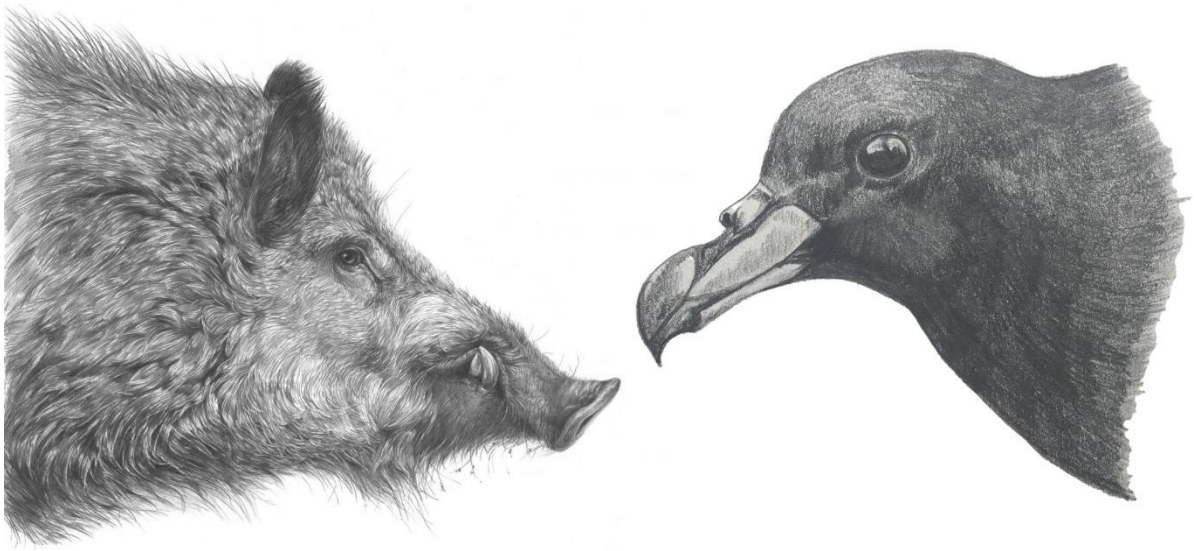
Understanding the significance of a culturally-valued *mahinga kai* species (wild pig, *Sus scrofa*) for seabird conservation, and for local community, on Aotea (Great Barrier Island)



Original illustrations of wild boar by Natalya Gabeeva, and tākoketai (black petrel *Procellaria parkinsoni*) by Virginia Nichol

Christine Mansford

A thesis submitted in fulfilment of the requirements for the degree of Master of Science in Biological Sciences

Waipapa Taumata Rau | The University of Auckland

May 2023

Abstract

Wild pigs (*Sus scrofa*) have damaging effects on ground and burrow nesting seabird species because they forage destructively, disturbing nests and habitat, and predating upon eggs and chicks. Yet, these impacts are not well understood in Aotearoa. There is also little understanding of how such impacts can be managed on islands where seabirds breed, that are inhabited by human communities who value wild pigs positively as *mahinga kai* (a source of food). To address these knowledge gaps, I employ a combination of quantitative ecology (ground-based transect surveys, wildlife-camera monitoring, and seabird burrow inspections), and, qualitative social research (social impact assessment, and semi-structured interviews with local community, including pig hunters), on Aotea (Great Barrier Island), in the Hauraki Gulf of northern Aotearoa New Zealand. Research objectives were to quantify pig (and other predator) activity and impacts, and supply relevant social context to inform wild pig management on inhabited islands. Limited evidence for pig impacts was found, although pigs were frequent in suitable seabird breeding habitat, and seabird burrows associated with a presence of pigs were infrequent and located in well-protected sites. Abundant rats, and feral cats, highlight that multi-species predator impacts are an issue for seabird conservation. Socially, pigs are important for food security for some *whānau*, and hold cultural significance as *mahinga kai*, making eradication currently unfeasible as a management option to promote seabird recovery. Yet, hunters are permissive of some methods for controlling pigs around seabird breeding areas that are, typically, hard for hunters to access. There is support for managing pigs for broader ecological objectives, from other groups in the community. These findings highlight the complex relationships of humans to valued introduced-species, and the need for management approaches to reconcile a range of ecological, social, and cultural values. On Aotea, focusing pig management on seabird breeding sites in combination with managing other predators, and involving local hunters closely in management planning and implementation, offer feasible ways forward for managing the impacts of pigs and improving the conservation of important seabird species.

Acknowledgements

Thank you to the community of Aotea (Great Barrier Island) for having me on your *motu* and sharing your *korerō* with me. I learned more than I could have ever imagined, for which and I am forever grateful. To Rodney Ngawaka (Ngātiwai), for so generously gifting your *manaaki* and sharing your *mātauranga* during my visits to Aotea, and connecting me with hunters and locals - without you this study simply wouldn't have been possible, so I owe everything to you. To Jade Williams, Lousie Mack & DoC staff for hosting my stays on Aotea, for which I'm incredibly grateful.

To Elizabeth Bell, whose seabird research provided the background to this study, and her team, on whose field expertise and support I depended. To Gaia Dell'Ariccia, Shanti Morgan and others from Auckland Council, whose specialist knowledge and assistance was highly valued.

To my supervisor James Russell, for seeding the idea for this project and being a constant source of guidance – it has been a privilege and pleasure to study under you. To my co-supervisor Ally Palmer, for introducing me to the field of anthropology and being a wonderful mentor in the subject, as well as in the craft of writing. And to all the Auckland University staff and students whose empathy was so appreciated amidst pandemic-related uncertainty.

I was fortunate enough to be awarded two grants from DOC to assist with the costs of my research project, and so I would like to convery my deepest thanks to Carol Rolando and Igor Debski for making these possible.

To Janice Molloy, Jo Ritchie, Makere Jenner, Tim Higham, Dean Carol, Jovana Balanovic, Phil Lyver and others whose insights were valuable in shaping this project, thank you.

And finally to Andrew, for putting up with me over the course of researching and writing this thesis, I'm fortunate to have had your tolerance and support.

Contents

Abstract.....i
Acknowledgements.....ii
Contents.....iii
Chapter One: Introduction
1.1. Background context.....7
1.1.1. The social challenges of conservation on inhabited islands.....7
1.1.2. Conservation controversies.....9
1.1.3. The roots of contention: values, philosophes, and trust issues.....10
1.1.4. *Mahinga kai* and indigenous models of conservation.....12
1.1.5. The problem with wild pigs (*Sus scrofa*).....12
1.1.6. Seabird conservation.....14
1.2. Intentions, and location of research.....15
1.2.1. Research intentions.....15
1.2.2. Study location on Aotea (Great Barrier Island).....16
1.3. Notes.....18
Chapter Two: Ecological impacts of wild pigs (*Sus scrofa*) on tākoketai (black petrel, *Procellaria parkinsoni*), on Aotea (Great Barrier Island)
2.1. Introduction.....19
2.1.1. Wild pigs (*Sus scrofa*) introductions and impacts.....19
2.1.2. Significance of Aotea for seabird conservation.....22
2.1.3. Past and present status of wild pigs on Aotea.....24
2.1.4. Tākoketai biology, distribution, and conservation.....26
2.2. Methods.....28
2.2.1. Site details and overview.....28
2.2.2. Field survey methods.....29
2.2.2.1. Burrow characteristics.....29
2.2.2.2. Ground disturbance.....30
2.2.2.3. Pig (and other predator) incidence..... 30
2.2.3. Data analysis.....32
2.2.3.1. Overview.....32
2.2.3.2. Burrow characteristics.....32
2.2.3.3. Distribution of pig sign within seabird habitat.....32
2.2.3.4. Ground disturbance.....32
2.2.3.5. Pig (and other predator) incidence..... 33
2.3. Results.....33
2.3.1. Comparison of burrow characteristics between grades of seabird habitat.....33
2.3.2. Distribution of pig sign within seabird habitat..... 35
2.3.3. Ground disturbance by pigs at Cooper's Castle medium-grade site.....38
2.3.4. Pig and other predator activity within seabird habitat..... 41
2.3.5. Evidence of direct predator interactions with burrows.....46
2.4. Discussion.....47
2.4.1. Temporal and spatial patterns of pig and other predator activity.....47
2.4.2. Habitat modification resulting from ground disturbance.....49
2.4.3. Direct predator interactions with tākoketai.....49

2.4.4. The implications of pig and other predator impacts for tākoketai.....49
2.5. Conclusions.....52
Chapter Three: Social characteristics of Aotea (Great Barrier Island)
3.1. Introduction.....53
3.1.1. Inhabited islands as places.....53
3.1.2. Island conservation, and invasive mammal management.....55
3.1.3. Social impact assessment concepts and techniques.....56
3.2. Methods.....58
3.2.1. Social assessment of Aotea.....58
3.2.2. Historical research on human-pig interactions on Aotea.....59
3.3. Results.....59
3.3.1. Ecological setting of Aotea.....59
3.3.2. Social setting of Aotea.....62
3.3.3. History of pigs, and pig hunting, on Aotea.....66
3.3.4. Current discourses around pigs on Aotea.....70
3.4. Discussion.....71
3.4.1. Social profile of Aotea.....71
3.4.2. Capacity of the community to adapt to, and innovate, ecological change.....72
3.4.3. Impacts, and feasibility of pig management.....74
3.5. Conclusions.....75
Chapter Four: Values and practices attached to wild pigs (*Sus scrofa*) on Aotea
4.1. Introduction.....76
4.1.1. *Mahinga kai* versus invasive species: a case of different values.....76
4.1.2. Hunting values.....77
4.1.3. Clashes between hunting and conservation values and objectives.....79
4.1.4. Needs of future pig management.....80
4.2. Methods.....81
4.2.1. Methodological overview..... 81
4.2.2. Semi-structured interviews.....82
4.2.3. Site details.....83
4.2.4. Qualitative analysis of interview transcripts.....85
4.3. Results.....85
4.3.1. Overview.....85
4.3.2. Pig hunting purposes and practices.....86
4.3.3. *Mahinga kai* values, conservation values, and hunter code of practice.....87
4.3.4. Issues contributing to tensions around pigs.....89
4.3.5. Community recommendations for managing pigs.....92
4.3.6. Hunter knowledge of pigs, and ecology.....92
4.4. Discussion.....94
4.4.1. The role of pigs and pig hunting on Aotea.....94
4.4.2. Pig hunting as a dynamic, biocultural process.....96
4.4.3. Ecological values and hunter expertise: opportunities for cooperation.....97
4.3.4. Social barriers to success.....98
4.5. Conclusions.....100
Chapter Five: Final conclusions, recommendations, and reflections.....102
5.1. The role of pigs in seabird decline.....102
5.2. Technical, and strategic management recommendations.....103
5.3. Reflections on transdisciplinary, socio-ecologic research.....104

5.4. Future research directions.....105
APPENDIX 1.....106
APPENDIX 2.....107
APPENDIX 3.....109
APPENDIX 4.....111
References.....112

CHAPTER ONE

Introduction

1.1. Background context

1.1.1. The social challenges of conservation on inhabited islands

Islands comprise only 5.3% of Earth's total land-area but support the greatest concentration of biodiversity, due to high levels of species endemism (Kier *et al*., 2009). Islands have also lost the most biodiversity to extinction (Tershy *et al*., 2015). Most island extinctions have been caused by invasions of mammalian predators, against which endemic island communities have not co-evolved defences (Clout & Russell, 2008; Doherty *et al*., 2016). As well, human systems on islands tend to be tightly coupled with biodiversity, and so are particularly are threatened by ongoing biodiversity loss (Tershy *et al*., 2015). Managing invasive mammals on islands, often through permanent eradication, has become a foundational conservation action to preserve biological and cultural heritage (Spatz *et al*., 2022). The conservation and wider social gains from such efforts are significant, however, islands are unique places with unique social characteristics, and so the challenges and opportunities that come with managing predators in these landscapes are also distinctive (Jones *et al*., 2016*;* Russell *et al*., 2017a; Russell & Stanley, 2018).

Aotearoa is a nation of islands, comprised of over 850 islands, islets and rock stacks (Parkes *et al.*, 2017). With most of the country's smaller islands now cleared of invasive mammals, a focus of present conservation is the larger islands which are permanently inhabited (Bellingham, 2009; Glen *et al*., 2013; Parkes *et al*., 2017). Typically in the range of 10,000-100,000 ha, these include Aotea (Great Barrier Island, in the northeastern Hauraki Gulf region), Rakiura (Stewart Island, in the Foveaux Strait), and Rēkohu (Chatham Island, in the southeastern region of the country's Exclusive Economic Zone). Owing to isolation from other landmasses, evolution on these islands has produced numerous species and assemblages of biota that are endemic to a local or regional level (Mortimer *et al*., 1996; Towns *et al.*, 2012). As well, these islands are important breeding sites for seabirds, some of which have been lost to extinction on the main islands of the North Is. and South Is. (colloquially referred to as the 'mainland'), making them significant places for marine avifaunal recovery (Mulder *et al*., 2011). Because of their unique biodiversity and importance for seabirds, Aotearoa's medium-sized islands are valued highly by conservation managers and are a priority for invasive mammal management (Towns *et al.*, 2012; Russell *et al.*, 2015).

A range of tools are available for managing invasive mammals via long-term suppression or total eradication using toxins, trapping, and culling (Murphy *et al*., 2019). On the medium-sized islands, it is technologically feasible to completely remove many species of invasive mammal using

combinations of these tools. However, such a task is complicated by the fact that medium-sized islands have human inhabitants (including indigenous Māori), who have values and usages connected to the landscapes and species that invasive mammal management seeks to act upon, and which can conflict with the ecologically-focused objectives of conservation managers (Parkes *et al*., 2017). As a result of these human dimensions, invasive mammal management on some inhabited islands in Aotearoa is contested, as it has been found to be in other parts of the world (Oppel *et al.*, 2011; Bassett *et al.*, 2016; Glen & Hoshino, 2020.) This is vexing, considering the concentration of biodiversity on inhabited islands, and the high rates of biodiversity decline that these places have already suffered. In addition, Aotearoa has specific goals for ridding the country of predators by 2050 (Russell *et al*., 2015; Tershy *et al*, 2015; Leclerc *et al*., 2018)

Perhaps it is not surprising that conservation in inhabited places is challenging; conservation has always been a champion for nature, so can be perceived as a threat to anthropocentric (i.e., human) interests (Redpath *et al*., 2013). But times have changed since conservation was regarded as a 'fringe' activity in Aotearoa; it is now a well-funded, mainstream initiative, integrated from the back-yard to the landscape scale (Young, 2004). Despite this, there are still areas of conservation that are conflicted, such as the control of pests on inhabited islands (Towns *et al.*, 2011, Ogden & Gilbert, 2009). Ultimately conflicts are counterproductive; they erode trust between invested parties, consume resources and delay actions to protect biodiversity (Crowley *et al*., 2017). It is clear in these situations that transformative approaches to conservation management are required, which reconcile ecological values with human lifestyle values and embrace humanity as a part of ecosystems. These approaches, although labour intensive and involving much compromise, enable a productive way for ideologically opposed groups to collectively work through issues and reach positive outcomes for biodiversity (Egan *et al*., 2011; Redpath *et al*., 2013; Butler *et al*., 2015).

Social understandings are necessary to inform transformative approaches, about how groups of humans relate to, interact with, and value the natural environment and wildlife (Bennett *et al*., 2017). These nature connections are strongly influenced by culture, and place (Hjort af Ornäs & Svedin, 1992; Stewart *et al*., 2013). As places, inhabited islands have been recognised as special, having ecological and social histories that are often markedly different from nearby larger landmasses, and other islands (McCall, 1994). Understanding the unique place-based characteristics of individual islands, including local heritage, culture and practices, is therefore a necessary component of scoping the feasibility of invasive mammal management (Saunders *et al*., 2021). To inform these approaches, transdisciplinary socio-ecologial research is required. Such research integrates diverse academic disciplines from the social and natural sciences, and draws on non-academic expertise, in the production of new knowledge and theory (Tokar & McGregor, 2012; Pooley *et al*., 2014). This approach of combining empirically derived data with local knowledge, can produce detailed understandings of the unique, place-based conditions that pertain to specific islands, both socially and

ecologically. Given that much of the landscape that conservation operates within is becoming increasingly peopled, understanding the human dimension to conservation is not limited to inhabited islands, but is relevant to all contemporary conservation management.

1.1.2. Conservation controversies

For such a well-intentioned pursuit, conservation is surprisingly conflict-prone. It has been pointed out that "most wildlife management problems start out as biological problems but eventually become people problems" (Teague, 1979, as cited in Manfredo, 1989). In Aotearoa, and internationally, controversy surrounds wildlife management, particularly of some invasive mammals, producing polarised debates (Redpath *et al*., 2013; Hill *et al*., 2017). This is understandable, given that 'management' in the case of invasive mammals is most often lethal, which is difficult for most people to accept without qualm (Fraser, 2006). However, specific control methods, species, and even geographic areas have each attracted their own specific controversies (for examples see Kannemeyer, 2011; Farnworth et al., 2014; Bidwell & Thompson, 2015).

The use of toxins, specifically sodium fluoroacetate (also known as compound 1080; commonly abbreviated to '1080'), is probably the most well-documented, and longest-running contemporary conservation debate in Aotearoa (Warburton *et al*., 2022). Concerns about the spread and range of impacts of introduced mammals (including deer, goats, pigs, brushtail possums, mustelids, rabbits, wallabies, and rats) on conservation lands, plantation forests, and agriculture, drove pest managers to investigate toxic agents and techniques for delivery that could be used over large areas, and be more effective than conventional ground-based methods of trapping and shooting. Compound 1080, the synthetic sodium salt of the natural vertebrate toxin fluoroacetic acid, was first registered as a cereal bait for aerial delivery in 1964. This technique initially targeted possums (*Trichosurus vulpecula*), a vector of bovine tuberculosis and threat to forests, but was adopted for controlling ship rats in the late 1980s (Green, 2004; Innes *et al*., 1995). Deer hunters were the first to object to this practice because of the non-target deaths of deer, and native birds, that often occurred following 1080 drops (Green, 2004). The toxicity of 1080 is not limited to deer though; the compound is toxic to all vertebrates, and deaths of dogs and livestock have been documented. As well, 1080's mechanism of action is less humane in some mammals than others, especially carnivores (Eason *et al*., 2011; MAF, 2010). There is also the perception that 1080 can act as a water contaminant, and harm human health, although this is not backed by evidence (Green & Rohan, 2012). Because of these issues, a concerted campaign against 1080 emerged, led mostly by hunters, farmers, and citizens interested in human-health and animal welfare, around shared concerns relating to impacts on non-target species, and perceived risks to environmental and human health (Hansford, 2016). Department of Conservation (DoC) staff have

encountered serious harassment from 1080 objectors, receiving frequent verbal or written threats, and sometimes physical intimidation (Morton & Neilson, 2018).

Opposition to toxin use can also extend to the range of other compounds used for vertebrate pest control in Aotearoa. These include the first and second generation anticoagulant toxins, pindone, diphacinone, and brodifacoum (among others), which are registered for rabbit, possum, and rat control. Compared to 1080, these toxins are less humane, and persist for longer in the environment and animal tissue (Fisher *et a*l., 2003; Beausoleil et al., 2015). With the exception of brodifacoum, they are typically used for long-term suppression of pests on the mainland in the form of cereal-baits, delivered in bait stations that are designed to target specific pest species. Conservation operations using this method have reported tampering or theft of bait stations, in an effort to sabotage toxin application (Department of Conservation, 2018). Brodifacoum is also registered for broadcast application via aircraft for eradications on off-shore islands. The 2017 rat eradication operation on Rākitu Island in the Hauraki Gulf, which utilised aerial brodifacoum, was opposed ardently by nearby Aotea (Great Barrier Island) residents, and involved acts of protest including a two-week occupation of DoC land (Peart & Woodhouse, 2021).

Objections to control of specific target species, have been encountered. Consent of *mana whenua* (traditional Māori land owners) Ngāti Wai was insisted upon for the eradication of *kiore* (Pacific rat, *Rattus exulans*, introduced to Aotearoa by Māori) from Te Hauturu ō Toi (Little Barrier Island) (Kapa, 2003). Lethal management of unowned cats is a contested area of conservation such that cats were omitted from Predator Free 2050 ambitions, despite being a major predator (Rouco *et al*., 2017). Feral and roaming dogs are an issue in Northland, but regional authorities are partly limited in their ability to control them, because of perceptions that dogs are pets, and should not be destroyed (Venuto, 2022). Some citizens appear to have become quite attached to the feral wallabies which are a pest in parts of the country. On Kawau Island for instance, where wallabies were introduced by Governor George Grey in the 19th century, residents are deeply divided in opinion over proposals to remove the wallabies completely, and this has created conflict within the community (Morris, 2021).

1.1.3. The roots of contention: values, philosophies and trust issues

The ways in which opposition to conservation is expressed are incredibly varied, with studies documenting how long-running and complex invasive species conflicts can become (Estévez *et al*., 2015; Crowley *et al*., 2017; Griffiths *et al*., 2019). These studies also illustrate how frequently opposition is not simply against the basis of 'the facts' establishing the need for conservation, but rather, it is informed by values, philosophies, and beliefs that a person holds deeply, and are not easily changed. This has the implication that simply presenting more information to objectors won't change

their stance (*sensu* Park, 2020). Values that have been attached to invasive species as resources, are notable in this respect. These values have often developed over long histories of intentional introduction and subsequent utilisation of invasive species, primarily as food. As a result, practices and traditions – important contributors to culture – have amassed over time. Thus, the values related to invasive species are not merely material; they are symbolic of culture and heritage (Goulet, 1993; Riley, 2013).

As a way of examining contention surrounding values in conservation, Sandbrook (2015) asked, 'What is conservation?'. In practice, conservation as it pertains to nature is simply the range of actions that humans take, that preserve the quality of the natural environment (Sandbrook, 2015). Yet, the paradigm of conservation which has become dominant around the world is Western in construct, which has obscured the fact that there are many different cultural approaches to conservation (Kidd, 2016). With roots in the environmental movement of the late 19th century, Western conservation is essentially a mission-driven, or 'crisis' discipline, with ambitions to preserve wilderness in a pristine state, free from the destructive forces of humanity (Soule, 1985; Adams, 2004; Wilshusen *et al*., 2002). At its core, is a Western worldview which separates humanity from nature, and an idealised notion of nature as 'wilderness' from which humans are excluded (Cronon, 1996). Science is another foundation; especially the discipline of invasion biology, which is inherently value-laden (Elton, 1958). These influences serve to objectively reduce the natural world into component parts, and attach value judgements that distinguish between invasive and indigenous species; what belongs within ecosystems and what doesn't; what species are good and what are bad (Callicott *et al*., 1999). Although this characterisation is somewhat exaggerated (most natural scientists now acknowledge we live in a world dominated by humans), it does typify some of the assumptions which underpin mainstream conservation.

Although the Western model of conservation recognises the intrinsic value of nature and places priority on the protection of native biodiversity, it is problematic for people who value invasive species as resources, or who have lived (often sustainably) in the wilderness, for millennia (Berkes, 2012., Lyver *et al*., 2019). It is also a dilemma that ecological dynamics cannot be separated from human dynamics in the biosphere, such is the extent to which humans have changed the planet (Folke *et al*., 2005). 'The trouble with the wilderness', as writers have put it, is that it is more of a construct than a reality (Cronon, 1996; Rose, 2007). Although there is no doubt that human activities, especially the introduction of species that become invasive, can have enormous detriment on ecosystems, eradicating all invasive species and excluding people from ecosystems is not necessarily a logical response.

Beyond fundamental differences in values and perceptions, conflict in conservation can also be a product of relationships. Mace (2014) asked "Whose conservation?", which is a good question for

illustrating the point that most conservation is carried out by authorities, and groups and individuals with considerable means and power (Shackleton *et al*., 2023). These entities, typically, have engaged with stakeholders and made decisions using top-down approaches, which involve limited dialogue and fail to build trusting relationships (Green & Rohan, 2012; Crowley et al., 2017). Lack of trust can drive fears of disingenuous motivation and a sense of disempowerment, so that conflict is not necessarily a product of management proposals *per se*, but of poor relationships between conservation managers and stakeholders (Young *et al*., 2016).

1.1.4. Mahinga kai, and indigenous models of conservation

Indigenous worldviews are holistic, seeing humans as interconnected with the natural world (Sarkar, 2005). Indigenous peoples' societies are commonly embedded within dynamic socio-ecological contexts, and have customs which reflect deep knowledge of biodiversity and ecologically responsible behaviours (Berkes, 2003; Lyver & Tylianakis, 2017). As well, indigenous groups have concepts and constructs regarding human-nature relationships, that inherently promote care for the environment. For Māori, such a concept is the living-entity status that features of the natural environment (particularly those of the terrestrial landscape) are able to hold, as ancestral and spiritual figures that Māori consider themselves descended from (Harmsworth & Awatere, 2013). Legal recognition of this concept has occurred so far in the Te Urewera Act 2014, in which Te Urewera (the Urewera ranges region) has all the rights, powers, duties, and liabilities of a legal person. Customary resource use practices occur within this framework, and are governed by principles of *kaitiakitanga*, or guardianship of resources for future generations (Selby et al., 2010). *Mahinga kai*, or harvest of food resources, is one such example, that has enabled long-term, sustainable management of many indigenous species. *Mahinga kai* involves a comprehensive set of practices including long-term observation of environmental conditions and state of the resource, sustainable harvest, and adjustment of harvest in response to changes in abundance (Lyver et al., 2019). Populations of several species of 'muttonbird' seabirds - ōī, tītī, and toanui – have been maintained in this way for centuries (Rewi, 2022). Some introduced species, such as pigs, have also come to be regarded as *mahinga kai*, because of their value as food, and the length of time that they have been established and utilised in Aotearoa.

1.1.5. The problem with wild pigs (Sus scrofa)

As with other game animals, wild pigs (*Sus scrofa*) present a paradox for conservation: On one hand, they are an invasive species which can have profound ecological consequences for indigenous ecosystems, and on the other, they are much valued by some groups of people as a food resource, or *mahinga kai*, as this is known to indigenous Māori in Aotearoa. Presently, pigs occupy much of

Aotearoa's Crown owned conservation estate, and other conservation areas that are held in private ownership (McIlroy & Nugent, 2021). Hunters regularly access these areas to harvest pigs (mostly in places that are easily accessible from settlements), and maintain pig populations through practices of selective harvest, neutering, and capture or breed and release, such that in places, wild living pigs are actually quite well-tended (Hunter, 2009). These practices contrast with those of conservation authorities (the Department of Conservation, and local Councils), who are mandated with pig control, on the grounds that pigs cause ecological damage (Reeves, 2011). Community-led conservation groups sometimes share the same space as hunters, where they carry out ecological restoration activities (Radio New Zealand, 2021). This has brought hunters into conflict with conservation groups, instances of which have been quite politicised (see 'Pig Politics' video documentary of pig-related conflict on Aotea (New Zealand Herald, 2019 https://www.nzherald.co.nz/nz/pig-politics-full-series/JSVOLACRYBVS4GEGQIPL6SWLRU/). These conflicts have resulted in patchy implementation of pig management: where conservation is least conflicted with pig hunting, such as in the Auckland region, effective pig management takes place. In conflict-prone areas, such as Northland and Aotea, authorities are limited in the scope of pig management. This is a problem because in these conflicted areas that endemic biota with high-conservation values are found, such as kauri (*Agathis australis*) and seabirds, which pigs impact upon disproportionately (Bengson *et al*., 2017).

Conflict around pigs is related to their long history in Aotearoa as a food resource. Pigs were the third mammal to be introduced to Aotearoa, after *kiore* (Pacific rat, *Rattus exulans*) and *kuri* (Polynesian dog, *Canis familiaris*), which were introduced by early Polynesian settlers (King & Forsyth, 2021). The first introduction of pigs to Aotearoa occurred as a gift to Māori, by French explorer Jean-François Marie de Surville in Doubtless Bay, 1769. Captains Cook and Furneaux also gifted pigs to Māori, and liberated several into the bush, on the second and third British voyages to the country in 1773 and 1774 respectively (Beaglehole, 1961; Salmond; 1991; Salmond, 1997). Sealers, whalers and traders brought more pigs from the 1790s, to barter with local Māori and release to supply food (Salmond, 1997). Māori quickly took up rearing pigs, to trade with the growing number of European settlers who required food (Petrie, 2006). As a result of these activities, populations of feral pigs arose around human settlements and dispersed further into the environment, providing food for successive waves of early settlers. Indeed, the hunting opportunities of Aotearoa were an enticement for many a prospective settler keen to escape the class system in Britain, where hunting was reserved for the elite (Donne, 1924; Reis, 2014). Since the 1960s, pig hunting has grown in popularity, and is currently the main form of control of pig populations in Aotearoa (Clarke, 1989).

Recognition of pigs as ecological pests is more recent. Although the damaging effects of pigs on pasture and native vegetation (as a result of destructive foraging, using the snout to root through soil) were known early on (for example, Falla's 1948 observation of reduced vegetation on Auckland Island, as a result of pigs), pigs have not been considered a major ecological threat in Aotearoa, because of generally low population densities, and because of the more immediate threat presented by stoats, rats and possums (Clarke & Dzeiciolowski, 2012). However, an accumulation of observational evidence, describing ongoing decline and localised extinction of seabird populations, and major changes in plant communities on Auckland Island, suggests that pigs may impact disproportionately on some species that are vulnerable to ground-disturbance and predation (Chimera *et al*., 1995; Bengson *et al*., 2017; Wehr *et al*., 2018; Russell *et al*., 2020). A slew of literature from abroad, particularly Hawai'i, and regions of Australia and North America into which pigs are rapidly expanding, also demonstrates the ecosystem-wide effects that pigs can have outside their natural range. An exhaustive review of these impacts is outside the scope of this introduction, and the reader is referred to papers by Barrios-Garcia & Ballari (2012), Bengson *et al*. (2017), and Wehr *et al*. (2018), which comprehensively review pig impacts on indigenous biodiversity.

The competing interests that surround pigs at present, resulting from anthropocentric values of pigs as a food resource, and ecocentric values of pigs as pests, complicate the matter of pig management considerably. Regardless of stance, this is a problem for all involved, which needs resolution. Not only is it an ecological problem; it is also a human-human one, that is rooted in values. Social research aimed at understanding these values, and whether they can be reconciled, is therefore crucial for contemporary conservation's success.

1.1.6. Seabird conservation

Seabirds are a taxonomic group heavily impacted by wild pigs, because many species breed in nests on or beneath the ground surface, and so are vulnerable to perturbation and predation by pigs (Gaskin & Rayner, 2017). Aotearoa's seabirds have declined in recent decades, relative to terrestrial birds (with seabirds representing 16 or 73% of all 22 bird taxa that have worsened in status –see Robertson *et al*., 2021). This decline is in spite of decades of increase in efforts to suppress rodents and mustelids, which are key predators of birds, suggesting that seabird decline is related to factors additional to small predators (Croxhall *et al*., 2012). One factor is the life history strategies of seabirds, with low reproductive rates and long chick rearing periods, which are not well-adapted to withstand predation by rats, cats, mustelids, pigs and hedgehogs (Mulder *et al.*, 2011). Another leading cause of mortality is being caught and drowned in commercial fishing lines and trawl nets (Richard *et al.*, 2020). As well, many seabirds rely on pelagic prey, and make migrations over vast

distances of ocean, so they are highly susceptible to fluctuations in food supply, and extreme weather, that are expected to intensify in a regime of climate change (Grémillet & Boulinier, 2009; Croxhall *et al*., 2012). On land, seabirds are also threatened by large predators – cats, dogs, and pigs – which are valued by humans, and so are challenging to control (Dias et al., 2019; Whitehead, 2019). There is a need to better understand these key threats on land, and manage them more effectively. Pigs in particular require investigation, because of the paucity of data on their ecological impacts. Together with enhanced social understandings of how pigs are utilised and valued, such research has the potential to identify novel management solutions to a vexed conservation issue.

1.2. Intentions, and location of research

1.2.1. Research intentions

In multiple locations around Aotearoa, pigs pose a threat to seabirds but are valued by *mana whenua* and the hunting community as *mahinga kai*. This has produced a 'pig problem' for conservation management on 'seabird islands' (those with vulnerable and important populations of seabirds), for which the range and extent of pig impacts on seabirds are not well quantified, and nor is it known what local pig hunters, and community more widely, think are acceptable in terms of approaches to manage pig impacts. It is necessary to address these two current knowledge gaps – ecological, and social – in order to understand the scope of the problem, and to generate findings which may inform appropriate responses. The goals of this study are to address the knowledge gaps, specifically:

1. Ecological:

- How are pigs distributed on a landscape-scale, throughout seabird habitat on a 'seabird island'?
- What interactions, both indirect and direct, do pigs have with breeding seabirds and seabird habitat, and how might these impact on seabird breeding? How are these related to environmental variables such as time of year and habitat?
- How abundant are pigs around breeding seabirds, relative to other predators (such as rats and feral cats) i.e., how significant a threat are pigs for seabirds?

2. Social

- What are the social characteristics, including demographics, local culture and practices, of the community on a seabird island, and how do these factors affect the feasibility of managing pigs around breeding seabird sites in future?

- How are pigs valued, by *mana whenua*, the hunting community, and other island inhabitants? How are seabirds, and conservation more generally, valued simultaneously? What areas of common value for the environment exist?
- How amenable are *mana whenua* and hunters to options for managing pigs around breeding seabirds?

These questions will be investigated using a combination of ecological methods (ground-based transect surveys, and wildlife-camera surveillance, see **Chapter 2**), social impact assessment (**Chapter 3)**, and qualitative social research (semi-structured interviews, see **Chapter 4**), carried out within seabird breeding habitat and the island community, respectively.

The purpose of this research is to contribute to the state of socio-ecologic conservation knowledge, and to inform conservation practice, through:

1. Gathering ecological data to provide a clear sense of what is happening between pigs and seabirds, and which may be used to advocate for seabird conservation within the context of pig-dependent communities.

2. Clarifying the values, and cultural understandings, that are held in relation to management of pigs, and finding common ground that could form the basis for community and conservation managers to communicate and collaborate around.

3. Using these findings to make recommendations for addressing the 'pig problem', that are based on common values, and scientific evidence.

