Parakeet population of Chalky Island. Similarly, comparisons of the Yellowhead populations were restricted to Blumine Island and Chalky Island, as the species does not currently occur on Maud Island. All remaining species including Bellbirds, Silvereye, and Tui occurred at each site.

The Bellbird densities estimated were reasonable given the area of habitat available on each island. A previous study, examining Bellbirds in the Hauraki Gulf indicates that the density of the Tiritiri Matangi Island population, following the eradication of rats, was approximately 600 birds in an area of 197 ha (Lee, 2005). This equates to an estimate of 3.05 birds/ha, which corresponds to the estimates produced for Maud Island and Chalky Island (see Table 4.2 and Table 4.4). The Blumine Island population was estimated at a higher density than these populations (see Table 4.3), which is attributed to the high proportion of detections recorded near observers (see Figure **4.4**).

Silvereyes are a widespread species that occur in high densities at many locations in the South Pacific region. In an assessment of the effects of ecological succession on passerines in Central Otago, Wilson, Norbury, and Walker (2014) estimated the collective density of Silvereyes at 2.15 birds/ha. Similarly to Bellbirds on Blumine Island, the density estimates for Silvereye on Maud Island (Table 4.2) and Blumine Island (Table 4.3) likely overestimated the population size due to the large number of observations recorded at close proximity to the observers. The Chalky Island estimates indicate the Silvereye population was smaller than the other islands (Table 4.4), though this analysis was based on a restricted sample size.

Estimates of Tui density for the three island sites examined align with estimates produced for a population found on an island located off the coast of the Chatham Islands. In an assessment of the Tui population present on South East Island, Dilks and Kearvell (1996) estimated that the 218 ha site supported 237 mature individuals and a further 195 juveniles to total 432 individuals. This indicates

that the Tui density on this small island was between 1.09 and 1.98 birds/ha. The estimates produced for Maud Island, Blumine Island, and Chalky Island are within this range of values (see Table 4.2, Table 4.3, and Table 4.4), though our analysis did not account for the maturity of the birds observed.

On Blumine Island and Chalky Island, Yellowheads were estimated to occur at relatively high densities compared to a mainland site in Fiordland. Using observation data from Elliott (1996), Choquenot (2006) estimated the density of adult Yellowheads at 1.17 birds/ha. This mainland site consisted of a 30 ha Beech forest, which also supported a small stoat (*Mustela erminea*) population for the majority of the study (Elliott, 1996). Given the small area of this site and the presence of a known nest predator, it is unsurprising that the estimated density of Yellowheads was higher on both Blumine Island (Table 4.3) and Chalky Island (Table 4.4).

The research we present here provides the first step in examining the success of the Malherbe's Parakeet populations established on Maud Island, Blumine Island, and Chalky Island. Though to clarify whether access to suitable nesting sites is limiting the expansion of these translocated populations, we recommend a thorough examination of nest site availability at each island release site. We also recommend a thorough examination of the Maud Island population to ascertain whether the species is still present on the island. For the remaining islands, we advocate regular population monitoring using fixed point surveys and consider the evaluation of the Mayor Island population a high priority for future research into the recovery of this critically endangered parakeet species.

CHAPTER 5

Conclusions and Recommendations

ABSTRACT

This thesis presents an assessment of the most precise and efficient method for surveying the critically endangered Tasman Parakeet (*Cyanoramphus cookii*) population on Norfolk Island. This is followed by interannual estimates of population size for the Tasman Parakeet population, which provide an insight into the effectiveness of conservation management on Norfolk Island. In addition, estimates of density are provided for the critically endangered Malherbe's Parakeet (*Cyanoramphus malherbi*) populations established on the predator-free offshore islands of New Zealand, representing the first published estimates for the Blumine Island and Chalky Island parakeet populations. The following discussion examines the key findings and implications of this research for the conservation of Tasman Parakeets on Norfolk Island and the management of Malherbe's Parakeets established on the offshore islands of New Zealand. In addition, a list of priority conservation actions is provided for each study species.

SURVEY METHODS

The final analysis conducted in Chapter 2 and the preliminary analysis presented in Appendix C both indicate that the fixed point survey method was the most suitable method for monitoring the Tasman Parakeet (*Cyanoramphus cookii*) population. The results of statistical resampling show that this survey method produced the greatest precision of the methods examined. Furthermore, the effort required to obtain this precision was far lower for fixed point surveys, than the effort required for generating the same precision using line transect surveys. In addition, both statistical resampling and modelling of the data show that fixed point surveys offered superior efficiency, as they obtained the highest number of detections per unit of effort.

POPULATION TRENDS

The findings of Chapter 3 indicate that the Tasman Parakeet population increased in size during the four years of sampling conducted on Norfolk Island. In 2014, Tasman Parakeets occurred at relatively low densities within the 310 ha region of remnant native forest. In the three years that followed, there was a mean increase of 0.263 birds/ha within the area. In contrast, the Crimson Rosella (*Platycercus*

elegans) population remained relatively stable despite active control of the population. From 2014 to 2017, the introduced competitor occurred in similar densities to those described by Dutson (2013), with as little as 12% difference between the four years of sampling conducted in this study.

Although the long-term population trends were unable to be determined from the results of Chapter 4, the findings offer valuable insight into the relative success of the translocated populations of Malherbe's Parakeet (*Cyanoramphus malherbi*). On Blumine Island, the Malherbe's Parakeet population had expanded, occurring in relatively high densities compared to the other sites examined. In contrast, the Maud Island population appeared to have declined significantly since the population assessment conducted in 2009 by Ortiz-Catedral et al. (2012). Similarly, the density estimates from Chalky Island indicate that the Malherbe's Parakeet population was still present, although it had expanded little due to the establishment of Yellow-crowned Parakeets (*Cyanoramphus auriceps*).

RESEARCH LIMITATIONS

The primary limitation of this research was that estimates of density had to be produced using small sample sizes. Both Tasman Parakeets and Malherbe's Parakeets are difficult to detect in the field, as they are cryptically coloured and occur in low densities at their respective localities. For Tasman Parakeets on Norfolk Island, sample sizes ranged from eight to 21 during the four years of sampling. These small sample sizes limited the ability to fit detection functions and likely reduced the accuracy of estimates (see Chapter 3). Similarly, the sample sizes used to model the density of the Malherbe's Parakeet populations ranged between zero and 27, which prevented the production of estimates for one island population and contributed to suboptimal model fitting for the others (see Chapter 4).

In addition, the comparative analysis conducted in Chapter 2 was limited to survey methods that were applicable to the study species. Consequently, the analysis had a relatively narrow scope, including only fixed point and line transect surveys. The remaining survey types were unable to be examined, due to their limited applicability for the study species. For example, roost counts were excluded from the analysis because the *Cyanoramphus* parakeets investigated do not regularly exhibit communal roosting behaviour. Similarly, the precision of the mark recapture method was unable to be

examined, as surveys occurred long after sufficient numbers of marked individuals were present in these populations.

A further limitation of this research was the restricted distribution of the study species. Both Tasman Parakeets and Malherbe's Parakeets occur on isolated islands, which limited the accessibility of the study sites. Consequently, the duration of sampling was shorter than in other studies, which tend to examine large and easily accessed populations. The research conducted on Norfolk Island occurred across multiple trips, none of which exceeded two weeks. The short duration of sampling limited the determination of fine-scale trends, though the small area of occupancy allowed the coverage of key habitat and locations for sufficient comparison across consecutive years. The sampling duration was also limited at New Zealand sites, where field data had to be collected during a single trip to each island. The length of time spent sampling on these islands ranged between three and four days, which restricted the analysis for each site and prevented the determination of trends.

IMPLICATIONS FOR CONSERVATION

Due to the threatened status of both Tasman Parakeets and Malherbe's Parakeets, they are considered high priority species for conservation management (Department of the Environment, 2015; Olah et al., 2018). The research presented in this thesis provides essential information regarding the suitability of the survey methods used to monitor these species. In addition, the assessments of each population give insight into the status of these species and the effectiveness of current management efforts. If interpreted from a conservation management perspective, the findings could assist in the improvement of population monitoring and contribute to the continued survival of these highly threatened species.

For monitoring the recovery of the Tasman Parakeet population on Norfolk Island, identifying an efficient and reliable survey method has been recognised as an important priority (Ortiz-Catedral et al., 2018). Historically, monitoring of this population had been conducted using a variety of methods, which limited the comparability of estimates. However, the findings of Chapter 2 indicate that of the applicable methods, fixed point surveys offer the greatest precision and efficiency. This finding is interesting in the context of long-term monitoring, as adopting this standardised survey method could allow the generation of accurate population estimates while minimising the time investment required

to obtain reasonable precision. Additionally, the suitability of this survey method for monitoring the Tasman Parakeet, suggests it may also perform well with other cryptically coloured parrot species.

For the conservation of Tasman Parakeets, the gradual increases in estimated density are an indication that the population is beginning to recover from the declines reported by Ortiz-Catedral (2013). These findings are important for the continued management of the species because the habitat of Mount Pitt will eventually become limiting and result in the dispersal of parakeets outside of the national park area. To maintain this parakeet population across a larger area will require increased management, as the regions outside of the national park currently support mammalian predators and have few areas of habitat suitable for Tasman Parakeets. Additionally, interactions between parakeets and members of the local community are likely to increase following their dispersal from the Mount Pitt area, so consideration must be given to community outreach.

The persistence of Crimson Rosellas in the Mount Pitt section of the Norfolk Island National Park suggests that further control is required for this introduced population of competitors. The results of Chapter 3 show that the Crimson Rosella population has fluctuated very little and that they remain abundant compared to the Tasman Parakeet. These findings are pertinent to the conservation of the Tasman Parakeet, as the ecological flexibility of Crimson Rosellas allows them to compete strongly with the parakeet population. The presence of this large population of competitors is likely to limit the resources available to the Tasman Parakeet population, but further research is required to determine the extent to which the recovery of the endemic parakeet species is impacted by this competitor.

In New Zealand, the differential success of the Malherbe's Parakeet populations established on offshore islands is an indication of the importance of long-term monitoring for the management of threatened species. The findings of Chapter 4 suggest that Malherbe's Parakeets are no longer able to be detected on Maud Island, representing the potential loss of the species from this island. This is significant for the conservation of Malherbe's Parakeet, as their decline and disappearance from this location represents a further range restriction, which increases their vulnerability to extinction at the remaining sites. The limited expansion of the Chalky Island population of Malherbe's Parakeet is equally interesting in the context of species recovery, as it offers insight into the ability of Malherbe's Parakeets to cope with the presence of a sympatric population of competitors. For the Chalky Island

population, it appears increased management is required to ensure there are sufficient resources for the released Malherbe's Parakeet population, as they occur in lower densities than the Yellow-crowned Parakeet despite an establishment period of eight years.

The Malherbe's Parakeet populations examined at each translocation release site had a mean establishment period of 6.3 years; however, the results of Chapter 4 indicate population size differed substantially between each site. The high density of Malherbe's Parakeets on Blumine Island provides evidence of the effect that site-specific characteristics can have on the establishment success of this species. Given that Malherbe's Parakeets appeared to succeed at the site where mature vegetation and potential nesting cavities were relatively abundant, habitat composition and nest availability should be considered prior to translocations. Additional factors that warrant consideration are the size of the founder population, whether competitive species are present at the site, and whether the site is free of predatory species, all of which may limit the expansion of a translocated population.

PRIORITIES FOR SPECIES CONSERVATION AND RESEARCH

Considering the results of this research and the implications for continued species management, the following actions are recommended for the conservation of both the Tasman Parakeet and Malherbe's Parakeet. In addition to assessing the principle conservation management requirements for each population, the recommendations also indicate areas that require further research to address the absence of information associated with these threatened *Cyanoramphus* parakeet populations. The recommendations and research needs discussed are not presented in any particular order, as they each represent an important component of overall management and if implemented, they may contribute to the continued recovery of these species.

TASMAN PARAKEET

LONG-TERM POPULATION MONITORING

The Tasman Parakeet population has been assessed on a number of occasions throughout the past four decades of management, providing valuable information for the conservation of the species. However, the sporadic approach to sampling has limited the comparison of estimates over time and prevented

identification of fine-scale population trends. Since the parakeet population has shown a positive response to recent management efforts (see Chapter 3), regular monitoring is essential to assessing the continued recovery of the species. To effectively monitor the Tasman Parakeet population and determine the effectiveness of continued conservation management, it is recommended that a long-term monitoring programme is established. In addition, it is recommended that regular monitoring of the introduced Crimson Rosella population is conducted to determine whether efforts to control the population are continuing to limit the expansion of this competitive species.

Since resources and funding are often limited for conservation projects, it is important to determine cost-effective methods of achieving management objectives. In the case of establishing a monitoring programme for Tasman Parakeets and Crimson Rosellas on Norfolk Island, the fixed point survey method used throughout the present study and in the assessment by Dutson (2013) is an excellent option. The results of Chapter 2 indicate that fixed point surveys are an efficient method of sampling, which can generate precise estimates without observers having to expend excessive effort in the field. In addition, a minimal investment would be required to implement this type of sampling, as the established grid of predator bait stations offers an ideal source of known points for management staff to utilise. Furthermore, the training required for observers to become proficient in this method is minimal, which when combined with a robust design and the use of precision sampling equipment can reduce observer bias when generating estimates.

For monitoring the parrot populations on Norfolk Island, fixed point surveys are considered the most suitable approach to sampling. This method is less invasive than methods such as mark recapture, as it requires individuals to be detected rather than captured (Legault et al., 2013; Whitman et al., 1997). This is particularly important for threatened species such as the Tasman Parakeet, as the handling required to mark individuals can have detrimental effects on bird survival (MacKenzie et al., 2005). Furthermore, the annual effort and cost required to mark individuals from both parrot populations is likely to exceed that of the fixed point survey method. In addition, the repeatability of fixed point surveys will allow management staff to examine the relative abundance of each population at a finer scale and accurately monitor trends. Given these advantages, it is recommended that fixed point surveys are adopted as the principal method for monitoring.

CONTROL OF INTRODUCED COMPETITORS

The introduced Crimson Rosella remains a key competitor of Tasman Parakeets in the Mount Pitt section of the Norfolk Island National Park (Hill, 2002; Ortiz-Catedral, 2013; Taylor, 1985). This introduced species competes for both feeding and nesting resources, often excluding Tasman Parakeets from suitable nesting cavities. To reduce the impact that this competitor has on the Tasman Parakeet population, Parks Australia has attempted to control the expansion of the Crimson Rosella population by destroying active rosella nests and sporadically culling the adult birds which occupy the national park area. The findings of Chapter 3 indicate that these control measures are currently having little effect on reducing the size of the Crimson Rosella population present within the national park.

To effectively reduce the Crimson Rosella population and the effect that this species has on the recovery of the Tasman Parakeet, it is recommended that current competitor control efforts are intensified. Since 2014, the control programme has removed approximately 1020 Crimson Rosellas from the Mount Pitt region (Parks Australia, personal communication, 2018). However, the widespread distribution of Crimson Rosellas on Norfolk Island is thought to contribute to a gradual influx of individuals into the national park area following culling events, which results in a limited reduction in population size. It is proposed that Crimson Rosella control is expanded to target individuals that occur both within the Mount Pitt area of the national park and those across the wider Norfolk Island area.

The removal of this species from areas outside the national park may present a challenge for conservation management. The current methods for controlling the Crimson Rosella population include the removal of eggs, destruction of nests, and the use of firearms to humanely dispatch adult individuals. However, the practicality of these methods may be limited in the open habitat of Norfolk Island. Potential limitations include the difficulty of locating nest sites, public perception towards removal of this competitive species, and the dangers associated with using firearms in an uncontrolled environment where members of the public occur. To address the health and safety risks of firearm use, management staff could use alternative removal methods, such as mist netting, to capture birds prior to their destruction. To improve the perception of these competitor control actions would require a combination of outreach and consultation with local residents.

PREDATOR MANAGEMENT

Predation by introduced mammalian species has contributed to the decline of numerous island endemics and is a significant threat to endangered bird species that are restricted to islands (Blackburn et al., 2004; Doherty et al., 2016; Tershy et al., 2015). For the Tasman Parakeet, the introduction of rats (*Rattus* spp.) and feral cats (*Felis catus*) to Norfolk Island has contributed to declines in population size (Forshaw, 2002; Taylor, 1985). Prior to management, the predation of eggs, chicks, and females at the nest (Figure 5.1) was particularly significant (Hicks & Greenwood, 1989; Hill, 2002) and in other wild populations of *Cyanoramphus* parakeets has been implicated in exacerbating male-biased sex ratios (Elliott et al., 1996a; Kearvell & Farley, 2016; Young & Kearvell, 2001).

Figure 5.1: Photograph of a rat (*Rattus* spp.) attempting to access the entrance of an active Tasman Parakeet (*Cyanoramphus cookii*) nest. Photo credit: Luis Ortiz-Catedral

To prevent further declines in the Tasman Parakeet population, Parks Australia established a programme targeting mammalian predators within the national park area (Hicks & Greenwood, 1989; Hill, 2002). Initially, this led to an increase in breeding attempts by parakeets and improvements in population size (Innes, 1995). However, a reduction in the intensity of predator management has been associated with the Tasman Parakeet population declining to a minimum of 46 individuals in 2013 (Ortiz-Catedral, 2013; Ortiz-Catedral et al., 2018).

Following a period of intensive predator management by Parks Australia, the results of Chapter 3 indicate that a species-specific approach to conservation management led to an increase in the size of the Tasman Parakeet population. If these gradual increases in population size continue, the available habitat within the Mount Pitt section of the national park will likely become limiting, leading to the dispersal of Tasman Parakeets across Norfolk Island. If this occurs, the dispersed parakeets will likely utilise suboptimal nesting cavities and become vulnerable to nest predation, as occurred with Red-crowned Parakeets when nesting sites became limiting on Little Barrier Island (Greene, 2003). To reduce the likelihood of predation outside of the national park, it is recommended that predator management is intensified and extended, with the intention of developing a full-scale eradication plan for the predators of Norfolk Island.

As an Important Bird Area, increasing the intensity of predator management on Norfolk Island is likely to benefit not only the Tasman Parakeet but also, the migratory seabirds and at-risk endemics that occur on the island (Australian Government, 2014). At an area of 34.6 km^2, Norfolk Island is a good candidate for the eradication of introduced mammalian predators. The eradication of predators at this scale has previously been achieved on Raoul Island, a 29.38 km^2 uninhabited island to the northeast of New Zealand (Ortiz-Catedral, Ismar, et al., 2009). The removal of these invasive species from Raoul Island resulted in an expansion of the resident *Cyanoramphus* parakeet population and serves as further evidence of the benefits of predator management (Ortiz-Catedral, Ismar, et al., 2009). A similar eradication using aerial poison drops and targeted baiting has been proposed for Lord Howe Island; however, as an inhabited island, there has been some public resistance due to the potential impact on humans, domestic animals, and non-target species (Wilkinson & Priddel, 2011).

To implement an eradication plan of this scale on Norfolk Island would require consultation with local residents and careful planning to mitigate the potential impact of predator management techniques. However, an intensification of rodent control within the national park and expansion of the bait station network is currently in progress (Australian Government, 2014), representing the first step towards the potential eradication of mammalian predators from the island. Further steps to restrict the cat population on Norfolk Island could include a neutering programme for the existing domestic

cat population, introduction of legislation prohibiting the importation of cats to the island, and the continued trapping and destruction of feral cats within the national park.

SPECIES TRANSLOCATION

The Tasman Parakeet is considered a distinct species of *Cyanoramphus* parakeet (Boon et al., 2001) and is currently restricted to a small area of remnant forest in the Mount Pitt section of the Norfolk Island National Park. Establishing an allopatric breeding population would help to safeguard this insular species from extinction, especially in the case of a catastrophic population collapse within their current range on Norfolk Island. It is recommended that this additional breeding population of Tasman Parakeet is established through a soft-release translocation of fledglings acquired from managed nest sites; ideally at a location with an abundance of resources and an absence of predators.

There are two release sites that would be suitable for this type of species translocation: Phillip Island, a partially vegetated island to the south of Norfolk Island that is free of mammalian predators (Coyne, 2010; Director of National Parks, 2008); and Lord Howe Island, a large vegetated island to the southwest of Norfolk Island, which supported a population of Lord Howe Island Parakeet (*Cyanoramphus novaezelandiae subflavescens*), prior to their decline to extinction (Hutton, Parkes, & Sinclair, 2007). Both release sites have been suggested in previous research (Hill, 2002; Taylor, 1985), as they present an excellent opportunity for the translocation and establishment of an additional Tasman Parakeet population.

Historically, the dense vegetation of Phillip Island was thought to support a population of Tasman Parakeets (Hill, 2002). However, the introduction of goats (*Capra aegagrus hircus*), pigs (*Sus scrofa domesticus*), and rabbits (*Oryctolagus cuniculus*) to the island in the 1700s resulted in a significant degradation of the original habitat (Bird, 2010; Coyne, 2010; Mills, 2009). Since the eradication of these introduced pests in the 1980s, the native vegetation has started to recover (Coyne, 2010; Mills, 2009). Currently, the island is dominated by relatively bare slopes (Figure 5.2), however preliminary evidence suggests the resources provided by the limited vegetation present would be sufficient to support the Tasman Parakeet (Waldmann, 2016).

Figure 5.2: Photographs showing the structural composition of habitat on Phillip Island and Meyer Island. The predominantly bare habitat of Phillip Island, with small Norfolk Island Pines (*Araucaria heterophylla*) and invasive scrub in the foreground (top); the cliffside habitat of Meyer Island (bottom left); and the vegetated slopes of Meyer Island (bottom right). Photo credit: Luis Ortiz-Catedral

The remaining habitat of Phillip Island is similar in structural composition to that of Meyer Island (Figure 5.2), a small satellite island that occurs off the coast of Raoul Island, to the northeast of New Zealand (Brook, 1998). This predator-free island supports a population of the Kermadec Red-crowned Parakeet (*Cyanoramphus novaezelandiae cyanurus*) that consists of up to 100 individuals (Veitch, Miskelly, Harper, Taylor, & Tennyson, 2004). A close relative of the Tasman Parakeet, the Kermadec Red-crowned Parakeets are able to effectively utilise the relatively scarce habitat available on Meyer Island (Figure 5.3) and demonstrate the ability of *Cyanoramphus* species to persist in suboptimal habitats when introduced competitors and predatory species are absent.

Figure 5.3: Photograph showing a pair of Kermadec Red-crowned Parakeets (*Cyanoramphus novaezelandiae cyanurus*) on the rocky cliffside habitat of Meyer Island. This habitat is regularly used by foraging parakeets and has a similar structural composition to the habitat found on Phillip Island. Photo credit: Luis Ortiz-Catedral

An alternative translocation site for the Tasman Parakeet is Lord Howe Island, which appears well vegetated compared to Phillip Island (Figure 5.4). Historically, the island was inhabited by the Lord Howe Island Parakeet, however, persecution as pests of fruit crops resulted in their decline to extinction in 1869 (Hutton et al., 2007; Recher & Clark, 1974). Since then, parakeets have been absent from the island. As part of an ecosystem approach to conservation management on Lord Howe Island, Hutton et al. (2007) suggested the Tasman Parakeet as a potential replacement to occupy the niche vacated by the extinct Lord Howe Island Parakeet. This suggestion offers the opportunity for a collaborative conservation effort between Norfolk Island and Lord Howe Island, where the Tasman Parakeet benefits from the establishment of an additional breeding population and Lord Howe Island benefits from the ecosystem services provided by the reintroduction of a parakeet population.

A potential factor limiting the establishment of Tasman Parakeets on Lord Howe Island is the presence of mammalian predators. The feral cat population of Lord Howe Island has been subject to control and by the 1980s was eradicated (Miller & Mullette, 1985; Parkes, Macdonald, & Leaman, 2002; Priddel, Carlile, Fullagar, Hutton, & O'Neill, 2006). However, rats and mice have persisted despite numerous attempts to control the populations present on the island (Billing, 2000; Billing &

Harden, 2000; Hutton et al., 2007; Wilkinson & Priddel, 2011). On Norfolk Island, nest predation by rodents has contributed to the decline of Tasman Parakeets present in the national park (Forshaw, 2017; Hill, 2002; Ortiz-Catedral, 2013). Accordingly, if the rodent population is not effectively eradicated from Lord Howe Island prior to translocation, the success of an introduced population of parakeets could be limited.

Figure 5.4: Photograph showing the vegetation of Lord Howe Island. Photo credit: David Stanley

In addition to ensuring that predatory species have been eradicated, the dietary resources available on Lord Howe Island must be quantified prior to translocation of Tasman Parakeets to ensure the island is able to sustain an introduced population. Similarly, a further investigation of the dietary requirements of Tasman Parakeets would be beneficial for establishing the daily nutritional requirements and the carrying capacity of Phillip Island. Furthermore, the availability of nesting hollows should be investigated for both release sites and if there are no suitable cavities available, artificial nests should be provided.