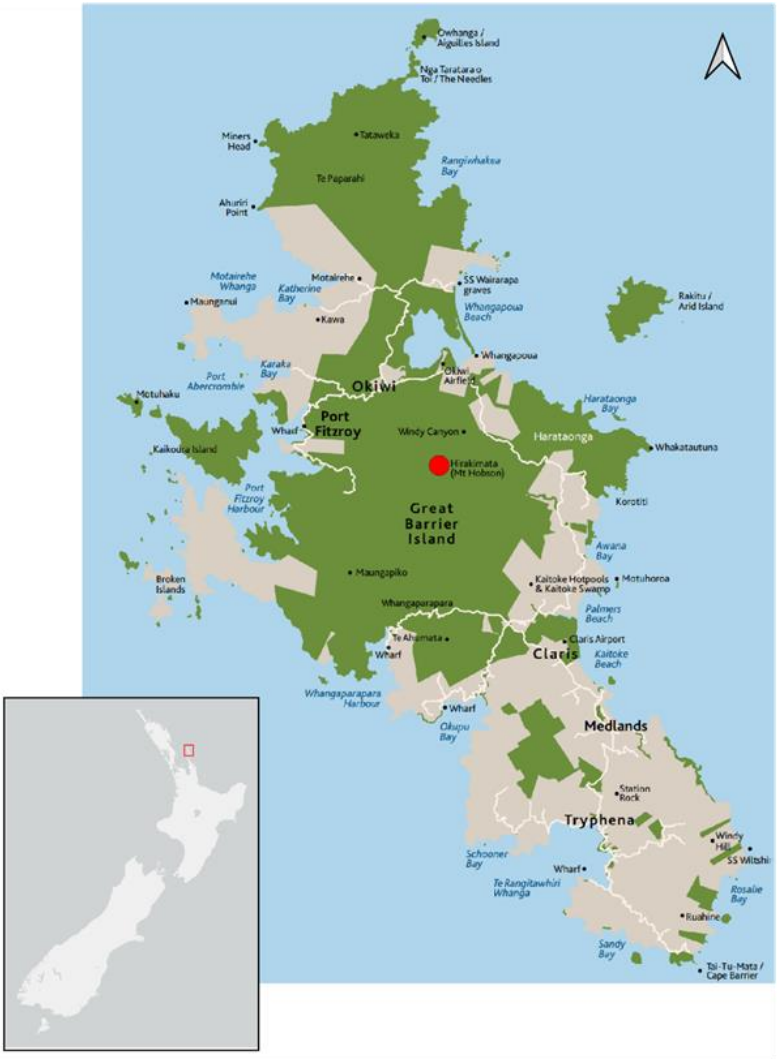
Overall, the purpose of this research is to support informed, empathetic and productive conversations around how pigs could be managed for seabird conservation on inhabited islands, and Aotearoa more broadly. As well, the research intends to be relevant in an international sense, by contributing understandings of how invasive species conflicts can arise, and potentially be resolved.

1.2.2. Study location on Aotea (Great Barrier Island)

The location for this study is the island of Aotea (Great Barrier Island), situated approximately 100 km northeast of Auckland in Tīkapa Moana (Hauraki Gulf) (**Map 1.1**). Tīkapa Moana is a global hotspot of seabird diversity. Within this region, Aotea is the largest island providing habitat for breeding seabirds, that is free of predatory mustelids, Norway rats, possums, and hedgehogs. Importantly, the island is the location of the main breeding colony of tākoketai (black petrel, *Procellaria parkinsoni*): an endemic seabird formerly widespread over the mountain ranges of Aotearoa, which is now restricted to breeding on Aotea and Te Hauturu ō Toi (Little Barrier Island) in

Tīkapa Moana. Breeding sites on Aotea are critical for recovery of the species (Gaskin & Rayner, 2017).

Map 1.1. Map of Aotea (Great Barrier Island), displaying conservation areas, and location of the main tākoketai (black petrel *Procellaria parkinsoni*) breeding colony at Hirakimatā (Mt Hobson, 627m). (Modified from ESRI and Auckland Council maps).



Aotea has a permanent population of approximately 1000 residents, which temporarily swells during summer with seasonal (i.e. holiday home owning) residents. Approximately 20% of the population are Māori, who *whakapapa* (relate, through direct descent or other kinship ties) to *mana whenua* Ngāti Rehua Ngātiwai ki Aotea, who have continuously occupied the island since the 17th century. Other resident groups comprise descendants of farmer-settlers, newer residents who have immigrated since the 1970s, and itinerant workers. Pigs were introduced in the late 18th century, and have been attended through a combination of husbandry and hunting practices since. Presently, a small but significant group of the community on Aotea, represented mainly by *mana whenua* and descendants

of farmer-settlers, practice pig hunting. Pigs, and hunting of them, overlap in parts with seabird breeding habitat and it is this overlap that is the focus of this study.

1.3. Notes

Throughout this thesis I will use Te Reo Māori terms, which will be italicised on first mention and translated as closely as possible into English. It is also assumed, due to the different disciplinarity of chapters (ecology, and social science), that chapters will be examined by different people, and for this reason some repetition appears throughout.

CHAPTER TWO

Impacts of wild pigs (*Sus scrofa*) on tākoketai (black petrel, *Procellaria parkinsoni*), on Aotea (Great Barrier Island)

2.1. Introduction

*2.1.1. Wild pig (*Sus scrofa*) introductions and impacts*

By definition, invasive species are those which occur outside their natural range and impact negatively on ecosystems (Blackburn *et al*., 2011). Native to continental Europe, Asia and North Africa, wild pig (*Sus scrofa*) invasions have been assisted by intentional human introductions over many millennia (Albarella, 2007; Barrios-Garcia & Ballari, 2012). In the Pacific, introductions of pigs are thought to have first occurred with the migration of Austronesian-speakers from southeast peninsular Asia during the Neolithic period, from 3,500 years ago (Sand, 2021; Horsburgh *et al*., 2022). Polynesian voyagers in the last millenium dispersed pigs more widely, although surprisingly, not to Aotearoa (perhaps because with the abundance of moa and seals, there was no need). The introduction was eventually made by European explorers travelling via Tahiti and Tonga in the late 18th century, and more recently invasion has been facilitated by natural range expansion and intentional translocation by hunters (Salmond, 1991; West, 2008; Bevins *et al*., 2014; Courchamp *et al*., 2003).

This human-mediated history has produced interesting taxonomy: many wild pigs are the hybrids of domesticated breeds of *S. scrofa* that became feral, and populations of wild ancestors, which were still present at the same that domesticated animals escaped from their confines (White, 2011). There has been some confusion as to how classify wild pigs on the basis of genetics; usually, wild animals that are descended from domestic individuals are deemed 'feral.' However, because some truly wild-type populations of *S. scrofa* exist in Europe and Asia, and some interbreeding still occurs, this terminology is inaccurate and 'wild pig' is instead used. To further complicate matters, populations of pigs living in apparently wild situations may in fact be tended by people, so cannot be considered truly feral. To deal with these genetic and social complexities, and avoid distinguishing pigs in Aotearoa from those of the same species elsewhere in the world, I too adopt the convention of 'wild pig', and the abbreviation of 'pig'. This terminology has the benefit of being socially acceptable to those groups that value pigs, and recognisable to lay audiences.

Despite being domesticable, pigs are nonetheless a wild-living animal with a wide-native range, suggesting pre-adaptions that enhance survival (Baskin & Dannell, 2003). These adaptions include high fecundity, with sows (female pigs) beginning to breed in under a year, and having more than one litter of 4-10 piglets annually (Choquenot, 1996). A broad omnivorous diet provides that pigs can

feed easily year round (Gentle *et al*., 2015; Parkes *et al*., 2015; Krull & Egeter, 2016). Within pigs' native range, humans are currently the main predator, and in their introduced range, natural predators and pathogens are mostly absent, removing the constraints to population growth (McIlroy & Nugent, 2021). Pigs also appear to be quite cold tolerant, inhabiting altitudes of up to 1,400m, as well as the sub-antarctic Auckland islands (McIlroy, 1989; Russell *et al*., 2020).

In recent years, wild pigs have attracted much attention as ecological pests, because of the exceptionally wide range of negative consequences which they have within indigenous ecosystems (Barrios-Garcia & Ballari, 2012; Wehr *et al*., 2018; Risch *et al*, 2019). Indeed, pigs are something of a 'hot topic' in conservation at present. One of the most conspicuous effects of pigs is disturbance of the ground surface caused by 'rooting' - pigs' primary mode of foraging for food beneath the ground surface, which can turn over significant quantities of soil (Lincoln, 2014). This can have a range of effects on vegetation and habitat quality through suppression of seed germination and recruitment, particularly of some species (Drake & Pratt, 2001; Ickes *et al*., 2003); transmission of soil-borne plant pathogens, causing disease and mortality of trees (Krull *et al*., 2013); and, damage to soils and water quality, through compaction, erosion , and sedimentation (Ford *et al*., 1998; Long *et al*., 2017). Over time, these effects decrease the quality of habitat for faunal communities, including soil microbes and invertebrates, ground-nesting birds, amphibians and reptiles (Vtorov, 1993; Doupé *et al*., 2009; Brown *et al*., 2012). Other pig behaviours of wallowing in water-filled depressions, trampling, and nest building can further exacerbate the effects of rooting (Campbell & Long, 2009).

Pigs are predators – a fact which is less well-known than their damaging environmental effects. Omnivorous in diet, pigs consume many sources of protein including carrion, live prey (particularly those which spend part of their life cycle at ground level), and juvenile stages such as larva and eggs (McIllroy & Nugent, 2021). Numerous taxa of prey have been noted, including birds, insects, snails, shellfish, crustaceans, frogs and lizards, small mammals, and domesticated animals (Pavlov, 1981; Coblentz & Baber, 1987; Wilcox & van Vuren, 2009; Jolley *et al*., 2010; Krull & Egeter 2016; Sanders *et al*., 2020; van Ee *et al*., 2020). Although pig predation is often described as opportunistic, some studies (for example, Pavlov's 1981 study of lamb predation by pigs) suggest that if prey is readily available, pigs will consume live prey preferentially. Population reductions and localised extirpations of ground-dwelling or breeding taxa have been recorded in relation to pig predation, particularly in regions where pigs are increasing in range and abundance.

The ground-nesting and burrowing seabirds are amongst the most well known examples of taxa affected by pigs. Tākoketai (black petrel, *Procellaria parkinsoni*), which were once widespread across the North Island of Aotearoa, are notably absent from all but two small island sites that have been inaccessible to pigs and stoats (Imber, 1987). In the Kaikoura mountains of the South Island, localised extinctions of Hutton's shearwater (*Puffinus huttoni*) colonies have been observed where

pigs are present, despite rat and stoat control (Cuthbert, 2002). On the subantarctic Auckland Islands, pigs together with cats are thought to responsible for the elimination of several seabird and land-nesting birds, including southern royal albatross (*Diomedea epomophora*) (Russell *et al*., 2020). Similarly, some of the species associated with seabirds have also diminished; falcons (*Falco novaeseelandiae*), the natural predators of burrowing petrels, have continued to decline (Miskelly *et al*., 2022), while tuatara (*Sphenodon punctatus*), a large lizard prone to periods of immobility that occupy seabird burrrows, have gone extinct from all but predator-free islands (Crooke, 1973).

Direct observations of pig predation have been recorded too. Challies (1975) found near complete remains of yellow-eyed penguin (*Megadyptes antipodes*) and Auckland Island prion (*Pacyptila crassiostris*) in the stomach contents of pigs occupying coastal areas of Auckland Island. Chimera *et al.* (1995) found bird feathers and other remains amongst the food items contained in the stomachs of 12% of pigs shot on Auckland Island, in 1989. De Roy observed a pig predating a mollyhawk chick from the nest at South West Cape, Auckland Island (De Roy *et al*., 2008). Depredation of Hawai'ian petrel (*Pterodroma sandwichensis*) and Newell's Shearwater (*Puffinus newelli*) by pigs on the island of Kaua'i, accounted for 10.4% of all depredation observed over a six-year period from 2011-2017 (Raine *et al*., 2021). In Spain, pigs were identified as the primary predator of artifical ground-nests lured with chicken and quail eggs (Mori *et al.*, 2021).

From the few long-term studies available, the negative effects of pigs have been shown to be density dependent (Hone, 2012). Occasionally, pigs can have beneficial effects on ecosystems via suppression of exotic weeds or stimulus of seed germination, and some studies suggest that pigs may not adversely affect native forest regeneration in Aotearoa (Wardle, 1984; Parkes *et al*., 2015). As a result, there is not consensus on the significance of pig threats to the Aotearoa environment, because although negative, the effects of pigs may not be comparable to those of possums, rats and mustelids (McIlroy & Nugent, 2021). However, for rare species that are highly susceptible to pig impacts, such as seabirds, that have continued to decline in spite of increased rodent and mustelid control over recent decades, and that show curious patterns of range restriction and local extinctions in areas associated with pigs, it is likely that pigs are significantly implicated. The wealth of observational evidence of pig predation events, and nest destruction, gives weight to this possibility. Yet to date, very little study quantifying pig impacts on seabirds through habitat disturbance and predation has been undertaken in Aotearoa. More study is needed, to fill this knowledge gap and better understand the role that pigs play in driving seabird decline.

A major constraint on investigating pigs is that they are a game animal and are culturally valued by groups of people including Māori and hunters, particularly on inhabited islands (Towns *et al*., 2013; Norton *et al*., 2016; Parkes *et al*., 2017). In these places, hunters regularly access public conservation land for hunting, and hold expectations of continued hunting access in future, making pig

management (and potentially research) contentious. These factors formed a consideration in the design of this study. Study areas and methods of data collection were chosen so as not to interfere with pig hunting, or potentially arouse suspicions around the research, which could have the effect of creating tensions between researcher and local hunters, and compromising data collection. Although this approach limited the spatial and methodological scope of the immediate study, it does hold benefits. This is because contentions surrounding invasive species management most often stem from value-derived concerns, thus, producing objective knowledge a way that is respectful of those values may sequester more trust from groups who are skeptical about 'the facts', encouraging stronger belief in the existence of issues, and acceptance of the need for future interventions (Frank, 2019).

2.1.2. Significance of Aotea (Great Barrier Island) for seabird conservation

Tīkapa Moana (the Hauraki Gulf region encompassing the waters and small islands lying off the coast of northeastern Aotearoa) is hotspot of seabird biodiversity, with 27 seabird species known to breed in the region, of which 16 (59%) are national endemics (Gaskin & Rayner, 2017). Free from mustelids (stoats, ferrets, and weasels), Norway rats, and possums, and the largest island in the region with extensive habitat suitable for several species of burrowing seabird, Aotea offers an ideal seabird recovery site (Forest & Bird, 2014). Notably, Aotea is the breeding site for the largest of the two remaining breeding populations of tākoketai (black petrel *Procellaria parkinsoni*), which were formerly widespread over the mountain ranges of Te Ika a Māui (the North Island) and northwestern Te Wai Pounamu (the South Island) of Aotearoa (Imber, 1987). The recovery of these two populations, is critical for the survival of the species.

Originally occupied by Māori, Aotea was colonised by European immigrants from the mid-1800's (Armitage, 2004). The ecology of the island bears the legacy of early Māori fires (used as a method for harvesting large flightless birds), and extractive industries of timber milling and mining that Europeans operated for periods over the 19th to early-20th centuries. Fire was used for deforesting areas of land for conversion to pasture, particularly over rolling hill country near the coast, and a number of areas are prone to repeated burning by wildfire, in hot and dry conditions (Ogden, 2006; Allen & Holdaway, 2010). Introduced mammalian predators (kiore rats *Rattus exulans*, ship rats *Rattus rattus*, cats *Felis catus*, and pigs) have caused local extinctions and major decline in populations of bird, reptile, and invertebrates. Herbivores (rabbits *Oryctolagus cuniculus*, goats *Capra hircus*, and cattle *Bos taurus*) have modified vegetation sequences (Ogden, 2006). Goats and most feral cattle have been eradicated, but rats and cats are abundant, and pigs although low in abundance are an issue specifically for seabirds and wetland birds, and generally for the island's ecosystems.

Since the decline of timber harvesting and farming in the 1940s, much of the area that was deforested has been allowed to regenerate, and 43% of the island is now protected as Aotea Conservation Park,

an area which covers 12,282 ha^{-1} of forested, mountainous terrain (DoC, 2022). The main block of Aotea Conservation Park occurs in the central region of the island, encompassing Hirakimatā (Mt Hobson, 627m) and the surrounding rugged hills. This area is the least modified of all Aotea landscapes, and supplies habitat that is particularly for tākoketai, with the highest densities of burrow found beneath virgin kauri (*Agathis australis*) forest at the summit (Bell *et al.*, 2021). The summit area is surrounded on most sides by steep rocky terrain, effectively forming a 'sky island' from which pigs appear to be naturally excluded. This habitat has been assessed as 'high-grade' for seabirds, on account of the quality of unmodified forest cover, high burrow density, and absence of pigs (Bell *et al.*, 2021). Elsewhere on the island, few burrows are known, but potential habitat is present in the regenerating mixture of kauri/broadleaf/conifer forest at lower altitudes, especially surrounding Hirakimatā. This area has been classified as 'core medium-grade' habitat for seabirds. Medium-grade habitat in other forest types and locations across the island is classified as 'other medium-grade'.

The core medium-grade habitat above 300m.a.s.l. is particularly significant for tākoketai recovery, because it is substantially larger (833 ha^{-1}) than the high-grade habitat in the immediate vicinity of Hirakimatā (108 ha^{-1}). A distance sampling exercise located 115 burrows on transects in core medium-grade habitat, from which 6260 breeding adults were estimated to be present (Bell *et al.*, 2021). This is approximately double the number of breeding adults estimated to occur at Hirakimatā, of 3064 adult birds (Bell *et al*., 2019). These figures establish that although the burrows within core medium-grade habitat are lower in density than the high-grade habitat, there are many more of them, and so they represent a major proportion of the breeding population on Aotea. As well, the core medium-grade is contiguous to Hirakimatā, so supplies range into which tākoketai could naturally expand, from the most densely populated area. This is important because tākoketai are highly philopatric birds, returning to breed very close to their natal burrows, making natural range expansion (as opposed to translocation) the most viable form of population increase.

There are some sites within the core medium-grade habitat that appear to be particularly suitable for tākoketai, with elevations above 300m.a.s.l., closed canopies of mature and regenerating kauri and broadleaf forest, and proximity to 'launch rocks' that tākoketai require to take flight. As well, these sites are associated with burrows. The Cooper's Castle (465m) area for example, which follows a high ridgeline interspersed with rocky bluffs, has tracts of maturing forest, and 23 known burrows located along the walking track that traverses the ridge. Tākoketai claw marks are scored heavily into rocks, suggesting the seabirds were once more abundant here. Similarly, Mt Heale (510m), Matawhero (425m), and Nga Puke Tararua (Hog's Back, above 300m), are comprised of ridged and steeply sloping topography covered in the forest type favoured by tākoketai, in which burrows are located. These sites hold potential as sites for studying the impacts of pigs and other predators on tākoketai, as well as for future species recovery.

It should be remarked that tākoketai are not the only seabird to inhabit the mountainous ranges on Aotea. Tītī (Cook's petrel, *Pterodroma cookii*), a smaller seabird than tākoketai, occupy roughly the same habitat and breed on Aotea, as well as the main breeding location of nearby Te Hauturu o Toi (Little Barrier) Island. If past reports (Bartle, 1967) are anything to go by, which describe up to fifty tītī circling the summit of Hirakimatā in the early evening, along with frequent discovery of cat-killed corpses (neither of which are observed any more), then it could be surmised that tītī may be more heavily more impacted by predation than tākoketai. This further justifies the need to investigate the impacts of predators, including pigs, within Aotea Conservation Park.

The Park holds cultural significance for *mana whenua* Ngāti Rehua Ngātiwai ki Aotea (NRNWKA), and is also hunted for pigs by local *whānau* (families) and other hunters in the community, who hold expectations of continued hunting access in the future. The NRNWKA Hapū Management Plan makes it clear that management of the Park must enable *mana whenua* to exercise their cultural practices, include accessing resources of *mahinga kai* (food), *rongoa* (medicine), and *raranga* (weaving), amongst others. Pigs are an important source of *mahinga kai* on Aotea, and historically, tākoketai were too, being harvested around March when chicks were at their plumpest (Bell & Brathwaite, 1964). Pig research and management therefore relates to two different forms of *mahinga kai*.

2.1.3. Past and present status of pigs on Aotea (Great Barrier Island)

Historic records suggest that pigs were probably introduced to Aotea shortly before 1796, by the island's Māori inhabitants (Tatton, 1994). These pigs, known as 'Captain Cookers', most probably descended from the Polynesian stock that Captain Cook had transported from Tahiti to mainland Aotearoa, some twenty years earlier (Donne, 1924). Confined mainly to islets lying close to Aotea's shore, some of these animals inevitably escaped or were intentionally liberated, especially in response to inter-tribal conflict, and colonial land transactions, that marked the mid-19th century (R. Ngawaka, Ngāti Wai, pers. comm., 2022). Domesticated breeds of pigs were introduced to Aotea by European farmer-settlers in the 1840s, which from time to time were liberated into the bush to suppress regrowth of vegetation, and to supply game for hunting (Armitage, 2004). Since then, wild-living pigs have dispered widely into the landscape, and without major physical boundaries or predators other than humans, range widely across the island throughout most forest, wetland, dune and cultivated systems, that are held under both public and private ownership. Local hunting is currently the only form of control of wild pigs, of which numbers appear to be low (DoC, 2022).

A trend of increase in abundance of pigs was noted in the post-World War Two era, as land previously cleared by fire or milling, began to revert to forest, and became heavily covered with bracken fern, supplying abundant food for pigs. Following major culls by the Forest Service (later the

Department of Conservation), and gradual decline in principal food supply as canopy cover overtopped fern, pig abundance has dropped. Anecdotal evidence suggests that pig numbers do occasionally fluctuate, but the population appears to be stable (G. Wilson, pers. comm., 2022). Pig distribution and abundance has been described as patchy. It was reported in the 1970's that pigs were 'dense' in Tryphena, Rosalie Bay and Cape Barrier – areas of reverting farmland at the southern end of the island. At the same time, pigs were 'few' throughout kauri forest in the Kaiaraara area (Lloyd, 1979, in Armitage, 2022). Presently, pigs are known anecdotally to occur most often in flat or low-lying areas which are damp, including Kaitoke Swamp, the Kaiaraara and Wairahi river valleys, and Okiwi and Harataonga basins. It is thought that these areas may act as 'reservoirs' of pigs within the environment, between which pigs potentially move. Interestingly, pigs are conspicuously absent from some areas, despite being abundant in areas adjacent. The reasons for this are not well understood, although likely related to local variables such as hunting pressure, vegetation cover, topography and food availability.

With no long-term pig monitoring underway on the island, except for voluntary reporting of pig harvest by hunters, densities of pigs have not been established, and little is known to science about pig activity and impacts on indigenous species. Pigs are not known to occupy the highest altitude areas of kauri forest in Aotea Conservation Park, around the summit of Hirakimatā, where the main tākoketai breeding site occurs. A piglet was reported to have been chased up to the summit by hunters on one occasion, but otherwise sign is absent (Bell, pers. comm., 2021). Elsewhere, hunters report harvesting around 5-6 pigs per year, which would seem to confirm low numbers, although the hunting effort required to catch this number of pigs is not known. However, of concern to tākoketai and seabird recovery generally on Aotea, is that pigs inhabit the lower-altitude areas of forest (core and other areas of medium-grade habitat) that are suitable for seabird breeding, and can act as top-predator of adult birds, chicks and eggs, as well as damaging burrows and habitat. Torn up burrows and the remains of a dozen tākoketai were observed in the 1995/1996 breeding season, and pig sign along the track network is often noticed (Bell & Sim, 1996; Bell *et al*., 2022). Pigs might be hypothesised to impact on tākoketai breeding success in a number of ways: 1) by predating eggs and chicks, reducing breeding success, 2) by damaging burrows and surrounding habitat, arresting breeding attempts by pairs of adult birds and reducing burrow densities long-term, 3) displacing or predating adult birds, removing breeding birds from the population and reducing the effective breeding population size, and, 4) affecting tākoketai behaviour, which may indirectly impact on breeding. For these multiple impacts, it is possible that pigs are as significant a threat as cats and rats (ship rat, *Rattus rattus* and kiore, *Rattus exulans)*, that are known seabird predators, and require more investigation.

Hunting by local hunters is currently the only form of pig managemagement on Aotea. Because hunters value pigs, island-wide eradication is currently not considered to be socially feasible. It is not known how socially-feasible targeted management of pigs in specific sites (e.g., seabird breeding

sites) is either. There is a paucity of data relating to pig impacts at seabird sites, and a lack of 'solid evidence' that establishes the need for targeted management. This evidence is necessary to inform strategies, and for advocacy in the community, which is vital for obtaining support and 'social license' for managing pigs.

2.1.4. Tākoketai (*black petrel*, Procellaria parkinsoni) *biology, distribution, and conservation*

Endemic to Aotearoa, tākoketai (black petrel, *Procellaria parkinsoni*) are a pelagic seabird that spend most of the year at sea, before returning to breed in burrows over the austral summer-autumn seasons. Like most other species of petrel, tākoketai are long-lived, slow to mature, and produce only one egg per season that is laid in an underground burrow, located on ridgetops or steep slopes under closed canopy forest (Imber, 1987). These burrows are located some distance from the sea, and at quite high altitudes – most have been recorded at elevations of over 300m (Gaskin & Rayner, 2017). Traditionally, tākoketai were harvested by Māori, and were often seen with pods of whales, feeding on schools of squid and small fish. Early naturalists to explore Aotearoa described tākoketai as widespread across the mountain ranges of the North Island and northwestern South Islands (Medway, 2002). Today, tākoketai are restricted to breeding on the islands of Aotea and Te Hauturu ō Toi (Little Barrier) Islands (Heather & Robertson, 1996). Habitat loss and predation by introduced mammals are the reasons for this range contraction, and it is probably because stoats (*Mustela erminea*) never made it to Aotea and Te Hauturu, that tākoketai still survive on these islands. However, the impacts of predators on seabirds are poorly understood.

Estimated at around 5,000 breeding pairs of adults (Bell *et al*., 2021), the Aotea population of tākoketai is the largest of the two remaining breeding populations, and is mostly restricted to suitable habitat within the central region of the island surrounding Hirakimatā (high-grade habitat). Distribution of burrows within this habitat is uneven, occurring in the highest densities under virgin kauri forest covering the fortress-like summit of Hirakimatā (Mt Hobson, 627m), which is surrounded on most sides by precipitous, rocky terrain (**Plate 2.1**). Descending from Hirakimatā into regenerating and mature forest at lower-altitudes (core medium-grade habitat), burrows are fewer, and tend to occur in sites that appear well protected. Very few burrows have been detected elsewhere on the island, although surprisingly, a number are found near sea level, inside a predator-free, fenced sanctuary (Glenfern) amongst old-growth pūriri forest. The reasons for this uneven distribution are thought to be a combination of habitat quality, and predation pressure, however these factors have not been investigated before.

During breeding season on land, key threats to tākoketai are cat, rat, and pig predation, and habitat disturbance by pigs (Bell *et al*., 2013). As tākoketai have an extended breeding period (between October – June, approximately) and breed at ground level, they are vulnerable to predation.

There is currently no widespread monitoring, or control, of these predators on Aotea, and their incidence and impacts within seabird breeding habitat have not been studied. Of the limited data available, community monitoring would suggest that rats and cats are ubiquitous throughout most ecosystems on Aotea (Ogden & Gilbert, 2009), and Bell & Sim's 1996 research established that both rats and cats are found at high elevations around Hirakimatā. Cat trapping (using live-capture traps) is undertaken along the track network of Aotea Conservation Park, that passes through some areas of seabird breeding. Rat trapping using Goodnature A24 self-resetting traps is currently underway on Hirakimatā, but does not occur elsewhere (Bell *et al*., 2022).

Plate 2.1. The fortress-like summit area of Hirakimatā, surrounded on most sides by steep, rocky bluffs. Pictured is the northwest elevation, from Kaiaraara track.

At sea, tākoketai are the species of Aotearoa seabird most at-risk from bycatch in commercial fisheries in local waters, and off the coasts of Peru and Ecuador, where the birds migrate over the austral winter-spring (Richard, 2020). It is estimated that 10% of fledglings make it back to breed. Being a migratory seabird, tākoketai are also likely to be susceptible to changes in at-sea conditions that are expected to occur (and are already occurring) under a regime of climate change, including increased frequency and severity of storms, marine heatwaves and decline in food supply (Bellard, 2012). Although the population of tākoketai on Aotea currently appears to be stable, and tākoketai are ranked as Vulnerable under the New Zealand Threat Classification system (suggesting that as a species, tākoketai are 'doing ok'), the Aotea population is not showing any signs of the growth that is

needed for long-term recovery and resilience to climate change (Grémillet & Boulinier, 2009). The greatest prospects for species recovery lie in natural population increase and range expansion into suitable habitat, achieved through managing predators. Past attempts at translocation have been unsuccessful: beginning in 1986, 249 tākoketai chicks close to fledging were translocated from the main breeding colony at Aotea, to the smaller population depleted by cat predation on Te Hauturu. Over the next 10 years, only 11 of the transferred birds were relocated, of which 9 had returned to Aotea (Imber *et al*., 2003). Because pigs (and other predators) occur within the range available for natural tākoketai expansion, and threaten breeding and population growth, it is critical to understand their impacts in relation to tākoketai breeding.

The purpose of this study is to gather important preliminary data on the incidence of predators around tākoketai breeding areas, with a special emphasis on pigs, and to document evidence for direct and indirect impacts of pigs on tākoketai (in the form of ground disturbance, burrow site characteristics, and direct interactions with burrows or birds). I use these findings to comment on pigs' potential role in producing the pattern of uneven burrow distribution that is observed, and their significance as a threat to tākoketai recovery on Aotea.

2.2. Methods

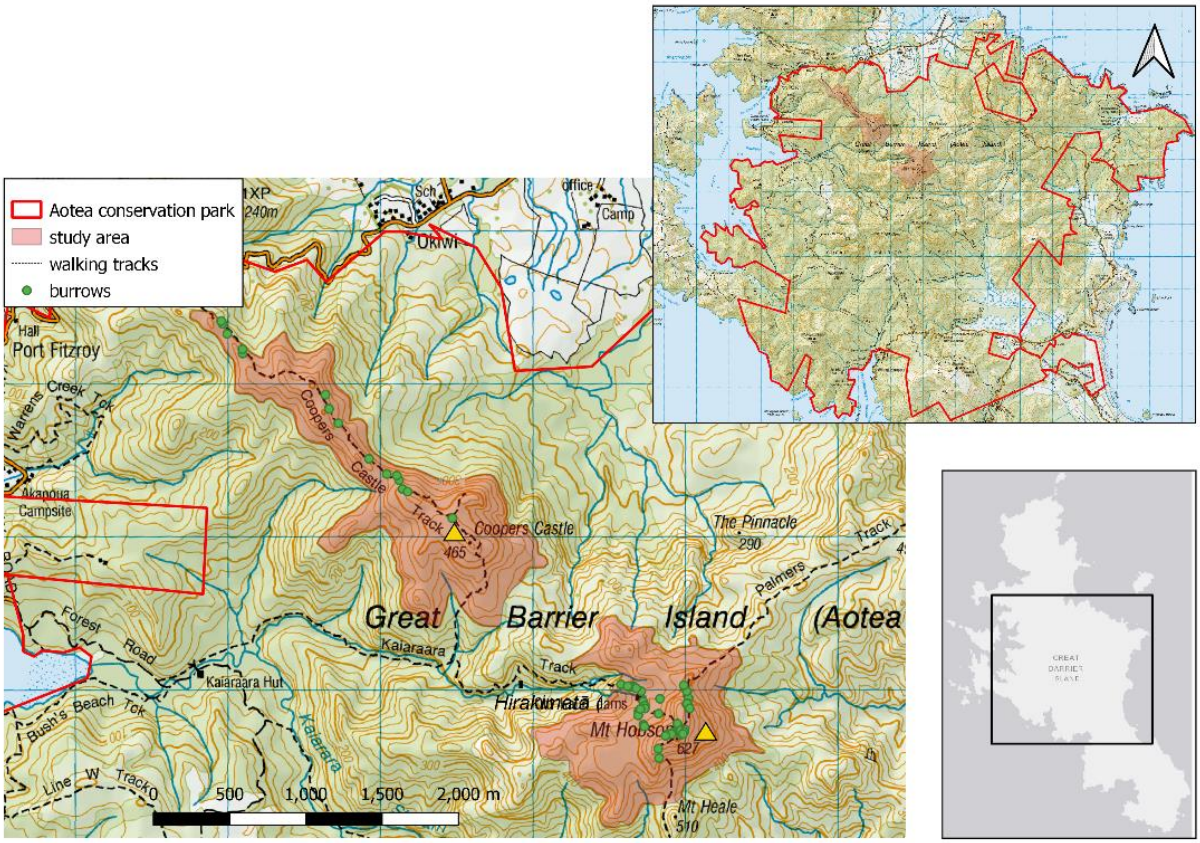
2.2.1. Site details & overview

The study was based in seabird breeding habitat in the central region of Aotea Conservation Park surrounding Hirakimatā (Mt Hobson, 627m), on Aotea (Great Barrrier Island). This habitat is characterised by rugged hills covered in mixed regenerating forest, and a small patch of virgin kauri-conifer forest around the summit. This area has been classified by Bell *et al*. (2020; 2021) into zones of high-grade, and core medium-grade habitat, on the basis of factors including elevation, topography, vegetation cover, presence of tākoketai breeding burrows and presence of pigs (**APPENDIX 2**). Pigs are known to occur throughout lower-elevation areas, although rarely around the summit. Cats and rats occur throughout. Both cats and rats are trapped at Hirakimatā, but only cats are trapped at lower elevations. A study area was defined above 300m.a.s.l. within core medium-grade tākoketai habitat around Cooper's Castle (425m), where pigs are present. A control area was defined above 400m.a.s.l. within high-grade tākoketai habitat at Hirakimatā (627m), where pigs are absent. Low-grade habitat within Kaiaraara Valley, connecting the study and control sites, was also investigated (**Map 2.1**).

Additionally, this study made use of an unpublished dataset containing incidental observations of all pig sign (both recent, and old), collected by Elizabeth Bell and team progressively over the 2018/2019, 2019/2020, and 2020/2021 breeding seasons. These data recorded pig sign on transect

surveys used to estimate tākoketai breeding population size on Aotea, over all potential tākoketai habitat (classified into areas of high, medium (core), and medium (other) grades). For methods pertaining to these data, see **APPENDIX 1**.

Map 2.1. Map of study areas at Cooper's Castle and Hirakimatā (Mt Hobson) in core seabird breeding habitat on Aotea (Great Barrier Island), with the intervening Kaiaraara Valley. (Mapped on Land Information New Zealand NZTopoMap).



2.2.2. Field survey methods

2.2.2.1. Burrow characteristics

Tākoketai (*Procellaria parkinsoni*) typically breed in burrows excavated into soft soil beneath the bases of rooted and fallen trees, but are capable of utilising a range of other sites. The physical characteristics of these sites were described, and the diameter of the tree base (or other structure, sheltering the burrow) recorded, at all burrows known within the Cooper's Castle study site (N = 23). Burrrows were also inspected for occupancy, confirmed through the presence of sitting adults or chicks, or a combination of other indicators of attendance including fresh faeces, a noticable 'seabirdy odour', and a burrow entrance clear of leaf litter and mounded with freshly overturned soil, often

containing debris (eggshell, feathers) from inside the burrow. A random sample (n = 46) of the 476 burrows known within the control site at Hirakimatā were similarly described and measured.