COMMUNITY OUTREACH

It is recommended that community outreach is increased on Norfolk Island to further emphasise the value of the Tasman Parakeet and encourage local involvement with conservation initiatives. The results presented in Chapter 3 indicate that within the Mount Pitt section of the Norfolk Island

National Park the Tasman Parakeet population is gradually increasing in size. If this trend continues, it is possible that Tasman Parakeets will begin to disperse outside of the park to feed in the fruit trees of local properties. A renewal of community outreach efforts could help community members to recognise the value of this extremely threatened species and improve attitudes towards Tasman Parakeets as they begin to disperse across the developed areas of the island and interact with the wider community.

Initial engagement with the Norfolk Island community has involved the distribution of a variety of educational materials and has been facilitated by both non-governmental organisations and park management staff, as part of the Tasman Parakeet recovery programme (Ortiz-Catedral, Nias, Fitzsimons, Vine, & Christian, 2017). In addition to educational visits from Parks Australia staff, local school students have been encouraged to assume stewardship of the Tasman Parakeet; many receiving symbolic parakeet soft toys during seminars (Ortiz-Catedral et al., 2017). In addition to this, public seminars have been given to raise awareness for conservation of the Tasman Parakeet among adult residents and visitors (Ortiz-Catedral et al., 2017). Promotional posters (Figure 5.5) have also been distributed to local businesses, encouraging pride for the Tasman Parakeet with high impact images and text written in the local dialect. Further outreach efforts are recommended to consolidate the awareness and pride established during this initial community engagement.

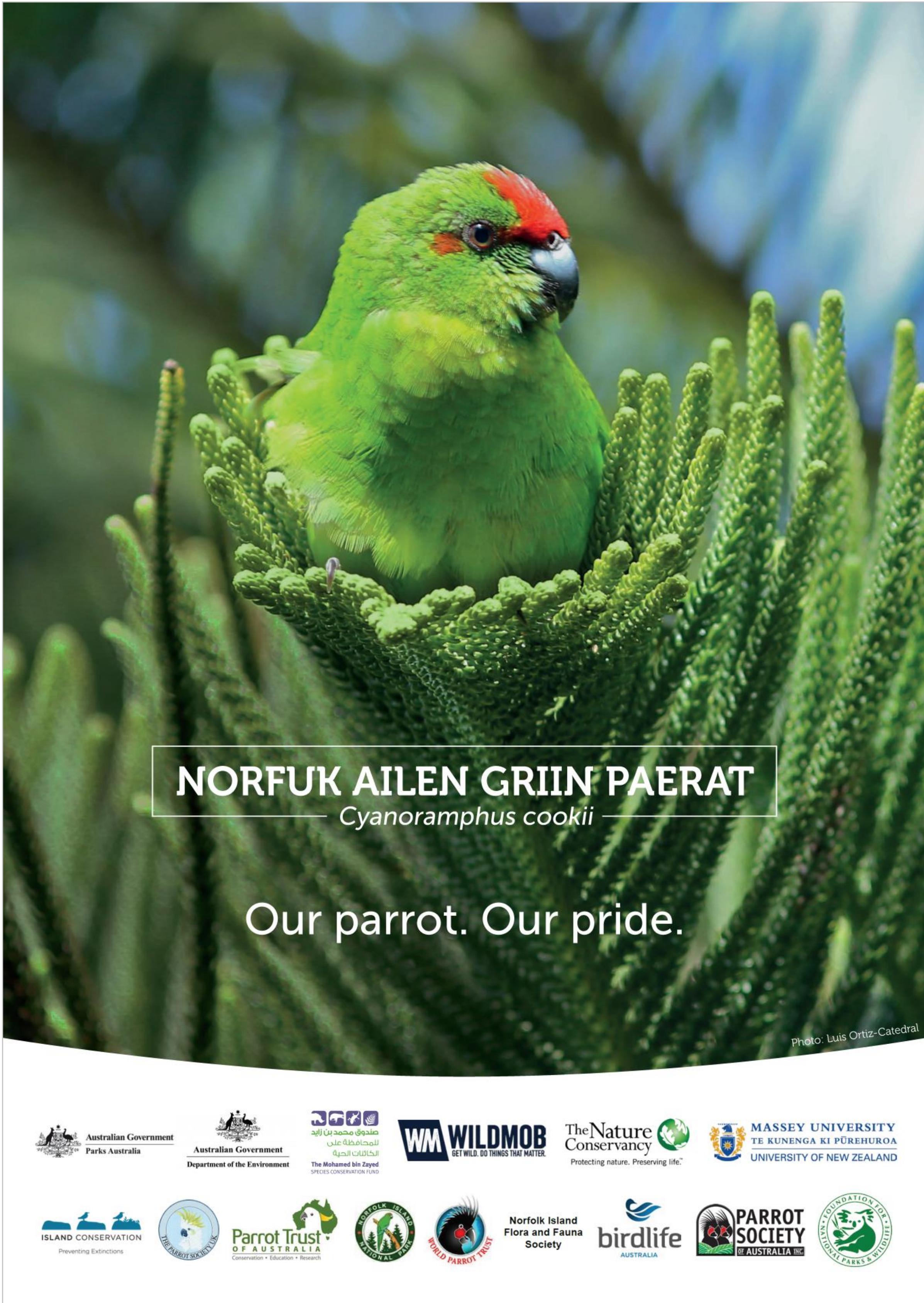

Figure 5.5: An example of the posters distributed on Norfolk Island as part of community outreach.

MALHERBE’S PARAKEET

PREDATOR MANAGEMENT

The introduction of mammalian predators to New Zealand has resulted in the decline and extinction of numerous bird species (Holdaway, 1989, 1999; Innes, Kelly, Overton, & Gillies, 2010). Of the species which remain, cavity nesters such as the *Cyanoramphus* parakeets are particularly vulnerable to predation (Greene, 2003; Holdaway, 1999; O'Donnell, 1996). The frequency with which these parakeets forage at ground level and use low-level habitat has likely contributed to the high levels of predation experienced by these species (Greene, 2003; Hansford, 2017). For instance, predation has effectively resulted in the extinction of Red-crowned Parakeets from the mainland, with the remaining populations only thriving in areas where mammalian predators are absent (Hansford, 2017; Higgins, 1999; Taylor, 1985). Similarly, the Malherbe’s Parakeet population has become restricted to three sites in the South Canterbury region, with four island populations established by translocation to limit the effects of predation (Andrews et al., 2013; Elliott & Suggate, 2007; Kearvell & Farley, 2016).

For these parakeet populations, nest predation by rodents and mustelids (*Mustela* spp.) presents a substantial threat to species conservation (Elliott et al., 1996a; Higgins, 1999). During seed masting seasons, the production of a high volume of seeds by trees contributes to increases in rodent and mustelid populations, resulting in an increase in the predation of eggs, chicks, and incubating females (Elliott, 2016; King, 1983; Murphy & Dowding, 1995). To reduce the impact of predation and seed masting events on parakeets and other endemic birds, the New Zealand Department of Conservation regularly conducts trapping and baiting of mustelid and rodent populations (Elliott, 2016; Hansford, 2017; Kearvell, 2016). At both mainland and offshore island restoration sites these techniques are used to control and limit predator populations (Parkes & Murphy, 2003; Saunders & Norton, 2001).

Given that the mainland population of Malherbe’s Parakeet has experienced substantial declines following predation associated with recent seed masting events (Hansford, 2017; Robertson et al., 2017), protection of the Malherbe’s Parakeets that remain on predator-free offshore islands is a key priority. Of these island sanctuaries, the close proximity of Maud Island, Blumine Island, and

Chalky Island to the other nearby islands and the mainland increases the risk of invasion by predators; particularly mustelids. This is exemplified by the stoat (*Mustela erminea*) invasions which occurred on Maud Island in the 1980s (Elliott et al., 2010; Veale et al., 2012). Given the difficulties associated with permanent eradication of these predators from islands (King, 1994), it is recommended that the Department of Conservation maintain high levels of predator management at the sites where Malherbe's Parakeets are well established.

NEST SITE PROVISIONING

The results presented in Chapter 4 indicate that the Malherbe's Parakeet populations established on offshore islands occur at different densities. All individuals released to these sites, including the population present on Mayor Island, have been sourced from a single captive population (Kearvell & Farley, 2016). However, the results of Chapter 4 indicate that there has been differential success in the establishment of the populations monitored during this research. One explanation for this is the differences in habitat composition and nest site availability on each island. Though these parameters were not directly quantified, the largest population of Malherbe's Parakeet occurred on Blumine Island, which has the largest area of mature vegetation.

An examination of Malherbe's Parakeets on Maud Island revealed that the species is able to utilise alternative nesting sites in the absence of mature native forest (Ortiz-Catedral, Kearvell, et al., 2009). However, the recent loss of the habitat where these nesting sites occurred appears to have negatively impacted the parakeet population on Maud Island, as the species was unable to be detected during the present study. This further emphasises the importance of access to suitable nest sites for parakeet populations. One approach to addressing the potential shortage of nesting cavities at the release sites is the direct management of nesting through the provisioning of nest boxes or artificial cavities. In other translocated *Cyanoramphus* parakeet populations, nesting success appears similar between nest boxes and natural nesting cavities (Ortiz-Catedral & Brunton, 2009a) and for Forbe's Parakeets on Mangere Island, provisioning of nesting boxes enhanced breeding success (Greene, 2000).

POPULATION MAINTENANCE

To facilitate the recovery of the Malherbe's Parakeet population, the Department of Conservation has translocated captive-bred parakeets to four predator-free offshore islands (Hansford, 2017; Miskelly & Powlesland, 2013). The number of parakeets used to establish these populations varied, with fewer individuals translocated to Chalky Island than the other three island sites (Forshaw, 2017). The results of Chapter 4 indicate that despite the small number of Malherbe's Parakeet introduced to Chalky Island, the population persists; though it has experienced little expansion. The remaining populations that were monitored occurred at different densities, with no parakeet detections recorded on Maud Island and a relatively high density estimated for the Blumine Island parakeet population.

Given that two of these Malherbe's Parakeet populations now occur in low densities, it is recommended that the Department of Conservation attempt to restock the existing translocated populations. Since the translocated populations of Malherbe's Parakeet were originally established using small founder groups from the same captive population (Forshaw, 2017), limited genetic diversity could potentially contribute to reduced breeding success in the populations present on Mayor Island, Maud Island, Blumine Island, and Chalky Island. Following Andrews (2013), this restocking should be conducted using individuals from the remnant wild populations in southern Canterbury. Alternatively, the captive breeding programme should include individuals from these remnant populations to maintain genetic diversity (Andrews, 2013). Introducing new individuals to these populations will strengthen parakeet numbers and could potentially increase genetic diversity, helping to reduce the likelihood of inbreeding depression, genetic drift, and the Allee effect.

TARGETED ISLAND ASSESSMENTS

The findings of Chapter 4 indicate that the Maud Island population of Malherbe's Parakeet has declined to such an extent that parakeets were unable to be detected during surveys. These surveys occurred seven years after an assessment by Ortiz-Catedral et al. (2012) indicated successful establishment and breeding among the individuals released to the island. To determine whether Malherbe's Parakeets are still present on the island, it is recommended that a further comprehensive assessment of the population is conducted. Given that the parakeet population now occurs in

extremely low densities on Maud Island, assessing the presence of the species requires greater survey effort than was possible during the rapid population assessments presented in this research.

During this research, the Mayor Island population of Malherbe's Parakeet was unable to be assessed due to logistical constraints. This 13 km^2 island (37.2862° S, 176.2514° E) is located 25 km offshore in the Bay of Plenty, North Island, New Zealand and has served as the release site for over 90 captive-bred Malherbe's Parakeets (Forshaw, 2017). The vegetation at this site primarily consists of mature Pohutukawa (*Metrosideros excelsa*), Rewarewa (*Knightia excelsa*), and Kanuka (*Kunzea ericoides*) forest (Atkinson & Percy, 1955; Empson, Flenley, & Sheppard, 2002). Given the relatively large size of the island, the reported abundance of mature forest, and the large founder population released, the Malherbe's Parakeets are likely to have established successfully. However, a formal assessment of the Mayor Island population of Malherbe's Parakeet is required to ascertain whether successful establishment and population growth has occurred at this site.

LONG-TERM POPULATION MONITORING

Despite the critically endangered status of Malherbe's Parakeet, there is a distinct lack of population data for many of the sites where this species occurs. The absence of this information makes it difficult to accurately assess population trends and may limit effective management for species recovery. The results presented in Chapter 4 represent the first published estimates of the Malherbe's Parakeet populations translocated the Blumine Island and Chalky Island. However, a long-term monitoring programme needs to be developed, as the results indicate differential success between the Malherbe's Parakeet populations established on each island after a minimum period of four years, with the Maud Island population declining to such an extent that parakeets were unable to be detected.

To address this absence of data, it is recommended that the Department of Conservation develops a long-term monitoring programme to regularly assess each of the existing Malherbe's Parakeet populations. By regularly conducting surveys of these populations, management staff will be able to examine fine-scale population trends and gauge the level of management required for the Malherbe's Parakeets that occur at each site. This is especially important for determining whether further predator control, nest site provisioning, or restocking is required at any of these sites.

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APPENDIX

APPENDIX A

COLLABORATIVE RESEARCH AGREEMENT

Australian Government

Director of National Parks

COLLABORATIVE RESEARCH AGREEMENT

between

DIRECTOR OF NATIONAL PARKS

and

MASSEY UNIVERSITY

in relation to collaborative research on

the Recovery of Norfolk Island Green Parrots

Agreement Reference: 3000027307

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PARTIES

DIRECTOR OF NATIONAL PARKS, ABN 13 051 694 963 (**DNP**)

and

MASSEY UNIVERSITY, a body corporate of Palmerston North with offices in Palmerston North, Wellington and Old Albany Highway, Auckland, New Zealand, 0632 (**Research Organisation**)

BACKGROUND

A. DNP is vested with the title to, and is responsible for the management of, Norfolk Island National Park and Botanic Gardens, a Commonwealth reserve established under the *Environment Protection and Biodiversity Act 1999* (**the Reserve**).

B. The Research Organisation has proposed to collaborate with DNP to conduct research in the Reserve.

C. DNP is satisfied that the proposed research addresses the current research and monitoring priorities of the Reserve.

D. DNP and the Research Organisation have agreed to carry out collaborative research in accordance with the terms and conditions of this Agreement.

OPERATIVE PART

1. Interpretation

1.1 In this Agreement, unless the contrary intention appears:

Confidential Information means:

(a) the information described in Item K [*Confidential Information*]; and

(b) the information that is agreed between the Parties after the commencement of this Agreement as constituting Confidential Information for the purposes of this Agreement.

DNP's Contribution means the resources (including Funds and in-kind contribution) specified in Item G [*DNP's Contribution*] that will be contributed by DNP towards the Research under this Agreement;

DNP Material means any Material:

(a) provided by the DNP to the Service Provider for the purposes of this Agreement; or

(b) derived at any time from the Material referred to in paragraph (a);

Intellectual Property includes all copyright (including rights in relation to phonograms and broadcasts), all rights in relation to inventions (including patent rights), plant varieties, registered and unregistered trademarks (including service marks), designs, and circuit layouts, and all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields but does not include Moral Rights, the rights of performers or rights in relation to Confidential Information;

Material includes information and the subject matter of any category of Intellectual Property rights;

Moral Rights	the right of integrity of authorship (that is, not to have a work subjected to derogatory treatment), the right of attribution of authorship of a work, and the right not to have authorship of a work falsely attributed, as defined in the *Copyright Act 1968* (Cth).
Personnel	means a party's officers, employees, agents, contractor staff or professional advisers engaged in the performance or management of this Agreement;
Research	means the research project described in Item D [*Research*];
Research Material	means all Material: (a) brought into existence under this Agreement as part of, or for the purpose of, performing this Agreement; (b) provided or required to be provided to the DNP as part of the Research; or (c) derived at any time from the Material referred to in paragraphs (a) or (b);
Research Organisation's Contributions	means the contribution by the Research Organisation for the Research specified in Item H [*Research Organisation's Contribution*].
Specified Personnel	means the Research Organisation's Personnel specified in Item C [*Specified Personnel*] who are Personnel required to perform all or part of the Research;

1.2 In this Agreement:

(a) a reference to the Research Organisation includes the Research Organisation's Personnel and a reference to DNP includes DNP's Personnel unless the context requires otherwise;

(b) words importing persons include a partnership and a body whether corporate or otherwise;

(c) word in the singular include the plural and words in the plural include the singular;

(d) if a part of the Agreement is read down or severed the other provisions of the Agreement are not affected.

(e) reference to an Item is to an Item in the Schedule, and the Schedule and any attachments form part of this Agreement;

(f) where any conflict arises between the terms and conditions contained in the clauses of this Agreement and any part of the Schedule (and attachments if any), the terms and conditions of the clauses prevail;

1.3 This Agreement records the entire agreement between the parties in relation to the subject matter.

1.4 No variation of this Agreement is binding unless it is agreed in writing between the parties.

1.5 This Agreement will be construed in accordance with the laws of the Australia Capital Territory.

2. Commencement and Duration

2.1 Despite the date of signing this Agreement is deemed to have started on 1 March 2013, and unless terminated earlier in accordance with this Agreement, will finish at the end of the period set out in Item F [*Research Period*], and the Research Organisation has complied with clauses 8 and 16.

3. Research

3.1 The parties agree to carry out the Research to a high standard and in accordance with the *Environment Protection and Biodiversity Act 1999* and other relevant laws.

3.2 The Research Organisation and DNP will work together to deliver the outcomes in the timeframes set out in Item D [*Research*], and provide each other with information about the Research as needed.

3.3 The parties agree to contribute to the Research as set out in this Agreement.

3.4 The Research Organisation will be responsible for obtaining the necessary approvals (such as Animal Ethics Approval, permit to access biological resources) to carry out the Research. The Research Organisation agrees to, upon request, provide a copy of the approvals to DNP.

3.5 The Research Organisation will abide by the conditions set out in Item E [*Environmental Conditions*].

3.6 If one party is unable to meet its obligations under this Agreement, it will inform the other party as soon as possible and the parties will work together to find a resolution.

4. DNP's Contribution

4.1 DNP agrees to contribute the facilities and assistance set out in Item G [DNP's Contribution] to the Research.

4.2 The Research Organisation agrees to use DNP's Contributions only for the purposes of the Research.

4.3 The Research Organisation agrees to submit invoices which comply with Clause 6 for payment, and any supporting documentation required by DNP.

5. Research Organisation's Contribution

5.1 The Research Organisation agrees to contribute to the Research, the facilities and assistance set out in Item H [*Research Organisation's Contribution*].

6. Not used.

7. Not used.

8. Not used.

9. Subcontractors

9.1 The Research Organisation must not subcontract the performance of any part of the Research without prior written approval from DNP.

9.2 DNP may, when giving its approval of a subcontractor, impose any terms and conditions DNP considers appropriate. DNP may revoke the approval on any reasonable grounds.

10. Personnel and Specified Personnel

10.1 The Research Organisation agrees that the persons in Item C [*Specified Personnel*] will be responsible for carrying out the activities in relation to the Research.

10.2 DNP may give notice on reasonable grounds, requiring the Research Organisation to remove Personnel (including Specified Personnel) from the Research.

10.3 Where clause 10.2 apply, the DNP may request the Research Organisation to provide suitable replacement Personnel (including Specified Personnel) at the earliest opportunity.

10.4 If the request(s) made under clause 10.3 can not be met, DNP may terminate this Agreement in accordance with the clause 25.1.

11. DNP Material

11.1 DNP agrees to provide Material to the Research Organisation as specified in Item I [*Material to be Provided by DNP*].

11.2 DNP grants to the Research Organisation a royalty-free, non-exclusive licence to use, reproduce and adapt the DNP Material for the purposes of this Agreement.

11.3 The Research Organisation agrees to ensure that all DNP Material is used strictly in accordance with any conditions or restrictions set out in Item J [*Use of DNP Material*], and any direction by DNP.

12. Intellectual Property in Research Material

12.1 This clause 12 does not affect the ownership of Intellectual Property in any Material which came into existence prior to the commencement of this Agreement.

12.2 Intellectual Property in Research Material shall, upon creation, vest in accordance with Item P [*Intellectual Property*]; and if not specified in Item P, will vest in DNP.

12.3 Where specified in Item P [*Intellectual Property*], DNP grants to the Research Organisation a permanent, irrevocable, royalty-free, world-wide, non-exclusive licence (including a right of sub-licence) to use, reproduce, adapt and exploit the relevant Material for its own non-commercial educational and research purposes.

12.4 Where specified in Item P [*Intellectual Property*], the Research Organisation grants to DNP a permanent, irrevocable, royalty-free, world-wide, non-exclusive licence (including a right of sub-licence) to use, reproduce, adapt and exploit the relevant Material (including any Research Organisation's Material that is incorporated into that Material, or from which the Material is derived) for non-commercial purposes relating to reserve management.

12.5 If requested by DNP, the Research Organisation agrees to bring into existence, sign, execute or otherwise deal with any document which may be necessary or desirable to give effect to clause 12.4.

12.6 The Research Organisation warrants that it is entitled, or will be entitled at the relevant time, to deal with the Intellectual Property in the Research Material in the manner provided for in this clause 12.

12.7 This clause will survive the expiration or termination of this Agreement.

13. Moral Rights

13.1 Other than as provided in clause 13.2, the Research Organisation will, unless otherwise agreed by DNP in writing, ensure that each person who is or will be the author of any Research Material provides a written consent to DNP

permitting DNP (including its Personnel) to conduct any act which would otherwise infringe the Moral Rights held by that person.

13.2 Research Materials such as scientific journals, reports, thesis, conference papers, lectures, multimedia presentations, which are in a draft format prepared for publication or becomes published, will be attributed in accordance with Item L [*Attribution*].

13.3 This clause will survive the expiration or termination of this Agreement.

14. Confidential Information

14.1 Parties agree not to disclose each other's Confidential Information (unless required or authorised by law or Parliament) without prior written consent.

14.2 A Party may impose any conditions or restrictions it considers appropriate when giving its approval under clause 14.1 and the other Party must comply with any such conditions.

15. Personal Information

15.1 The parties agree, when dealing with personal information arising from this Agreement, to maintain the privacy of Personal Information in accordance with the Australian Privacy Principles set out in the *Privacy Act 1988* (Cth).

16. Reporting

16.1 The Research Organisation and DNP agree to meet to discuss and review the progress of the Research as specified in Item N [*Reporting*].

16.2 The Research Organisation agrees to prepare and provide DNP with the information and documents specified in Item N [*Reporting*].

17. Acknowledgment and Publications

17.1 In:

(a) promotional Materials arising from Research; and

(b) in Research Materials which are intended for or results in publication

the parties agree to use the acknowledgement set out in Item M [*Acknowledgment*].

17.2 Where DNP is an author in Research Materials which are intended for or results in publication, the parties agree to observe the publishing policy in Attachment C [*DNP's Publishing Policy*].

18. Media

18.1 The Research Organisation agrees to notify DNP as soon as possible after receiving any request for media comment about the Research and consult DNP prior to issuing any comment to the media regarding the Research.

19. Conflict of Interest

19.1 The Research Organisation warrants that, to the best of its knowledge,

(a) no conflict with the interests of DNP exists; or

(b) the Research Organisation has disclosed known conflicts of interests to DNP

as at the signing of this Agreement.

19.2 If, during the term of this Agreement a conflict of interest arises, or appears likely to arise, the Research Organisation agrees to:

(a) notify DNP immediately in writing; and

(b) make full disclosure of all relevant information relating to the conflict; and

(c) take such steps as DNP may reasonably require to resolve or otherwise deal with the conflict.

20. Work Health and Safety

20.1 In carrying out its obligations under this Agreement, both parties must comply, and use reasonable endeavours to ensure that its Personnel complies with relevant work health and safety legislation.

20.2 The Research Organisation agrees, when using DNP's premises or facilities, to comply with all reasonable DNP directions and procedures relating to work health, safety and security (including the Commonwealth's smoke-free work-place policy) whether specifically drawn to the attention of the Research Organisation or as might reasonably be inferred from the circumstances.

21. Access to Premises and Records

21.1 The Research Organisation agrees to assist DNP in respect of any inquiry into or concerning the Research or this Agreement, including providing reasonable access to premises, records and Materials relevant to the Research.

22. Indemnity

22.1 The Research Organisation indemnifies DNP from and against any:

(a) costs or liability incurred by the DNP;

(b) loss of or damage to property of the DNP; or

(c) loss or expense incurred by the DNP in dealing with any claim against it, including legal costs and expenses on a solicitor/own client basis and the cost of time spent, resources used or disbursements paid by the DNP,

arising from either:

(d) a breach by the Research Organisation of this Agreement; or

(e) an act or omission involving fault on the part of the Research Organisation or its Personnel in connection with this Agreement.