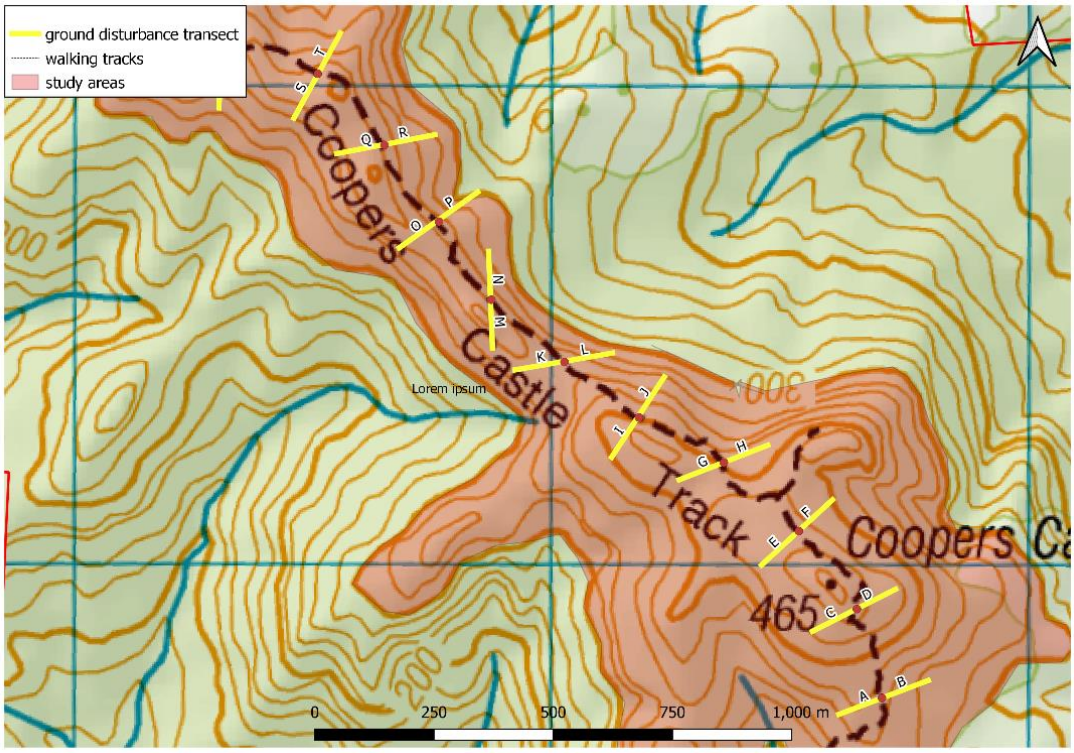
2.2.2.2. Ground disturbance

Pigs leave conspicuous signs of activity through rooting, trampling, and wallowing (NPCA, 2018). Such activity can disturb extensive areas of the ground surface beneath which seabirds can potentially breed. To quantify the extent of disturbance caused by pigs to seabird breeding habitat, nested transects (lines of ten, 10m transects, measuring 100m-long in total) were arranged at 200m spacings on either side of the walking track following the ridgeline through Cooper's Castle study site, were established (**Map 2.2**). These were navigated along a set bearing, and surveyed once in the middle of tākoketai breeding season, in February 2023. Hazards and obstacles, such as bluffs or inpenetrable thickets of scrub were circumnavigated where possible, or transects were truncated where neccessary for safety. The proportion (%) of the ground surface along each 1m wide transect that was freshly disturbed by pigs (through rooting, trampling, and wallowing) was estimated, and later converted to area (m^2). 'Fresh' disturbance was determined subjectively, but consistently, as freshly overturned or trodden soil with no- to light- coverage of litterfall. Vegetation cover (scrub, regenerating forest, and mature forest), vegetation composition (kānuka, broadleaf, mixed broadleaf-podocarp, or other), surface moisture (such as pooled or running water, or boggy ground), and aspect were noted for each transect. The presence of 'other' pig disturbance (defined as any disturbance, whether fresh or old) within 5m of either side of transects was also noted.

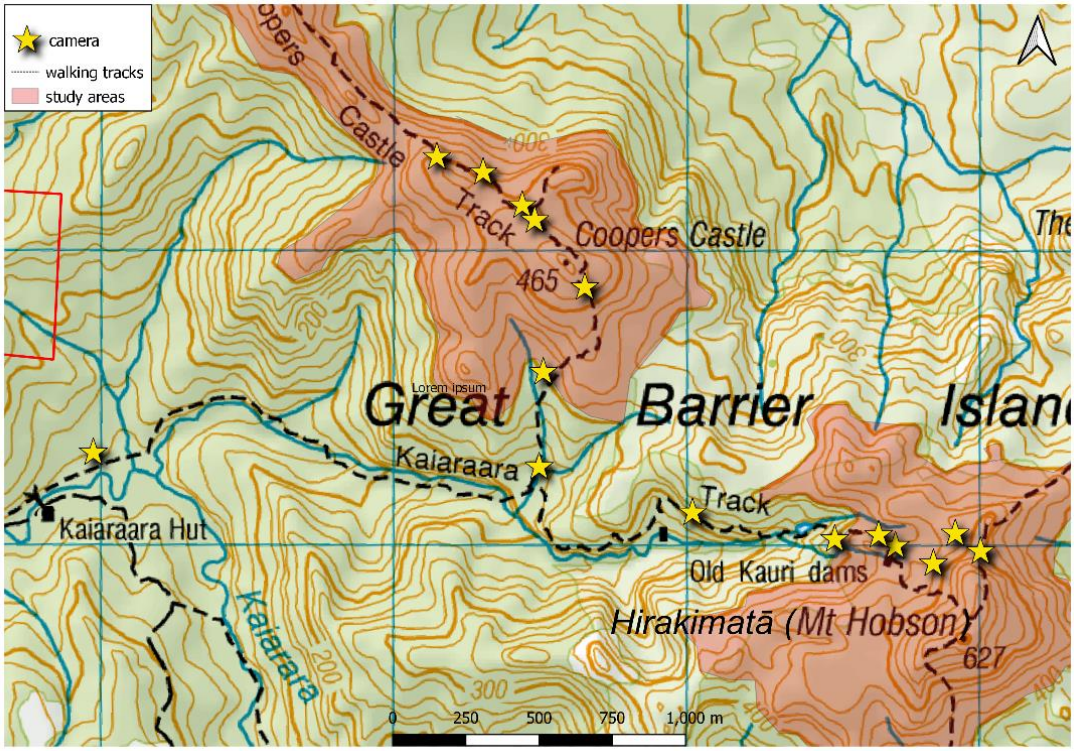
2.2.2.3. Pig (and other predator) incidence

Continuous camera monitoring was undertaken over 255 days, from 01 June 2022 – 10 February 2023 within the study site at Cooper's Castle, control site at Hirakimatā, and low-grade adjacent habitat in Kaiaraara valley. Six Browning Dark Ops Elite HD (model BTC-6HDE) wildlife cameras were scattered within the vicinity of tākoketai burrows in the Cooper's Castle study site, and Hirakimatā control site (located within 25m of the walking tracks that traverse the sites). Three cameras were scattered in the low-grade Kaiaraara Valley site, in the vicinity of the track only, as burrows had not been located in this area (**Map. 2.3**). Cameras were mounted on tree trunks approximately 30cm above the ground, in small clearings in vegetation that allowed for a clear field of view. Mounting was done this way, to optimise captures of target wildlife and avoid non-target captures of human park users (hunters, rangers, hikers, etc.). Vegetation was clipped back to avoid falsely triggering the cameras. Progamming was set to record 10 second video with a delay between videos of 30 seconds. Cameras were checked sporadically to replace batteries and SD cards.

Map 2.2. Location of ground disturbance transects at Cooper's Castle study site. Transects were nested in lines of ten, 10m transects (measuring 100m-long in total), arranged at 200m spacings on either side of the walking track following the ridgeline through the site. (Mapped on Land Information New Zealand NZTopoMap).



Map 2.3. Location of wildlife cameras within Cooper's Castle and Hirakimatā study areas, and Kaiaraara Valley. (Mapped on Land Information New Zealand NZTopoMap).



2.2.3. Data analysis

2.2.3.1. Overview

Statistical analysis was performed in RStudio version 2022.07.02+576 (RStudio Team, 2022). Models were fitted with package 'lme4' (Bates, 2010). Graphs were produced with RStudio package 'ggplot2' (Wickham *et al*., 2023), and Microsoft Excel native graphing functions (Microsoft Corporation, 2023). Model assumptions were verified using both visual and statistical tools in RStudio package 'DHARMa' (Hartig, 2022).

2.2.3.2. Burrow characteristics

Mann-Whitney's 'U' test was used to test the significance of the difference in burrow site diameter, between study (pigs present) and control (pigs absent) sites.

2.2.3.3. Distribution and abundance of pig sign within seabird habitat

To ascertain which categorical predictor variables (habitat grade, site, forest cover, and vegetation composition) might be most explanatory of the presence of pig sign on independent transects, a logistic generalised linear model (GLM) was fitted, with pig sign as the binary (0/1) response, and categorical predictor variables of habitat grade, site, forest cover, and vegetation composition as fixed effects. Because of collinearity of the predictor variables, models failed to converge and it was not possible to determine the strength and significance of effects to levels within each category. Instead, a non-parametric ANOVA (Chisquare X^2) was run on the output of the GLM to identify effects amongst categories.

2.2.3.4. Ground disturbance

Heavy skewing of the data (by the prevalence of zeros, whereby 153 of 188 observations had a value of zero) rendered standard generalised linear mixed modelling inappropriate. Instead, a two-part modelling approach was chosen, suited to non-negative, continuous types of observations, and the theoretical consideration that two disinct data-generating processes may be involved in producing zero versus non-zero outcomes (Olson & Schafer, 2001). This approach permitted for each process to be modelled separately. First, a binary response variable was assigned to each observation (0 for zero values, 1 for non-zero values), and fitted to a logistic generalised linear mixed model (GLMM), with fixed effects of aspect, slope, other pig sign, surface moisture, forest cover, and vegetation composition. Nesting of transects was a random effect. Second, a gaussian GLMM regression for the

non-zero observations was performed. Models constructed in this way conformed to the assumptions of normality and homoscedasticity of residuals.

2.2.3.5. Pig (and other predator) incidence

Camera footage was reviewed using ZIP Classifier software (ZIP, 2023). Detections of predators (pigs, cats, and rats) and birds (tākoketai, and other birds) were recorded, in addition to the timestamp, number of individual animals, any identifying features of individuals (including sex, maturity, pelt markings) of each video detection. A detection was defined as the positive identification of wildlife to the genus or species level, in footage that was captured 60sec or more apart. Exceptions to this definition were small rodents (which were indistinguishable between juvenile rats and mice, making identification to genus level unfeasible), which were classified 'rodents'. Also, different individuals of the same species, that were captured less than 60sec apart, were considered separate detections and were recorded. Any wildlife footage that could not be positively identified (for example, in blurry or cryptic images), was not recorded. Detection frequency data of predators (pigs, cats, rats and rodents), and non-predators (tākoketai, and other birds), were quantified and described, and analysed for temporal and spatial patterns.

2.3. Results

2.3.1. Tākoketai burrow characteristics within medium- and high- grade seabird habitat

Considerably more burrows have been located within the high-grade habitat surrounding the summit of Hirakimatā (*N*=476), than within the core medium-grade habitat at Cooper's Castle (*N*=23). Differences in the physical characteristics of burrow sites were apparent between the two grades of habitat. Typically, tākoketai burrows are excavated into soft soil beneath the bases (trunks, and roots) of trees. Of the Cooper's Castle burrows, only 30.4% of were located beneath tree bases. The majority (43.5%) were situated above-ground, within the protective structures of tree-trunk cavities, mainly represented by pūriri (*Vitex lucens*). 21.7% of were located beneath large boulders. 4.3% were beneath clumped grass. The mean diameter of these sites (tree bases, boulders, and grass) was massive (153.5 ± 114.1cm). In contrast, almost all (95.7%) burrows sampled at Hirakimatā (n = 46) were located beneath the bases of small-to-medium sized tree stems, of various species. 4.3% were beneath grasses. The mean diameter of these sites was significantly smaller than at Cooper's Castle ($\bar{x}$ = 24.3 ± 18.3cm, U=989.5, $p = 4.73^{-9}$). Burrow occupancy, a measure of the proportion of burrows attended by adult pairs of tākoketai during breeding season, was lower at Cooper's Castle (30.4%)

than Hirakimatā (60.9%), during the 2022-23 season over which the study took place (**Plate 2.2, Table 2.1**).

Plate 2.2. Typical sites for tākoketai burrows within Cooper's Castle core medium-grade seabird breeding habitat at **(a)** are well-protected structures such as the massive trunk cavities of ancient pūriri, while within high-grade habitat at Hirakimatā **(b)**, are in soil beneath small-to-medium sized trees with mean diameter = 24.3cm.

a.

b.

Table 2.1. Characteristics of tākoketai burrows (total number of known burrows, type of burrow site, diameter of burrow site, and burrow occupancy) located within sites of medium-grade seabird breeding habitat (Cooper's Castle) and high-grade seabird habitat (Hirakimatā), on Aotea Great Barrier Island over the 2022-2023 breeding season.

Burrow characteristic	**High-grade habitat (Hirakimatā)**	**Medium-grade habitat (Cooper's Castle)**
Study burrows		
N	478	23
Sample		
n	46	23
Burrow site		
Percentage %		
Standing tree base	95.7	30.4
Tree cavity	0	43.5
Boulder	0	21.7

Other (grasses)	4.3	4.3
Diameter of burrow site		
Mean ± SD (cm)	24.3 ± 18.3	153.5 ± 114.1
Burrow occupancy		
% burrows occupied	60.9	30.4

2.3.2. Distribution of pig sign within seabird habitat

A total of 430, 100-m long transects covering 42,170m were surveyed across potential seabird habitat on Aotea. 46 (10.7%) of these transects had pig sign present. Pig sign was absent from all transects within high-grade habitat (Hirakimatā), where access is via a steep, rocky ascent; and, from within the predator-proof fenced area at Glenfern Sanctuary, in northwest Aotea. Pig sign was present in the medium grade habitat, and was more frequent in the core area surrounding Hirakimatā (occurring on 34 or 7.9% of all transects surveyed), than other areas to the north, and south of Aotea (occurring on12 or 2.8% of transects). Pig sign was most frequent on transects at sites that are considered most optimal for seabird recovery in the core (having a presence of breeding burrows, high ridges/slopes, and closed canopy forest): Cooper's Castle (4.5%), Matawhero (1.4%), Ngā Puke o Tararua (Hog's Back) (1.1%). Te Paparahi (2.3%) and Windy Canyon (1.1%) also had frequent pig sign, but burrows have not been located in these areas. These findings seem to agree with local reports that pigs are generally low in number and do not occupy high-grade seabird habitat at Hirakimatā, probably because of the barriers to access and foraging opportunities that precipitous, rocky terrain presents. However, they also indicate that pigs tend to frequent sites around the main breeding colony of tākoketai (on Hirakimatā), that are especially favourable for tākoketai breeding and recovery (**Fig. 2.1**).

Figure 2.1. Presence or absence of pig sign on 430 transects surveyed by Bell *et al*. (2020; 2021) across potential seabird habitat on Aotea (stratified into areas of high, core medium, and other medium grades, shown inset). (Mapped using Land Information New Zealand NZTopoMap).

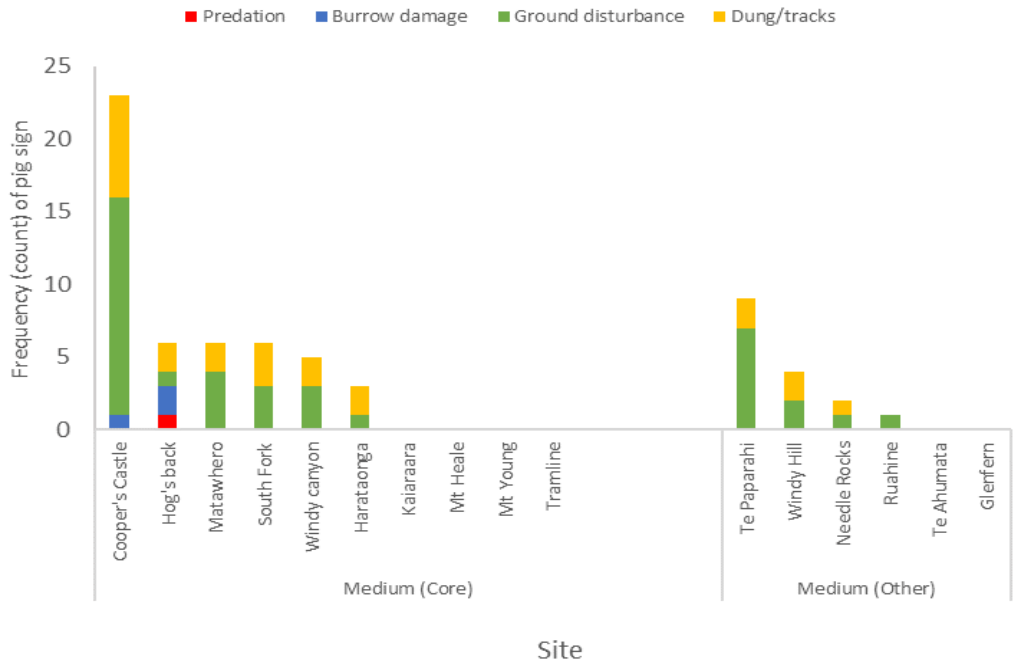
Non-parametric (Chi-square) ANOVA(GLM) showed that the variance in pig sign was mainly due to site differences, rather than habitat grade or vegetation composition. Forest cover was not a signifcant predictor (**Table 2.2**). These relationships indicate that the 'real' sources of variation might be other variables (including hunting pressure) that data were not collected for, which would be useful to examine in future.

Table 2.2. Non-parametric ANOVA(GLM) of categorical factors affecting pigs sign in potential seabird habitat.

Predictor	**D.f.**	**Deviance**	**Residual deviance**	***P (>Chi)***
Grade	2	33.6	258.9	**<0.001**
Site	16	71.2	187.7	**<0.001**
Forest cover	1	3.3	184.4	0.07
Vegetation composition	4	12.2	172.2	**0.016**

Ground disturbance (rooting, wallowing, and trampling) was the most frequent (n = 27) type of pig sign noted on transects, and dung/tracks were also common (n = 18). Tākoketai burrow damage was noted once at Cooper's Castle, and twice at Hog's Back, where burrow cavities had been broken into and exposed by pigs, exposing nest bowls (n = 3). Evidence of tākoketai predation was noted once at Hog's Back, where scattered feathers and wings (typical of pig predation) were found in the vicinity of a damaged burrow (n = 1) (**Fig. 2.2**).

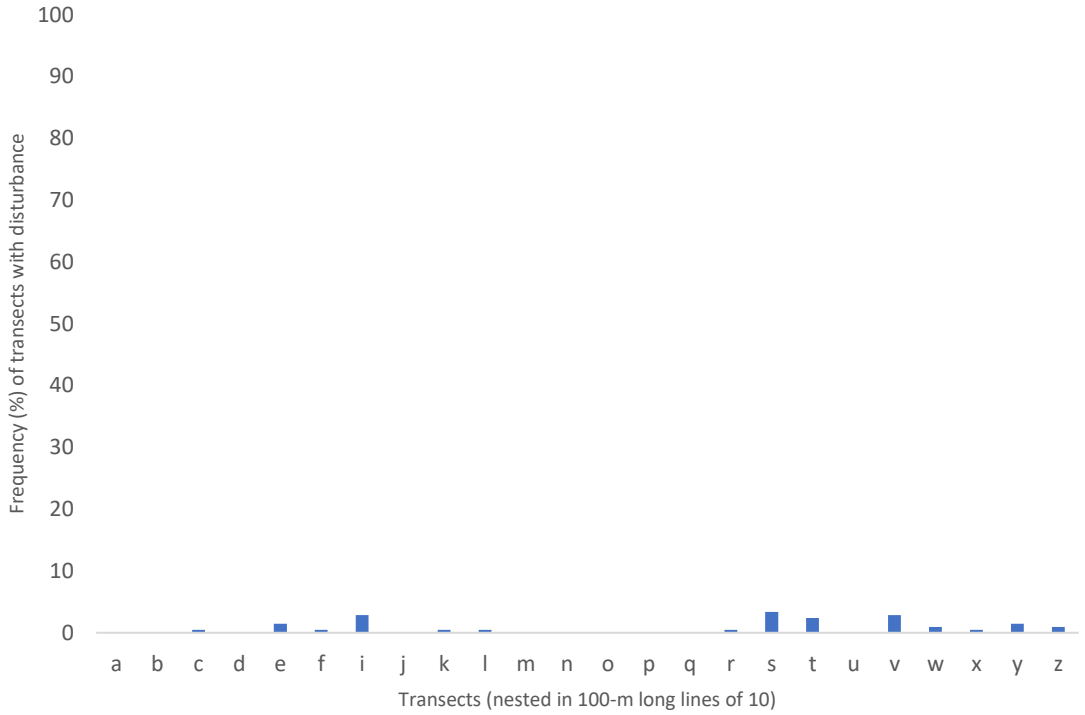
Figure 2.2. Counts of pig sign (predation, burrow damage, ground disturbance, and dung/tracks), noted on 430 transects at sites of medium (core) and medium (other) grades of seabird habitat.



2.3.3. Ground disturbance by pigs at Cooper's Castle

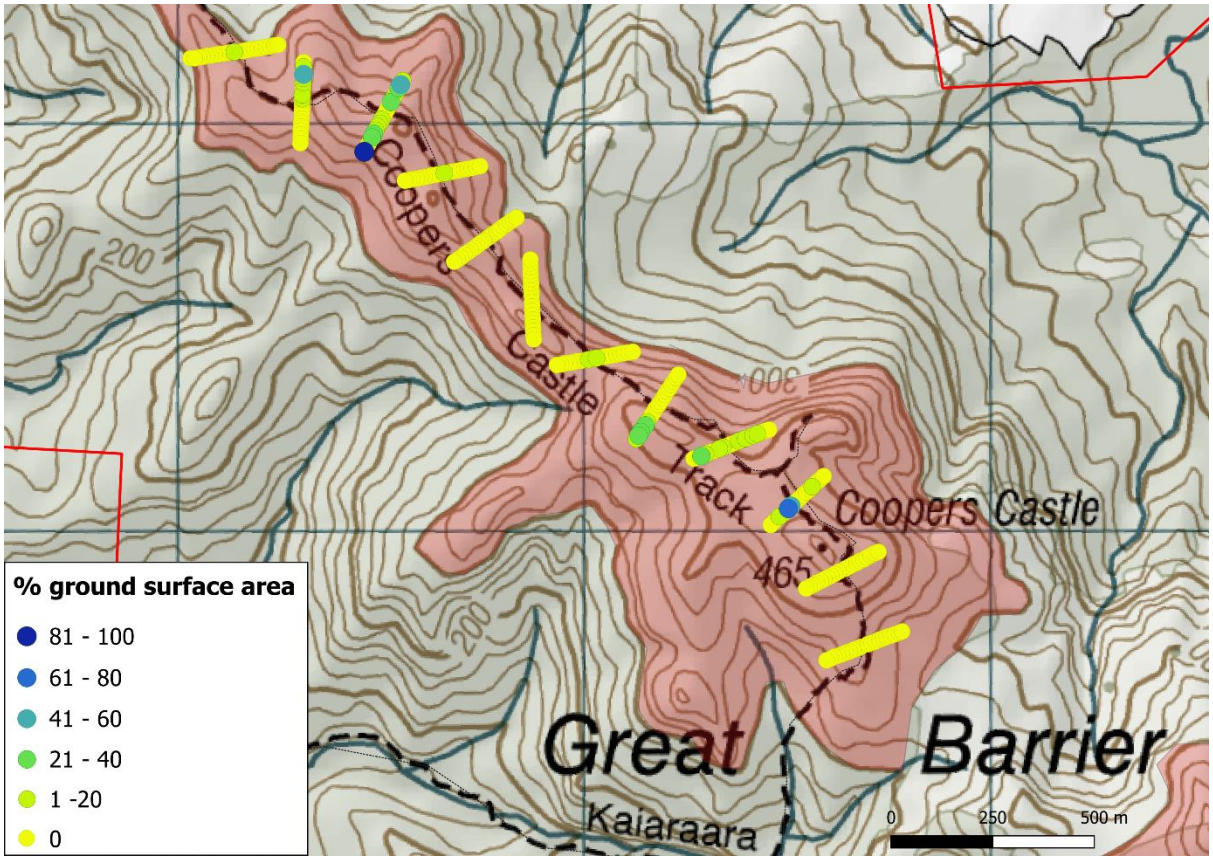
A total of 208 transects covering 2056 m were surveyed at Cooper's Castle. Fresh disturbance was scattered in patches over the ground surveyed, on 42 (20.2%) of all transects. This was most frequent around the plateau-like area toward the southern region of the site (transects e-l), and the northern region of the site covered (transects r-x). Interestingly, disturbance was not often encountered in the mid-region (transects m-q) (**Fig. 2.3**).

Figure 2.3. Frequency (%) of transects with ground disturbance by pigs at Cooper's Castle site of core medium-grade seabird habitat



Fresh disturbance appeared mainly as patches of rooting, which was highly varied in coverage of the ground surface surveyed, from 0.2-10m^2 (2 to 100%) of transects surveyed (**Fig. 2.4**). Mean surface area of ground disturbed by pigs was 4.5m^2 ± 12.0 SD of all ground surveyed. Less extensive patches were observed to be disturbed to shallow depths (from 5-15cm beneath the soil surface, approximately), while more extensive patches were disturbed to greater depths (up to 30cm, approximately, beneath the soil surface). One particular transect (s10) gave the visual impression of having been 'bulldozed', such was the tillage of a contiguous, although localised, zone of soil. Also evident were exposure of roots, and uprooting or burial of seedlings and understory vegetation. One transect cluster (i) intersected a pig run, decending a SSW slope via a shallow drainage channel. Here, disturbance was evident in the form of trampled, muddy ground, and patches of rooting.

Figure 2.4. Surface area (m^2) of ground disturbed by pigs on transects at Cooper's Castle



More apparent than fresh disturbance directly on transects, was 'other' disturbance – a combination of old disturbance, and any other fresh disturbance - within the vicinity (within 5m to either side of transect) of transects. 73 (35.1%) of transects had some form of disturbance nearby. In some patches, particularly around the plateau-like southern region of the site, this disturbance appeared to be long-term and repeated, such was the modification of the forest floor into an undulation of hummocks and muddy depressions, the perturbed state of the litter layer, with little undergrowth (**Plate 2.3**).

Pig disturbance was generally less frequent on south and southeasterly facing slopes, but the binomial GLMM suggested aspect was not significant. Disturbance was less frequent under mature forest cover than regenerating forest ($\beta = -2.22$, 95% CI = [-3.44,-1.0], $p<0.0001$), and was very infrequent under scrub (possibly because of the inpenetrability of vegetation), although this was not significant. Surface moisture was weakly associated with disturbance frequency ($\beta = 1.67$, 95% CI = [0.41,2.93], $p<0.01$), as was other pig disturbance in the vicinity of transects ($\beta = 1.17$, 95% CI = [0.05, 2.29], $p<0.05$). A weak, negative association with mixed broadleaf-podocarp vegetation cover was also found ($\beta = -1.96$, 95% CI = [-3.52, -0.39], $p<0.05$). Area of ground disturbed (m^2) was found to be positively associated with NE and SW slopes, other disturbance, and mixed broadleaf-podocarp vegetation,

however these effects were not statistically significant. There was no relationship between distance from the track, and disturbance.

Plate 2.3. Ground disturbance from pig rooting: (a) section of Cooper's Castle walking track, very freshly overturned by pigs (left), **(b)** a patch of repeatedly disturbed ground within vegetation, with a conspicuous absence of small seedlings, and muddy, exposed soil, **(c)** exposure of roots beneath a secondary kānuka stand.

a. 

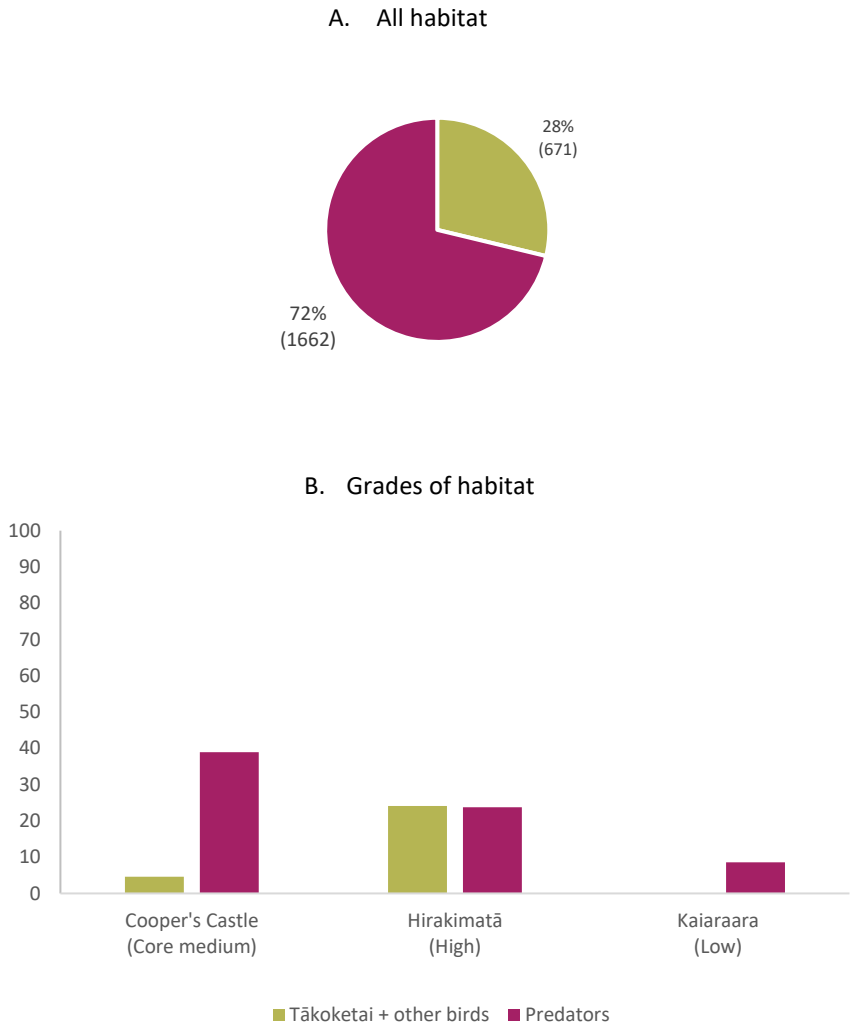
b. 

c. 

2.3.4. Pig and other predator activity within seabird habitat

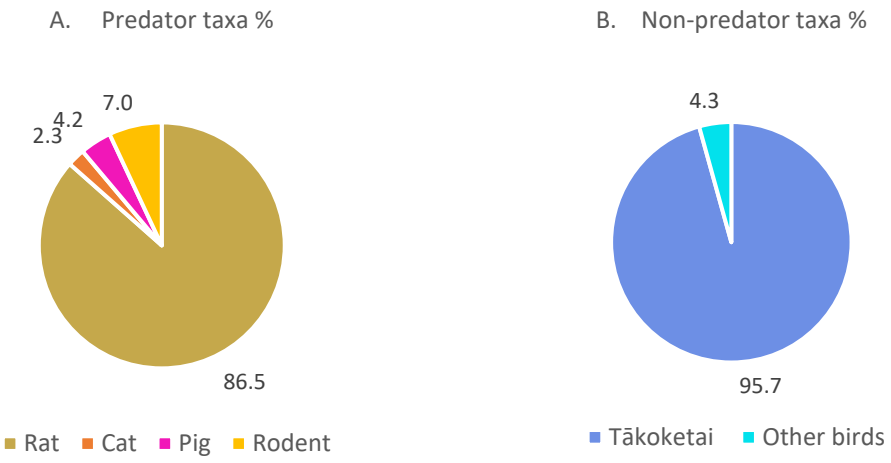
A total of 2,333 wildlife detections were captured by cameras over the 255-day monitoring period. Eleven taxa were identified, including one seabird (tākoketai), six other birds (banded rail, blackbird, piwakawaka, ruru, toutouwai, tūī), cats, pigs, rats and 'rodents' (the were indistinguishable between juvenile rats, or mice). Predators (cats, pigs, rats and rodents) represented 1,662 (71.3%) of all wildlife detections, while non-predators (seabirds and other birds) represented 671 (28.7%) (**Fig. 2.5.a)**. Wildlife detections were similar in total frequency between sites of high- and core medium-grade, however at Cooper's Castle (core medium-grade) predators were proportionately greater (38.9%) than at Hirakimatā (high-grade, 23.7%). Relatively few detections were made at Kaiaraara (low-grade), and these were composed entirely of predators (**Fig. 2.5.b**).

Figure 2.5. Wildlife detections, proportionate to predators (pigs, cats, rats and rodents) and non-predators (tākoketai and other birds) within **(a)** all seabird habitat on Aotea, **(b)** grades of seabird habitat (high-, core medium, and low- grade).



Amongst the predator taxa, rats were the most frequent predators (86.5%), followed by other rodents (7.0%), pigs (4.2%), and cats (2.3%) (**Fig. 2.6.a**). Of the non-predators, tākoketai were the most frequent (95.7%), while all other small birds were very infrequent (4.3%) (**Fig. 2.6.b**).

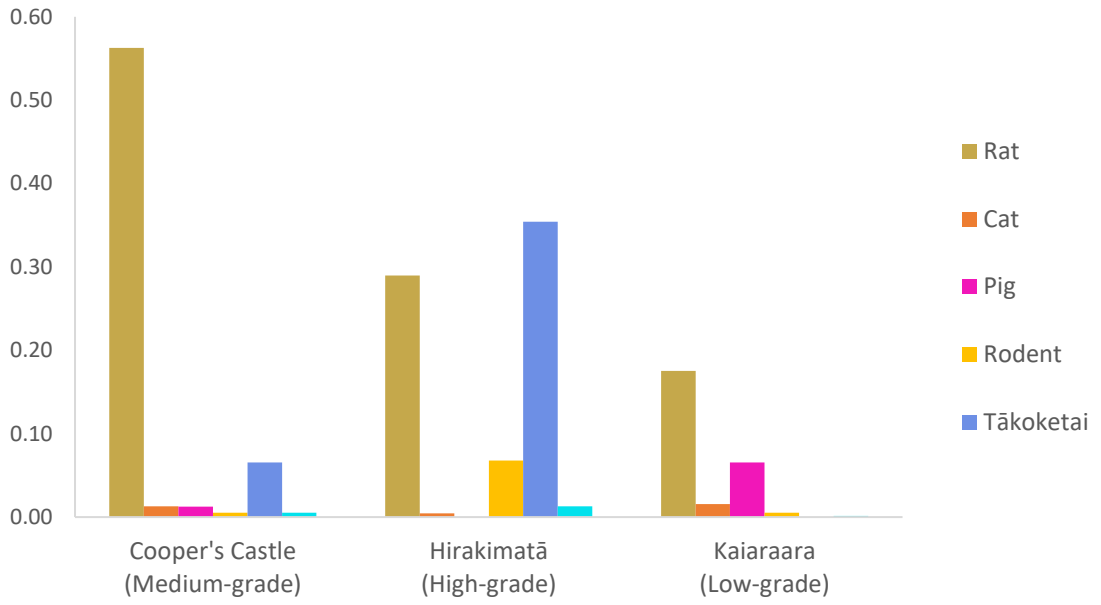
Figure 2.6. **Predator detections,** proportionate to taxa (pig, cat, rat and rodent) **(a),** and **non-predator detections,** proportionate to taxa (tākoketai, and other birds) **(b)**.