22.2 The Research Organisation's liability to indemnify DNP under clause 22.1 will be reduced proportionately to the extent that any act or omission involving fault on the part of DNP contributed to the relevant cost, liability, damage, loss or expense.

22.3 The right of the DNP to be indemnified under this clause 22 is in addition to, and not exclusive of, any other right, power or remedy provided by law, but the DNP is not entitled to be compensated in excess of the amount of the relevant cost, liability, damage, loss or expense

22.4 In this clause,

(a) "DNP" includes officers, employees and agents of the DNP; and

(b) "fault" means any negligent or unlawful act or omission or wilful misconduct.

22.5 This clause will survive the expiration or termination of this Agreement.

23. Insurance

23.1 The parties agree, for so long as any obligations remain in connection with this Agreement:

(a) to effect and maintain the insurance specified in Item O [*Insurance*], including those which survive the expiration or termination of this Agreement; and

(b) upon request, to provide proof of insurance.

24. Dispute Resolution

24.1 The parties agree to use their best endeavours to resolve any dispute arising from this Agreement via direct negotiation, before initiating any legal proceedings as follows:

(a) If one party has concerns regarding the performance of the Research, that party will raise concerns with the other party in writing; and

(b) Both parties will work together to address the concerns raised under this clause;

24.2 If no resolution results from direct negotiation, the parties agree to engage in mediation or another form of alternative dispute resolution before initiating any legal proceedings.

24.3 This clause does not preclude either party from commencing legal proceedings for urgent interlocutory relief.

25. Termination

25.1 One party may terminate this Agreement at any time by written notice of at least 3 months to the other party.

25.2 Where one party:

(a) fails to comply with its obligations under the Agreement and the other party considers the failure can not be remedied; or

(b) repeatedly fails to comply with its obligations under the Agreement; or

(c) by written notice, withdraws from carrying out the Research; or

(d) being a corporation, comes under one of the forms of external administration referred to in chapter 5 of the *Corporations Act 2001*, or an order has been made for the purpose of placing the corporation under external administration; or

(e) being an individual, becomes bankrupt or enters into a scheme of arrangement with creditors;

the other party may, by written notice -

(f) terminate this Agreement.

26. Negation of Employment, Partnership and Agency

26.1 Parties are not by virtue of this Agreement an officer, employee, partner or agent of the other party, nor does one party have any power or authority to bind or represent the other party.

27. Waiver

27.1 If a party does not exercise (or delays in exercising) any of its rights, that failure or delay does not operate as a waiver of those rights.

27.2 A single or partial exercise by a party of any of its rights does not prevent the further exercise of any right by that party.

27.3 In this clause, ‘rights’ means rights or remedies provided by this Agreement or at law.

28. Assignment

28.1 Both parties agree not to assign its rights and obligations under this Agreement without prior approval in writing from the other party.

29. Notices

29.1 A notice under this Agreement must be in writing, and:

(a) if given by the Research Organisation to DNP – signed by the Research Organisation and addressed to the DNP’s Representative in Item B [*DNP’s Representative*] or as otherwise notified by DNP; or

(b) if given by DNP to the Research Organisation – signed by the DNP’s Representative and addressed to Research Organisation’s Representative indicated in Item A [*Research Organisation’s Representative*] or as otherwise notified by the Research Organisation.

THE SCHEDULE

A. Research Organisation's Representative

Dr. Luis Ortiz-Catedral

Massey University East Precinct
Dairy Flat Highway (SH17)
Albany
0632
New Zealand

Telephone: +64 (09) 414 0800 ext. 43197
Facsimile: 06 350 5618
Email: L.Ortiz-Catedral@masssey.ac.nz

B. DNP's Representative

Craig Doolan

Norfolk Island National Park and Botanic Garden
PO BOX 310, Norfolk Island, South Pacific, 2899

Telephone: +6723 22695
Email: Craig.Doolan@environment.gov.au

C. Specified Personnel

C.1 Lead Researcher - Professor Dianne Brunton

i. The Lead Researcher is responsible for all Research Organisation's Personnel and for the Research Organisation's activities in relation to the Research.

C.2 Lead Researcher will be supported by the following Specified Personnel

Position	Name	Brief description of responsibilities
Lecturer	Currently Dr. Luis Ortiz-Catedral and Lead Researcher will seek DNP approval of any changes.	1. As outlined in Attachment A [*Research Plan*]

D. Research

1. Research Title

A PCR based survey for beak and feather disease virus on Norfolk Island (see Attachment A [*Research Plan*])

Research Objectives

1) whether or not the species is currently harbouring BFDV;
2) prevalence in the population i.e. 10% 50% etc.;
3) contrast prevalence of infection in Green parrots and Crimson rosellas;

4) determine if the virus is an endemic or introduced strain;
5) model the demographic trajectory of the Green parrot and Crimson rosella in a worst case scenario

Research Outcomes

This research will determine whether or not Green parrots and Crimson rosellas on Norfolk Island currently harbour Beak and Feather Disease Virus. If the virus is detected, we will be able to determine its placement within viruses worldwide by comparing genome sequences to available sequences on GeneBank. This information will be relevant for the management of the species since it will indicate the prevalence of the virus and its most likely source

Research Activities

DNP is responsible for the collection of samples
Research Organisation is responsible for analysis of samples and dissemination of results

2. Research Title

Breeding biology

Research Objectives

1) to establish breeding success rates;
2) collect morphological data to assist in other research areas and assess chick growth rates;
3) investigate historical versus current management practices;
4) investigate breeding behaviour

Research Outcomes

This research will assist in establishing baseline information about the ecology and biology of the species

Research Activities

1) DNP is responsible for all data collection
2) Research Organisation is responsible for assisting in data analysis
3) DNP and Research Organisation will co-author a peer reviewed journal article

4. Research Title

Investigating movements and behaviour via radio-tracking

Research objectives

To investigate:
1. Home range / territories
2. Dispersal rates
3. Survival rates / causes of mortality
4. Intra-specific interactions
5. Staff capacity building

Research outcomes

To understand how far away juveniles disperse in the landscape, to prioritise areas for cat/rat control/ nest provisioning and also to better understand their family dynamics and patterns of survival, pair formation and territories. This

project will also enable DNP staff capacity building so that DNP staff have the skills to monitor parrots using radio telemetry once they have been translocated to Phillip Island.

Research Activities

1) DNP is responsible for all elements of this project
2) Research Organisation is responsible for advice on project implementation

5. Research Title

Spatio-temporal variation in foraging areas of the Tasman Parakeet in the Norfolk Island National Park

E. Environmental Conditions

i. The Research Organisation must take all reasonable steps to minimise the impact of the Research on the environment.
ii. The Research must be conducted out of view of the general public where possible.
iii. Before entering or moving around the Reserve, the Research Organisation must take all reasonable steps to clean vehicles and other transport if they have been off sealed or graded roads.
iv. When visiting Phillip Island, the Research Organisation must abide by the Phillip Island Biosecurity Plan.
v. All traps, nets and any other devices used for capturing and securing animals, and any devices that are to be attached to animals, must be thoroughly cleaned, and free of any pathogens that may cause disease, before they are brought into the Reserve or moved between areas within the Reserve.
vi. The Research Organisation must comply with the conditions specified in Attachment B.

F. Research Period

The Research Period will commence 1st March 2017 and will end on, unless terminated earlier in accordance with this Agreement.

G. DNP's Contribution

DNP agrees to provide the following assistance and facilities, subject to the Reserve's operational needs:

i. Lifts in DNP vehicles;
ii. Use of DNP computers in the Reserve;
iii. Transfers to Phillip Island, so long as they coincide with existing staff transfers;
iv. Use of the Ranger Hut accommodation on Phillip Island;
v. Staff time and expertise;

H. Research Organisation's Contributions

The Research Organisation agrees to provide the following:

i. training and up-skilling DNP staff capacity to monitor Green Parrots using distance sampling methods

ii. a licence to DNP to use data, photos, analysis and other material resulting from the Research for non-commercial Reserve management purposes;

iii. radio trackers and equipment for monitoring

I. Material to be provided by DNP

DNP agrees to provide the following material to the Research Organisation, on the condition that the Research Organisation will use DNP's Material in accordance with the conditions and restrictions set out in Item J [*Use of DNP Material*].

i. DNP's data (such as photos and geo coordinates) relating to Green Parrots;

ii. The following biological material:

Description of biological material	Quantity
(A) Blood and feather samples from Green Parrot specimens	All specimens collected between July 2014 – July 2015
(B) Whole Crimson Rosella specimens	All specimens collected between July 2014 – July 2015

J. Use of DNP Material

Use of DNP's Material by the Research Organisation is on the condition that the Research Organisation agrees to:-

i. only use DNP's Material for the purposes of Item D [*Research*];

ii. obtain written approval from DNP before disclosing or sharing DNP Materials to a third party; and

iii. upon termination of this Agreement (unless DNP agrees otherwise), return all DNP Materials provided and destroy any copies held in the Research Organisation's possession.

K. Confidential Information

i. Location of Green Parrot nest sites

L. Attribution

L.1 – For Research Materials created jointly by DNP and the Research Organisation:

i. Abigail Smith and Dr. Luis Ortiz-Catedral or

ii. as agreed between the parties (including waiving attribution where appropriate).

L.2 – For Research Materials created by DNP or its Personnel:

i. or

ii. as advised by DNP (including waiving attribution where appropriate).

L.3 – For Research Materials created by the Research Organisation or its Personnel:

i. Dr. Luis Ortiz-Catedral; or

ii. as advised by the Research Organisation (including waiving attribution where appropriate).

M. Acknowledgment

DNP is to be acknowledged as follows:

i. This research acknowledges the support provided by the Director of National Parks, and park staff of Norfolk Island National Park and Parks Australia. The views expressed in this document do not necessarily represent the views of the Australian Government."

N. Reporting

N.1 – Meetings

The Research Organisation and DNP agree to meet:

i. At least once every 3 months during the Research Period to discuss and review the progress of the Research; and
ii. once at the end of the Research Period

N.2 – Reports

Reports to DNP are to be sent to

Norfolk Island National Park
PO BOX 310, Norfolk Island, South Pacific, 2899

The Research Organisation will provide:

i. reports as per Research Outcomes in Item D of the Schedule,
ii. copy of all reports, published documents (such as survey, journals, chapters), and recommendations for management and research arising from the Research within 1 month of publication or finalisation

O. Insurance

Each party shall maintain:

i. workers' compensation insurance for an amount required by the relevant State or Territory legislation; and

P. Intellectual Property

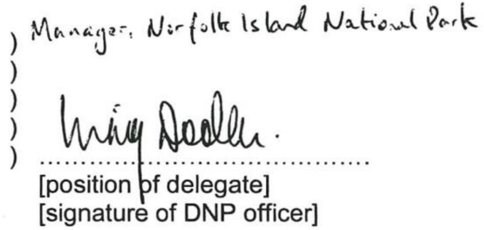
Parties agree that the intellectual property rights in the Research Material will be as follows:

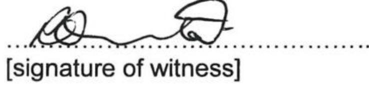
	Description of Research Material	IP Owner	IP Licence
1.	Research activity: **Disease and sex analysis**		
(A)	Disease data arising out of blood and feather analysis *(A PCR based survey for beak and feather disease virus on Norfolk Island)*	Jointly owned by DNP and Research Organisation.	
(B)	DNA sex data arising out of blood and feather analysis *(Determining the morphological differences in male and female green parrots)*	Jointly owned by DNP and Research Organisation.	
2.	Research activity: **Breeding biology – data arising from nest monitoring**		
(A)	Breeding succuss rates	DNP	As per clause 12.3
(B)	Data arising from motion sensor cameras during nest monitoring	DNP	As per clause 12.3
(C)	Chick morphological data	DNP	As per clause 12.3
(D)	Historical data on breeding succuss rates, banding records and egg morphology	DNP	As per clause 12.3
3.	Research activity: **Estimating seasonal variability in the food resources of Green parrots on Norfolk Island**		
(A)	Data arising from investigating food resources of Green parrots on Norfolk Island	Research Organisation	As per clause 12.4
4.	Research activity: **Investigating movements and behaviour via radio-tracking**		
(A)	Data arising from radio-tracking	DNP	As per clause 12.3
5.	Research activity: **Population estimates via distance sampling**		
(A)	Data arising from population studies via distance sampling	Research Organisation	As per clause 12.4

EXECUTION

Signed as an Agreement

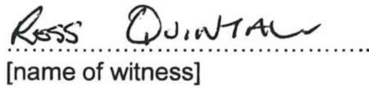
Signed on behalf of **Director of National Parks** by its duly authorised officer in the presence of:





....
[signature of witness]

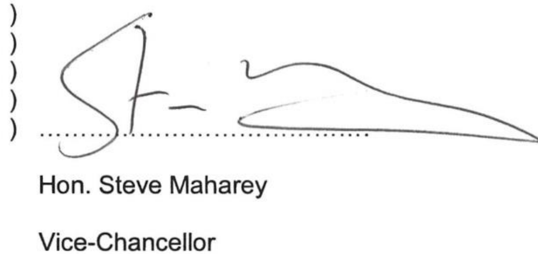
....
[position of delegate]
[signature of DNP officer]



....
[name of witness]

24/05/2016
....
[date of signature]

Signed on behalf of **Massey University**, by its duly authorised officer in the presence of:



....
[signature of witness]

....
Hon. Steve Maharey

Vice-Chancellor

....
[name of witness]

9 June 2016
....
[date of signature]

ATTACHMENT A

Attachment A to the Collaborative Research Agreement.