Differences were apparent in the relative frequency (detections per camera-day) of these predators at different sites. Pigs were detected most often within low-grade Kaiaraara valley (RF = 0.064), and were absent from high-grade Hirakimatā. Pigs and cats were detected in near-equal frequency in medium-grade Cooper's Castle (RF = 0.013, and 0.014 respectively). Cats were least frequent in high-grade Hirakimatā (0.005). Rats were most frequent at Cooper's Castle, intermediate at Hirakimatā, and least frequent in Kaiaraara valley. Other rodents were detected most frequently at Hirakimatā, suggesting potentially more mice or kiore than lower elevations. Tākoketai were much more frequent within high-grade Hirakimatā (RF = 0.354) than medium-grade Cooper's Castle (0.065), and were absent from within low grade Kaiaraara valley. Other birds were also most frequent within high-grade habitat (RF = 0.013), were less frequent in medium-grade habitat (RF = 0.005), and virtually absent from low grade habitat (RF = 0.001) (**Fig. 2.7**).

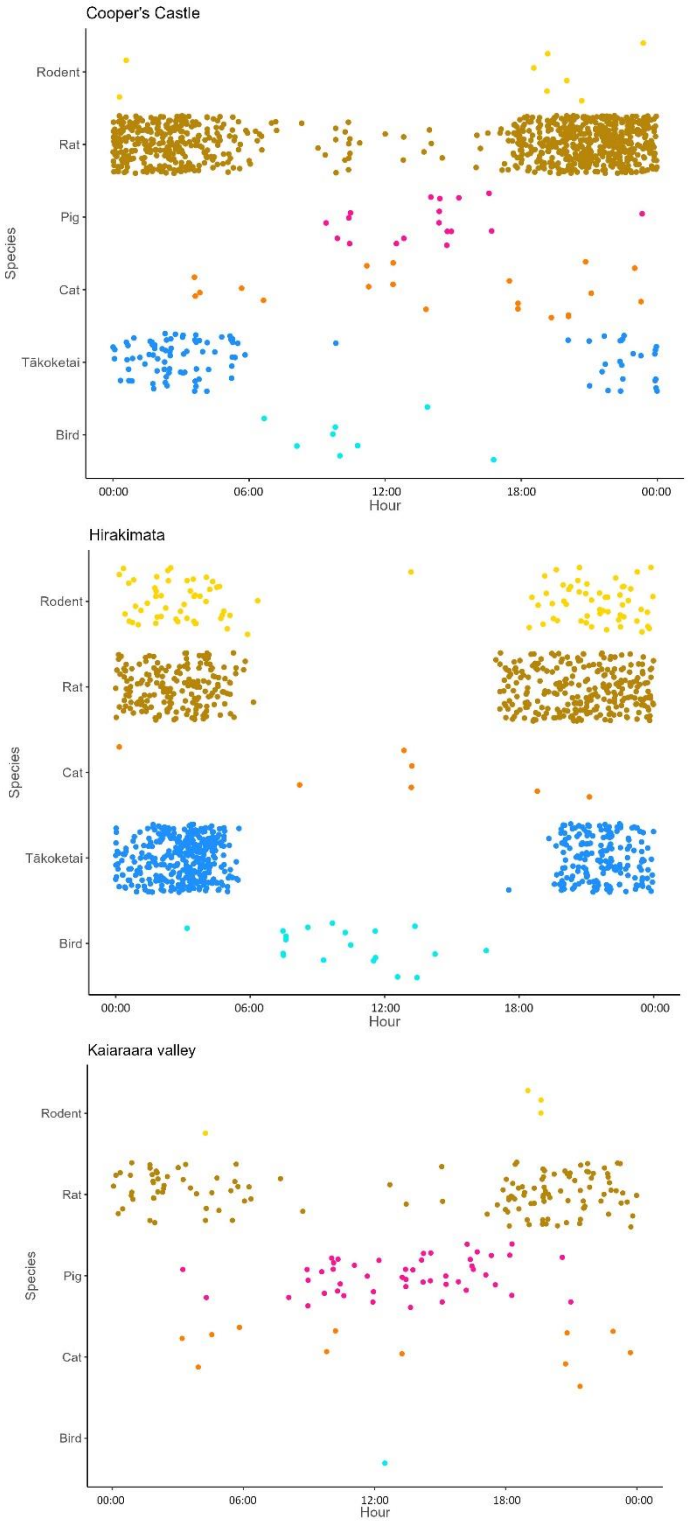
It was not possible to identify or sex individual pigs, however pigs were frequently detected in small groups, often with one adult, and of 2-3 juveniles (weaners or suckers), which suggests these groups were composed of sows and offspring.

Figure 2.7. Relative frequency (detections per camera-day) of taxa, at Cooper's Castle, Hirakimatā, and Kaiaraara valley sites monitored.



Activity patterns of taxa were compared between Cooper's Castle , Hirakimatā, and Kaiaraara valley sites. Taxa had similar patterns of activity across all sites. Tākoketai were active nocturnally, over an approximately 9-hour period from 20:00 – 05:00. Rats also exhibited nocturnal activity, over approximately 12-hours from 18:00 – 06:00. Rodents were active for the same nocturnal period as rats. Cats were active at all hours across the 24-hour time period. Pigs were diurnal, being active over 9-hours from 09:00 – 18:00. Birds were also active during daytime, and interestingly, at Cooper's Castle, some rat activity was recorded during the day, while it was not at Hirakimatā (**Fig. 2.8**).

Figure 2.8. **Diel (24-hour) activity patterns** of all wildlife taxa detected at Cooper's Castle, Hirakimatā, and Kaiaraara valley sites.



Seasonal activity patterns showed some variation between sites. Tākoketai activity was greatest over November-January at both sites, in relation to the start of breeding season. At Cooper's Castle, rat, cat, and pig activity also increased during this period. At Hirakimatā, however, rat and cat activity

peaked in September-October, so was out of synchrony with tākoketai breeding. This may be driven by differences in food availability at the Hirakimatā site, that are a consequence of differences in the composition of vegetation at higher elevations (**Fig. 2.9**).

Figure 2.9. Seasonal activity patterns of tākoketai, rodents (rat, and other), pigs, and cats at Cooper's Castle, Hirakimata, and Kaiaraara valley

2.3.5. Evidence of direct predator interactions with burrows

There was not strong evidence for pig interaction with tākoketai burrow sites at Cooper's Castle. No pigs were detected in footage from cameras positioned directly on burrow sites. However, visual inspections of the burrow sites over the course of the study did detect some fresh disturbance of the leaf litter layer within 5m of burrows (CC03, CC17, and CC18, all which are located within protective structures). At burrow CC17, disturbance reached the burrow entrance. These suggest pigs are foraging close to, and encountering burrow sites, but are not necessarily investigating burrows further and attempting to 'break in' to them, if burrows are located within protective structures. Cats, on the other hand, were detected investigating burrow entrances on two occasions at Cooper's Castle, and twice at Hirakimatā. Findings of direct predator interactions are summarised in **Tables 2.3.a.; 2.3.b**

Table 2.3.a. Observations of predator (pig, and cat) interactions with tākoketai burrows at Cooper's Castle

Site	Observation date/time	Predator species	Description, and/or image of interaction
Cooper's Castle	08-11-2022	Pig	Fresh ground disturbance near burrow CC03 (in root ball cavity of fallen pūriri)
	01-08-2022 11:16A	Cat	Tabby cat, climbing toward burrow CC01 entrance 
	19-01-2023	Pig	Fresh disturbance of litter layer near burrow CC18 (in trunk cavity of fallen pūriri)
	04-02-2023 09:49AM	Cat	Tabby cat, approaching entrance of burrow CC01 
	09-02-2023	Pig	Fresh disturbance of litter layer near, and up to, the entrance of burrow CC17 (underneath clumped grass/boulder)

Table 2.3.b. Observations of predator (cat) interactions with tākoketai burrows at Hirakimatā

Hirakimatā	07-06-2022 09:12AM	Cat	Black cat, investigating entrance of burrow H407 
	28-07-2022 01:51PM	Cat	Black cat, investigating entrance of burrow H101 

2.4. Discussion

2.4.1. Spatial and temporal patterns of pig (and other predator) activity

Pigs appear to be interacting the most (indicated by the frequency of pig sign on transects) with elevated sites that have regenerating and mature forest cover, which tākoketai favour for breeding. In wild ungulates, habitat selection is usually driven by a combination of foraging choice and predator avoidance (Borkowski & Ukalska, 2008; Bjørneraas *et al*., 2012). Forested, elevated sites on Aotea may offer foraging opportunities, and safety from hunters (with dogs), who are the major predator of pigs on the island, relative to more heavily hunted lower elevations. Camera surveillance of the Cooper's Castle tākoketai breeding site, and the valley (Kaiaraara) connecting this with other breeding sites, supports this idea. At Cooper's Castle, which is an undesirable hunting location because of difficult and hazardous terrain, pig activity occurred over most of the year, suggesting fairly permanent occupation of the area by pigs rather than seasonal or transient occupation. Conversely, in Kaiaraara valley, which is easily accessible to hunters, pig activity was distributed to a peak in late winter, and then some activity over summer – periods that coincide with low hunting

pressure over cold/wet months, and the off-season in which hunting is not permitted by DoC. Both Cooper's Castle and Kaiaraara valley areas have similar soils and vegetation types (secondary broadleaf-conifer forest) providing ample forage. It is possible that on a coarse scale, the 'landscape of fear' created by hunters, is a major determinant of pig habitat selection and activity on Aotea (Palmer *et al*., 2023). Numerous studies show how pigs adapt tempo-spatially, to avoid human predators (for example, Kramer *et al*., 2022; Franckowiak *et al*., 2018), Cooper's Castle and other similar sites of seabird breeding habitat may be acting as 'islands of refuge' where pigs can avoid predation, and safely feed. The presence of piglets and weaners in detections at Cooper's Castle, indicating the suitability of the area for sows to breed, could be interpreted as a further sign of safety.

Without being able to identify pigs to the individual level (although it was possible to determine age), it was not possible to track individuals over time and determine patterns of movement. However, given that the social units of pigs detected at Cooper's Castle appeared to be 'sounders' - groups of related sows and their young, than remain fairly stable and maintain territory as a unit rather than individually - it is likely that the pigs detected in Kaiaraara valley over winter originated from Cooper's Castle, given the proximity of the two areas, and the fairly small home range size of wild pigs in Aotearoa (Martin, 1975; McIlroy, 1989). On Aotea, the effects of sounder territoriality, and hunter constraint, may combine to produce geographically quite distinct population units, similar to persecuted populations of pigs elsewhere (Sparklin *et al*., 2009). Under this scenario, male offspring would disperse and make long-range movements, but females would tend to remain more sedentary. GPS tracking would be required to confirm this.

The seasonality of pig, and other predator (cat, rat, and other rodent) activity followed the same pattern as tākoketai at Cooper's Castle, which is a concern because of the multiple predation risks posed to tākoketai during breeding season. On a positive note, the diel activity of pigs did not overlap with that of tākoketai. While tākoketai were noctural (being active between the hours of 20:00PM – 05:00AM, peaking), pigs were diurnal (between 09:00 - 18:00). Predator activity patterns are often synchronised with those of prey (Lang *et al*., 2019), but on Aotea, diel pig activity appears to be independent of tākoketai, reducing the risk of direct encounters and predation events of adults, and juveniles, as they exit and re-enter burrows at night. It does not reduce the chance of burrows being damaged or predated when they are occupied around the clock by adults sitting on eggs, or chicks, though. The monitoring period of this study did not cover the fledging period (from March-May, during which time flightless chicks spend time outside burrows and are highly vulnerable to predation), however if the diurnal activity pattern of pigs is sufficiently strong, it may not change much during fledging season. The activity of cats did overlap with tākoketai, posing a predation risk to birds outside burrows. It is unlikely that rats are predators of adult or large juvenile tākoketai, however high rat frequencies would undoubtedly attract cats to the area, increasing the risk to tākoketai of predation by cats.

In the case of the absence of pigs from Hirakimatā, which is curious given the availability of prey over summer and autumn (breeding tākoketai), foraging choice may be explanatory. The ascent to Hirakimatā covers ground that is precipitous, rocky, and with shallow soils, which are sub-optimal for foraging as well as being a physical barrier to access (Elledge *et al*., 2013). Although this topography might deter hunters (creating a refuge similar to Cooper's Castle), the expenditure of energy required to reach tākoketai may represent too great a trade-off for optimal foraging (Clontz *et al*., 2021).

2.4.2. Habitat modification as a result of ground disturbance

Although fresh disturbance by pigs was scattered over a low proportion (4.7%) of the ground surface surveyed, it was visually apparent that the ground surface was quite altered in patches at Cooper's Castle. This suggests that disturbance has been repeated, which could have have a range of effects. As well as negatively affecting the physical structure of the substrate in which tākoketai excavate burrows and breed (effectively reducing the availability of habitat for breeding), pig disturbance could diminish the regeneration of canopy that tākoketai favour (Long, 2009; Taylor *et al*., 2011; Krull *et al*., 2013b). This may occur through suppression of seedling recruitment, disrupting above-below nutrient cycling communities and processes, and transmission of soil-borne pathogens that cause disease and mortality in important species of vegetation, the most notable of which is kauri (*Agathis australis*) (Wehr *et al*., 2019, 2020; Bassett *et al*., 2017; Lewis *et al*., 2019). Changes in vegetation as a result of long-term inhabitation by pigs has been well documented on Auckland Island, where the original megaherb vegetation has been all but removed from the areas accessible to pigs (Campbell & Rudge, 1984). There is some uncertainty as to significance of effects resulting from low-levels of disturbance, though (Parkes *et al*., 2015). Exclusion experiments, involving fencing pigs out of defined areas for some time (usually multiple years), would be required to establish the range and severity of potential effects resulting from disturbance (Hone, 2012).

2.4.3. Direct predator interactions with tākoketai

Camera monitoring over a 255-day period at Cooper's Castle did not detect any pig interactions with tākoketai burrows, which conflicted somewhat with the data from transect surveys over multiple sites, which recorded low incidences of burrow damage and predation. These differences may be as a result of monitored burrows being in sites that were well protected (in tree cavities, under boulders), while burrows that were observed to be damaged were in vulnerable sites. Additionally, incidences of activity that are rare, are typically difficult to detect and require specialised methods to quantify. Low frequency of detection may in part be an artifact on the detection and analysis methodology that were utilised in this study. Nevertheless, the data suggest that pigs currently interact with burrows that remain in vulnerable locations, thus have the potential to continue to eliminate and predate these

burrows, but have less interaction with burrows that are well protected. Pig may therefore have differential impacts, in relation to burrow site characteristics. Longer-term burrow monitoring is required to investigate this more.

Cats were recorded investigating burrow entrances at both Cooper's Castle, and Hirakimatā, although cats were less frequent at Hirakimatā. Cats are major seabird predators, but because burrows typical of Hirakimatā (dug into soil beneath rooted trees) have entrance passages that are too long and narrow for cats to readily access, it is thought that tākoketai become vulnerable to cat predation as juveniles, when they emerge from burrrows to strengthen wings and practice flight (Warham, 1996; Bell & Sim, 2000). Cat predation of this type have been noted on multiple seasons since long-term study of the Aotea breeding population began in 1995/1996 (for example, Bell and Sim, 2000). At Cooper's Castle, burrows may be more accessible by cats, because it was observed that burrow sites (typically in the trunk cavities of massive trees), had wider entrance passages. Pig, through damaging vulnerable burrows and driving and driving selection for novel burrow sites, may thus be indirect drivers of cat predation. Once again, longer-term burrow monitoring is necessary to determine how often cats are accessing (and potentially predating) burrows in different sites.

Given the high frequency of detection of rats, it can be expected that rat predation (of eggs and chicks), occurs. While rat predation of tākoketai was initially thought to be of infertile eggs (Imber, 1987), Bell & Sim (1996) consider that predation of fertile eggs left unattended for long periods, and small or unhealthy chicks, may also occur. At Hirakimatā, rat predation rate has varied between 1.3% to 8% over 28 monitoring seasons, and is related to rat density, which is influenced by year-to-year fluctations in climate and food supply. With considerably more rats at Cooper's Castle than Hirakimatā, the rate of predation by rats is probably higher than at Hirakimatā.

2.4.4. The implications of pig and other predator impacts for tākoketai

Historically, tākoketai were widespread across mountain ranges of the North Island, and more widely distributed and abundant across Aotea. Nowadays on Aotea, the seabirds are largely constrained to breeding in the central region of the island, within which burrow distribution is uneven. There is no doubt that part of the reason for present-day patterns of distribution of species on Aotea is historic modification of the habitat by humans, by burning and timber extraction. As well, there are naturally-occurring habitat differences. However, with human disturbance long-since ceased, and habitat protected as Aotea Conservation Park, predators are the major factor currently limiting seabird population range and abundance.

The pattern of uneven burrow distribution and differences in burrow site characteristic between areas where pigs are present, and where pigs are absent, is certainly interesting, and does suggest that pigs

have played a historic role in eliminating many burrows, and reducing burrow densities across tākoketai natural range. Comparisons of burrows and presence/absence of pigs, across multiple sites, are necessary to make robust conclusions about the association of pigs with burrow distribution.

Because of the limited evidence for direct pig impacts provided by this study, it is difficult to comment conclusively on the consequences of pigs specifically on current and future tākoketai breeding, and population trends. Yet, it is possible to discuss the potential consequences of combined predators (pigs, cats, and rats) on tākoketai breeding at different areas with different species and levels of predator, and also to explore how pig impacts may differ from those of other predators. Long-term study of the main tākoketai breeding population at Hirakimatā, which is free of pigs but with moderate rats and some cats, was initiated by Elizabeth Bell in 1995/1996. Cumulative data on a range of population parameters including breeding success, recruitment, and survival, have been collected, providing indicators of population status and performance. Breeding success (a measure of the survival of chicks to fledging stage), varies slightly from year to year on Hirakimatā, with a 27-year average of 69.7% (Bell *et al*., 2022). Adult survival is high, and the population appears to be stable, although not increasing. This suggests that tākoketai populations can persist in the presence of moderate levels of predation by cats and rats. Burrows on Te Hauturu ō Toi, which is completely predator-free, had 82.5% breeding success at time of monitoring in 2016/17 (Bell *et al*., 2018). Considering that this study detected frequent pigs, cats, and rats at lower-elevation breeding habitat, it reasonable to assume that tākoketai breeding throughout the majority suitable seabird habitat, is less successful than on Hirakimatā. Additionally, pigs are larger predators than cats and rats, so it is possible they predate adult birds (sitting in burrows), and diminish adult survival and the proportion of the population able to breed. This is particularly important for the capacity of the population to increase. Since the Hirakimatā population is static (neither increasing nor decreasing), it can be postulated that over most island of the island, the population is in decline and compromised in ability to increase, as a result of combined predator pressure. Over time, this may result in localised extinctions from sites that are most affected by predators, further contracting range, and threatening future viability of the species. This pattern has been documented in seabird colonies in the Kaikoura mountains and Auckland Island, in relation to pigs (Cuthbert, 2002: Russell *et al*., 2020). Trend reversal has been apparent in response to removal of pigs from Poor Knights Island, and removal of rats from seabird breeding sites in Hawai'i (Raine *et al*., 2020; Friesan *et al*., 2021). These factors justify the need for managing pigs, and other predators, more effectively around seabird colonies on Aotea in future, if population recovery is a goal.

2.5. Conclusions

Wild pigs have been linked with environmental degradation and declines of species globally, yet their role in driving seabird decline is not understood. The goals of this research were to describe and quantify direct and indirect impacts of pigs on tākoketai (black petrel, *Procellaria parkinsoni*) and tākoketai breeding habitat on Aotea (Great Barrier Island), to better understand the consequences of wild pigs for patterns and trends in seabird breeding populations. Methods employed were transect surveys, burrow inspections, and camera surveillance.

Transect surveys recorded frequent pig sign at sites suitable for tākoketai breeding, and pigs were detected more frequently than feral cats (a major seabird predator) by cameras within seabird habitat. Yet, the surface area of ground disturbed by pigs was low, and observations of direct impacts - burrow damage and predation events - were very infrequent. These findings demonstrate the potential for pigs to have multiple impacts, but limited incidences make it difficult to draw conclusions about how pigs are implicated in seabird population decline.

The low frequency of burrows, and marked difference in burrow site characteristics at the site associated with pigs, was interesting, and suggests that historically pigs have probably had the effect of eliminating burrows and reducing burrow density, and driving selection for novel burrow sites. These sites, although better protected from pig intrusion, appear more accessible to cats. Thus indirectly, pigs may be a driver of cat predation. Cats, and an abundance of rats, highlight the multi-species threats to seabirds, that must be considered.

In summary, this study demonstrated that pigs are a frequent predator around seabird breeding sites on Aotea that can potentially have multiple impacts, but their role in driving seabird decline and range contraction requires more investigation. To this end, surveys to locate burrows across a wider range of sites, and ongoing monitoring of these burrows in combination with continuous predator monitoring, are necessary to better understand the relationship between pig (and other predator) impacts, and seabird breeding and population trends.

CHAPTER THREE

Social assessment of Aotea (Great Barrier Island)

3.1. Introduction

3.1.1. Inhabited islands as places

Islands are difficult to define physically as places because they vary so much in size, and distance from larger landmasses (Royle, 2014). Socially, islands are also variable, ranging enormously in terms of population size, and level of independence from major populations (McCall, 1994). However, the social challenges with which conservation has been met on inhabited islands relate to the islands which are occupied by small, self-supporting communities of people. For the purposes of framing the social challenges to conservation on islands, I define inhabited islands similarly to Russell *et al*. (2018) as those a sufficiently long distance from larger landmasses as to have meaningful (both physical, and psychological) isolation; with small communities and the infrastructure necessary to support community function (e.g., healthcare, schools, services and facilities); and, with functioning local economies. This definition is broad enough to consider a diversity of islands in Aotearoa, but precludes those which are effectively the same as urbanised suburbs of a nearby city (such as Herald Island, in Auckland's Waitematā harbour), and those which have only itinerant inhabitants (such as defence, or conservation workers).

The defining feature of 'islandness' is isolation from larger landmasses, determined by the stretch of ocean separating islands and continents (or larger islands), and the regularity of ferry or air services between the two (Hay, 2006). Practically, this imposes disconnection from major infrastructure, and often self-sufficiency in terms of supplying power, water, food, transport and waste treatment. Psychologically, the strong physical boundary of the ocean, coupled with the presence of 'hinterland' (open, natural space, that is not densely populated) can give islanders have a very keen sense of place in relation to the 'outside' world, that is core to construction of island identity (Hintjens, 1991; Hay, 2013). This is of course dependent on the view that ocean is a boundary – for ocean-going indigneous people including Māori, and archipelago-dwellers, open water may present more of connector than a barrier to areas within a wider territory (Hau'ofa, 1994; Grydehøj & Hayward, 2014).

Often, islands have been long inhabited by indigenous peoples (Terell, 1988). In recent centuries, European colonists and migrants have secondarily settled many islands, especially in the southern Pacific (Flynn *et al*., 2002). Another, recent, tide of settlement (from the latter part of the 20th century to the present), has been related to the 'intentional lifestyle' movement, driven by conscious choices (often of affluent urban dwellers) to live simpler existences in idyllic locations (Benson *et al.*, 2003).

As a result of such varied settlement histories, inhabited island communities, despite being small, can be surprisingly diverse. This introduces considerable complexity, in terms of the interests and values that islanders hold in relation to the natural environment, that must be navigated by conservation managers (Russell et al, 2018).

In contrast to metropolitan areas, islands have few residents and limited resources, placing limitations on economic activity and employment opportunities for islanders to pursue, relative to larger regions. Economies are often dependent on lucrative forms of primary production such as fisheries, and tourism, to bolster subsistence and small-scale economies, and are typically more reliant on external wealth (in the form of migration, remittances, aid and benefits – the so-called MIRAB model) for funding development (Bertram & Watters, 1985; 1986). Low assests, and thus low capacity for autonomous development, can make islands vulnerable to changes in government and politics (Bertram, 1993; Petzold, 2018). As well, island populations are tightly coupled with the natural environment (through livelihoods being based largely on natural resources), thus sensitive to any changes within socio-ecologic systems (Tershy *et al*., 2015). Given that enhancement and protection of biodiversity is a process which effects major change in society (through requiring change in the way people live), and the natural environment (through changes in wildlife and habitat, and the way they are managed), islands therefore have the potential to be significantly impacted by wildlife management activities (Taylor, 2019).

Despite islanders' sense of independence, many islands are administered by the nearest nation state, which can create a persistent tension, between perceived rights to local self-determination, and necessary compliance with centralised regulations (Royle, 2014). Change on islands, can be highly contested. Similarly, newer groups of residents on islands can be perceived as 'outsiders' by older residents, leading to factionalisation in the community, and clashes over views about what is important and what is the right way to go about doing things (Farrier, 2011). Nevertheless, a strong sense of community spirit and reciprocity tends to prevail in times of adversity (Hay, 2006).

Similar to rural communities, culture on islands can be steeped in tradition, because of the necessity of maintaining 'tried and true' customs and practices, that have been adapted specifically for ensuring survival in remote and challenging environments (Howie, 2008; Royle, 2014). Although tradition is not static, the rate at which change occurs on islands can be slowed by limitation of resources (both material and financial), low rates of immigration, and high rates of emigation of young people from islands to cities to pursue education and employment. This frequently produces an older age-structure to island populations, making the adoption of novel habits less likely than in populations with younger people (Burholt *et al*, 2013).

Because of their isolation, relatively 'unspoilt' environments (relative to more heavily developed areas), and often strategic geo-political positioning, islands have long been romanticised as paradises,

by continental dwellers (Peron, 2004). Ecologists have shown particular interest in islands, as places of origin and refuge for unique and endangered wildlife (MacArthur & Wilson, 1967; Myers *et al*., 2000). But despite this, islanders themselves have not been looked upon favourably, being regarded as backward in comparison to city folk (for an Aotearoa example of this, see Falla's 1948 account of the social setting of Rēkohu/Chatham Islands). This continental view of island inhabitants, as well as being incorrect, has been harmful because like any form of cultural imperialism it has tended to reduce islands to the level of resources for claim and exploitation, and 'laboratories' for research and experimentation, without regard for the people who live there (Baldacchino, 2006; 2008). Island communities, therefore, are often wary of engaging with outsiders (Peron, 2004).

3.1.2. Island conservation, and invasive mammal management

Islands are hotspots for biodiversity, because of high degrees of species-endemism (Mittermeier *et al*., 2011). Invasions of mammalian predators are associated with the decline of biodiversity worldwide, and have driven extinctions on islands, especially of birds (Courchamp *et al*., 2003; Simberloff *et al*., 2013). For this reason, and the technological feasibility of removing predators from small sites, islands have been the focus of predator eradications in Aotearoa, and internationally (Bellingham *et al*., 2010; Parkes *et al*., 2017). Aotearoa has a long and successful history of eradicating predators (mainly rats) from it's smallest islands, due in part to these islands having been uninhabited by people, and, the attachment of little value by people to the rats specifically targeted for eradication (Russell & Broome, 2016). Through decades of refinement of island eradication techniques, it is now possible to eradicate multiple predator species (including large species, like cats and pigs) from much larger islands (Glen *et al*., 2013; Griffiths *et al*., 2014). However, these islands are often inhabited by human communities, who often value invasive species, which adds additional complexity to their management (Oppel *et al*., 2011; Wittmer *et al*., 2018). As well, islands often have unique social characteristics which can exacerbate the propensity for invasive species management to be contested (Russell *et al*., 2018).

Wild pigs (*Sus scrofa*) are a good example of complicated management. Historically, pigs were introduced to small islands lying off mainland Aotearoa by Māori, whalers, sealers, and explorers, to supply food (Clarke & Dzieciolowski, 1991). The pig populations on small, uninhabited islands comprised some of the earliest eradications in Aotearoa, eliminating pigs from 24 islands (DIISE, 2023). Of the four off-shore islands around Aotearoa on which pigs remain, plans are in place to eradicate pigs from Maukahuka (Auckland Island), which although uninhabited, is one of the largest ($459 km^2$) islands in the world ever to be targeted for eradication (Russell *et al*., 2022; DIISE, 2023). The three other off-shore islands on which pigs are present – Aotea (Great Barrier Is.), Rēkohu (Chatham Is.), and Rangitoto ki te Tonga (D'Urville Is.) - have communities of human inhabitants,

some of whom utilise pigs for food. Eradication of pigs from these islands is currently not considered to be socially feasible, because segments of the populations on these islands value pigs, and because there is a history of fraught predator management more generally on these islands (Ogden & Gilbert, 2009; Predator Free 2050 Limited, 2021). Alternative options for suppressing pig populations (such as toxins, culling) also have the potential to be contentious with local hunters, and other segments of the community. However, pigs are generalist omnivores with destructive foraging behaviour, that are able to act as top-predators, and cause extensive modification of the habitat characteristics of ecosystems outside their natural range (Barrios-Garcia & Ballari, 2012). Island ecosystems evolved in the absence of large mammals and are disproportionately affected by pigs (Risch *et al*., 2021), thus, conservation of island biodiversity would undoubtedly benefit from improved management of pigs.

Given the social complexities to managing pigs on inhabited islands, improving management is contingent on understanding the unique social context of these islands, both in a general sense (i.e., in relation to whole communities), and, in relation to specific groups (for example, pig hunters, whom I focus on in Chapter Four). It is the purpose of this chapter to explore the social setting of wild pigs and conservation on Aotea (Great Barrier Island) generally, using social impact assessment. Social impact assessment (hereafter abbreviated to SIA) is a framework that has been recommended for investigating the human dimensions to conflicted areas of conservation, in particular the management of invasive mammals (Prenzel & Vanclay, 2014; Crowley *et al*., 2017). So far, such assessment has been employed specifically to Rākiura (Stewart Island), and more generally to inhabited islands of the Hauraki Gulf islands, in relation eradication of Aotearoa's 'top three' predators – rats, mustelids, and possums (Russell K. *et al*., 2017; Russell *et al*., 2018). Thus, social assessment would be particularly appropriate tool for exploring the social dimensions to pig management on Aotea, and establishing what (if any) approaches are most socially feasible.

3.1.3. Social impact assessment concepts and techniques

Social impacts are the aspects of interventions (policies, plans and projects) which directly or indirectly affect the lives of humans and human communities. They may be positive or negative, and relate to any aspect of human life, including quality of environment, day-to-day activities, health and wellbeing, identity, culture, social cohesion, democracy, wealth and economy, rights, and aspirations (Vanclay, 2003; Vanclay, 2015). Social impact assessment (hereafter referred to as SIA) is the practice of predicting, monitoring, and managing the impacts associated with change and development in society (Esteves *et al*., 2012; Taylor & Mackay, 2016). Based in sociology, it is a welfare-oriented discipline, with a focus on participatory processes, and enhancing the positive outcomes of change (Esteves *et a*l., 2012). Beyond being an instrument for predicting the impacts of projects (which it can be, in a narrow sense), the scope of SIA these days broadly encompasses

research, social monitoring, and development activities (Taylor & Mackay, 2016). SIA has long been associated with processes of land-use change, including urban planning, civil & environmental engineering, and resource extraction, and is mandatory under the Resource Management Act 1991 in Aotearoa. Yet, SIA has not been routinely applied to wildlife management, particularly management of invasive mammals, despite having been applied to other areas of conservation management in Aotearoa (specifically, national park and marine reserve establishment) (Taylor, 2020). This is despite the landscape scales on which invasive animals (and their management) occur, and the potential for these landscapes to be shared by communities of human inhabitats, some of whose interests potentially conflict with conservation managers' (Crowley *et al*., 2017). Although the focus of such projects is on ecological outcomes, they are also potentially transformative in terms of social outcomes, which can introduce uncertainty into the future (particularly for groups living close to or utilising areas of conservation interest), and be a source of contention and conflict (Lyver *et al*., 2019). Globally, such tension is predicted to increase, as conservation ambitions and human populations simultaneously grow. This is a major risk to conservation, as tensions can manifest as non-compliance, protest, and legal actions, hampering projects significantly (Estévez *et al*., 2015). Because of SIA's capability at recognising, and responding to human concerns, it holds considerable power as a tool for predicting, preventing, or circumventing opposition to conservation management (Blackburn *et al*., 2010). As well, through being a particpatory process, SIA has the potential to make management more democratic and socially legitimate, and ultimately, more effective (Crowley *et al*., 2017).

Modern best practice of SIA spans the whole project life-cycle, throughout all stages of planning and implementation, and involves components of social assessment, participatory engagement, monitoring, and management (Esteves *et al*., 2012). The social assessment component relates especially to invasive mammal management planning, as it supplies the relevant social context for identifying issues and impacts (both good and bad), and assessing the feasibility of the various options for management that are available (Russell *et al*., 2018). In essence, social assessment characterises the nature, and way of life of populations, and considers the issues which they face. Assessment draws on numerous sources of information (including statistical data, local government records and reports, historic records, published social research, media articles, and direct engagement with local community), and involves procedures of scoping, profiling, and impact assessment. Scoping usually comprises a preliminary investigation, involving: locating sources of data, defining the problem to be addressed, constructing a broad overview of the population, and identifying issues to be explored. With respect to invasive mammal management, characterising the ecological setting of the place of interest, determining land ownership, and, identifying important social groupings in the population (for example, of indigenous peoples and their tribal and/or family groups, key stakeholders, any other social affiliations or segments within the community), are also relevant (Taylor *et al*., 2004; Russell *et*

al., 2018). Additionally, I propose that where invasive mammals are valued by humans (through utilisation as food, or other form of relationship (s) to animals), that the historical basis of these human-animal interactions be examined, to provide context for the complex values, and hence significance, that wild animals can hold. Profiling comprises a detailed secondary analysis of the data gathered in scoping, constructing a 'baseline' of the population in terms of demography, livelihoods and lifestyles, culture, and psycho-social factors. Impact assessment considers the range of management interventions available, and identifies potential impacts on the community, both positive and negative, that may result from each. With respect to invasive mammal management on inhabited islands in Aotearoa, some common areas of impacts are: employment and livelihoods, local economy, recreation and tourism, and amenity value (Russell *et al*., 2018; Taylor *et al*., 2020).

In this research, I produce a social assessment of Aotea, with a special emphasis on the history and practice of pig hunting on the island. I employ this assessment to evaluate the potential impacts of managing pigs on Aotea's community, and discuss the feasibility of pig management on the island, with reference to the island's social characteristics and capacity to adapt to change. I finally make recommendations for the strategic framing of pig management in future, on Aotea.

3.2. Methods

3.2.1. Social assessment of Aotea

I referred to ecological literature, surveys, and reports relating to Aotea, to describe the island's ecological setting. The social scoping process involved consultation of a wide range of social information, including: statistical data (Census 2013 and 2018), social surveys and research, local government records and reports, and media articles relating to Aotea. I reviewed all copies of the local Aotea newspaper, the Barrier Bulletin, that were published in the five years from August 2017 to August 2022, and I spoke with local contacts in the community. Social media sources, although available, were not consulted for reasons of reliability, and privacy. Using the data gathered, I constructed a social profile for Aotea, identifying key island social characteristics (local character, issues, and capacity for change). I then evaluated the impacts of that pig management could potentially have on the island community, and the subsequent feasibility of potential approaches for pig management.

3.2.2. Historical research on human-pig interactions on Aotea

I employed a range of sources for this research. For Māori oral history, I spoke to local *kaumātua* about their recollections and understandings of traditional pig and *mahinga kai* practices by *mana whenua* Ngāti Rehua - Ngātiwai on Aotea, and other islands within the tribal territory of the Hauraki Gulf. For written histories, I consulted a range of published literature, academic papers, institutional reports and historic records covering the period of contact between Māori and British from the late 1700's, to the present day. In this material I searched for references to pigs, denoted by the terms *pig, feral pig, pork, hog, boar, swine, quadrupeds, ungulates and mammals*. Using the texts identifed, and oral accounts, I reconstructed historical contexts and events relating to pigs since the time of first introduction, to establish how the relationship of Māori and settlers on Aotea to pigs had changed over time, and what the drivers of this change were.

3.3. Results

3.3.1. Ecological setting of Aotea

Situated approximately 85km from Auckland City and 285km^2 in size, Aotea is the largest island within the Hauraki Gulf Marine Park (HGMP), and sixth-largest nationally (Bassett *et al*., 2016). The ecology of the island is important because it is considerably less modified than the mainland, supporting diverse habitats, and, numerous rare and endangered species, some of which are endemic to the island. Aotea is also free of many mammalian pests and predators, including goats, deer, possums, Norway rats, and mustelids (stoats, ferrets, and weasels), and hedgehogs (Ogden & Gilbert, 2009). Lying off Aotea are numerous small islets and rockstacks, including Rākitu and Kaikoura, which are now predator-free, as are 46 of all 50 islands within the HGMP (Predator Free New Zealand, 2023).

Aotea is one of the richest areas in the Auckland region for plant biodiversity, because of speciation that has occurred since separation from the main North Island landmass, approximately 10,000 years ago (Cameron, 2004; Moore, 2004). The island hosts 75 species of regionally and nationally threatened plants, including the endemic prostrate kānuka (*Kunzea sinclairii*), and Great Barrier tree daisy (*Olearia allomi*). The island also has one endemic species of skink (niho taniwha or chevron skink, *Oligosoma homalonotum*), and is a refuge for 12 other species of lizard, pepeketua (Hochstetter's frog, *Leiopelma hochstetteri*), nationally critical matuku (Australasian bittern, *Botaurus poiciloptilus*), nationally vulnerable tākoketai (black petrel, *Procellaria parkinsoni*), pāteke (brown

teal, *Anas chlorotis*), kākā (*Nestor meridionalis*), and banded rail (*Gallirallus philippensis*) (DoC, 2014).

The landscape on Aotea is dominated by forest-covered mountain ranges, which bisect the island along a north-south axis, and summit at Hirakimatā (Mount Hobson, 627m) (Ogden, 2004). Around the coast, the processes of weathering and infilling have produced a great variety of environments, including broad ocean beaches and dune systems, estuaries and wetlands, headlands, rocky escarpments, vegetated coastal cliffs, sheltered bays, intertidal flats and deep water inlets. Notable ecological areas on Aotea include: virgin kauri-conifer forest at Hirakimatā, where the main population of tākoketai breed; the dense, mature 'northern bush' block at Te Paparahi, dominated by ancient pōhukawa, pūriri, karaka, and kohekohe; the saltmarsh environment at Whangapoua; the freshwater wetland system at Kaitoke, which is the largest in the Auckland region and breeding habitat for matuku, pūweto (spotless crake, Zapornia tabuensis), and mātātā (fernbird, Poodytes punctatus); and, the naturally uncommon broadleaf shrublands which occur on the impoverished, rhyolitic substrates around Windy Canyon (Singers et al., 2017). Furthermore, these habitats are preserved in a largely unfragmented state, in sequences from mountain-to-sea that are rarely seen on the main islands of Aotearoa.

Approximately 16,000ha (63%) of the total area of Aotea is currently administered by the Department of Conservation. The majority of this area is comprised by the 12,282ha (43%) Aotea Conservation Park, which was consolidated in 2015 (**Fig. 3.1**). The park is managed with the input of the Aotea Conservation Park Advisory Committee, of whom *mana whenua* Ngāti Rehua Ngātiwai ki Aotea (NRNWKA) represent half the committee members (Aotea Conservation Park Advisory Committee, 2022). The whole island is classified as an 'outstanding natural landscape' (ONL) under the Resource Management Act, and has additional overlays of 'outstanding and high natural character' (which differ from ONL) applying to the coastal zone (Auckland Council, 2023). Areas have been cleared and settled around the coast, however much of this area is reverting to kānuka (*Kunzea robusta*) and mānuka (*Leptospermum scoparium*) 'scrub'. Rats (kiore, *Rattus exulans*, and ship rat, *R. rattus*), and feral cats (*Felis catus*) are abundant on the island, and are a major driver of bird decline (Ogden & Gilbert, 2009). Community groups are spearheading site-based efforts to control these predators, and restore habitat on-island and small islets lying off-island (**Table 3**). Landscape-scale predator eradication to date has until recently been limited by departmental underfunding (resulting from a national prioritisation system which emphasises species, rather than whole systems), and difficulty in gaining community consensus on the need for, and methods involved in eradication (Ogden & Gilbert, 2011). However, in response to partnership with NRNWKA and empathetic engagement with the community, a collective 'Ecology Vision' was formed (McEntee & Johnson, 2016). Following this, phased rat and cat eradication was initiated in the northern Te Paparahi region of the island (Saunders *et al.*, 2021). Pigs are present on the island in reportedly low numbers, but are an

issue for species recovery, especially ground-nesting wetland birds and seabirds. No management of pigs is undertaken on conservation land, except for harvest by local hunters, and DoC initiated control by at some localised sites of high-priority (for example, pāteke breeding sites). This is because the appreciation of pig impacts has only been recent, and thus pigs have not been a part of any national or regional wild animal management plans (D. Clarke, pers. comm., 2022).

Figure 3.1. Aotea local board area, depicting settlements and geographic features, Department of Conservation (DoC) land, and privately owned areas of land on Aotea (Great Barrier Island). (Modified from Auckland Council map)

3.3.2. Social setting of Aotea

There is no mains power, reticulated water, sewerage treatment or public transport on Aotea, requiring that inhabitants live a self-sufficient, 'off-grid' lifestyle. Many roads are unsealed, flood when it rains, or are cut off by tides, and communication services are more expensive and less reliable than the mainland, intensifying the isolation of island life. There are two regular transport and freight services (provided by Barrier Air planes, and Sealink ferries), however in bad weather these can be erratic, and the cost of freight is high, so food, fuel, and maintenance items are costly and slow to reach Aotea. As a result, islanders supplement their provisions in different ways, including with home grown produce, homekill, and wild pigs, and, repair rather than replace items – leading to an inherently sustainable lifestyle (Peart & Woodhouse, 2020).

Aotea is the ancestral home of *hapu* Ngāti Rehua - Ngāti Wai, who have continuously occupied the island as *mana whenua* since conquest of its original Ngāti Tai inhabitants, in the 17th century (McBurney, 2009). During the European colonial period beginning in the 19th century, a number of 'boom and bust' industries operated on the island, including timber extraction, silver and gold mining, and whaling, which brought European migrants and settlers to the island. A number of farms were established during this period (Auckland Council, 2019). Although these industries have long since ceased and farming is no longer commercially viable, some farms, and descendents of farmer and miner familes still remain on the island. From the 1970s the island became a popular destination for 'hippies' to pursue communal lifestyles, and for people seeking self-sufficiency or the opportunity for self-employment, usually in the tourism sector. These residents now make up a significant portion of the population (Ogden & Gilbert, 2009).

Today, the island has a population of 936 usual residents (at the time of Census 2018), which over the summer months swells with as many part-time, holiday home owning residents (concentrated mostly in Tryphena). The population is predominantly European, and Māori, the latter of whom who make up 21% of the population (compared to 12% in Auckland). Segments within the resident population have been characterised by Ogden & Gilbert (2011), in relation to length and nature of association with the island, and usual term of residence. These are: Māori, farmer settler, more recent residents since the 1970s, and itinerent worker residents. The values of the former two groups are considered to be 'traditional', while the latter two are more 'progressive', although this is a generalisation.

Eight small settlements are scattered around the island's beach and coastal areas, varying in terms of size, population density, and demographic make-up. Tryphena, the southernmost settlement, is the most densely-populated, especially in summer. In the southwest, Oruawharo (Medlands Beach) is notable for it's development of coastal sections adjacent to farmland; some of which have had high-value architecturally designed dwellings erected. Civic services are concentrated in south-central Claris/Kaitoke, and there is a deep natural harbour at northwestern Port Fitzroy. Kawa and Motairehe

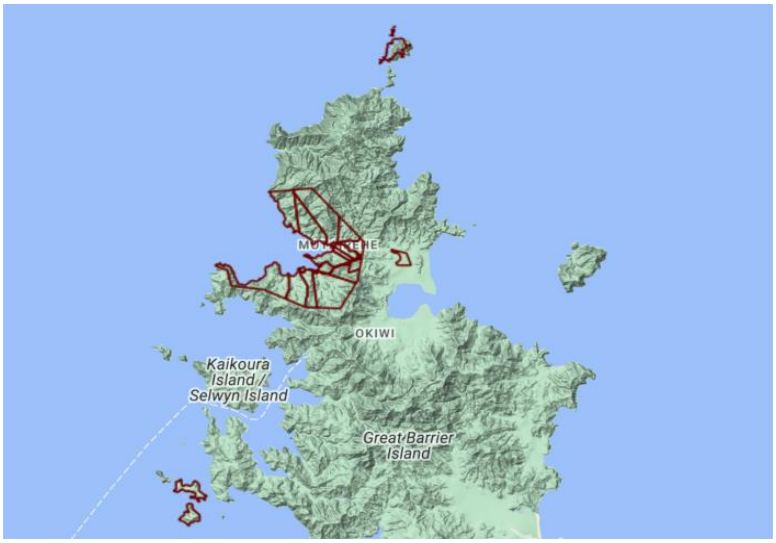
(in Te/Katherine Bay) are the northernmost settlements, both which are within the 24,269 acre area of land which was 'reserved' for Māori by the government in 1856 (New Zealand Government, 2016). The northern region of the island is considerably less populated than the south. There are wahi tapu (places of significance) relating to earlier Māori occupation that have importance for other Hauraki iwi groups, however Ngāti Rehua - Ngātiwai are recognised as *mana whenua* and *mana moana* (tribal custodians of the land, and water space) of Aotea and it's surrounding islets including Rākitu and Rangiahua, and several islands in the Hauraki Gulf including Te Hauturu ō Toi (Little Barrier Island) and the Pokohinu (Mokohinau Islands) group.

Following a peak in the 1990s, the Aotea population has slowly declined, and shifted to a much older age structure (median age is 53, compared to 35 in Auckland). This structure is further evidenced by the high rate of home ownership (60%), and low median income reflecting the proportion of residents not in the labour force. The population was virtually unchanged between the 2013 and 2018 censuses, however since the COVID-19 pandemic, the local board estimates the population has grown by around 30 per cent, to approximately 1,200 people (Weitenberg, 2022). Whether these new residents will remain long-term, is uncertain.

Economically, Aotea is one of Auckland's less prosperous areas, on acccount of the small population and proportion of older residents no longer in the labour force. Tourism is a major driver of the local economy, with most income derived from rental accomodation, hiring, and real estate (ATEED, 2020). However, tourism also places pressure on the islands limited infrastructure and services, such that the kind of growth model favoured by islanders is one which enhances value, rather than volume, of visitors, as indicated in the local board's Visitor Strategy (Milne *et al*., 2018). Fewer people are in full-time employment on Aotea, and median income ($21,200) is lower than Auckland. or Aotearoa generally (**Tab. 3.1**). Most jobs are in 'management' roles, reflecting the predominance of self-employment in small, owner-operated business.

The island is well provisioned with community services and facilities on the island including three primary schools (Kaitoke, Mulberry Grove, and Okiwi) and learning hub to assist distance-learning students, Auckland Council local branch office and library, Aotea Health Centre, museum, waste transfer station and second-hand shop, sports and social clubs, and post office. Local businesses include three grocery stores, several cafe and food retailers, petrol station, mechanic, building supplies depot, pharmacy, laundomat, liquor shop, and micro-brewery.

Figure 3.2. Areas of collectively-owned Ngāti Rehua-Ngātiwai tribal land on Aotea (Great Barrier Island), surrounding northwest Motairehe Whanga (Katherine Bay), southwest islets of Rangiahua & Mahuki, and northernmost Owhanga (Aiguilles Is.). Generated using using Manaaki Whenua Māori Land Visualiser.



The majority (63%) of the island is composed of DoC land, however it is important to note that this land is marked for redress to Ngāti Rehua-Ngātiwai, in the *hapu*'s Deed of Settlement with the government. Approximately 5% of the island (1,420 ha) of land in Motairehe Whanga (Katherine Bay) is collectively owned Māori land, as are three off-lying islets (Aiguilles, Rangiahua, and Mahuki) (**Fig. 3.2**). The remainder of the island is made up of a mosaic of privately owned land (including smaller blocks around settlements, substantial 'bush blocks', and farmland), land held in trust (including Kaikoura island), and Auckland Council reserve land.

Table 3.1. Summary of population statistics of usual residents on Aotea from Census 2018[a], compared to the Auckland region and all Aotearoa.

	Aotea	**Auckland region**	**Aotearoa**
Area and population			
Size (km^2)	285	4,894	268,021
Usually resident population	936	1,517,718	4,699,755
Population density (per km^2)	3	310	18
Population change 2013-2018	0.3%	11%	10%
Age			
Youth (<15 years)	15%	20%	20%
Working (15-64 years)	61%	68%	65%
Seniors (≥65 years)	25%	12%	15%
Ethnic diversity			
Pakeha/European	92%	54%	70%
Māori	21%	12%	17%
Pacific	3%	16%	8%
Asian	2%	28%	15%
Other	2%	1%	1%
Middle Eastern, Latin American, African	0%	2%	2%
Education [b]			
Year 1-8 enrolment change 2013-2018	-21%	9%	9%
Year 1-8 enrolment change 2018-2022	40%	-1%	-1%
Tertiary study (full-time)	11%	23%	21%

Employment			
Full-time employment	35%	52%	50%
Part-time employment	21%	14%	15%
Unemployed	7%	4%	4%
Not in labour force	37%	30%	31%
Income			
Median income	$21,200	$34,400	$31,800
Residents earning > NZ$50,001	16%	35%	23%
Median income change 2013-2018	5%	16%	11%
Occupation sector			
Management	25%	18%	18%
Professional	16%	26%	23%
Technicians and trades	10%	11%	12%
Community and personal services	13%	9%	10%
Clerks and administration	9%	12%	11%
Sales	7%	10%	9%
Machinery operators and drivers	5%	6%	6%
Labouring	15%	8%	11%
Dwellings			
Unoccupied	51%	6%	10%
Tenure of households			
Dwelling owned or partly owned	60%	45%	51%

a Statistics New Zealand, 2018.
b Ministry of Education, 2023.

Table 3.2. Indicators of growth (visitors, and building consents), for Aotea

	Aotea
Estimated number of visitors per annum	23,000 – 28,000[a]
New dwellings consented in 2018	7[b]

a Estimated from maximum passenger carriage to Aotea, by Barrier Air (12 seats, 42 flights per week), and, Sealink Ferry (48 seats, 7 times per week) during summer months (December-February), and reduced volume (50%) of passengers carried over remainder of the year (March-November) during which time airplane flights continue as for summer, and ferries sail three times per week. An unknown number of visitors to Aotea arrive by private sailing boat.
b Census 2018

37% of Aotea residents are active in a range of local conservation activities, including backyard rat trapping (supplied by the Aotea Trap Library), weed control and native planting on private property, and ecosystem restoration efforts on conservation and reserve land (Table 2.3) (Aley & Russell, 2019). There are two sanctuaries (Glenfern, in Port Fitzroy, and Windy Hill, in Rosalie Bay), which undertake land-scape scale predator management, and provide a number of jobs for local residents. A survey of the four Hauraki Gulf islands which are inhabited by small communities (Aotea, Waiheke, Kawau, and Rakino) found residents to have strong environmental attitudes, although support for rat eradication on Aotea (67%) was the weakest of all islands surveyed (Aley & Russell, 2019). This may be an outcome of the strong attitudes of some groups in the community regarding toxin use (for achieving eradication), in combination with past engagement (Ogden & Gilbert, 2011), and eradication (specifically, the Rākino 2017 rat eradication) efforts, which sparked major opposition from some island residents (Saunders *et al*., 2021). Revision of the approach to engagement and eradication, through partnership with *mana whenua*, has achieved success in obtaining support for rat

and wild cat eradication in the north of the island (the Tū Mai Taonga project). Overall, these suggest that eco-consciousness is part of the Aotea mind-set, however support for eradication is dependent on involvement in the scoping, planning and leadership of programs.

Ngāti Rehua-Ngātiwai ki Aotea (the trust representing Ngāti Rehua-Ngātiwai *hapū,* hereafter referred to as NRNWKA) have yet to settle their Treaty grievances. After lengthy negotiations, a Deed of Settlement was signed with the Crown, but has not yet been ratified due to issues over the integrity of the *hapū* beneficiary database (Peart & Woodhouse, 2020). Environmental protection is of major interest to NRNWKA, as a means of maintaining the close relationship of *mana whenua* with their ancestral *whenua* (land), *wahi tapu* (sacred places), resources (including *mahinga kai*, or food resources), and *tāonga* (treasured) species (NRNWKA, 2016).

Table 3.3. List of community-initiated conservation initiatives on Aotea

Activity	**Description**
Charitable trusts	Aotea Great Barrier Environmental Trust
Education programs	Aotea Pestival Aotea Conservation Workshops
Landscape-scale cat and rat eradication	Tū Mai Taonga
Back-yard rat trapping	Aotea Trap Library
Wildlife sanctuaries	Glenfern Sanctuary (Port Fitzroy) Windy Hill Sanctuary (Rosalie Bay)
Restoration projects	Awana catchment Okiwi Community Ecology Oruawharo-Medlands Ecovision Kaitoke swamp Kākāriki project (Okiwi) Mohunga peninsula Motu Kaikoura Mulberry Grove (Tryphena)
Other initiatives, and local businesses	Aotea Bird Count Medlands Community Garden Motu Nursery Envirokiwi

3.3.3. History of pigs, and pig hunting, on Aotea

Before the arrival of Europeans, pigs were absent from Aotea as they were from the rest of Aotearoa and its offshore islands. The first introductions of pigs to Aotearoa were made by the early European explorers (De Surville, Furneaux, and Cook), to Māori in the late 18th century (Donne, 1924). The exact timing of the introduction of pigs to Aotea is not known. The earliest reference to pigs on the island is an account of the visit by the English whaling brig the *Mermaid* on 3 November, 1796, over

twenty years after pigs had first been introduced to Aotearoa. Published in 1937 in a newspaper article, this account is notable because of the detail recorded by Captain Trevarthen over the course of the ship's two month stay, including of the food brought to the ship by Māori residing at Akapoua (Port Fitzroy) on the northwest coast:

> *November 3 – a dark, large prau came off from the island bringing one* ***hog*** *and many fishes. The indians rubbed their faces against our pilot's face and all of them cried, as they are relations* (Lee Fore Brace 1937 cf Tatton 1994)

This account, if reliable, suggests that by the end of the 18th century pigs had been successfully introduced to Aotea and were being exchanged by Māori, with visiting ships.

Prior to this, the very first introduction to Aotearoa was made by the French explorer Jean-François-Marie de Surville, who gifted two small pigs, male and a female, to Māori in Tokerau (Doubtless Bay), on the 26th December 1769. These are not thought to have survived, however (Salmond, 1991). On Cook's *Endeavour* expedition in the same year, no record was made of pigs being gifted or exchanged with Māori, or liberated anywhere on land, despite the ship's logs and journals noting numerous exchanges of other goods around the country (Salmond, 1991).

On Cook's second and third voyages though, pigs were certainly introduced. The animals were intentionally acquired from Tahiti and Tonga, to distribute amongst Māori. At Raiatea (home island of Tupaia, navigator of Cook's first voyage to Aotearoa), so many pigs were brought on board that the captains eventually refused to take any more. On the 7th June, 1773, Cook had one boar and two sows liberated in Tōtaranui (Queen Charlotte Sound), and some months later upon leaving the sound, left another three sows, a boar, two hens and three cocks in the bush at the end of West Bay.

Some time between 21st October and 2nd November 1773, two pairs of pigs were given to Matau-a-Māui (Hawkes Bay) chief Tuanui. Cook was evidently anxious that these might establish, so he asked Tuanui to promise that he wouldn't kill any of the animals. On the departure of Cook's third visit to Tōtaranui, over 18 October – 10 November 1774, Cook asked his men to look out for the pigs and chickens that had been released into the bush when they last visited the Sound. A black boar was sighted on the beach, at which Cook was pleased (Salmond 1991; 1997).

Another major introduction of pigs to the North Island was made twenty years later in 1793 by Captain Philip Gidley King, Lieutenant-Governer of New South Wales and Norfolk Island. King gave two boars and ten sows to Tukitahua, the *rangatira* (chief) who he had earlier kidnapped and taken to Norfolk Island (Salmond, 1991). The pigs were released on an island near North Cape (Donne, 1924). By 1795 only one animal was left. King then established relations with the northern chief Te Paki, and sent a total of 56 pgs in three ships in 1804 and 1805 (Petrie, 2008).

It is likely that Cook's and King's introductions of pigs to Hawkes Bay and Northland, in 1773 and 1793 respectively, established the North Island population of pigs. Tīkapa Moana is a sheltered body of water linking the north-eastern coast of mainland Aotearoa with more than 50 islands, through which Māori passage by waka for trade, seasonal migration and maintaining tribal connections was frequent (Law, 1972). The transport of pigs from the mainland to the outer Hauraki Gulf islands would have been made easily, and coastal voyaging would have facilitated the rapid movement of pigs from one area to the other. Through the *pounamu* (greenstone) trade (Rout & Reid, 2006), it is also possible that pigs were transported from the South Island.

The next concrete evidence of pigs on Aotea is found in an account of the 'Tryphena Massacre' that occurred in 1838, during the period that Ngāpuhi were enacting raids of retribution on southern iwi. The account describes Pakeha traders arriving at the island to pick up a load of pigs, that were destined for the Bay of Islands:

> *Toward the end of **1838**, Ben, Jake and Kent sailed from The Wade (now Silverdale) to Aotea to get a load of **pigs** from the people there with whom they had arranged to get it some weeks before* (Henderson, 1948)

The account goes on to mention the provision of one of these pigs to feed a *taua* (war party) who were sheltering on Te Hauturu o Toi (Little Barrier Is.), without food:

> *Now go ashore and make a hangi. We will bring some **pork** and riwai (potatoes). How many are you? Thirty? We'll feed you for a start.' The cutter was sailing in and anchored in one and a half fathoms. They handed over a large **pig** to the natives, who were not too far gone to prepare it for the hangi, and two buckets of potatoes from the cargo* (Henderson, 1948)

Local Māori oral tradition speaks of pigs being raised on *motupoaka* (pig islands) off the shore of the main Aotea island, to prevent damage to cultivated gardens:

> *I don't know the English names of them, ah Flat Island [Rangiahua], was one of them. Where the gannets were was another, Kaikoura, Mahokinui, Motuhaku, ah Rakitū, and we just went over there recently. The old people they were smart, they worked out that pigs could cause a lot of damage so they took them off and put them out on those islands* (Ngawaka, 2022)

This alludes to an early animal-husbandry type of relationship between Māori and pigs. The alternative European names given to the islet group to which Rangiahua belong, of Broken Islands / Pig Islands, attests to this tradition. However, one of the uncertainties in this history is the precise time that pigs were first introduced to Aotea. Some sources (Le Roy, 1978) attribute Captain James Cook with first introducing pigs to Aotea, however this is probably incorrect. The extensive ship logs and journals from Cook's journeys indicate that Cook did not actually make landfall or contact with

the island or it's inhabitants, or distribute pigs within Tīkapa Moana (Hauraki Gulf). He did however skirt the south-western coast of the island and take time to name the 'Barrier Isles' on his first voyage in the *Endeavour*, in 1769:

> *being defended from the Sea by a Chain of Large and Small islands which I have called* ***Barrier Isles****, lying aCross the Mouth of it extending themselves N.W. and S.W. 10 Leagues. The S. end of these islands lies 4 ½ Leagues from the N.W. point of the River, which I have named Rodney; it lies W.N.W. p Leagues from Cape Colville, Lat. 36 15'; Long. 184 58' W* (Edwards, 1999)

Other historians describe the later liberation of domestic breeds of pigs by European farmer settlers. Ron Lloyd, the manager of the Forestry Department on Great Barrier Island wrote:

> *The* ***pig*** *too was liberated on the island to provide food.* ***Between 1845 and 1850****, Malcolm, one of the settlers liberated* ***pigs*** *and cattle at Tryphena. With the burning of the coastal scrub areas at Tryphena, fern came away to the exclusion of other vegetation and provided good* ***pig*** *food. From time to time since, local farmers have liberated domestic pigs into the bush areas in an effort to maintain sufficient numbers to provide sport and food* (Armitage, 2022)

Lloyd also noted change in pig distribution and numbers, post- World War Two, stimulated by the growth of native bracken fern (*Pteridium esculentum*) in areas reverting from clearance to native bush:

> *The* ***numbers of pigs*** *in our forest (in the north-central area of the island) are few. At Tryphena, Rosalie Bay, and around Cape Barrier they are dense. In 1946, the annual report for this station mentioned that was only an odd pig here or there in the forest. During the last six years (1973-79) 300 have been destroyed. The reason for their build up since 1946 would be due to a slight extent by liberations by farmers, but principally to a better food supply and more suitable cover as areas gradually become reclothed by fern after milling ceased in 1942. Some areas suitable to pigs have never been infested, and the reason for this is not known*

Through the introduction of domesticated pig breeds from Europe, the pigs of Aotea today are a mixture of the 'Captain Cooker' Polynesian pig introduced by Cook, and Tamworth, Berkshire, Duroc and other varieties. This is evident in the varied shape, size, and pelt colour and pattern of wild pigs seen across the island today. It is uncertain exactly when human-pig relationships transitioned from predominantly husbandry to hunting, but it is likely to have been in relation to events which forced major change to the Māori way of life on Aotea, in the mid-19th century. The escape or liberation of pigs would certainly have occurred during this period, establishing pigs as a wild-living resource for

harvest. The system of pig hunting that has emerged on Aotea is a hunter-governed one that includes 'territories', although these would appear to be less contested today than in previous years (it was mentioned to me by an anonymous informant, that there were once 20 different hunting 'blocks' in the northern zone of the island), when hunter numbers were higher. Department of Conservation rules and regulations, and conservation legislations have somewhat overlaid this system, for instance: the Department only recognises 3 hunting blocks, and it is illegal to translocate pigs. However, hunters still recognise historic territories, and continue to tend to pigs in various ways. It would be interesting to study hunter customs and practices further, if access to this normally reticent group was possible.

3.3.4. Current discourses around pigs on Aotea

Without supermarkets, wild foods including pigs and *kaimoana* (seafood), are an important source of *mahinga kai* (food) for many families in the community, especially *mana whenua* Ngāti Rehua-Ngātiwai, and other groups with long-standing ties to the island (R. Ngawaka, Ngātiwai, pers. comm., 2022). In the more remote areas on the island, pigs provide a source of protein which is accessible, and also affordable, which is important given the island's low median income, and the high cost of foodstuffs freighted to the island. Hunting is the main form of harvesting pigs, although this may be performed in tandem with raising pigs for slaughter. Pig hunting is a valued as a tradition; it is passed down through generations, and contibutes a strong sense of identity to some individuals, both male and female. It was clear from interviews with the hunting community (which I present in Chapter 4 of this thesis), that some hunters are committed to preserving the wild pig population, and pig hunting, on Aotea, and perpetuating a way of life in which pigs are central. As one hunter stated, 'if it weren't for hunting, I probably wouldn't live here anymore'.

Not all residents on Aotea are supportive of the presence of pigs or hunting on Aotea though. Over recent decades, Aotea has become a popular destination for out-of-towners, who own holiday homes or who have moved to the island to reside permanently, bringing with them progressive middle-class values such as property improvement and environmentalism. The free ranging habits of pigs, and the damage they can cause to gardens and plantings if unfenced, as well as to the natural environment, have shaped negative perceptions amongst recent residents, who are unaccustomed to the presence of pigs on the island (Anon., 2022). This has sparked debate, and at times, conflict, between newer, and older groups of residents who value pigs. A comment in the local Barrier Bulletin newspaper, suggests that this debate has run for over 50 years (Davenport, 2022).

National media coverage of the 'pig debate' (a New Zealand Herald documentary titled 'Pig Politics', made in 2018) suggests that the issue of pigs and pig hunting has become increasingly politicised on Aotea, with views tending to be highly polarised between strong support for or against pigs, without

apparent middle ground. Major voices in this debate are neighbouring pro-pig Kaitoke Beach landowners, and anti-pig Medlands Beach landowners, who represent traditional and progressive values respectively. These differing views have led to longstanding disagreement, and at times physical altercation (Black & Callister-Baker, 2019). I was advised by a conservation coordinator for Aotea, that pigs were a 'sensitive' topic that needed to be approached empathetically (J. Ritchie, pers. comm., 2021). However, the literature on the long-running 'cat debate' (surrounding management of domesticated and feral cats in Britain and the United States) has demonstrated that polarisation is often not as extreme as media would make out (Crowley *et al*., 2022; Palmer, 2022), and this is likely to be the case on Aotea. Still, it is apparent that dialogue and cooperation around pigs, are indeed strained.

Statistics surrounding the actual number of hunters, their hunting efforts, and number of pigs harvested are limited. Based on the number of hunting permits issued by DoC each year, there are thought to be between 16-18 hunting families on the island, which may be an underestimate if unpermitted hunting potentially occurs. Hunters report harvesting 5-6 pigs per year. Hunting is permitted in two blocks in the centre and north of Aotea Conservation Park, between 15 February and 15 December. Hunting on larger blocks of private land occurs via arrangement with landowners. Individual hunters typically hunt within defined areas which they maintain as 'territories', giving exclusive rights to pigs and hunting access. Detailed information on territories was not available for this study. Information on hunting on Aotea is publicly available on the DoC website, but hunting by visitors to the island is uncommon, unless by invite of local hunters.

3.4. Discussion

3.4.1. The social profile of Aotea

Although only a 30-minute flight from Auckland City and promoted as a holiday 'paradise', in reality Aotea is a remote and challenging place to live long-term. This has shaped a community which is intentional, resilient, self-reliant, and committed to preserving their way of life and the natural character of the island (Great Barrier Local Board, 2020). In this way, the community exhibits traditional rural and island characteristics (Dillon, 2008; Howie, 2008). Qualities of patience, ingenuity, reciprocity, and humility are necessary for survival on the island in a practical sense, and as a result, they are appreciated by islanders. Independence, and freedom from social control are also valued. This sense of non-conformity translates to attitude towards authorities; islanders rarely involve the Police in disputes, preferring to sort matters out for themselves, and regarding being part of a larger, regional authority as generally oppressive (Malcouronne & Morton, 2018). The many

different conservation projects active in the community are testimony to islanders independence, and desire for ownership of endeavours. Collectively, there is a comprehensive suite of conservation skills in community, from administration and management, knowledge of science and ecology, volunteer coordination, and 'boots-on-the-ground' skills in habitat restoration, predator trapping, and pig hunting. Pig hunters, in particular, possess valuable knowledge and skills for managing pigs.

Because of the proximity to Auckland, islanders are acutely aware of the size of the population that lies 'on their doorstep'. Islanders are avoidant of 'going the way of Waiheke', an island which at 22km from downtown Auckland, has become densely populated (Schultz, 2022). This creates a constant tension on Aotea between embracing visitors which support the island's economy, and resisting over-burden of visitors on the island's environment, community, infrastructure, and services. The potential for ongoing subdivision and development of land to interfere with the intrinsically 'wild' character of the environment, and change the nature of the community, is a cause for concern, as is the unaffordability (due to pricing on the Auckland real estate market) of property for most islanders. Aotea residents make it clear that they favour a sustainable development model, which benefits the community (such as via job creation), without incurring environmental costs. Resilience, and food security have been emphasised as key goals of development in the most recent Local Board Plan, following exposure of some of the weaknesses of remote living over the course of the COVID-19 pandemic (Aotea Local Board, 2020).

These findings indicate that championing self-determination, and having acceptance of Aotea 'on its own terms' are key to any program of change, of which potential pig management in future is one. Collaboration through empowering leaders within the community, and tapping into the broad skill base that islanders (particularly pig hunters) possess, will be important for motivation. As well, recognition of island needs and aspirations, such as opportunities for employment, will be important for obtaining acceptance and support (Oppel *et al*., 2010). Similar to Rākiura (Stewart Island), it is unlikely that Aotea residents would be motivated by the prospect of attracting more visitors to the island, because of the potential for tourism to have negative impacts (Leppens, 2005). Down to earth attitudes of conservation managers, embodying respect, practicality, and humility, will also need to be manifest, to relate well to and work effectively with islanders.

3.4.2. Capacity of the community to adapt to, and innovate, ecological change

The adaptive capacity of social systems relates to ability to respond to change (adaptation), and to drive change (innovation) (Folke *et al*., 2002; Moore & Westly, 2011). Adaptive capacity is built upon the following factors: availability of resources; information and knowledge; social organisation and institutions; and, psycho-social factors (Lemos et al, 2007; McClanahan and Cinner 2012). The

tight coupling of Aotea's community with the natural environment has the consequence that any intervention affecting the environment, has potentially wide-ranging social impacts, which may challenge the adaptive capacity of the community over short timescales. Therefore, the scope and timeframe of interventions must be considered with this in mind. Aotea's small-scale economy, low average income, high-cost of living, and limited job opportunities, potentially limit the resources available for many residents to shift easily in response to change. As well, are the emotional and cognitive resources which people have for contemplating and accommodating new situations: these are possibly measured on Aotea at the moment, in the wake of the pandemic, and in context of the major rat and cat eradication program that is in the early stages of implementation. It is conceivable that energy to direct towards another conservation project may not be freely available, and 'engagement fatigue' may be an issue for some residents (Attree *et al*., 2011). Availability of resources might also be limited for *mana whenua* Ngāti Rehua-Ngātiwai, for whom treaty settlement has been protracted and arduous, and takes priority over other matters. On the other hand, Aotea residents are resourceful, and well equipped with the skills to innovate change from the ground-up, given the right timing. Overall, these factors suggest that a phased, or gradual, approach to pig management is required, with medium- to long-term goals. Through benefiting the natural environment, such management would positively impact the livelihoods and lifestyles of many residents, and boost the local economy.

Although small, the Aotea community is diverse, resulting from successive waves of settlement by Māori, European farmers and prospectors, and newer residents from the time of the 'hippie' era. There is also a significant transient population, composed of holiday home owners, and seasonal business operators and workers, who consider themselves part of the community. This confers a range of different, and at times competing, interests and views regarding conservation actions, that have contributed to quite significant social conflict. Past experiences of rat and cat eradication on Aotea have demonstrated that the whys and hows of achieving management goals are debated (Ogden & Gilbert, 2011). This strongly suggests that future island-wide consensus on pig management is not likely to be achieved (in the same way Saunders *et al*. (2021) found that it was not achieved for rat and feral cat eradication on the island), but rather that different groups may agree on different things, at different times. Thus, an adaptable, site-based approach, matching the scope and scale of pig management to specific socio-ecologic contexts that are unique to the different regions of the island, may enable solutions for managing the impacts of pigs to be found. The social profile highlights the propensity of island communities to social conflict, that has been reported internationally (Reis & Hayward, 2013). Social conflict can be considered a negative impact of pigs, in some regions of the the island (specifically, the south and south-central regions).Conflict can also be considered a negative impact of management interventions, but in the scenario that pig management is solutions-focused with the specific aim of averting conflict, then impact may be positive.