Spatio-temporal variation in foraging areas of the Tasman Parakeet in the Norfolk Island National Park

ATTACHMENT B

A. General Conditions

A.1 In this Attachment B, unless the contrary intention appears:
EPBC Act means the *Environment Protection and Biodiversity Conservation Act 1999* and all regulations, management plans and instruments made under it, and includes any legislation that amends or replaces it;
EPBC Regulations means the *Environment Protection and Biodiversity Conservation Regulations 2000* and includes all regulations that amend or replace them.

A.2 The Research Organisation must comply with the EPBC Act, the EPBC Regulations, the management plan, the conditions set out in this Agreement, and any other signs, notices, information, guidelines, codes of conduct, protocols or directions issued by, or under the authority of, DNP relating to the reserve.

A.3 The Research Organisation must comply with all Commonwealth, State or Territory laws relating to the Research.

A.4 The Research Organisation must hold all permits, licences and other authorities required by law for the conduct of the Research.

A.5 The Research Organisation must maintain, and must ensure its Personnel maintain, relevant training, qualifications and experience to competently conduct the Research.

A.6 The Research Organisation must carry a copy of this Agreement while conducting the Research, and must produce it for inspection when requested by a ranger or warden.

A.7 The Research Organisation must not, and must take all reasonable steps to ensure that its Personnel do not, walk off track or use any road, track or area that is permanently, temporarily or seasonally closed or restricted by fences, gates or signs, unless specifically authorised by this Agreement or a permit.

A.8 The Research Organisation must not, and must take all reasonable steps to ensure its Personnel do not:
- (a) behave contrary to the EPBC Regulations or any warning or regulatory signs;
- (b) pick fruits, flowers or branches, or otherwise damage any native plants;
- (c) interfere with, feed, handle or disturb any native animal, or damage or disturb a nest or dwelling place of a native animal;
- (d) touch or interfere with any rock art, sacred site or cultural artefact;
- (e) impede public access to any part of the reserve.

A.9 The Research Organisation must notify DNP, in writing, within seven days if:
- (a) the Research Organisation sells any part of the organisation to which the Agreement relates, or for any other reason ceases to conduct the Research;
- (b) the Research Organisation is a company and there is a change in the owners of the majority of issued shares in the company.

A.10 If the Research Organisation is a company or other incorporated body, it must not, without the approval of DNP, have as a director or office holder a person who has been convicted[1] of an offence[2] against the EPBC Act within the previous ten years.

A.11 The Research Organisation must not, without the approval of DNP, use directly in the conduct of the activity to which this Agreement relates the services of any person who has within the previous ten years been convicted of an offence against the EPBC Act prior to the commencement of the Agreement.

A.12 If any of the Research Organisation's Personnel contravene a provision of the Agreement, DNP may:
- (a) notify the Research Organisation of the contravention; and,
- (b) direct the Research Organisation to cease using the services of that person within the reserve for a specified time, and the Research Organisation must forthwith comply with that request.

Note: In this situation DNP will give written notice to that person of the decision, stating that he or she may apply to the DNP to reconsider the decision and that, subject to the Administrative Appeals Tribunal Act 1975*, he or she may subsequently apply to the Administrative Appeals Tribunal for review of the reconsideration.*

A.13 The Research Organisation must ensure that its Personnel are fully informed of and understand these conditions before they commence taking part in the Research.

A.14 The Research Organisation must ensure that appropriate risk management systems, strategies and procedures are in place to minimise foreseeable risks to its Personnel, DNP Personnel, members of the public, and the environment and heritage values of the reserve, and must produce evidence of such systems, strategies and procedures upon request by DNP.

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[1] A person is taken to have been convicted of an offence if, within five years, the person has been charged with, and found guilty of, the offence but discharged without conviction or has not been found guilty of the offence, but a court has taken the offence into account in passing sentence on the person for another offence. Part VIIC of the *Crimes Act 1914* includes provisions that, in certain circumstances, relieve persons from the requirement to disclose spent convictions and require persons aware of such convictions to disregard them.

[2] Such an offence includes, for an offence under such a law, section 6 of the *Crimes Act 1914* or sections 11.1, 11.4 or 11.5 of the Criminal Code (which deal with being an accessory after the fact, attempting to commit offences, inciting to or urging the commission of offences by other people and conspiring to commit offences) or an equivalent provision of a law of a State or Territory.

A.15 The Research Organisation is responsible for the safety, well-being and behaviour of its Personnel, and must take all reasonably practicable steps to ensure that no person is exposed to risks to their health or safety whilst in the reserve.

A.16 If any of the Research Organisation's Personnel is killed, injured, becomes ill, goes missing or is involved in or witnesses a dangerous incident while in the reserve, DNP must be notified as soon as possible and the Research Organisation and its Personnel must comply with all requests and directions from DNP Personnel.

Note: "dangerous incident" means an incident that exposes a person to a serious risk to their health or safety.

A.17 The Research Organisation must ensure its Personnel carry sufficient potable water for the conduct of activities in the reserve.

Note: DNP recommends that, in hot weather, people carry and drink one litre of water for every hour they are active.

A.18 The Research Organisation must make good all damage to the reserve, to the extent that the damage was caused or contributed to by the conduct of the Research or a breach of the Agreement by the Research Organisation.

B. Scientific Research Conditions

B.1 The Research Organisation must take all reasonable steps to minimise the impact of the Research on the environment.

B.2 As much as possible, the Research must be conducted out of the view of the general public.

B.3 The Research Organisation must notify DNP as soon as possible after receiving any request for media comment about the Research. The Research Organisation must consult DNP prior to issuing any comment to the media regarding the Research.

B.4 The Research Organisation must take all reasonable steps to clean vehicles and other transport used in the conduct of the Research, before entering or moving around the reserve, if they have been off sealed or graded roads, to minimise the spread of weed seeds and pathogens in the reserve.

B.5 The Research Organisation must ensure that any vessel used in the conduct of the Research is registered, has appropriate safety equipment on board at all times, and is operated and maintained in accordance with all relevant and applicable laws, and must, if requested by DNP, provide copies of all relevant certificates and other documents evidencing compliance with this condition.

B.6 The Research Organisation must ensure that all traps, nets and other devices used for capturing and securing animals, and any devices that are to be attached to animals, are thoroughly cleaned and free of pathogens that may cause disease, before they are brought into the reserve or moved within the reserve.

B.7 If the Research involves taking whole or part of any organisms, the Research Organisation must record the name of each type of organism, location, date and quantity taken at each location.

B.8 The Research Organisation must ensure that all waste materials and chemical substances relating to the Research are placed in appropriate containers designed to fully confine material, removed from the reserve, and disposed in an environmentally responsible manner.

B.9 The Research Organisation must not discharge into the environment any fuels, fuel-tainted bilge water, chemical wastes from treatment or cleaning of vessels, or any other substance that is likely to adversely affect the environment.

B.10 The Research Organisation must not use a vessel with anti-fouling that contains tributyltin compounds.

B.11 The Research Organisation must ensure compliance with instructions issued from time to time by DNP regulating boat speed and measures to be taken to avoid or minimise environmental damage from water-related activities.

C. Norfolk Island Conditions

C.1 On each visit to the reserve, and at least five business days prior to conducting any Research activities, the Research Organisation must provide DNP with details of all vehicles and persons participating in the Research activities during the visit, and all further details DNP may reasonably request.

C.2 The Research Organisation must be contactable via radio or telephone (or both) at all times when conducting Research activities in the reserve, including on Phillip Island.

C.3 Research Organisation Personnel must not drive, ride or tow vehicles other than on designated roads and parking areas.

Note: Maximum size of vehicle permitted in the reserve:

Mount Pitt Road	*Park except Mt Pitt Road)*
Length: 6.5 metres	*Length: 7.0 metres*
Width: 2.2 metres	*Width: 2.3 metres*
Wheelbase: 3.7 metres	*Wheelbase: 2.8 metres*

C.4 The Research Organisation must endeavour to minimise damage to tracks, and in particular not to cause the tracks to become deeply rutted.

C.5 The Research Organisation must comply with directions from DNP staff and officers of the Norfolk Parks and Forestry Service regarding access conditions in the Forestry Area.

C.6 The Research Organisation must not interfere with any seabirds or nests on Phillip Island unless specifically authorised by this Agreement.

C.7 The Research Organisation must be accompanies by a guide approved by the Park Manager when undertaking Research on Phillip Island.

ATTACHMENT C

Attachment C to the Collaborative Research Agreement.

Parks Australia Research Publishing Policy

Parks Australia
Research Publishing Policy

This policy sets out the process Parks Australia follows to guide the publication of scientific activities undertaken in Commonwealth reserves and/or by Parks Australia staff. The policy ensures that our research and natural resource management practices are underpinned by a rigorous scientific foundation, and that findings of these activities are made widely available to inform science, policy and management actions for improved conservation outcomes.

Purpose

Parks Australia is strongly committed to promoting professional and institutional publication standards for scientific research and related activities, including information from monitoring and management programs, conducted by Parks Australia staff and/or in Commonwealth reserves (Booderee National Park; Christmas Island National Park; Kakadu National Park; Norfolk Island National Park; Pulu-Keeling National Park; Uluru-Kata Tjuta National Park; the Australian National Botanic Gardens; and the Commonwealth marine reserve networks). In this policy, Parks Australia is inclusive of the Director of National Parks (DNP).

Parks Australia is committed to ensuring accessibility of research publications, including through open access and high profile journals, and online publications. Parks Australia is also committed to promoting the wider communication of scientific research findings, including outcomes which may assist in meeting operational needs for effective management and conservation. This is consistent with the Australian Government's approach to enabling open access to publicly funded information.

This policy outlines a cooperative process for the preparation of scientific publications and communication of the outcomes of scientific research and related activities conducted by Parks Australia staff and/or external (non-Department) researchers in Commonwealth reserves.

The intent of this process is to ensure that appropriate members of the Parks Australia Division and the Department of the Environment (the Department) are provided with a timely opportunity to consider scientific papers and ensure staff co-authorship meets institutional requirements. It is not the intention of the policy to restrict or censor publication of scientific activities. Rather, the policy aims to allow the Department and other Australian Government agencies the opportunity to monitor potential sensitivities and prepare, where necessary and appropriate, responses to the research prior to its release.

Objectives

This policy establishes standards and protocols for the authoring and publishing of outcomes from scientific research and related activities undertaken in Commonwealth reserves and/or by Parks Australia staff publishing information in connection with the Australian Government.

Scope

This policy applies to all authors who intend to publish results of scientific research, including information resulting from monitoring programs, undertaken in, or using data collected from, Commonwealth reserves. This includes publication of data collected from Commonwealth reserves or data owned by Parks Australia. Data may include, but are not limited to: photographs; video/audio recordings; spatial or geographic information; monitoring/survey data; genetic and ecological data. Publications include scientific papers in journals, book chapters, conference papers and technical reports.

Parks Australia staff should follow standard Departmental procedures in obtaining approval to publish fact sheets, abstracts, web material or social media. This will generally require approval by the relevant Branch Head and Parks Australia Public Affairs.

A separate data sharing and/or licensing agreement may be required for external (non-Department) researchers to obtain, publish or disclose to a third party, data owned by Parks Australia (e.g. data collected by Parks Australia staff and/or from Commonwealth reserves). In accordance with Australian Government, Department and Parks Australia policies on information management and Creative Commons licensing, which encourage greater 'open' access to information, data solely owned by Parks Australia will be made freely available to the public under the most open Creative Commons (CC) licence possible (generally the Creative Commons By Attribution v.3 licensing model).