3.4.3. Impacts, and feasibility of pig management

Pigs were introduced to Aotea almost 250 years ago; a time which has been sufficient for pigs to take on cultural symbolism for residents with considerably long ties to the island, most notably *mana whenua* Ngāti Rehua-Ngātiwai, and farmer-settlers. There is a small, but significant proportion of the population (c. 17 active hunters and their families) who want pigs, and pig hunting, to remain on Aotea in perpetuity. Pigs currently occupy an important place for *whānau* (Māori family groups) on Aotea, which in some cases are an amalgam of *mana whenua* Ngāti Rehua-Ngātiwai, and *Pākehā* (European) farmer-settlers, as a result of intermarriage between the two groups of oldest residence. These factors confirm the unfeasibility of eradicating pigs from the human rights perspective of food security, and from the cultural/heritage perspective of Māori and early settler groups, who have long standing ties and traditions related to the island.

I sense from the protectionist stance of some *whānau* (specifically, the Blackwell family, interviewed in the Pig Politics documentary series) regarding pigs, that there is a sense of ownership of pigs, even those that are wild-living. This may relate in part to ideas about land ownership, in particular the notion that whatever is within the bounds of the physical property (in this case, pigs), belongs to the property owner (von Essen *et al*., 2017). Given that Ngāti Rehua-Ngātiwai are the ancestral owners of Aotea, and have rightful claim to conservation lands which are in current possession of the Crown, it is understandable that pigs may be considered a form of property (New Zealand Government, 2016b). Futhermore, the landscape in question is not just a conservation landscape but a cultural landscape, where generations of people have lived closely with nature (Fowler, 2002). I sense that another part of the perception of ownership stems from the care that pig hunters exercise towards pigs. Although the final act in a pig hunt is the killing of the pig, until that point, pigs are tended in ways such as being allowed to grow to maturity before harvest is made, and sometimes, being reared for a period as piglets before being released into the wild. These findings mirror the complex ways in which people relate to, and establish a 'claim' to wildlife. (Manfredo, 2009). There is also the phenomenon of social hierarchies on islands, whereby islanders who are descendants of early settlers are positioned in a higher socio-political stratum than more recent residents, particularly those who are 'transient' (Farrier, 2011). It is quite possible that older groups see their ways of life, including pig hunting, as a right, that does not need to be negotiated with newer groups of residents or conservation managers, thus producing resolve to protect pigs and pig hunting. These are complex issues, which highlight the need for the integration of interdisciplinarity, and in particular, social impact assessment, at all stages of planning and implementing pig management as a facet of ecological restoration on inhabited islands.

3.5.Conclusions

Social impact assessment (SIA) is the process of predicting, monitoring, and managing the social impacts of a proposed project, which in this case, is future management of wild pigs on Aotea (Great Barrier Island). The focus of SIA in this context, is all potential social impacts, both positive and negative, of potential pig management planning and implementation on Aotea, and the implications of these impacts for feasibility of different approaches to managing pigs.

Assessment identified potentially negative impacts of pig management on *mahinga kai* values and food security, and aspects of the traditional culture and heritage of *mana whenua* Ngāti Rehua-Ngātiwai and early settler groups, confirming the unfeasibility of eradicating pigs on Aotea, in the foreseeable future. Diversity of social groups within the community (and the attendant diversity in views on pigs), and limited capacity of the community to adapt rapidly to change, imply that an adaptable, site-based strategy offers the most feasible route to management of pigs in the medium- to long-term.

Adaptable pig management has the potential to impact positively on the island's biodiversity and environmental quality, and to benefit livelihoods and lifestyles that are tightly coupled with this environment. There is also the potential for pig manangement to play a positive role in reducing social conflict, that is the consequence of strained relations between neighbours for- and against- pigs, in the absence of any coordinated program to manage pigs. An opportunity for pig management therefore, is to find 'middle ground' and provide site-specific solutions that balance interests, and defuse tension between opposed groups.

Key to the success of prospective pig management in future, would be partnership with *mana whenua* Ngāti Rehua-Ngātiwai, as treaty partners and key stakeholders in pigs on Aotea. Adaptability to match regional, socio-ecologic scales and contexts, will also be requisite. Areas of leverage will be empowering leadership in the community, utilising local skills and knowledge (particularly of hunters), and providing meaningful benefit to the community (such as employment). Instrumental in this approach, will be the ability of ecologists and conservation managers to embrace the thinking that landscapes are 'cultural landscapes', as well as 'conservation landscapes', and to accept communities on their own terms. To this end, I recommend close engagement with the community, with a focus on building trust (especially of hunters), and facilitating effective dialogue around envisioning future pig management, as a short-term pathway forward. To facilitate this, and to further the development of socio-ecologic paradigms for conservation research and management, I recommend that social impact assessment be integrated fully into future pig management planning and implementation on Aotea, and other islands that are inhabited.

CHAPTER FOUR

Values and practices attached to wild pigs (*Sus scrofa*) on the inhabited island of Aotea (Great Barrier Island)

4.1. Introduction

4.1.1. Mahinga kai *versus invasive species: a case of different values*

The term 'invasive species' was coined by biologists to describe organisms which have established outside their native range, and which adversely affect the other species which naturally occur there (Elton, 1958; Blackburn *et al*. 2011). Conservation efforts are aimed at preventing the arrival and establishment of these species, or ridding ecosystems of them, to protect indigenous wildlife. Paradoxically, humans have often intentionally introduced invasive species (without knowledge that they could become invasive), and attached value to them as resources (Riley, 2013). Introductions of game animals (including species of deer, and pigs) to Aotearoa, are one such example. The pragmatic terms by which they are commonly referred, including 'wild meat', 'game animals', 'valued introduced species', and '*mahinga kai*' (meaning food resource, in Te Reo Māori) reflects this, in contrast to the negative implications of 'invasive species'.

The values component of invasive species management has historically not been well recognised by the agencies that are tasked with managing invasive animals. Rooted in biological science, conservation is often self-regarded as objectively knowledge-based (Boyce *et al*., 2022). But conservation is a social endeavour, based on ideas about the intrinsic and extrinsic value of non-human life, and so it is inherently based in part on values (Manfredo, 2008). The values which predominate conservation management in countries with a colonial legacy are Western, empirical, and dualist, separating nature from humanity and organising life forms into native and non-native, good and bad (Infield *et al.*, 2018). Yet the biosphere is not so black and white and monocultural, and nor are the values and concepts which pertain to nature and its conservation; on the contrary, they are diverse, reflective of culture, place, connections to nature and usages of it (Ducarme *et al*., 2020).

It can be considered that the conventional Western model of conservation is not well-equipped for operating in the socio-ecological context of the biosphere, within landscapes that are inhabited by people, and are set to become increasingly so (Adams, 2004; Folke *et al*., 2005). Traditionally, many of these landscapes have been occupied by indigenous peoples, and today support large societies made up of diverse cultural groups. Ideas of nature, and belongingness in nature, that are contained within Western conservation ideology, may not hold legitimacy for many groups of people, and these

people are less likely to support proposals for conservation management originating from such ideology (Descola, 2013). As well, there is the problem that conservation has restricted indigenous peoples from dwelling on and utilising their traditional tribal lands and resources (Brockington, 2006). These issues have been at the heart of ongoing conflict, which is at risk of seriously hampering global biodiversity efforts (Redpath *et al*., 2013).

An adaptive, co-management approach to conservation has been recommended for reducing conflict and managing living systems and species, including those that are invasive, in the Anthropocene (Berkes *et al*, 1991; Olsson *et al*., 2004). The so-called biocultural, community-based, participatory and place-based conservation models are examples of adaptive co-management that have emerged in recent decades (Lyver *et al*., 2019). Essentially, these approaches work by diversifying the values base and distributing the power and responsibility in conservation management between central (e.g., government) and local (e.g., indigenous, and community groups) levels. Beyond being participatory (*sensu* Arnstein, 1969), these approaches are based on real partnerships – relationships which, although complex to establish and navigate, offer adequate mechanisms for working through conflicts and finding satisfactory solutions. In Aotearoa, adaptive co-management has been employed in the harvest of many marine and freshwater species, tītī (muttonbird, *Puffinus griseus*), and prevention of the spread of plant pathogen and invasive seaweed species (Moller, 1996; Freitas *et al*., 2020). The recent 'Te Ara ki Mua Framework for Adaptive Management of Wild Animals' released by the Department of Conservation (DoC) (2022) signals a similar intent toward managing game animals, including pigs, which are culturally valued as wild meat or *mahinga kai*, but are ecologically impactful. Moving toward such an approach for managing pigs in Aotearoa requires new knowledge of how Māori and hunters value and utilise pigs, and to what degree these can be reconciled with ecologically-based conservation values. Specific objectives of this chapter (Chapter Four) are to establish the values and usages associated with pigs on Aotea (Great Barrier Island), and to identify what (if any) approaches for managing pig impacts are acceptable to hunters on the island.

4.1.2. Hunting values

Of Aotearoa's many invasive species, the game animals are amongst the most highly valued by some groups of people. These animals include pigs, introduced in the late 18th century by European explorers, and goats, deer, tahr, and chamois, which were introduced by later European colonists to provide hunting for food and sport (Donne, 1924; Hunter, 2009). Although to highly urbanised people hunting for food may seem an unnecessary practice, given the availability of farmed meat, hunting is a tradition that is more than simply an end to obtain meat, but a cultural practice (Marlowe, 2007). For those living in remote areas, where food supply can be costly and erratic, hunting may be practiced for subsistence, ensuring food security (Dickson *et al*., 2009). For others living nearer

urbanised centres, wild meat may be viewed as a healthier, and more sustainable option than meat obtainable in supermarkets (Hunter, 2009; Corradini *et al*., 2022). It has also been argued that hunting is a more ethical mode of acquiring meat, because animals have a higher quality of life, and are effortful to obtain; resulting in higher greater appreciation and less wastage by human consumers (Nelson *et al*., 2005).

Particularly for Māori, pig hunting is important because pigs have come to be seen as a 'traditional' source of food, or *mahinga kai*, because of the length of time that they have been established in Aotearoa, and because they act as a substitute for more traditional, native *mahinga kai* species that Crown legislation or population declines have restricted Māori from gathering (Nugent *et al*, 2003). Although Māori people appear not to have brought pigs with them when they settled Aotearoa, pigs are distributed throughout most of the Pacific, and are present on the islands that linguistic evidence suggests are the Māori ancestral *Hawaiki* (homeland) (Anderson, 2017). Thus, pigs are reflective of Pacific *whakapapa* (ancestry) for Māori. The cultural linkage value of pigs, is also relevant in context of the large population of Pacific island peoples living in Aotearoa (Secretariat of the Pacific Community, 2007).

As well as being a food-gathering activity, hunting is an exercise which immerses humans in nature – a world governed by non-human species and systems. Such immersion is valuable for bringing about heightened awareness of the need for respect of these systems, which is necessary in society (Pauley, 2003; Marvin, 2005). The observations of nature made while hunting, over time, may amount to substantial knowledge about the ecology of local areas, especially in relation to patterns of animal occupancy and changes in environmental health. Far from being 'anecdotal', this collective, long-term knowledge derived from first-hand experience is legitimate and reliable, and complementary to scientific knowledge (Gadgil *et al*., 1993; Petersen *et al*., 2011; Berkes *et al*., 2000).

Hunters report that hunting provides positive experiences in learning, kinship, connection with nature, and self-reliance, such that it has been described as 'the best part of life' and may form a strong part of a person's identity (Condon *et al*., 1995; Marvin, 2005). For indigenous people, including Aotearoa Māori, hunting and gathering from nature has cultural significance, with Māori representing the main ethnic group of hunters in the country (New Zealand Conservation Authority, 1997; Sport New Zealand, 2022). With over 200 years of heritage in Aotearoa, game animal hunting is a quintessentially rural tradition, which continues to be practiced by predominantly rural communities. For these groups, hunting holds significance as a symbol of culture and heritage, and is an ongoing component of their contemporary culture (Hunter, 2009).

Although steeped in tradition, hunting is not static. Since the COVID-19 pandemic, there has been a 2% increase in the number of men who hunt (Sport New Zealand, 2022). Increasingly, women are becoming involved in hunting, and conservation is growing within the value system of hunting, to

responsibly manage populations of invasive game animals and maintain ecosystem health (Cosgrove, 2018; New Zealand Game Animal Council, 2020). These factors, coupled with the array of cultural provisions supplied by hunting, support the argument that hunting is more than just a sport, but a dynamic, trophic cultural practice which is guided by ecological principles (Cahoone, 2009). Hunters assert that by promoting connection to nature and assisting in the reduction of game animal populations, hunting can contribute to mitigating the negative impacts of these species, and play a role in biodiversity restoration (Morris, 2010). There is evidence that game animal harvest can reduce browsing intensity in forests (Husheer & Robertson, 2005; Hothorn & Müller, 2010). Hunting has drawn much criticism though, on the epistemic grounds that hunters may not kill enough to get the biodiversity benefits sought (Parkes et al., 19960, and, on the ethical grounds that some of practices within hunting (such as killing animals for trophies) cannot be justified as forms of nature connection or conservation (Tickle & von Essen., 2020). These sorts of clashes are common, and have well covered in literature from Aotearoa, and abroad (Nugent & Fraser, 1993; von Essen *et al*., 2017).

4.1.3. Clashes between hunting and conservation values and objectives

In contrast to hunters, who value game animals positively, conservation scientists and managers in Aotearoa have tended to view game animals less favourably, on the grounds that game herds damage to environment when insufficiently controlled (see, for example, Veblen & Stewart, 1982; and DoC's policy statement on deer, 2001). As such, agencies are mandated with the control of game animals on public conservation land by a range of legislation, specifically the Wild Animal Control Act 1977 and Biosecurity Act 1993 (Miskelly, 2014). Further legislation, the Conservation Act 1987, gives the directive that conservation land administered by DoC, is managed for a range of ecological, cultural and historic heritage, and recreational values and interests. Herein lies the central tension to game animal controversy in Aotearoa – the conservation estate that hunters rely on for harvesting game, is a space which must be shared amongst users and custodians with multiple, and often competing, interests (Fraser, 2000).

One gets the sense when reading hunter advocacy group statements, that hunters feel quite alienated from DoC (see, for example, New Zealand Tahr Foundation's statement on tahr management). In principle, this might stem from referral to game animals throughout policy as 'invasive species', which gives emphasis only to the negative ecological impacts of these animals and not the positive impacts they have for hunters, who utilise and value them (Davis *et al*., 2011). Although one important policy item, the Biodiversity Strategy (2020), and one policy framework, the Te Ara ki Mua Framework for Adaptive Management for Wild Animals (DoC, 2022), contain neutral terminology of 'wild animals', this usage is only very recent, and has not filtered through to other policies, as yet. Although not articulated, the symbolic 'ownership' of game animals by the Crown, implied through

Crown legislation of game, and property rights over the land where game animals are commonly found, might be a motivation for resistance for hunters, who themselves assert a claim to game via harvest (von Essen *et al*., 2017). On the other hand, conservation field-operators have reported being intimidated by pig hunters while carrying out their duties, and pig hunting clubs have taken formal action against plans by conservation agencies to manage pigs more intensively (such as, Tokoroa Pig Hunting Club did against Environment Waikato, after which pigs were removed from the regional pest management plan) (Waikato Times, 2009).

Interestingly, clashes seem not to be over the principle of lethal control of valued animals, *per se* - hunters themselves kill the animals and have demonstrated they are willing to cull herds to prevent overgrazing of native vegetation. Instead, it is the specific objectives informing control that come into conflict with hunter objectives, that are problematic. For example, agency-led culling of game herds to low or near-zero densities, sits at odds with hunter objectives for maintaining herds for sustained harvest. Hunter groups have also criticised DoC for targeting areas which are most accessible for hunters, such as national parks, whilst leaving the heaviest densities of game animals in hard-to-access areas, where they can cause considerable damage. Culling operations have been described by hunter groups as being being indiscriminate, removing good-quality breeding or trophy animals, and impacting the long-term viability of the herd (New Zealand Tahr Foundation, 2022).

4.1.4. The needs of future pig management

There is currently no national strategy in place for managing pigs on Crown-managed conservation land (Nugent *et al*., 2003). Sustained hunting, by recreational hunters, is reported to be the main form of pig management in these areas, with the addition of some limited management by DoC staff and contractors at high-priority sites, and incidentally over the course of other predator control operations (Clarke & Dzieciolowski 1991; NPCA, 2018). The few exceptions to this have been the eradication of pigs from many of Aotearoa's small, uninhabited islands; culling exercises to exclude or eliminate pigs from becoming established in new areas; and the current proposal to eradicate pigs from Maukahuka (Auckland Island) (Nugent *et al*., 2003; Clout & Russell, 2006; Horn *et a*l., 2022).

Ongoing reliance on recreational hunting is not considered sufficient to manage pigs long-term, as hunter motivation to pursue pigs in low-density or hard-to-access areas is low (Parkes *et al.*, 1996). Hunting with dogs (which is the predominant method of hunting pigs) may also be too risky for areas where indigenous taxa are vulnerable to dog-attack. Additional measures, such as specialised contract-hunting, trapping, fencing, or poison-baiting are considered necessary to ensure effective pig suppression, but, the use of such methods would likely not be acceptable to hunters, should they overlap with popular hunting areas (Latham &Yockney, 2017).

To avoid conflict, and find acceptable solutions for managing pigs more intensively, meaningful engagement and negotiation with hunters (as those with a primary stake in wild pigs), within a wider program of partnership with Māori and other community stakeholders, is required. The so-called adaptive management, and co-management approaches are characterised by being adaptable to ecological uncertainties and changing scales and contexts, and being integrative of ecologial and social values, respectively. Calls have been made for the approaches to be adopted for managing wildlife, including the invasive species, for some years (Taiepa, 1997; Parkes *et al*., 2006; Lyver *et al*., 2019). I argue that a synthesis of both approaches might offer a novel way forward for improving pig management in Aotearoa.

Although some skepticism continues to surround co-management arrangements (see, for example, Warwick's criticism of tītī (muttonbird, *Puffinus griseus*) co-management, 2010), and widespread adoption of the tenets of co-management remains elusive, the instances of where co-management has been employed to manage invasive species demonstrate success. In Aotearoa, examples include management of *Caulerpa brachypus* seaweed and kauri dieback disease (*Phytophthora agathidicida*), which employed a combination of *rāhui* (customary Māori restrictions) and science-based biosecurity measures, to prevent the spread of both organisms (Lambert et al., 2018; Biosecurity New Zealand, 2023). Exclusion of ungulates (water buffalo, horses, and pigs) from freshwater billabongs and sites of cultural importance to indigenous peoples in northern Australia have stimulated the rapid recovery of vegetation and water quality (Ens *et al*., 2016). A number of international studies suggest that co-management works better than externally-led or community-led based management alone, because of the combination of knowledge systems (McLanahan *et al*., 2006; Gutiérrez *et al*., 2011). Of course there is the potential for co-management between conservation and hunter groups to be done badly, but if appropriate mechanisms are in place for reducing uncertainty, and resolving conflict, there is also potential for great success (von Essen *et al*., 2015; Redpath *et al*., 2013; Pollard *et al*., 2019).

4.2. Methods

4.2.1. Methodological overview

In this study, I take an ethnographic approach to social research in the community on Aotea (Great Barrier Island); an inhabited island in Tīkapa Moana (the Hauraki Gulf, in northeastern Aotearoa), where wild pigs are a current conservation concern. Ethnography is essentially the study of people in their natural environment, rather than in a clinical setting. Techniques of ethnography typically involve the researcher positioning themselves inside the day-to-day world (e.g., community or workplace) of participants, and being involved in their activities, in a manner which allows

spontaneous interaction. Data collection involves both direct observations (e.g., field notes) and interviews with participants. The benefit of an ethnographic approach is that it builds trust, enabling in-depth investigation of social practices, as well as supplying relevant location-based context (obtained through first-hand experience) (Madden, 2017). To be present within the community on Aotea, I conducted a total of five (approximately fortnight-long) trips to Aotea between April 2022 - February 2023. On the first trip (28 April-11 May), I met contacts, and connected with a local *kaumātua* (elder), who was a leader in the community and instrumental as a 'gatekeeper' to pig hunter. Through this *kaumātua*, I was introduced in person to hunters, and others in the community with a stake in pigs (as a result of interests in conservation, local history, and owning property). I struck up spontaneous conservations with locals, visited local businesses and attractions, and attended various events (such as sports and social gatherings, and the annual Manu (divebombing) Competition). Through *kaumātua* and my own connections, I was able to introduce my study and recruit participants. On subsequent trips, I employed semi-structured interviews to address the research questions, relating to pig values and practices, conservation values, and perceptions of pig management (outlined below). As a Pākehā female, I remained reflexive to the influence that my identity and experiences could play in the formation of interpretations regarding the research.

4.2.2. Semi-structured interviews

I conducted semi-structured interviews in–person with hunters and members of the community with a stake in pigs, over a 14-day period from 6-20 June, 2022. These carried out at variety of locations including participants' homes, sites of interest that participants wished to show me, or the living room of the DoC unit where I was accommodated. Follow-up to interviews (further interviewing, participatory observation) was carried out over 10-days from 20-30 July, 2022. Participants were recruited indirectly in most cases, by a *kaumātua* (elder) of Māori community that I had engaged with. Three participants were recruited directly by me, on the recommendation of *te kaumātua* or other participants, or through my own connections. Rather than the snowballing method (Noy 2008), whereby one participant recommends the researcher to another potential participant, and so on, this approach to recruitment was utilised because it was considered *tika* (right) for someone without connections on the island (i.e. myself) to go though a trusted *kaumātua* member of the community, rather than being reliant on study participants.

Semi-structured interviews are conversational between the interviewer and interviewee, structured around a few open-ended questions on key topics. This approach is valuable because it allows participants to open up and talk about what is important to them, which can capture nuance and depth in perspectives, and potentially reveal information that hadn't been previously considered by the researcher (Ogborn *et al*, 2003). I refer to interviews as *kōrero* - conversations - here. During *kōrero*, I

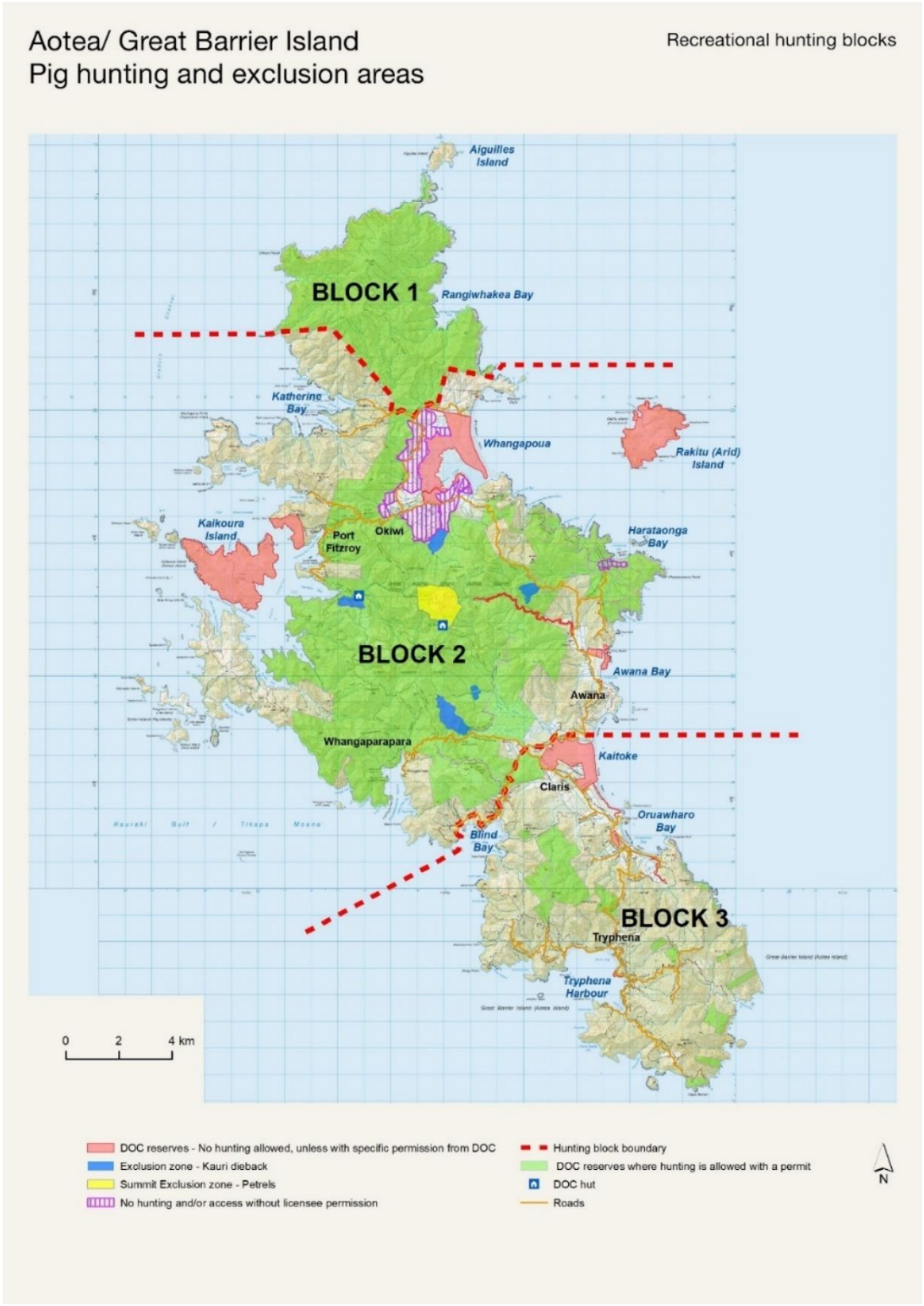
let participants guide the conversation, and asked key questions relating to how and why pig hunting was important, knowledge gained from time in the bush, and thoughts around pig management, as they fitted with flow of the *kōrero*, or as required to elicit more detail. For a full list of guiding questions refer to **APPENDIX 3**. Oral or written consent was obtained from participants, and where permitted, I audio recorded interviews or took written notes during *kōrero*. Where participants weren't comfortable with audio recording or it was impractical to take notes, I transcribed from memory immediately afterward. Participants were invited to review their interview transcripts. This research was approved by the University of Auckland Human Participants Ethics Committee on 26 October, 2021 (Ref: 23329).

4.2.3. Site details

Aotea (Great Barrier Island) is situated in Tīkapa Moana (the Hauraki Gulf), approximately 100 km north-east of central Auckland. With a land area of 285 km^2 it is the sixth-largest island in Aotearoa, and largest in Tīkapa Moana, which is a hotspot for global seabird diversity (Gaskin, 2014). With extensive tracts of habitat significantly less modified than the adjacent mainland, Aotea is an important 'seabird island', and is the breeding site of the largest of the two remaining colonies of endemic tākoketai (black petrel, *Procellaria parkinsoni*), which have been extirpated from mainland Aotearoa (Imber, 1987). Much of the island (43%) is currently administered by the Department of Conservation, under the single entity of Aotea Conservation Park which was formed in 2015 from numerous smaller areas. The 12,282ha park provides for a range of cultural, conservation, recreation and community interests, and allows for pig hunting in three designated blocks (**Map 4.1**). The central block (Block 2) is the largest and made up of multiple reserves north of Claris, of predominantly forest-covered hill country. The northern block (Block 1) is a smaller contiguous area of hilly coastal forest, and the southern block (Block 3) is comprised of scattered small blocks of regenerating forest and scrub. Pigs are the only animals available for hunting on Aotea, with wild goats having been eradicated from the island in 2005. The season is open for most of the year except for two months between 16 December – 14 January, while visitor numbers are at a peak. Hunting in any of the blocks requires a permit from DoC, and because of the ground-nesting seabirds which breed in the area, current bird aversion certificates (confirming behavioural training to avoid birds) are required for dogs. No rules and regulations surround bag limits or hunting methods, although dogs are not allowed within one kilometre of the Hirakimatā summit (627m), where tākoketai breed. Hunting is also not allowed in the exclusion zones that have been established to manage kauri dieback disease (caused by *Phytophthora agathadicida*) and pāteke (brown teal *Anas chlorotis*). Reporting of pig numbers taken is optional. Privately owned blocks of land, which often adjoin conservation land, are additional areas which can be accessed for hunting with permission from landowners and

adherence to any rules (such as number or type of dogs allowed) set by the property. An estimated 15 hunting permits are issued to hunters every year (C. Fraider, pers. Comm., 2023), and it is possible that unpermitted hunting occurs too.

Map 4.1. **Pig hunting and exclusion areas** administered by the Department of Conservation on Aotea (Great Barrier Island). The green shaded areas represent the areas available for hunting on public conservation land, which are arranged into three blocks. (Modified from an unpublished Department of Conservation map, 2021).



4.2.4. Qualitative analysis

I analysed *kōrero* data qualitatively, using a grounded theory approach. This approach describes a process of collecting and analysing data simultaneously, such that the 'theory' is developed as data is analysed, informing the direction of further collection and exploration of further data to tease out more detail (Glaser & Strauss, 1967; Thornberg & Keane, 2022). Unlike quantitative approaches which rely on preconceptions of the researchers, grounded theory approaches are inductive, and sensitive to information that may not have been considered prior. In this way, they provide excellent methodology for exploring emerging issues which are not yet well researched and understood, and so I considered them appropriate for studying emergent pig issues. I initially transcribed audio recordings by hand, and wrote memoranda for each transcript noting the important points of the *kōrero* and any other perceptions I had, such as my sense of emotion conveyed through the *kōrero* or in relation to particular points. After transcription, I spent time reading through transcripts to get an idea of major ideas or 'themes' that were evident across transcripts, and develop a better sense of the meaning and context of statements made, by relating them to other statements within the transcript and my accompanying memoranda. I then began coding and analysing *kōrero* transcripts using NVivo computer software Version 13 (QSR International, 2020). Coding of individual statements was made by initially attaching a main code denoting whether the statement related to an activity, a value, a concern, a perception or knowledge. As I progressed, I revisited each main code, reviewing for consistency and categorising into more specific sub-codes. Where it was apparent that some statements or sub-codes were not consistent with others, I regrouped with other codes or created new codes to accommodate. I continued coding until saturation was reached, noting patterns and relationships that emerged between themes, as I progressed.

4.3. Results

4.3.1. Overview

Research with participants yielded 20 *kōrero* in total, that ranged in length from in-depth talks that lasted several hours, to shorter conversations that usually did not exceed 30 minutes in duration. Seven participants were of predominantly Māori descent, thirteen of non-Māori. Four non-Maori participants were part of *whānau*, through marriage. Participant affiliations were hunting, conservation, or both. I do not share the genders of ages of these individuals, to maintain (as much as possible) anonymity within a very small island community. A full list of identity codes and affiliations of participants is provided in **APPENDIX 4**. The themes that arose through interviews could be grouped into five general areas: 1) pig hunting purposes and practices, 2) *mahinga kai* and

conservation values, and hunter code of practice, 3) hunter knowledge and ecological understandings, 4) issues contributing to pig tensions, and, 5) community recommendations for pig management and seabird conservation.

4.3.2. Pig hunting purposes and practices

The reasons for hunting were primarily for food, either currently "ninety-nine percent of what I eat [of meat] is pork" (PAR 10), or at some point in time "it's our Mad Butchers [a mainland butcher chain store]...back in the day I used to live off the land, and that was how I brought up my kids, hunting and gathering" (PAR 4). These responses emphasise the subsistence aspect of pig hunting, and the food security that hunting has historically provided and continues to provide to whānau living remotely on Aotea, where there are no supermarkets, and getting groceries on the island is expensive and difficult:

> it's not so much the hunters that like them (pigs), it's because we use the meat, if we hadn't have had the meat we wouldn't have survived. Dad was getting 5 pound a week, you'd have to wait for the boat to get out here and then there was the issue of refrigeration. And it's still the same (PAR 10)

Awareness of security appears to have been heightened by the pressures of inflation and disruption to the supply chain, resulting from the COVID-19 pandemic, and the impact of biosecurity measures to prevent the spread of the invasive seaweed *Caulerpa brachypus:*

> you've got the cost of freight which is something like six dollars a kilo, fuel is [NZD] four dollars twenty now and there's the *rāhui* on gathering seafood, so those things all add up and you really start to feel them (PAR 4)

Amongst some hunters, conservation provided part of the motivation for hunting: "you're doing a good thing by keeping pig numbers down, some years they seem to explode in some areas or for a time" (PAR 3). These hunters made regular and sustained efforts at hunting:

> trapping and hunting work well if you keep at it regularly...I hunt at least once a week. A few years ago I used to do it every day (PAR 10)

> I do all the trapping through the swamp and I hunt pigs too (PAR 19)

> These responses highlight the significant contribution that hunters have made over the years to controlling the pig population on Aotea, and toward controlling predator levels more generally.

The sport or recreation side of hunting was mentioned by one hunter, who spoke of their enjoyment in bonding with and training their dogs for hunting, and of the excitement of a 'bail' - the point of a hunt

at which a pig is found, and is kept at bay by dogs until the hunters arrive. Clearly part of the reason for hunting is the exhilaration and enjoyment of it. Although it wasn't explicitly mentioned by any hunter, I sensed that the challenge of pig hunting was part of its appeal to some hunters. Pig hunting is an inherently demanding activity, requiring fitness to trek rugged terrain in order to find pigs; skill to kill and gut a pig by knife, and strength to carry out a heavy pig carcass on one's back. The sense of satisfaction of overcoming these challenges, getting exercise and bringing home meat to put on the table would undoubtedly be of benefit psychologically and physically for hunters, contributing meaningfully to their health and wellbeing, as well as that of their families.

4.3.3. Mahinga kai *values, conservation values, and hunter code of practice*

To understand why hunting was valued as a practice, beyond providing food, I asked hunters why pigs, and pig hunting, were important to them. *Kaumātua* explained that pigs have cultural significance for *mana whenua* on Aotea, because of their *whakapapa* (lineage) as a resource that held chiefly status amongst *tīpuna* (ancestors), and because of the agency that this gave to people:

> When it comes to pigs you gotta think about their *whakapapa* (ancestry), where did they come from and what did that mean for people? Pigs were *te kai o te rangatira* (the food of chiefs), if you owned a pig after coming from eating birds you can imagine what that meant. So we have the term *kai o te rangatira*. From one chief to another, and everything is about trade which develops more over time so it was about that and thriving as a people (PAR 4)

Pigs therefore represent an ancestral *taonga* (treasure), and utilising this *taonga* today allows connection to *tīpuna*, and exercise of one's identity as *mana whenua*.