Parks Australia is committed to ensuring timely publication of high quality scientific research. As such, when a draft publication or manuscript is submitted to Parks Australia for approval (e.g. when a Parks Australia staff member is an author or co-author), the process will usually be undertaken within ten working days and every effort will be made to expedite the process. The Assistant Secretary for Parks biodiversity science will assist with reviewing any copyright or intellectual property issues and seek clearance (where required) from Public Affairs Parks Australia.

Related Policy/Protocols

The policy is prepared in accordance with various legislation, policy and institutional guidelines including:

- The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), as well as relevant reserve management plans prepared under the EPBC Act, which stipulate conditions for relevant research permits and reporting
- Permits required under the EPBC Act (1999) including for research undertaken in Commonwealth reserves. This policy will be provided to recipients of research permits issued by the DNP and is available at: www.environment.gov.au/epbc/permits/index.html
- The DNP Intellectual Property Guide and Chief Executive Instructions
- The Parks Australia Knowledge Management Strategy and related policies, which support the Department's Information Strategy 2013–2016 and the broader Australian Government information reform agenda
- The National Environmental Research Program (NERP) Communications Strategy, which identifies a process to facilitate public dissemination of NERP-funded research results, and to ensure researchers comply with the communications and media requirements of the Department of the Environment. It is available at: www.environment.gov.au/nerp
- The Australian Code for the Responsible Conduct of Research, which guides institutions and researchers in responsible research practices, including how to publish and disseminate research findings. It is available at: www.nhmrc.gov.au/guidelines/publications/r39

Parks Australia Research Publishing Policy

The policy is separated into four elements based on whether Parks Australia staff are author/s on the publication, whether the research was commissioned, and whether the research was undertaken in collaboration with Parks Australia or independently, as follows:

1. Publishing policy for Parks Australia Staff as primary authors
2. Publishing policy for commissioned research
3. Publishing policy for collaborative research (involving Parks Australia staff as co-authors)
4. Publishing policy for external (non-Department) researchers working in (or using data collected from) Commonwealth reserves.

A flowchart showing the publication process for each of the four elements, including obtaining approval from Parks Australia to submit a manuscript for publication, is provided at **Attachment A**.

A Publication Checklist is provided at **Attachment B** to assist with implementing this policy.

1. Publishing policy for Parks Australia Staff as primary authors

Parks Australia Staff (particularly the primary author) should comply with the following terms when publishing scientific research or related activities

- Ensure all co-authors have read, understand and agree with their name being included on the draft publication/manuscript. Where traditional owners are included in the author list, consultation should be undertaken in accordance with Park research consultation protocols (e.g. NERP Kakadu National Park research protocols 2013-2015).
- Acknowledge the Department, Parks Australia and/or the DNP as relevant for any financial or in-kind contributions to the research – ***see examples in Section 4***.
- Ensure the draft complies with all relevant copyright legislation.
- Before submitting a draft publication (or manuscript) to a journal or other publisher, complete the Parks Australia Publication Checklist (**Attachment B**), and submit for approval to the Assistant Secretary for Parks Island Biodiversity Science (following clearance from the relevant Branch Head/ Park Manager).
- Incorporate relevant information in the Scientific Knowledge in Parks Australia (SKIPA) database, including the location of any associated data or metadata.

2. Publishing policy for commissioned research

Parks Australia staff responsible for managing commissioned research (e.g. as a contract manager) in Commonwealth reserves should comply with the following terms when publishing scientific research or related activities:

- Obtain research permits prior to commencing research (where required), and comply with all permit conditions, including identification in draft publications of all permits and approvals issued under the EPBC Act.
- Ensure that conditions of the contract relating to outcomes of the research are met. Note that contract conditions may include the need for researchers to submit a draft publication to Parks Australia prior to submitting to a journal, conference etc.
- Acknowledge the Department (including Parks Australia and the DNP) appropriately for any financial or in-kind contributions to the research and include appropriate disclaimers in the publication (**see examples in Section 4**).

- Before submitting a draft publication to a journal or other publisher, complete the Publication Checklist (**Attachment B**) and submit with the draft publication for approval to the Assistant Secretary for Parks Island Biodiversity Science
- Ensure that relevant information is incorporated in the Scientific Knowledge in Parks Australia (SKIPA) database, including the location of any associated data or metadata, as well as contact details for external researchers holding the data.

3. Publishing policy for collaborative research (involving Parks Australia staff as co-authors)

Parks Australia staff involved in collaborative research should comply with the terms outlined in Section 1 when publishing scientific research or related activities. For example, where Parks Australia staff are co-authors on a manuscript, they are required to submit a draft manuscript to Parks Australia for approval prior to submission for publication (with the Publication Checklist at **Attachment B**).

Parks Australia staff involved in collaborative research should ensure that appropriate collaborative authorisations are in place, such as data licensing agreements, collaborative research agreements, and/or material sharing agreements (where specimens are provided).

Parks Australia staff involved in collaborative research should ensure that relevant information is incorporated in the Scientific Knowledge in Parks Australia (SKIPA) database, including the location of any associated data or metadata.

4. Publishing policy for external (non-Department) researchers working in Commonwealth reserves (or using data owned by Parks Australia)

Parks Australia requests that external researchers who undertake research in protected areas managed by Parks Australia comply with the following terms when publishing or communicating scientific research:

- All researchers are expected to follow standard codes of conduct for authorship and publication.
- All researchers are expected to obtain relevant research permits prior to commencing research, as well as material sharing agreements (where specimens are involved) and/or data sharing and licence agreements to use or publish data owned by Parks Australia.
- All conditions of the research permit or any other contract agreement with the Commonwealth as represented by the Department of the Environment, or DNP must be adhered to, including identification of all permits and approvals issued under the EPBC Act in draft publications.
- Appropriate acknowledgements of research permits should be included in the publication. In some cases it may be appropriate to acknowledge the assistance of Parks Australia staff – ***see examples below***. Where traditional owners are acknowledged the appropriate procedures should be followed, e.g. through reference to the Park research consultation protocols.
- Include appropriate disclaimers – ***see example below***.
- Provide a copy of draft publication(s) to Parks Australia prior to submission to a journal or other publisher for information. This process allows the Department (including the DNP and Parks Australia) the opportunity to monitor potential sensitivities and prepare, where necessary and appropriate, responses to the research prior to its release.
- Parks Australia encourages the wider communication of findings and conclusions of the research, including to those acknowledged in the paper.
- The Publication Checklist (**Attachment B**) may assist with adhering to the above terms.

Examples

Acknowledgement

(A component of this) This research was conducted in (*Park Name)* under Permit No. XXXXX. The authors wish to thank the relevant staff at Parks Australia, with particular mention given to *(names)*.

Or

This research was jointly funded by the Director of National Parks, Australia and *(other collaborators)*. This research was conducted in (*Park Name)* under Permit No. XXXXX. The authors wish to thank the relevant staff at Parks Australia, with particular mention given to *(names)*.

General disclaimer

The findings and views expressed are those of the authors and do not necessarily represent the views of Parks Australia, the Director of National Parks or the Australian Government.

Parks Australia Publication Checklist

The Publication Checklist (**Attachment B**) will assist with implementing this policy. The checklist is also available on the Parks Australia intranet (for staff) and can be obtained from Parks Australia (see contacts below).

The checklist should be submitted with the manuscript to the Assistant Secretary for Parks biodiversity science in Parks Australia and approved before the manuscript is submitted (e.g. to a journal) for publication. External researchers (non-commissioned research only) are encouraged but not required to complete the checklist or obtain approval before submitting manuscripts for publication.

Further Advice and contact

For all queries regarding this policy, or for further advice on the interpretation of this policy, please contact the Parks and Island Biodiversity Science Team.

Assistant Secretary, Parks and Island Biodiversity Science:

Name: Dr Judy West
Phone: 02 6274 2746 or 02 6250 9501
Email: judy.west@environment.gov.au

Policy Officer, Parks and Island Biodiversity Science:

Phone: 02 6274 2323 or 02 6274 1546

APPENDIX B

AUTHORITY FOR RESEARCH

Department of Conservation
Te Papa Atawhai

Authority for research and/or collection and/or introduction of material on public conservation

National Authorisation Number: 38183-RES

THIS AUTHORITY is made this day of

PARTIES:

The Minister of Conservation (the Grantor)

AND

Luis Ortiz-Catedral (National Holder) (the Authority Holder)

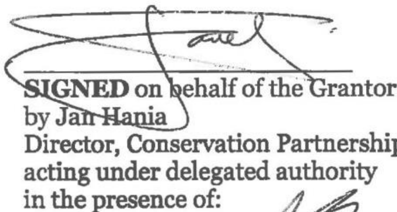
BACKGROUND:

A. The Director General of Conservation is empowered to issue authorisations under the Conservation Act 1987, the National Parks Act 1980 the Reserves Act 1977 and the Wildlife Act 1953 (the Conservation Legislation).

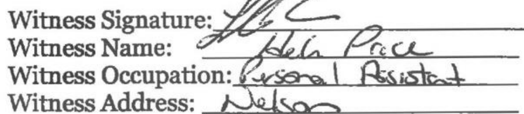
B. The Authority Holder wishes to exercise the authorisation issued under the Conservation Legislation subject to the terms and conditions of this authority.

OPERATIVE PARTS:

In exercise of the Grantor's powers under the Conservation Legislation the Grantor **AUTHORISES** the Authority Holder under the Conservation Legislation together with the right to exercise this Authority on the Land subject to the terms and conditions contained in this Authority and its Schedules.



SIGNED on behalf of the Grantor
by Jan Hania
Director, Conservation Partnerships for the North and Western South Island,
acting under delegated authority
in the presence of:



Witness Signature:
Witness Name: Helen Price
Witness Occupation: Personal Assistant
Witness Address: Nelson

A copy of the Instrument of Delegation may be inspected at the Director-General's office at 18-22 Manners Street, Wellington

SCHEDULE 1

1.	**Authorised activity (including approved quantities of material and collection methods).** (clause 2)	A meta-population analysis of reintroduced populations of Orange-fronted parakeets at Maud, Blumine and Chalky Islands.
2.	**The Land** (clause 2)	Maud and Blumine Islands - Marlborough Sounds, Chalky Island – Fiordland National Park.
3.	**Authorised Personnel** (clause 3)	Dr Luis Ortiz-Catedral Mark Delaney Michael Anderson
4.	**Term** (clause 4)	Commencing on and including November 6 2014 and ending on and including 30 November 2016.
5.	**Authority Holder's address for notices** (clause 10)	The Authority Holder's address in New Zealand is: Ecology and Conservation Lab, Building 5, Oteha Rohe, Massey University North Shore 0745
		The Grantor's address is: Permissions Hamilton Private Bag 3072 Hamilton 3240 Phone: 078581000 Email:permissionshamilton@doc.govt.nz

SCHEDULE 2

STANDARD TERMS AND CONDITIONS OF THE AUTHORITY

1. Interpretation

1.1 The Authority Holder is responsible for the acts and omissions of its employees, contractors or, agents. The Authority Holder is liable under this Authority for any breach of the terms of the Authority by its employees, contractors or agents as if the breach had been committed by the Authority Holder.

1.2 Where obligations bind more than one person, those obligations bind those persons jointly and separately.

2. What is being authorised?

2.1 The Authority Holder is only allowed to carry out the Authorised Activity on the Land described in Schedule 1, Item 2.

2.2 The Authority Holder must contact the Department of Conservation's local office(s) prior to carrying out the Authorised Activity in the Area.

2.3 The Authority Holder and Authorised Personnel must carry a copy of this Authority with them at all times while carrying out the Authorised Activity.

2.4 Unless expressly authorised by the Grantor in writing, the Authority Holder must not donate, sell or otherwise transfer to any third party any material, including any genetic material, or any material propagated or cloned from such material, collected under this Authority. Notwithstanding the preceding constraint, the Authority Holder may publish authorised research results.

2.5 The Authority Holder must lodge holotype specimens and a voucher specimen with a recognised national collection any taxon, which is new to science. The Authority Holder must immediately notify the Grantor of any such finds.

3. Who is authorised?

3.1 Only the Authority Holder and the Authorised Personnel described in Schedule 1, Item 3 may be involved in carrying out the Authorised Activity, unless otherwise agreed in writing by the Grantor.

4. How long is the Authority for - the Term?

4.1 This Authority commences and ends on the dates set out in Schedule 1, Item 4.

5. What are the obligations to protect the environment?

5.1 Other than what is authorised by this Authority, the Authority Holder must not cut down or damage any vegetation; or damage any natural feature or historic resource on any public conservation land being part of the Land; or light any fire on such public conservation land; or erect any structure such public conservation land without the prior consent of the Grantor.

5.2 The Authority Holder must ensure that it adheres to the international "Leave No Trace" Principles at all times (www.leavenotrace.org.nz).

5.3 The Authority Holder must not bury:

(a) any toilet waste within 50 metres of a water source on any public conservation land being part of the Land; or

(b) any animal or fish or any part thereof within 50 metres of any water body, water source or public road or track.

6. What are the liabilities?

6.1 The Authority Holder agrees to exercise the Authority at the Authority Holder's own risk and releases to the full extent permitted by law the Grantor and the Grantor's employees and agents from all claims and demands of any kind and from all liability which may arise in respect of any accident, damage or injury occurring to any person or property arising from the Authority Holder's exercise of the Authorised Activity.

6.2 The Authority Holder must indemnify the Grantor against all claims, actions, losses and expenses of any nature which the Grantor may suffer or incur or for which the Grantor may become liable arising from the Authority Holder's exercise of the Authorised Activity.

6.3 This indemnity is to continue after the expiry or termination of this Authority in respect of any acts or omissions occurring or arising before its expiry or termination.

7. What about compliance with legislation and Grantor's notices and directions?

7.1 The Authority Holder must comply with all statutes, bylaws and regulations, and all notices and requisitions of any competent authority relating to the conduct of the Authorised Activity. Without limitation, this includes the Conservation Act and the Acts listed in the First Schedule of that Act and the Health and Safety in Employment Act.

7.2 The Authority Holder must comply with all reasonable notices and directions of the Grantor relating to the conduct of the Authorised Activity.

8. Are there limitations on public access and closure?

8.1 The Authority Holder acknowledges that the public conservation land being part of the Land is open to the public for access and that the Grantor may close public access to that public conservation land during periods of high fire hazard or for reasons of public safety or emergency.

9. When can the Authority be terminated?

9.1 The Grantor may terminate this Authority at any time in respect of the whole or any part of the Land if:

(a) The Authority Holder breaches any of the conditions of this Authority; or

(b) in the Grantor's opinion, the carrying out of the Authorised Activity causes or is likely to cause any unforeseen or unacceptable effects

9.2 If the Grantor intends to terminate this Authority, the Grantor must give the Authority Holder either:

(a) one calendar month's notice in writing; or

(b) such other time period which in the sole opinion of the Grantor appears reasonable and necessary

10. How are notices sent and when are they received?

10.1 Any notice to be given under this Authority by the Grantor is to be in writing and made by personal delivery, fax, by pre paid post or email to the Authority Holder at the address, fax number or email address specified in Schedule 1, Item 5. Any such notice is to be deemed to have been received:

(a) in the case of personal delivery, on the date of delivery;

(b) in the case of fax, on the date of dispatch;

(c) in the case of post, on the 3rd working day after posting;

(d) in the case of email, on the date receipt of the email is acknowledged by the addressee by return email or otherwise in writing.

10.2 If the Authorised Holder's details specified in Schedule 1, Item 5 change then the Authorised Holder must notify the Grantor within 5 working days of such change.

11. What about the payment of costs?

11.1 The Authorised Holder must pay the standard Department of Conservation charge-out rates for any staff time and mileage required to monitor compliance with this Authority and to investigate any alleged breaches of the terms and conditions of it

12. Are there any Special Conditions?

12.1 Special conditions are specified in Schedule 3. If there is a conflict between this Schedule 2 and the Special Conditions in Schedule 3, the Special Conditions shall prevail.

SCHEDULE 3

SPECIAL CONDITIONS

Property of the Crown

1. All material collected remains the property of the Crown. This includes any dead wildlife, live wildlife, any parts thereof and any eggs or progeny of the wildlife. This includes any genetic material and any replicated genetic material. The Authority Holder must comply with any reasonable request from the Grantor for access to any collected material.

Track markers

2. The Authority Holder shall remove all track markers, flagging tape or other material used at the research areas for the purposes of the Authorised Activity within one (1) month of the Authorised Activity being completed.

Expectations of the public

3. The Authority Holder must use best endeavours to ensure that the Authorised Activity is not undertaken within sight of the public.

4. While undertaking the Authorised Activity the Authority Holder must not exclude or impede the public from accessing any sites, tracks or facilities.

5. If approached by members of the public while carrying out the Authorised Activity, the Authority Holder shall provide an explanation of why the Authorised Activity is taking place.

Biosecurity General

6. The Authority Holder must take all precautions to ensure weeds and non-target species are not introduced to the Land; this includes ensuring that all tyres, footwear, gaiters, packs and equipment used by the Authority Holder, its staff and clients are cleaned and checked for pests before entering the Land.

Didymo

7. The Authority Holder must comply with the Ministry for Primary Industry (MPI)'s "Check, Clean, Dry" cleaning methods to prevent the spread of didymo (*Didymosphenia geminata)* and other freshwater pests when moving between waterways. "Check, Clean, Dry" cleaning methods can be found at - http://www.biosecurity.govt.nz/cleaning. The Authority Holder must regularly check this website and update their precautions accordingly.

Chalky Island

8. The Concessionaire must comply and ensure its clients comply with the Ministry for Primary Industry (MPI)'s "Check, Clean, Dry" cleaning methods to prevent the spread of didymo (Didymosphenia geminata) and other freshwater pests when moving between waterways. "Check, Clean, Dry" cleaning methods can be found at - http://www.biosecurity.govt.nz/cleaning. The Concessionaire must regularly check this website and update their precautions accordingly.

9. In addition to complying with the Check, Clean, Dry rules for didymo, the concessionaire must make sure that they check for all other unwanted freshwater pests and make sure that they do not introduce any organisms into the island's freshwater (http://www.biosecurity.govt.nz/pests/salt-freshwater/freshwater) , especially Lagarosiphon major (http://www.biosecurity.govt.nz/pests/oxygen-weed).

10. Prior to travelling to Chalky Island, all crew must ensure that all gear complies with the Department's biosecurity guidelines. Please contact the Department's Biosecurity team for these guidelines. Gear shall be checked by Departmental staff prior to travelling to Chalky Island and the Department may charge for this time at $115+GST per hour.

11. No fires may be lit whilst on Anchor Island.

12. The Permit Holder must contact the Department's Fiordland Biodiversity team (Te Anau) at least two weeks prior to any planned trips to Chalky, in order to:
    - Ensure that the Permit Holder's planned dates do not impact on any planned works that the Department has in the area.
    - Find out and follow biosecurity guidelines that need to be met.
    - Learn about the location of any tracks on the island.

13. Where the Authority Holder employs an external company to assist in their activities on public conservation land, that company must hold a valid concession. The Authority Holder is required to operate under the terms of that company's existing concession.

Blumine and Maud Islands

14. The Authority Holder shall contact the Picton Office at least 5 working days prior to visiting Blumine and Maud Islands.

15. The Authority Holder shall forward a copy of the research findings, any reports and publications to the Grantor within one month of the documents being completed. This report should include any implications to conservation management. The report shall be forwarded electronically to dliddell@doc.govt.nz, citing Authority number 39696-FAU. The Authority Holder acknowledges that the Grantor may provide copies of these findings to tangata whenua.

Revocation clause

16. The Grantor may at any time revoke this Authority, or may at any time review/and or vary the conditions pertaining to this authority if any conditions contained in this Authority are breached or for any other reason that the Grantor may decide.

Variations

17. The Authority Holder may apply for variations to the Authority; this must be done by contacting the Permissions team where the original authorisation was processed.

APPENDIX C

PRELIMINARY ANALYSIS OF SURVEY METHODS

MODEL FITTING

We used R version 3.3.3 (R Core Team, 2017) to fit generalised linear mixed models to the data collected. During the initial modelling phase, we used different combinations of variables to produce a range of predictive models, each of which was fitted using a Poisson error distribution. These models included both fixed and random effects variables to accurately model the data within the log-link space. The variable of interest was the number of Tasman Parakeets detected. These counts were assumed to vary with season and year, with some random variation resulting from the survey points and transect lines, which were nested within a broader sampling space. Due to differences between the survey duration of each method (see Chapter 2), we had to fit survey time as an offset. Additionally, we specified treatment contrasts prior to model fitting to allow effective comparison between seasons.

Once the models were fitted, we assessed the relative contribution of each variable to the predictive performance and overall goodness of fit. We found the inclusion of additional variables had little effect on improving the suitability of the models, with the more complex models producing similar results to parsimonious alternatives. When selecting the final model for each survey type, we selected for parsimony in favour of model complexity, removing unnecessary variables such as the elevation at which the detection occurred to avoid overfitting the data. In both instances, our selected models included the year and season as fixed effects, allowing any temporal variation between and among survey types to be distinguished. Each model also incorporated random effects variables, with bait station (survey point) nested within the corresponding bait line and track section (transect line) nested within the track line for the fixed point survey and line transect survey data sets respectively.

After selecting a suitable model for each data set, we used the beta coefficients of the fixed effects variables to produce posterior predictions of the number of parakeets detected per hour. These predictions served as a proxy for the survey efficiency and were used to compare the suitability of the two survey methods. To improve the inference from these comparisons, we ran numerous simulations ($n = 100000$) for each model. After generating 100000 simulations for each model, we transformed the simulated data using the inverse of the log-link function to produce new data sets on the appropriate response scale. Once transformed, we used the simulated data to calculate the median of the predicted survey efficiency, including lower and upper bounds for the 95 % credible interval.

RESULTS

The data used to fit the generalised linear mixed models used in the analysis represents a total of 335.5 hours in the Mount Pitt section of the Norfolk Island National Park. This included 60.5 hours of fixed point surveys and 177.05 hours of line transect surveys. The duration of the line transect surveys varied from five to 70 minutes, whereas the fixed point surveys were standardised at 15 minutes, consisting of five minutes rest and ten minutes of observation. Collectively, the surveys yielded 567 Tasman Parakeet observations, 38% of which were visual. The two methods accounted for a similar number of observations; with 284 and 283 detections obtained by fixed point surveys and line transect surveys respectively. The number of surveys that yielded detections was also similar for both survey types; with 122 for the fixed point survey method and 126 successful surveys for the line transect survey method. However, the success rate was higher for fixed point surveys, with 50% of surveys resulting in successful detections, compared to a success rate of 33% for the line transect method.

Table C1: Posterior predictions of survey efficiency for two survey methods used to monitor the Tasman Parakeet (*Cyanoramphus cookii*) population in the Mount Pitt section of the Norfolk Island National Park.

Year	Season	Fixed Point Survey Method			Line Transect Survey Method		
		m	LCI	UCI	m	LCI	UCI
2014	Autumn	6.092	3.439	10.737	2.208	1.183	4.140
	Winter	4.574	2.953	7.079	1.956	1.483	2.581
	Spring	3.282	2.482	4.335	1.574	1.082	2.289
2015	Autumn	4.680	3.138	6.996	1.753	0.995	3.084
	Winter	3.520	2.682	4.617	1.552	1.149	2.098
	Spring	2.523	1.811	3.508	1.249	0.914	1.707

m median of the predicted survey efficiency (detections/hour), LCI lower bound of the 95% credible interval (detections/hour), UCI upper bound of the 95% credible interval (detections/hour).

The estimates of survey efficiency (Table C1) generated for the fixed point survey method indicate differences across both season and year of sampling. From autumn through to spring, the predicted efficiency of this survey method appeared to decrease, with fewer detections per hour recorded in spring. Similarly, between 2014 and 2015, there was an apparent decrease in the number of parakeets detected using the fixed point survey method. The effect of season was found to be statistically significant (Type III Wald Chi-squared test: $\chi^2 = 6.932,\ p < 0.05$), while the effect of year was not (Type III Wald Chi-squared test: $\chi^2 = 1.834,\ p > 0.10$).

The predicted efficiencies for the line transect survey method (Table C1) indicate a slight difference in efficiency across both season and year. Similarly to fixed point surveys, the number of Tasman Parakeets detected per hour appeared to decrease from autumn through to spring and between years. In contrast to the fixed point survey method, season did not have a significant effect on the predicted efficiency of the line transect survey method (Type III Wald Chi-squared test: $\chi^2 = 2.820$, $p > 0.05$), though the effect of year was significant at an α level of 0.10 (Type III Wald Chi-squared test: $\chi^2 = 2.922,\ p < 0.10$).

The strongest evidence for the superior efficiency of fixed point surveys is from autumn 2014, during which the predicted efficiency was 176% higher than the efficiency predicted for the line transect survey method. The differences between the two methods remained relatively high for the remaining combinations of season and year (Table C1), with a difference of 1.274 detections/hour in the spring of 2015 representing the smallest difference between fixed point surveys and line transect surveys.