Mahinga kai, or natural food resources, are important to Māori, of which pigs represent one: "it's more than just food, it's special because at a tangi or twenty-first what's expected is a pig or *kaimoana* (seafood)" (PAR 4). Traditionally *mahinga kai* was comprised entirely of endemic and native species, along with the *kūri* (Polynesian dog *Canis pacificus*) and *kiore* (Polynesian rat *Rattus exulans*) which were brought to Aotearoa by Māori ancestors. However, the introduction of legislature including the Wildlife Act 1953 and Conservation Act 1987, coupled with decline in abundance of traditional *mahinga kai* species, have served to restrict Maōri customary harvest. This further elevates the importance of pigs as a form of *mahinga kai* in a contemporary context.

Some hunters hunted to perpetuate family traditions and culture:

> My Dad hunted and I've been hunting for over 60 years (PAR 10)

> He's [partner] got 50 years' experience and my son, he's been hunting for 15 years. If you come and visit you can see our pet pigs, and my son keeps pigs in the back paddock. With my

> youngest son and all of my children when they were small, I went out hunting with them in a pack on my back. This family has always hunted pigs (PAR 13)

One hunter's living room was decorated almost entirely with pig artifacts and memorabilia, and portraits of family members on hunting expeditions, representing decades of accumulated experiences. These findings indicate that for some families, hunting has been integrated fully into a way of life, and is an activity around which multiple generations connect.

Expanding on values, I spoke with hunters about the ecology of Aotea and the importance of conservation, which demonstrated that holistic conservation values are inherent in hunter value-sets:

> I think we need to bring back the *mauri* (life force or essence) of this place. It's our *putaiao* or our environment which teaches us things. And it's *tiaki*, or care, that's about looking after that. The ultimate goal has to be about *mauri*, it's not that I'm anti- this or anti- that, I think that we should bring the birds back into our bush, you know that if we can create a *papakainga* (housing) that houses these species, why not? Why can't we do that? (PAR 4)

> we're all about preservation (PAR 6)

> we've planted pingao, marram, spinifex on the dunes and we don't allow dogs on the beach. We've always protected this bay and stopped our kaimoana from being overharvested, so that it will always be there for my mokopuna. Everything I do is for my mokopuna" (PAR 13)

Non-hunters frequently cited valuation of specific aspects (species of birds and plants) of ecosystems, and environmental quality, as the basis for their typically negative stances perceptions pigs, especially in relation to dune and wetland ecosystems:

> bird nesting, especially New Zealand Dotterel [an endangered species] is being disrupted...pigs dig up pingao [grass] and beach convolvulus [herb] and create sand patches ideal for weed establishment...raupo [rush] stands are being dug up for their underground tubers and other vegetation is also being excavated. Entire beds of rushes right on the creek edge are being rooted up/destroyed, leading to unstable banks, erosion, sediment in the creek...there is almost no chance of bittern re-establishing in the wetland while pigs breed and wander at will (PAR 20)

Other values were more personal, derived from the reward of planting and restoring property, and local reserves:

> I'm a preserver of life, and I love the birds...I've taken 12 years to plant this property. All those flaxes came from the same plant, just divided and planted out. I've planted varieties of nectar producing trees that are adapted to the climate and provide food for the birds, now tui are deafening here in Spring (PAR 17)

It was revealed through conservations with hunters that hunting on Aotea had a 'code' of practice recognised by most hunters. Underpinning this code was the concept of respect – for other hunters, for the *whenua* (land), and for the pigs whose lives would ultimately get taken by hunters. Another key concept within hunter code was that of 'territory' or the arrangement of hunting lands into different areas, based on geography and location of different hunters. This system was established historically, to ensure that all hunters had access to hunting grounds nearby, and would be able to meet their needs in terms of food and sport. Although hunting territories are less contested in the present day than in the past, hunters still demonstrate respect to each other by recognising others' areas, and asking permission to hunt in these. Respect for the land is demonstrated by not cutting lines into vegetation to get to pigs, and making a gift of the heart of pigs killed to *Paptūānuku* (mother earth); respect for pigs is shown by not being wasteful of the pig harvest, and letting some sows caught to go, so that they can breed. Although inevitably respect does not always get shown on every occasion, it is a system which shapes hunters' interactions with the environment and each other.

4.3.4. Issues contributing to tensions around pigs

Understanding causes of conflict around pigs was central to this study, so I asked participants about the issues that they perceived in relation to pigs, and about their concerns to do with pig management. Responses from non-hunters emphasised frustrations to do with escaped pigs living around the settlement of Oruawharo [Medlands Beach, see Map 4.1]. Most of these pigs are not in fact 'wild', but originate from nearby farms which bound the settlement. However, the social impacts being felt by pigs – roaming around; causing damage to gardens, compost bins, rubbish bags, and property – were significant for some local residents. It was felt that large pigs, when encountered, could be intimidating to small children or the elderly. These pigs were also impacting on conservation land nearby and restoration projects on private property, affecting the success of plantings "the issue is the pigs tear the seedlings up" (PAR 1). These responses demonstrate the issues being caused by the coincidence of pigs with an area undergoing residential development and ecological restoration, simultaneously.

The pigs at Oruawharo highlighted the ecological impacts that non-hunters considered to be a major issue in relation to pigs on Aotea. Oruawharo is an area which encompasses coastal, dune, and swamp lands, which, because of the rare and threatened bird species present including pāteke (brown teal) and matuku (Australasian bittern), is ecologically significant. The area is a site of restoration undertaken by community group Oruawharo Medlands Ecovision (OME) and the Department of Conservation (DoC).

> In terms of loss of protected biodiversity...bird nesting, especially of New Zealand dotterel is being disrupted, also the whole dune ecosystem is being severely impacted. The rear-dune wetlands, integral to the dune water-table, are perhaps even more severely affected leading to unstable banks, erosion, sediment in the creek and all the problems associated with that. The wetland is an important habitat for declining pāteke, it is also now confirmed as a significant site for bittern. Bittern is one of New Zealand's birds at most immediate risk of extinction due to habitat loss and predation...there is almost no chance of bittern re-establishing [through breeding] there while pigs breed and wander at will (PAR 20)

In reference to the situation at Oruawharo, one participant provided perspective through suggesting that media may be contributing to heightened negative perceptions of pigs on Aotea:

> these people who have pork, they get to everybody else, and then those people write to the paper and it gives the conservationists fuel for their fire. They stir the pot. Those people down in Medlands they bring this upon themselves, they want to live next to a farm and then they don't want pork on it (PAR 18)

Another participant suggested that lifestyle differences between older, farmer-settler residents and newer residents from urban backgrounds may be involved:

> people they've got to realise that it was a pig farm...some people would rather complain about it than do something about it. They're a different community to the older people that're sort of used to the country. Rather than doing what he [the landowner] is doing it would be better to go and talk to them and see what's going on, and see if there's any way he could help them out with the problem (PAR 10)

These findings suggest that local issues are perhaps symptomatic of a larger process of cultural collision between recent immigrants to the island and older farmer-settlers, into which pigs have been embroiled.

Observations about social characteristics, and broader social processes that may be in effect were offered by two participants:

> we keep encroaching on the animals' territory. Not so much up here where there are two landowners – Māori and Crown – but down there where they're cutting the land up into smaller and smaller blocks and more and more people are moving into the animals' space. The animals have always been there, it's humans that are disturbing them (PAR 5)

> there's a lot of inaction, people spend a lot of time arguing about how to do things rather than just getting out and doing them...the issue is that everybody here wants to do things their way, organising around anything cooperative is difficult (PAR 17)

Hunters spoke about what they perceived as a lack of respect coming from some members of the community representing 'conservationist' interests. Some of these comments were expressed in a tone of despondency, about what were perceived uncaring attitudes towards pigs, and the people who utilise them

> people won't listen to me, because of who I am. There's no respect, we've offered to help but they keep shitting on us (PAR 13)

> It's not pig numbers, in a year I'd only get 5 or 6 killers...the issue is that they just don't like pigs and so want them gone, it's not even about the effects pigs have on the environment, it's just about their own properties. They would rather make a big fuss than sort it out for themselves (PAR 14)

> with the conservationists it's all or nothing too, with [name], don't get me wrong, they're a dear friend and I respect what they're trying to do, but they don't care about anything else...they want to use poison everywhere, and when they tested for poison a few years ago the results came back that it was getting into the pigs (PAR 13)

Regarding issues to do with management of wild pigs on conservation land (as distinct from private properties adjoining Oruawharo swamp), hunters' concerns were mainly of a logistic nature, citing lack of funding: "DOC never has any money" (PAR 6), and, challenges of terrain: "part of the issue is the terrain up there. There're paths everywhere so pigs run off in all different directions, there are bluffs there that someone lost a dog off. I lost a dog over the waterfall on the Kaiaraara, luckily it was saved by the pool below (PAR 3)

Non-hunter concerns were around the effectiveness of hunters as pig managers, and the risks that ill-trained hunting dogs could pose to livestock:

> The people down here don't hunt as much as they used to; in fact I don't know any pig hunters down here now. I mean there's [name] that used to but I don't think he does any more (PAR 1)

> The other thing is that they've always let the sows go here, and I've heard that they're catching the males and cutting them and releasing them so they can get big. Yeah they're kind of breeding them in a way, letting sows go all the time and they can have up to ten, or let's say 6 to 8 babies, and they can breed twice a year (PAR 2)

> Down here seems like they've run out of young people to actually do it you know. Because keeping a dog is a big hassle; same with the dogs up there, they go missing all the time and you need to be a responsible dog owner to chase pigs. It costs, you're not saving money by eating pork you know, it costs a lot of money to have pig dogs and stuff (PAR 1)

4.3.5. *Community recommendations for solutions to the pig dilemma*

In order to understand perceived solutions to the issue of pigs impacting on petrels, I asked questions such as "what do you think the solutions are?", and "how do you feel about the idea of controlling pigs more around tākoketai areas?" Hunter responses were positive in tone: "there's no issues with controlling pigs, we just want to be able to keep on hunting them...if there're pigs that need to go, then that's what needs to happen" (PAR 14). "There's always been a kind of unspoken agreement that DoC can control pigs around the petrels" (PAR 9). With regard to the specific types of measures that could be employed to achieve control, hunting by local hunters was the most acceptable: "I reckon if you paid hunters to control them [pigs] there wouldn't be a problem. You'd have to turn them away, there'd be at least 20 turning up for the job" (PAR 8). Another hunter suggested fencing as an option for small areas: "I think small areas. Enclosing areas would work, fences keep pigs out well. You could work out the area you want to protect say down to 500 m and put a fence around it". These responses suggest that generally, hunters are not opposed to some forms of pig control, or exclusion of pigs from some tākoketai areas, in order to improve the seabirds' breeding success.

Both non-hunters and hunters expressed a need for communication of evidence, of pigs impacts and the need for pig management: "The solution I guess has gotta be through knowledge, cos a lot of them are naïve to what they [pigs] do. They'll defend the pigs before the biodiversity every time" (PAR 1). "I think what would help is having some information that helps people see what pigs can do to petrels. I don't think a lot of people know" (PAR 3)

4.3.6. Hunter knowledge of pigs and ecology

In this study, I asked various questions relating to hunter experiences and observations of pigs such as "what have you noticed about pigs over the years?", "where do you find pigs?", and "what have you noticed pigs eating?". One hunter remarked on the long-term trend of decline in pig numbers:

> the pigs have changed a lot since then...compared now to say twenty years you would have seen more. My dad used to shoot them before the war in the 40s and he said they were increasing and they were spreading out, back in those days when there was a lot of bracken fern...in the early days you wouldn't even need to use a dog, you'd just hear them fighting and stalk them (PAR 10)

The same hunter, who has hunted for over six decades on Aotea, and is regarded as a *kaumātua* in the community, had noticed a decrease in the size of pigs over the last three decades, which he attributed to domesticated varieties of pigs breeding with the "Captain Cooker" (the Polynesian pig, which was the first pig to be introduced to Aotearoa, by Captain Cook. The origin of these pigs were the

Tahitian and Tongan islands, which Cook visited on his voyages to Aotearoa. See Chapter 3, Section 3.3.3). Another elder hunter (PAR 5) stated, in reference to pig biology and behaviour:

> what you've got now are mutants. The Captain Cookers are strong and fast, and big through the shoulders. The *kunekune* or domestics [domesticated breeds of pigs, of European and Asian origin, that formed the majority of pig introductions from the 1800s onwards] are slow but they get fat. So you put them together and you get these pigs which are strong, fast and fat (PAR5)

> pigs are constantly on the move looking for food, if there's food they'll stay there for a week or so and then move on. The other thing that makes pigs move is people, as soon as they know people are in there they'll take right off (PAR 5)

As a result of time spent in the bush while hunting, hunters had developed a range of understandings about the environment, including decline in bird numbers:

> there are two things, preservation and deterioration; it's one or the other. How do we know that it's the other? Because it's gone silent. Fifteen years ago you would listen and hear the birds but now it's quiet. There are less cicadas too, in summer they used to drive you mad but now they're much quieter (PAR 5)

Two hunters were knowledgeable about tākoketai breeding areas and ecological significance:

> the petrels like the really steep slopes, under tree roots. They're not everywhere, mostly right up the top but if you know where to look you can find them. I reckon you could probably find them up [location], and other places like that if you looked. They need to be close to a place they can take off like a clear space; they can land just by crashing through the treetops but to take off again they need to be able to walk to somewhere they can launch from (PAR 6)

> Every muttonbird is coming home with 200 grams of fish and is turning that into fertiliser. Imagine how much fert is coming onto the island and that's how you grow totara on rock faces and mountains, and kauri, because you've got birds ferting the shit out of it (PAR 18)

Hunters acknowledged the damaging effects that pigs could have: "I haven't seen any burrows torn up myself but I know it does happen. It was amazing where [name] found sign of petrels; I had no idea they were there. And that's where there's cross over with the pigs, because they move right through there." (PAR 3); "pigs are carnivorous animals. They won't necessarily eat plants if they don't have to, they're selective and will eat just rats, lambs, birds if that's what is there where they are" (PAR 5); "I do understand how people feel, I have a vegetable garden so I know how upsetting it can be when a pig gets into it so that's why I've got it fenced. Pop hates pigs on his pasture, we all know the damage

that pigs can cause." (PAR 13); "yeah they [pigs] would definitely be able to smell the petrel burrows" (PAR 15).

In their time of hunting, hunters stated not having seen pigs around the Hirakimatā summit area because of changes in the substrate to steep rocky ground, which pigs don't like to forage in: "pigs won't go up to the top because it's steep, and it's rocky underfoot. Has anyone ever seen one up there?" (PAR 6); "the pigs have never gone up there (Hirakimata) in the 70 years that I've been here...it's stony with the gravel on the track. They go past it but they don't go up any further up the Kaiaraara Track" (PAR 10). Four hunters remarked on not having seen signs of pig interference with petrels or petrel burrows (e.g. depredating on birds, or rooting up burrows), despite having come across dead petrels, including those that had clearly been killed by cats, made clear by the removal of the breast from the bird, leaving the wings and feet behind. Additionally, hunters mentioned seeing rats and other birds that had been depredated by cats, and the frequency of encountering cats or cat sign on Aotea. This might suggest that hunters consider that cats are a more significant problem than pigs, or that they feel that pigs are being unfairly 'blamed' for bird depredations, similar to the way cat owners in Britain have insisted that dogs, rather than cats, are the real issue for wildlife (Palmer, 2022).

4.4. Discussion

4.4.1. The role of pigs and pig hunting on Aotea

Unlike some modern forms of hunting which tend to commodify hunting experiences through expensive gear and tourist-like experiences, hunting on Aotea is more atavistic, exemplified by a very simple set of methods and motivations, that bring hunters into intimate contact with wild animals, and with nature. This is similar perhaps, to what Von Essen (2020) characterised as the 'local' community of modern-day hunting practice, that demarcates hunters according to their affinity to place and position in relation to the influence of modernisation.

For indigenous cultures and rural communities throughout the world, hunting is important primarily as a source of food (Jordan, 2014). This is evident on Aotea, where for some hunters, wild pork currently provides the main source of protein, as it has in the past. The subsistence aspect of pig hunting is perhaps amplified by Aotea's isolation. At almost 100km from the mainland, the island is sufficiently far away for freight of fresh foodstuffs to be expensive and sometimes erratic, with the consequence that permanent residents are reliant on homegrown produce and locally sourced meat. Although it is possible for pigs to be raised or farmed, the land required for this is not available

everywhere, and is dependent on other resources (such as land, and money to buy pig feed) which are not available to some. Pigs therefore provide food security, the need for which has been keenly perceived in recent years as a result of trade disruptions, and biosecurity measures (which have meant a *rāhui* or restriction on fishing in some areas, to prevent the spread of invasive *Caulerpa* seaweed).

Also important, is the significance of pig hunting for island culture. As an ancient, universally human practice that persists in the present day, hunting is part of human heritage (Jordan, 2014). Such heritage has undoubtedly shaped the distinctive culture on Aotea, which is characterised by self-reliance and close connection to the land (Armitage, 2001). Hunting is also a recreational pursuit, in the sense that it supplies experiences that are enjoyable and that contribute health and wellbeing (Hunter, 2009). Because of these positive experiences, pig hunting has continued to be practiced on Aotea, occupying a central place in the lives of some island families, which the significance of cannot be overlooked.

Pig hunting holds nuanced meaning for Māori, who form 21% of the population of permanent residents on Aotea, and make up the majority of pig hunters on Aotea. Māori culture is epitomised by close relationships with nature, therefore *mahinga kai* practices which facilitate these relationships, as well as the knowledge systems which support them, are critical for Māori culture (Wehi & Lord, 2017). In this way, pig hunting allows the exercise of relationships and culture that are vital to *mana whenua*. *Whakapapa*, or lineage, is an important concept in Māori culture because it influences the nature of relationships. Despite pigs being a non-native animal introduced by Europeans, they are esteemed as *te kai o te rangatira*, because of the positive contribution they have made to Māori society. This symbolism is not dissimilar to that of the pig to indigenous peoples throughout the Pacific, as emblems of cultural, economic and political power (Kirch, 2014: Sand, 2021). On Hawai'i, where *pua'a* (pigs) have been present for over 1000 years, they are reflected in spirituality and myth as the demigod Kamapua'a (Charlot, 1987). Although pigs have been in Aotearoa for a shorter time than Hawai'i and other Pacific islands, the significance of pigs has nevertheless developed rapidly, and is especially high for Māori.

Socially, however, pigs are an issue because of the diverse community make-up of the island, and the fact that some groups oppose the presence of pigs. A great deal of opposition stems from property owners in the Oruawharo (Medlands Beach) settlement, backed by those with predominantly conservation interests, because of the effects that wandering pigs have on gardens and the surrounding dune-swamp environment. This issue, and the subsequent media publication of dissident voices, might give the impression that the island is overrun by pigs and major conflict surrounds management of pigs across the entire conservation estate. But this research suggests this is not the case. DoC has for many years been able to carry out predator management (including pigs) around sites for sensitive species, such as pāteke. This suggests that the 'pig problem' on Aotea may be more of a

manufactured conflict than an actual one (*sensu* Palmer, 2022), and may be explained by the process of cultural collision taking place, as newer residents and from cities clash with longer-term residents of rural areas (Costello, 2007). The real 'pig problem' for DoC, and conservation in general on Aotea, is that there are many additional sensitive sites (including tākoketai breeding habitat) that are not currently protected from pigs, and it is not fully understood how hunters would feel about more of these sites being protected in future.

Although a separate issue to wild pigs on conservation land, the pigs originating from farms and around Oruawharo are nonetheless related, because they drive perceptions about pigs in general, and because there is biological potential for these pigs to disperse and breed with wild pig populations. Technically, pigs that are neither wild nor on conservation land are not an issue for conservation agencies to deal with. But inaction as a result of a technicality is not a viable option, because if unaddressed, this issue will continue to drive conflict and generally damage relationships. If collaborative decision making around pigs is a goal of conservation management in future, then trust and relationships are all-important. To this end, agencies (DoC, and Auckland Council) could support a site-based intervention to contain pigs where they are desired (i.e., farms), and exclusion and/or removal of pigs where they are not (i.e. residential properties, and restoration areas), using methods that hunters and farmers find acceptable (such as employing a local hunter, or live trapping and slaughter for consumption). This may go a long way in defusing tension and gaining social license for collective decision making around pigs long-term.

4.4.2. Pig hunting as a dynamic biocultural process

The term 'biocultural' refers to the relationships of humans with nature (Bridgewater & Rotherham, 2019). Because these relationships concern people, places, and biota that change over time, they are dynamic and evolving (Berkes, 2012). Such relationships are responsive to changes in the social and natural environment, including introductions of novel biological taxa or human movement, and are adaptive to novel interactions through inventions of new practices and traditions (Winter & McClatchey, 2009). Traditional resource use and hunting are examples of biocultural practices that have arisen through biocultural co-evolution (Lyver *et al*., 2019). Examination of the history of pig utilisation on Aotea demonstrates the shifts that have occurred in practices around *mahinga kai*. Traditionally, *mana whenua* on Aotea lived in a complex hunter-gatherer-agrarian society, harvesting a range of seasonally abundant species and growing crops (McBurney, 2009). Changes in the abundance of these resources in relation to human usage would inevitably have dictated that customary harvest change too. At the time of the arrival of Europeans and pigs, the larger species of birds including moa had long disappeared, and Ngāti Rehua-Ngātiwai relied instead on smaller species of birds including seabirds, the shellfish that were plentiful in Aotea's estuaries and coast, and

fishing. Kumara were cultivated in extensive gardens in low-lying, flat areas near the coast (Law, 1972). The latter part of the 18th century and the 19th century instigated a time of rapid biocultural co-evolution on Aotea. The introduction of successive plant and animals species by Europeans, including some that would become invasive, provided the biotic agents of change, and the pressures of colonisation provided the social ones. Pigs were one biotic agent of change, which were positive for Māori in a material sense. It is likely that the initial introduction of pigs to Aotea was made by Māori shortly before 1796, through exchanges with tribes in the Coromandel, Bay of Plenty, and Bay of Islands. To begin with, the relationship of Māori to pigs was of an animal-husbandry nature, with pigs raised within settlements or on *motupoaka* (pig islands) lying close to the main island. Semi-domesticating and rearing pigs probably began what was an agricultural revolution, increasing food production and creating a new form of economy, as it did elsewhere in Aotearoa, where until the 1860's Māori dominated food production (Petrie, 2013). The agency generated by food production and trade would grow in importance as customary access to other sources of *mahinga kai* became restricted. Aided by the musket, the Ngāpuhi *utu* (retribution) raids, which were followed by the rapid intensification of European colonisation, signalled a time of chaos for many North Island tribes. On Aotea this crystallised in 1838, when following defeat to Ngāpuhi, the sale of 20,000 acres of land in northern Aotea was made to the American trader William Webster and two associates (McBurney, 2009). Inevitably, inhabitation and pig farming would have been disrupted, accelerating the escape or liberation of pigs into the bush. Population increase in these free-roaming pigs would have stimulated a shift to hunting as the primary means of harvest, which has continued to this day. Eco-centric hunting (Cahoone, 2009), being that for the purpose of managing pig populations to maintain ecosystem health, has emerged as a practice and is likely to proliferate as a conservation ethic grows in society, similar to what has been reported about young Swedish hunters. This capacity for hunting to culturally change in response to contemporary social and environmental needs, demonstrates its utility as an adaptive resource management tool, that could be leveraged for seabird conservation in future.

4.4.3. Ecological values & hunter expertise: opportunities for cooperation

Conflict arises because of difference and disagreement, which can have the effect of polarising groups either 'for' or 'against' management (McCleay, 2013; Redpath *et al*., 2013). But what is interesting about apparently opposing groups is that when they are closely engaged with, it emerges that there are often many areas of shared value between seemingly opposed groups. The 'cat debate' literature illustrates this well; for sample groups that represented groups typically 'for' and 'against' domesticated cat management in the United States and United Kingdom, there was a surprising amount of similarity in core values around protection of wildlife, animal health and welfare, and

responsible pet ownership (Wald *et al*., 2013; Crowley *et al*, 2022). This is very much the case on Aotea, where concerns for the environment are deeply held between both hunter and predominantly conservationist groups, albeit for somewhat different reasons: a point which does seem to have been buried beneath other matters. For hunters, environmental health is fundamental for maintaining the health of pigs and people, as components of interdependent socio-ecological systems. For non-hunters, environmental health is important for maintaining the integrity of natural systems and supporting native species, and benefiting those people who value socio-ecological systems in that way. Nevertheless, interview data suggest consensus exists around the importance of environmental quality, and mirror the findings of McEntee & Johnson's (2016) engagement with the community, in the co-production of a collective 'Ecology Vision' for Aotea. Having consensus has been identified as instrumental in resolving disputes and reaching amicable agreements (Young *et al*., 2016a).

Knowledge of the environment that arises from hunting practice can be considered a form of traditional ecological knowledge (TEK), or 'way of knowing' which is gathered by indigenous and traditional cultures over long periods of time (Berkes, Colding & Folke, 2000). This knowledge essentially produces long-term insights into the relationships between environmental health and human inhabitation, and other factors such as climate change. Although qualitative (and thus assumed sometimes to be unreliable), this knowledge has enabled cultures to regulate human activities and natural resource usage to the present day, so that resources are available for future generations (Gadgil, Berkes & Folke, 1993). The ability of TEK to identify long-term trends in natural phenomena, as well as gather detailed understandings of ecology on local scales, has invited recognition by the scientific community in recent years (Huntington, 2000). On Aotea, the *mātauranga* (Māori knowledge, including traditional ecological knowledge) that Māori hunters possess of native and non-native ecosystems is extensive, encompassing native species, changes in the state of forest over time, seabird ecology, and pig biology, population dynamics and behaviour. Additionally, hunters have highly developed skills in accessing off-track areas, tracking pigs, and capturing and dispatching pigs efficiently. Given the typical limitations of budget for agency responses to ecological issues, the resources of hunter knowledge and skills are valuable, and could be harnessed to optimise the efficiency and effectiveness of managing pigs.

4.4.4. Social barriers to success

Surprisingly, control of pigs on conservation land for conservation purposes emerged as something of a non-issue in this study. Hunters clearly indicated knowledge of *taonga* (treasured) species and seabirds, and were well aware of the damaging effects that pigs can have. I did not detect any opposition to the idea of targeted management of pigs around seabird breeding areas, which are generally acknowledged to be at high elevations (and thus difficult to access, for hunting). Opposition

was encountered to the specific objectives and methodology by which such management might be undertaken. These oppositions included total eradication, the use of commercial hunters, poisons, and waste of pig meat, which effectively violate 'hunter code' for managing pigs as a food resource. There appeared to be general acceptance of the existing efforts of DOC at controlling pigs around high-value species, and that improved pig management in some areas is necessary for improved species recovery. These findings indicate that hunters, if respected, engaged and involved, are willing to lend support and assistance to efforts to manage the pig population for biodiversity restoration, as well as for *mahinga kai*.

Perceptions of wildlife are usually shaped by experiences of direct encounters, which are understood through values, philosophies, and beliefs (Lee, 2017). One of the characteristics of pigs on Aotea, is that in some areas they are farmed, and frequent the margins of forest or estuarine areas which adjoin pasture. These factors contribute a high level of visibility of animals that otherwise remain quite inconspicuous in the largely forested environment of Aotea. For farmers and long-time residents of Aotea, who are accustomed to pigs and have the requisite skills to deal with them if they're a nuisance, pigs are just part of the landscape and are seen to belong. For newer residents, like those in Oruawharo, who lack previous encounters with pigs or the skills to dispatch them, and who hold urban values, pigs are perceived as being incompatible with the landscape or 'alien' (Antonsich, 2021). These subjective perceptions appear to have been grafted onto debates about pigs and conservation more generally.

The 'turnaround migration' of urban dwellers to rural or semi-rural areas is not a new phenomenon, and has been well-documented in the American West and beach towns around Australia (Costello, 2005; Judd & Witt, 2015). When town collides with country, clashes are a feature, and these can relate to values about what is important for places of settlement, as well as attitudes on how to go about doing things. Neighbourly relations are frequently fraught, and on Aotea, tension seems to hinge on ideas of the 'right' way of dealing with roaming pigs, and of communicating frustrations, which has incited a protectionist stance from nearby farmers and hunters who appear to be increasingly resistant to 'change'.

Typically, conservation conflict is triggered by management proposals which have the effect of introducing change, and hence uncertainty into the future, which can provocative of anxiety – an emotions which can produce defensive behaviours, rather than conciliatory ones (Crowley *et al*., 2017; Halperin & Tagar, 2017). Pig-related conflict on Aotea appears not to have been sparked by proposals to manage pigs more extensively, but by disagreements between neighbours over how to manage pigs on private land. This 'pig debate' has been active for some decades and appears to be centred in one area (Oruawharo), rather than being widespread.

Distrust in DoC is probably the result of various management decisions which have been made since the Department's establishment on the island in 1987, that have been cumulative in effect. These decisions include the eradication of goats from mainland Aotea in 2005 and the rat eradication from Rakitū Island (2.5 km offshore from Aotea) in 2017, both which were major operations, and the latter (which although approved by the trust representing *mana whenua*), sparked major opposition from some groups, and some *whānau* (Peart & Woodhouse, 2020). As well, on a small island like Aotea, the Department (as an agency of government) is the conspicuous face of authority, which islanders are characteristically skeptical of (Royle, 2014).

4.5. Conclusions

This research was undertaken with the intention of understanding the values that hunters, and key community stakeholders hold regarding pigs on Aotea. Emphasised by the findings was the importance of pigs as *mahinga kai* (food) for *whānau* on Aotea, for reasons of food security, customary practice, and *whakapapa* (lineage) as '*te kai o rangatira'* (the food of chiefs) that provided status and agency for Aotea Māori in a historic sense. As such, *whānau* attach positive value to pigs. Other groups in the community with more recent connections to the island, particularly those residing or involved in restoration efforts near Oruawharo, in the south-central portion of Aotea, attach negative value to pigs because of the damage they can cause in the natural environment, and the nuisance they can be around built-up areas. Convergence of values was apparent around maintaining ecosystem health, although for *whānau,* this value was expressed more spiritually (as *mauri* or life force) than by other. These shared values provide a common ground, which apparently opposed groups may be able to collaborate around in determining management of the ecological impacts of a species which is culturally valued as *mahinga kai*.

Although controversial because of the connection to pigs, the practice of pig hunting can and does manage a predator, promote care and connection to nature, and generate understandings of the local environment, over long time-scales. As well, pig hunting is dynamic in response to changing social and ecological circumstances. Hunting therefore holds considerable potential as an adaptive conservation tool, which could be harnessed as a 'force for good' in future for managing pigs. The benefits of empowering hunters and *mahinga kai* harvest could be improved efficiency and reduced cost of management effort, with improved outcomes for indigenous biodiversity, including endemic species of seabird.

However, empowering local hunters will not be achieved through transactional means. Historic hierarchical trust issues need to be remedied first, through humble, respectful attitudes of conservation

managers as agents of government; open, transparent communication; and, genuine partnerships which are based on meaningful relationships and shared decision making. To start, explicit communication that *mahinga kai* is one of the values that DoC considers when balancing values to protect at a particular site, and, that there are no covert plans to eradicate or poison pigs, could help to alleviate fears. Actions like personal interaction, sharing knowledge, and aligning more closely with local expectations of service to community could assist in building trust.

This research highlights another important issue: the complicated nature of invasive species conflicts. From the outside, it might seem to observers reliant on hearsay or media commentary that such conflicts are the direct result of clashes in the values of conservation management with local resource use values. But in the case of pigs on Aotea, the matter that is more conflicted is a group of semi-domesticated pigs that roam from farms onto neighbouring areas that are mostly privately owned or the focus of restoration by conservation groups, in a localised area. Conservation managers are not directly involved in this, and nor are wild-living pigs on the conservation estate – which is the concern of conservation management, and this study. Effectively, the pig conflict on Aotea is a 'neighbour war', between older farmer inhabitants, and more recent immigrants, and the issue isn't simply pigs, it's the balance of power in how the area develops. Regardless, the pig debate has generated a lot of noise and drawn much attention to pigs, creating the impression that pigs are a highly contested subject between conservation managers and hunters. But this is not the case: hunter responses indicated acknowledgement of the need to manage pigs, and reported hunting for the purpose of managing the pig population, as well as for procuring food. Obviously, this is a very positive finding for conservation managers, because it suggests that managing pigs within the indigenous ecosystems of the conservation estate is not completely hamstrung by the expectations of local hunters, but rather may be complementary to them. Pig management will still need to be approached sensitively by conservation managers, but the prospects for the future look good.

CHAPTER FIVE

Final conclusions, recommendations, and reflections

This study was undertaken with the aim of investigating the ecological and social aspects of managing the impacts of wild pigs (*Sus scrofa*) on seabirds, on an inhabited island in Aotearoa (Aotea, Great Barrier Island). Chapter Two examined the ecological interactions and impacts of pigs with seabirds, and seabird breeding habitat. Chapter Three provided an overview of the social characteristics of the island, and the feasibility of potential pig management in future. Chapter Four reported the findings of interviews with pig hunters and key stakeholders in the community, exploring in-depth the values and practices of hunting, and perceptions of conservation management on Aotea. This research provided valuable insights into the impacts of pigs on seabirds, and the social context of pig management on inhabited islands in Aotearoa. These enable recommendations for future management approaches to be made.

5.1. The role of pigs as drivers of seabird decline

This study found pigs frequently within habitat suitable for seabird breeding on Aotea, but found limited evidence of their direct impacts on seabirds and seabird breeding habitat (incidences of burrow damage and predation, and area of ground disturbed). Therefore, it may be inferred that pigs have the potential to drive population decline in a range of ways, but such drivers may be minor. Specifically, these are: reduction of breeding success (if chicks are predated), diminished breeding opportunities (through eliminating burrows, and disturbing/displacing potential breeding pairs), and reducing the breeding population size (through predation of adult birds) (Raine *et al*., 2020). Similarly, it may only be cautiously inferred from the marked differences in burrow frequencies and site characteristics between areas with presence and absence of pigs, that pigs are implicated in elimination of burrows, and driving selection of burrow sites that are susceptible to predation by cats. The detection of abundant rats, and cats, as well as pigs around breeding burrows further indicates that pigs may play a contributing, rather than major role, in seabird decline. Nevertheless, it is unlikely that seabird populations could increase in the presence of multiple predators, and combined predator impacts. If predators are left unmanaged, continued disappearance of burrows and localised extinction of seabirds from sites that are most impacted is possible, threatening the long-term survival of the species (Cuthbert, 2002). These factors justify the need for better management of pigs, in combination with management of feral cats, and rats, around seabird breeding areas.

5.2. Technical, and strategic pig management recommendations

Sites that it would be beneficial to targeted for management in future are Cooper's Castle, Matawhero, Nga Puke o Tararua (Hog's Back), and Windy Canyon. These sites that are in the 'core' seabird habitat surrounding Hirakimata, provide optimal seabird breeding habitat, and are also most preferred by pigs. Ideally, management of any predator(s) should be carried out on the scale of whole landscapes, rather than individual sites, to reduce reinvasion of predators from surrounding areas, and to maximise the benefits of control (Glen *et al*., 2013). Because of the reality that this may not be socially feasible on Aotea because of hunter expectations, a more targeted approach may be necessary, to fit local social context within the wider ecological landscape. Ground hunting with dogs is reported to be a highly effective method for managing pigs in rugged, forested environments, and Aotea has a wealth of local hunters who could be employed to provide hunting services (Latham & Yockney, 2020). However, given the difficulty of access and the hazards present at target sites (such as bluffs), hunting may be more suited to low-elevation areas, such as Kaiaraara valley, than higher elevations. Other methods would need to be employed at high elevation sites, that focus on deterring or near-excluding pigs, especially during seabird breeding season. Acoustic or olfactory fear cues (such as sound recordings of humans and dogs, broadcast on sonic playback devices) offer potential in this regard, as pig fencing, which is the only other alternative for pig exclusion, is very expensive and difficult to maintain (NPCA, 2018). Such cue-based tools have been effective in deterring stoats from predating ground-nesting seabirds, in braided river systems (Norbury *et al*., 2021). A risk of hunting or deterring pigs is encouraging movement into other areas. Given the proximity of Hirakimatā (the site of the main tākoketai breeding population, that has not been invaded by pigs), careful monitoring of changes in pig range would need to be implemented, and responses initiated if pigs should shift range. Control of rats and cats should be undertaken at sites simulaneously with pig management, to avoid any indirect effects that could arise from the removal of pigs (Russell, 2011).

Interviews with hunters revealed that hunters are not opposed to the idea of pig management around breeding seabirds *per se*. Hunters value the environment and are aware of the impacts that pigs can have in the forest, and on seabirds. As well, hunters themselves are often conservationists, demonstrating that *mahinga kai* and conservation interests are not mutually exclusive, but rather complementary. This is a positive finding, and suggests that pig management on Aotea in future is socially feasible. However, there are caveats to this. First, are *mahinga kai* values and practices that are culturally important, and that negate the feasibility of certain methodologies (specifically, toxins), for controlling pigs. Second, are the unique social characteristics and composition of the Aotea community, that contribute a great diversity of issues and views regarding pigs and their management on Aotea, and heighten the 'particularity' of conditions on which support for pig management may be contingent. For this reason, an adaptive, site-based approach to pig management will be required, that

balances *mahinga kai* with intrinsic ecological values in its kaupapa (vision) and is responsive to different socio-ecologic contexts across the island.

5.3. Reflections on transdiciplinary, socio-ecologic conservation research

Many challenges were present in this study, arising most notably from the remote study location. Difficult backcountry terrain, limited surveys of seabirds, the potential for tension between researchers and local pig hunters, and, lack of standardised methods for monitoring pigs, all conferred considerable methodological constraints for ecological research. As a result, the ecological component of this study was aimed at quantifying and describing specific impacts at a previously surveyed site, rather than attempting to survey and examining multiple sites, or investigate relationships between pig activity/abundance, and severity of direct impacts. Easily obtainable indices of pig distribution (frequency of pig sign on transects), activity (frequency of detections by wildlife cameras), and habitat disturbance (ground disturbance), in combination with observational study (of tākoketai burrow characteristics), were used to provide valuable preliminary data on the range of impacts that pigs have, that could form the basis of future investigation. To this end, linking pig incidence or abundance measures, to impacts (i.e., establishing a damage function), would be particularly useful for establishing the relationship between pig population levels and ecological impacts (Nottingham *et al*., 2019), and establishing the 'threshold' to which pigs need to be managed at specific sites. It is also imperative to comprehensively monitor burrows at pig-impacted sites, to accurately gauge population parameters and the rate at which these colonies are potentially declining.

Statistically, the study highlighted the challenges of analysing ecological data in which observations are rare, and in which predictor variables are categorical (i.e. arbitrary) rather than actual measures (such as canopy cover/height, food species). Designing data collection with this in mind in future, would improve modelling, and thus predictive power (Heinze *et al*., 2018).

Socially, it was 'awkward' as an outsider, to conduct research via largely remote means. Engagement time was limited, and it was difficult to make and keep connections, which I felt limited the scope of social research considerably, and introduced bias. I would highly recommend that future researchers on islands have a view to stay for extended periods, to improve the quality of the researcher-participant relationship and facilitate opportunities for exchange.

Finally, this study emphasised the need for comprehensive integration of social and ecological concepts and methodology when investigating conservation issues in inhabited landscapes. For example, the ecological component of this study suggested that hunting pressure, and pig behaviour to avoid predators (hunters), may explain pig spatial distribution and temporal activity on Aotea, in

addition to environmental factors. Awareness, and integration of factors such as these from outset of research, would enable more comprehensive understandings to be drawn.

5.4. Future research directions

The findings of this research will have applicability to conservation management on other inhabited islands, and inhabited landscapes more generally. Research to establish causal links between pig impacts and seabird population status and trends on Aotea should be continued. As well, engagement with hunters and the community on Aotea should be continued, to attain greater understanding of the 'particulars' that will frame pig management strategy in future.

APPENDIX 1

Tākoketai breeding habitat stratification method (Bell *et al*., 2020)

Breeding tākoketai are unevenly distributed across Aotea, with significantly higher densities of breeding birds found on high altitude ridges under mature, unlogged, and unburnt native forest than at lower altitudes or in other vegetation types on the island (Marchant & Higgins 1990; Bell *et al*., 2020). For this reason, to optimise the efficiency of the sampling design, the island was stratified into high-, medium-, and low-grade seabird habitat strata. First, all existing data on the presence and location of tākoketai breeding burrows on the island were collated using ArcMap version 10.6.1. map layers describing altitude, vegetation type, and the presence and absence of feral pigs (a major threat to burrow-nesting shorebirds on land, e.g., Cuthbert 2002) were overlaid, and the relationship between these three habitat variables and the densities of known tākoketai burrows on the island were visually examined to create definitions of high-, medium-, and low-grade black petrel habitat strata on Aotea as described in **Table 1.**

Table 1. Definitions of high-, medium-, and low-grade tākoketai breeding habitat on Aotea (reproduced from Bell *et al.,* 2020)

Habitat stratum	Vegetation type	Altitude (metres a.s.l.)	Feral pigs	Area (ha)	Example sites
High-grade	Mature forest	>400m	Absent	108	Hirakimatā; Matawhero
Medium-grade	Mature forest	>400m	Present	3,207	Te Paparahi
		>250 – 400m	Present		Cooper's Castle; Nga Puke Tararua
		<250m	Absent		Glenfern Sanctuary
	Scrubland	>250m	Present		
		<250m	Absent		Glenfern Sanctuary
Low-grade	Mature forest	<250m	Present	24,520	
	Scrubland	<250m	Present		
	Other (e.g. farms)	<250m	Present		Okupu

APPENDIX 2

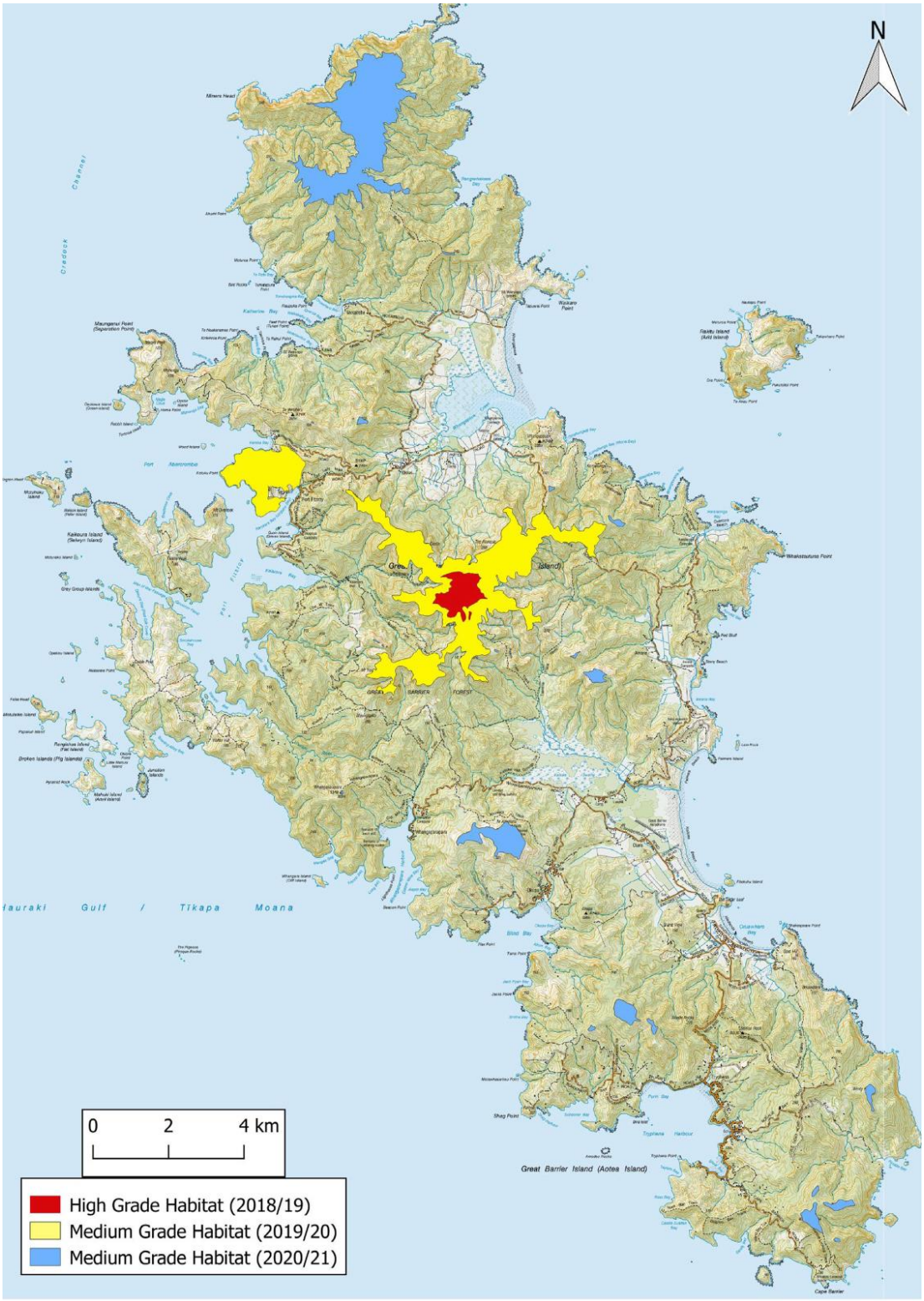
Distance sampling line transect survey method (Bell *et al*., 2020)

Line transect surveys were undertaken on Aotea (Great Barrier Island), in high- and medium-grade tākoketai habitat. These were spread over the summer seasons of 2018/2019 (high-grade habitat), 2019/2020 (core medium-grade habitat), and 2020/2021 (other medium-grade habitat). Random start points and compass bearings were generated for 100-m long line transects within each stratum. A team of two fieldworkers navigated to the start location of transect using a handheld Garmin GPS. One fieldworker then laid out a tape measure along the pre-defined compass bearing for the transect, before a second fieldworker slowly walked along the tape measure, scanning the ground. Pig sign was recorded as present or absent from each transect, and the type of sign (rooting, wallowing, runs, tracks, dung, live sightings, burrow damage, evidence of predation) was noted. Where obstacles or hazards were encountered, transects were truncated accordingly. A total of 391 transects were completed (**Table 2; Map 2**).

Table 2. Number of transects completed in the high- and medium-grade habitat strata on Aotea (Great Barrier Island)

Habitat statum	General area	No. of transects	Distance measured (m)		Total 2D area (ha)	Total 3D area (ha)
High-grade	Hirakimatā	80	7,582		97	107
Medium-grade	Core surrounding Hirakimatā	133	13,206		1,808	1,958
	Glenfern	50	4,958			
	Te Paparahi	100	9,926			
	The Needles	6	600			
	Ruahine	3	300			
	Te Ahumata	15	1500			
	Tramline	2	200			
	Windy Hill	2	200			

Map 2. Surveyed habitat strata on Aotea (Great Barrier Island)



APPENDIX 3

Questions for guiding semi-structured interviews

Topic 1 – introduction & importance of poaka (pig) hunting

How did you come to be on Aotea / Barrier?
Approximately how long have you been here?
What do you like about being here?
Do you identify as mana whenua or Māori?
Do you have members of your whānau/family who identify as mana whenua or Māori?
Do you currently go hunting, or have gone hunting in the past?
Why do you go hunting?
How often do you go hunting?
How important is hunting on this island?
What else is valuable/positive about pigs?

Topic 2 – poaka wisdom / mātauranga

How do you think the poaka are doing?
Have you noticed any changes in poaka over the years? For example, are they getting harder or easier to hunt, or going down or up in number etc.
Do you have any concerns about the poaka?
Thinking about where you hunt/see poaka, are there any areas where there are typically plenty of poaka, and areas where there are not many?
Have you ever noticed poaka up at the summit? What about Cooper's Castle?
Why do you think this is?
What do the poaka forage for?
What are poaka attracted to, or scared away by in the ngahere?
Have you noticed any pattern in poaka movements? Like are there any areas the poaka like to go to at different seasons, or times of day?
Do you think that poaka have any positive effects in the ngahere?
Do you think that poaka have any negative effects in the ngahere?
Thinking about poaka in relation to petrels, do you think that poaka can have any effects on the birds?
Have you ever seen poaka interacting with petrels or other seabirds, their burrows?

Topic 3– thoughts around how poaka are managed on Aotea

Do you have any concerns regarding the management of poaka on Aotea?
What do you think are the answers to these concerns?
What would you like to see in the future for poaka on Aotea?
Would you be supportive of trying to deter poaka (through harmless scent, sound or sight) from around the petrel colonies?
Would you be supportive of trying to exclude (through fencing) poaka from around the petrel colonies?
Do you have any questions / concerns about trying methods to deter to exclude poaka?
Are there any other potential ways of keeping poaka away from petrels that you can think of?

Would you be interested in helping protect the petrels by hunting poaka in the areas where they have their colonies?

Topic 4– knowledge & views around petrels (tākoketai)

Are you aware of the petrels living on Aotea/Barrier?

Do you know where the colonies are?

Have you personally had any experience of the petrels e.g. heard them at night, seen them on tracks at night?

Do you know anything else about the petrels?

Do you value the petrels being on Aotea? How & why?

What else do you value

Do you have any concerns about the petrels?

What do you think needs to be done to address these concerns?

Would you be interested in learning more about the petrels?

What would you like see in the future for the petrels?

Do you think the petrels can be successfully protected alongside poaka?

Topic 5 – conclusion

Do you have any other thoughts around poaka and / or petrels that you'd like to share, or are there any other issues you think are relevant/important that we didn't cover in this interview?

APPENDIX 4

List of study participants, and their affiliations. ‘Whānau’ is used in this instance to denote non-Māori participants who are part of Māori families. It is assumed Māori participants are inherently part of whānau.

ID	Māori	Non-Māori	Whānau	Hunter	Conservation
PAR1		Y			Y
PAR2		Y			Y
PAR3		Y			Y
PAR4	Y				Y
PAR5	Y			Y	
PAR6		Y		Y	Y
PAR7	Y			Y	
PAR8	Y			Y	Y
PAR9	Y				Y
PAR10		Y	Y	Y	Y
PAR11		Y	Y		Y
PAR12		Y			Y
PAR13	Y		Y	Y	
PAR14		Y	Y	Y	
PAR15	Y			Y	
PAR16		Y	Y		
PAR17		Y			Y
PAR18		Y		Y	Y
PAR19		Y		Y	Y
PAR 20		Y			Y

REFERENCES

Adams, W. M. (2004). *Against Extinction: The Story of Conservation*. Earthscan, London

Adger, N. & K. Vincent. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience* 337 399–410.

Albarella, U. (2007). *Pigs and humans: 10,000 years of interaction*. Oxford University Press, New York.

Aley, J.P. & Russell, J.C. (2019). A survey of environmental & pest management attitudes on inhabited Hauraki Gulf islands. *Science for Conservation Series* 336. New Zealand Department of Conservation, Wellington.

Allen, M.S., & Holdaway, R.N. (2010). Archaeological avifauna of Harataonga, Great Barrier Island, New Zealand: Implications for avian palaeontology, Maori prehistory, and archaeofaunal recovery techniques. *Journal of the Royal Society of New Zealand* 40(1), 11-25.

Anderson, A. (2017). Changing perspectives on Māori colonisation voyaging. *Journal of the Royal Society of New Zealand* 47(3), 222-231.

Antonsich, M. (2021). Native and aliens: Who and what belongs in nature and the nation? Area 53(2), 303-310.

Aotea Conservation Park Advisory Committee (ACPAC). (2022). ACPAC agenda and meeting 25-11-2022. https://ftp.doc.govt.nz/public/folder/oOkRQMxqEUKNepX4kTZWbg/aotea-conservation-park-advisory-committee/2022-minutes/20221125%20-%20ACPAC%20Agenda%20and%20meeting.pdf

Aotea Great Barrier Local Board. (2020). Aotea/Great Barrier Local Board Plan 2020. Auckland Council, Auckland.

Armitage, D. 2004. *Great Barrier Island.* (Revised edition). Canterbury University Press, Christchurch.

Armitage, D. (2022). The history of pigs on Great Barrier Island. https://sites.google.com/a/aotea.org/don-armitage/Home/great-barrier-island-fauna--flora/pest-control/the-history-of-pigs-on-great-barrier-island .(Accessed 20 May, 2022).

Arnstein, S.A. (1969). A Ladder of Citizen Participation. *Journal of the American Institute of Planners* 35, 216-224.

Attree, P., French, B., Milton, B., Povall, M., Whitehead, M. & Popay, J. (2011). The experience of community engagement for individuals: a rapid review of evidence. *Health and Social Care* 19(3), 250-260.

Auckland Council. (2019). Aotea Great Barrier Island Historic Heritage Survey - Appendix 1.2: Historic Context Statement. Auckland Council, Auckland. https://www.aucklandcouncil.govt.nz/arts-culture-heritage/heritage/heritagesurveys/aotea-great-barrier-island-historic-heritage-survey-appendix-1.2.pdf

Auckland Council. (2020). *Auckland Regional Pest Management Plan 2020-2030*. Auckland Council, Auckland. https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docsregionalpestmanagementstrategy/auckland-regional-pest-management-plan-2020-2030.pdf. (Accessed 25 April, 2022).

Auckland Council. (2023). Auckland Unitary Plan Operative in Part. Schedule 8 Outstanding Natural Character and High Natural Character Overlay Schedule. Auckland Council, Auckland. https://unitaryplan.aucklandcouncil.govt.nz

Auckland Tourism, Events, and Economic Development (ATEED). (2020). Aotea Economic Overview. Auckland Council, Auckland. 240 pp.

Baldacchino, G. (2006). Islands, island studies, island studies journal. *Island Studies Journal* 1(1), 3-18.

Baldacchino, G. (2008). Studying islands: on whose terms? Some epistemological and methodological challenges to the pursuit of island studies. *Island Studies Journal 3* (1), 37-56.

Barrios-Garcia, M.N. & Ballari, S.A. (2012). Impact of wild boar (*Sus scrofa*) in its introduced and native range: A review. *Biological Invasions* 14, 2283–2300.

Bartle, J.A. (1967). Records of Cook's and black petrels from Great Barrier Island. *Notornis* 14(1), 26-27.

Baskin, L.M., Danell, K. (2003). *Ecology of Ungulates: A Handbook of Species in Eastern Europe and Northern and Central Asia*. Springer, Berlin

Bassett, I. E., Cook, J., Buchanan, F., & Russell, J. C. (2016). Treasure Islands: biosecurity in the Hauraki Gulf marine park. *New Zealand Journal of Ecology* 40(2), 250-266.

Bassett, I.E., Horner, I.J., Hough, E.G., Wolber, F.M., Egeter, B., Stanley, M.C. & Krull, C. (2017). Ingestion of infected roots by feral pigs provides a minor vector pathway for kauri dieback disease *Phytophthora agathidicida. Forestry: An International Journal of Forest Research* 90(5), 640–648.

Bataille, C.Y., Luke, K., Kruger, T., Malinen, S., Allen, R.B., Whitehead, A.L . & Lyver, P.O'B. (2020). Stakeholder Values Inform Indigenous Peoples' Governance and Management of a Former National Park in New Zealand. *Human Ecology* 48(4), 439–453.

Bates, D. (2010). Linear mixed model implementation in lme4. Package lme4 vignette, available at: http://cran.r-project.org/web/packages/lme4/vignettes/Implementation.pdf

Beaglehole, J.C. (1961). *The journals of Captain James Cook on his voyage of discovery. Vol. 2: The voyage of the Resolution and Adventure 1772-1775*. Cambridge University Press, published for the Hakluyt Society.

Beausoleil, N.J., Fisher, P., Littin, K.E., Warburton, B., Mellor, D.J., Dalefield, R.R. & Cowan, P. (2016). A systematic approach to evaluating and ranking the relative animal welfare impacts of wildlife control methods: Poisons used for lethal control of brushtail possums (*Trichosurus vulpecula*) in New Zealand. *Wildlife Research* 43, 13.

Bell, E.A. (2013). Black petrel. In: C.M. Miskelly. (Ed.) New Zealand Birds Online. www.nzbirdsonline.org.nz (Accessed 20 May 2023).

Bell, B.D. & Brathwaite, D. H. (1964). The birds of Great Barrier and Arid Islands. *Notornis* 10(8), 363-383.

Bell, E.A., Burgin, D., Sim, J., Dunleavy, K., Fleishman, A. & Schofield, P. (2018). Population trends, breeding distribution, and habitat use of black petrel (Procellaria parkinsoni), 2016/17 operational report. *New Zealand Aquatic Environment and Biodiversity Report No. 198*. Ministry for Primary Industries, Wellington.

Bell, E.A., Mischler, C.P., MacArthur, N. & Sim, J.L. (2016). Black petrel (*Procellaria parkinsoni*)

population study on Hauturu-o-Toi/Little Barrier Island, 2015/16. Report to the Conservation Services Programme. Department of Conservation, Wellington.

Bell, E.A., Mischler, C., Sim, J.L. & Scofield, P., Francis, C., Abrahams, E. & Landers, T. (2016). At-sea distribution and population parameters of the black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2013/14. Report to the Conservation Services Programme. Department of Conservation, Wellington.

Bell, E., Ray, S., Crowe, P., Butler, D., Bell, M. & McArthur, N. (2020). Population trends, at-sea distribution, and breeding population size of black petrels (*Procellaria parkinsoni*) - 2019-2020 operational report. *New Zealand Aquatic Environment and Biodiversity Report No. 246*. Fisheries New Zealand, Wellington.

Bell, E., Ray, S. & Crowe, P. (2021). Population trends, at-sea distribution, and breeding population size of black petrels (Procellaria parkinsoni) on Great Barrier Island/Aotea: 2019-2020 operational report. *New Zealand Aquatic Environment and Biodiversity Report No. 270*. Fisheries New Zealand, Wellington.

Bell, E., Ray, S., Crowe, P., Butler, D., Bell, M. & McArthur, N. (2020). Population trends, at-sea distribution, and breeding population size of black petrels (*Procellaria parkinsoni*) - 2019-2020 operational report. *New Zealand Aquatic Environment and Biodiversity Report No. 246*. Fisheries New Zealand, Wellington.

Bell, E.A. & Sim, J.L. (1996). Survey and monitoring of black petrels on Great Barrier Island 1996. *Science for Conservation* 77. Department of Conservation, Wellington.

Bell, E.A, Sim, J.L. & Imber, M.J. (2000). Breeding biology and conservation of the Black Petrel Procellaria parkinsoni on Great Barrier Island, New Zealand. *Marine Ornithology* 28(2),

Bell, E.A., Welch, M. & Lamb, S. (2022). Key demographic parameters and population trends of tākoketai/black petrels (*Procellaria parkinsoni*) on Aotea/Great Barrier Island: 2021/2022. Unpublished Wildlife Management International Ltd. Technical Report to the Conservation Services Programme, Department of Conservation, Wellington.

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. Ecology Letters 15, 365-377.

Bellingham, P.J., Towns, D.R., Cameron, E.K., Wardle, D.A., Wilmshurst, J.M. & Mulder, C.P.H. (2009). New Zealand island restoration: seabirds, predators, and the importance of history. *New Zealand Journal of Ecology* 34(1), 115-136.

Bengsen, A.J., West, P.R. & Krull, C. (2017). Feral pigs in Australia and New Zealand: Range, trend, management, and impacts of an invasive species. *Ecology, Conservation and Management of Wild Pigs and Peccaries*, pp. 325-338. Cambridge University Press.

Bennett, N.J., Roth, R., Klain, S.C., Chan, K., Christie, P., Clark, D.A., Cullman, G., Curran, D., Durbin, T.J., Epstein, G., Greenberg, A, Nelson, M., Sandlos, J., Stedman, R., Teel, T.L., Thomas, R., Veríssimo, D. & Wyborn, C. (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation* 205, 93-108.

Benson, M. (2003). Migration and the search for a better way of life: A critical exploration of lifestyle migration. *The Sociological Review* 57(4), 608-625.

Berkes, F. (2012). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. (3rd Edition). Routledge, New York.

Berkes, F., Colding, J. & Folke, C. (2000). Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications* 10(5), 1251-1262.

Berkes, F., George, P., & Preston, R. J. (1991). Co-management: the evolution in theory and practice of the joint administration of living resources. *Alternatives: Perspectives on Society, Technology, and the Environment* 18(2), 12-18.

Bertram, G. & Watters, R.F. (1985). The MIRAB economy in South Pacific microstates. *Pacific Viewpoint* 26(3), 497–519.

Bertram, G. & Watters, R.F. (1986). The MIRAB process: Earlier analysis in context. *Pacific Viewpoint* 27(1), 47– 59.

Bertram, G. (1993). Sustainability, aid and material welfare in the small South Pacific Island economies: 1900– 1990. *World Development* 21(2), 247–258.

Bevins, S.N., Pedersen, K., Lutman, M.W., Gidleski, T. & Deliberto, T.J. (2014). Consequences associated with the recent range expansion of nonnative feral swine. *BioScience* 64 (4), 291-299.

Bidwell, S. & Thompson, L. (2015). Place invaders: Identity, place attachment and possum control in the South Island West Coast of New Zealand. *New Zealand Geographer* 71(2), 81-90.

Biosecurity New Zealand (2023). Exotic Caulerpa: How to spot it and report it. A Mana Whenua and Biosecurity New Zealand Partnership. Biosecurity New Zealand, Wellington.

Birdlife International. (2020). Species factsheet: Procellaria parkinsoni. IUCN Red list for birds (Accessed from www.birdlife.org on 4 April 2022).

Bjørneraas K., Herfindal I., Solberg E.J., Sæther B.E., van Moorter B. & Rolandsen C.M. (2012). Habitat quality influences population distribution, individual space use and functional responses in habitat selection by a large herbivore. *Oecologia* 168, 231–243.

Blackburn, T. (2011). A proposed unified framework for biological invasions. *Trends in Ecology & Evolution* 26(7), 333-339.

Blackburn, T., Pyšek, P., Bacher, S., Carlton, J.T., Duncan, R.P., Jarošík, V. & Wilson, J.R.U. A proposed unified framework for biological invasions. *Trends in Ecology & Evolution* 26(7), 333-339.

Blackburn, T.M., Pettorelli, N., Katzner, T., Gompper, M.E., Mock, K., Garner, T.W.J., Altwegg, R., Redpath, S.M. & Gordon, I.J. (2010) Dying for conservation: Eradicating invasive alien species in the face of opposition. *Animal Conservation* 13, 227-228.

Borkowski J. & Ukalska J. (2008). Winter habitat use by red and roe deer in pine-dominated forest. *Forest Ecology and Management* 255, 468–475.

Boulton, A. J., & Williford, A. (2018). Analyzing skewed continuous outcomes with many zeros: A tutorial for social work and youth prevention science researchers. *Journal of the Society for Social Work and Research 9*(4), 721–740.

Boyce, P., Bhattacharyya, J. & Linklater, W. (2022). The need for formal reflexivity in conservation science. *Conservation biology* 36(2), e13840.

Brockington, D. (2006). Parks and peoples: The social impact of protected areas. *Annual Review of Anthropology 35*(1), 251-277.

Brockington, D., Duffy, R. & Igoe, J. (2008). *Nature Unbound: Conservation, Capitalism and the Future of Areas*. Earthscan, London.

Brown, D.J., Jones, M.C., Bell, J. & Forstner, Michael R.J. (2012). Feral hog damage to endangered Houston toad (*Bufo houstonensis*) habitat in the lost pines of Texas. *The Texas Journal of Science* 64(1-4), 73-88.

Burholt, V., Scharf, T. & Walsh, K. (2013). Imagery and imaginary of islander identity: older people and migration in irish small-island communities. *Journal of Rural Studies* 31, 1-12.

Butler, J.R.A., Young, J.C., McGyn, I.A.G., Leyshon, B., Graham, I.M., Walker, I., Baxter, J.M., Dodd, J. & Warburton, B. (2015). Evaluating adaptive co-management as conflict resolution: Learning from seals and salmon. *Journal of Environmental Management* 160, 212-225.

Cahoone, L. 2009. Hunting as a moral good. *Environmental Values* 18(1), 67-89.

Caley, P. (1997). Movements, activity patterns and habitat use of feral pigs (*Sus scrofa*) in a tropical habitat. *Wildlife research* 24(1), 77–87.

Callicott, J.B., Crowder, L.B. & Mumford, K. (1999). Current normative concepts in conservation. *Conservation Biology* 13(1), 22-35.

Cameron, E. (2004). In: Armitage D (Ed.). *Great Barrier Island.* (Revised edition). Canterbury University Press, Christchurch. Pp. 82-103.

Campbell, D. J. & Rudge, M.R. (1984). Vegetation changes induced over 10 years by goats and pigs at Port Ross, Auckland Islands (sub-Antarctic). *New Zealand Journal of Ecology* 7 , 103-118.

Campbell, T.A. & Long, D.B. (2009). Feral swine damage and damage management in forested ecosystems. *Forest Ecology and Management* 257, 2319–2326.

Challies, C.N. 1975. Feral poaka (*Sus scrofa*) on Auckland Island: status, and effects on vegetation and nesting sea birds. *New Zealand Journal of Zoology* 2(4): 479-490.

Charlot, J. (1987). *The Kamapua'a literature: The classical traditions of the Hawaiian poaka God as a body of literature.* Brigham Young University, Hawaii.

Chimera, C., Coleman, M.C. & Parkes, J.P. (1995). Diet of feral goats and feral pigs on Auckland Island, New Zealand. *New Zealand Journal of Ecology* 19, 203–207.

Choquenot, D., McIlroy, J. & Korn, T. (1996). *Managing Vertebrate Pests: Feral Pigs*. Australian Government Publishing Service.

Clarke, C.M.H. & Dzieciolowski, R.M. (1991). Feral pigs in the northern South Island, New Zealand: I. Origin, distribution, and density. *Journal of the Royal Society of New Zealand* 21, 237–247.

Clontz, L.M., Pepin, K.M., VerCauteren, K.C. & Beasley, J. C. (2021). Behavioral state resource selection in invasive wild pigs in the southeastern United States. *Scientific Reports* 11(1), 6924–6924.

Clout, M. & Russell, J.C. (2006). The eradication of mammals from New Zealand Islands. In F. Koike, M.N. Clout, M. Kawamichi, M. De Poorter, and K, Iwatsuki. (Eds.). *Assessment and Control of Biological Invasion Risks*. Shoukadoh Book Sellers, Kyoto, Japan and the World Conservation Union (IUCN), Gland, Switzerland, pp.127-141.

Coblentz, B.E., & Baber, D.W. (1987). Biology and Control of Feral Pigs on Isla Santiago, Galapagos, Ecuador. *The Journal of Applied Ecology* 24(2), 403-418.

Cohen, P.J., Lawless, S., Dyer, M., Morgan, M., Saeni, E., Teoli, H. & Kantor, P. (2016). Understanding adaptive capacity and capacity to innovate in social–ecological systems: Applying a gender lens. *Ambio* 45, 309–321.

Condon, R.G., Collings, P., & Wenzel, G. (1995). The Best Part of Life: Subsistence Hunting, Ethnicity, and Economic Adaptation among Young Adult Inuit Males. *Arctic* 48(1), 31-46.

Conservation Act 1987. https://www.legislation.govt.nz/act/public/1987/0065/latest/DLM104081.html

Corradini, A. F., Marescotti, M.E., Demartini, E. & Gaviglio, A. (2022). Consumers' perceptions and attitudes toward hunted wild game meat in the modern world: A literature review. *Meat Science* 194, 108955.

Cosgrove, J. (2018, May 26). More women feeling the thrill of the hunt. https://www.stuff.co.nz/national/104232532/more-kiwi-women-feeling-the-thrill-the-of-the-hunt

Costello, L. (2007). Going bush: the implications of urban-rural migration. *Geographical Research* 45(1), 85-94.

Courchamp, F., Chapuis, J.L. & Pascal, M. (2003). Mammal invaders on islands: impact, control and control impact. *Biological Reviews* 78, 347–383.

Croll, D.A., Newton, K.M., McKown, M., Holmes, N., Williams, J.C., Young, H.S., Buckelew, S., Wolf, C., Howald, G., Bock, M.F., Curl, J.A. & Tershy, B.R. (2016). Passive recovery of an island bird community after rodent eradication. *Biological Invasions* 18(3), 703–715.

Cronon, W. (1996). The trouble with the wilderness: Or, getting back to the wrong nature. *Environmental History* 1(1), 7-28.

Crowley, S., Degrange, L., Matheson, D. & McDonald, R.A. (2022). Comparing conservation and animal welfare professionals' perspectives on domestic cat management. *Biological Conservation* 272, 10969.

Crowley, S., Hinchliffe, S. & McDonald, R.A. (2017). Conflict in invasive species management. *Frontiers in Ecology and Environment* 15(3), 133-141.

Crowley, S., Hinchliffe, S. & McDonald, R.A. (2017b). Invasive species management will benefit from social impact assessment. *Journal of Applied Ecology* 54(2), 351-357.

Croxall, J.P., Butchart, S.H.M., Lascelles, B., Stattersfield, A.J., Sullivan, B., Symes, A. & Taylor, P. (2012). Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International* 22, 1–34.

Cuthbert, R. (2002). The role of introduced mammals and inverse density-dependent predation in the conservation of Hutton's shearwater. *Biological Conservation* 108(1), 69-78.

Davenport, L. (2022, August). The problem with pork. Barrier Bulletin 836. Aotea (Great Barrier Island).

Davis, M., Chew, M., Hobbs, R., Lugo, A., Ewel, J., Vermeij, G., Brown, J., Rosenzweig, M., Gardener, M., Carroll, S., Thompson, K., Pickett, S. T. A., Stromberg, J. C., Del Tredici, P., Suding, K. N., Ehrenfeld, J. G., Grime, J. P., Mascaro, J., & Briggs, J. C. (2011). Don't judge species on their origins. *Nature* 474 (7350), 153–154.

Dawbin, W.H. (1949). The tuatara. *Tuatara* 2(2), 91-95. https://nzetc.victoria.ac.nz/tm/scholarly/tei-Bio02Tuat02-t1-body-d7.html

De Roy, T., Jones, M. & Fitter, J. (2008). Albatross: Their World, Their Ways. David Bateman.

Department of Conservation. (DoC). (2001). *Department of Conservation's Policy Statement on Deer*. Department of Conservation, Wellington.

Department of Conservation (DoC). (2014). CMS. Conservation management strategy: Auckland 2014-2024. Operative 17 November 2014. Department of Conservation, Wellington.

Department of Conservation (DoC). (2018, September 17). Pest control operation devaststed by theft. (Media release). https://www.doc.govt.nz/news/media-releases/2018/pest-control-operation-devastated-by-theft/

Department of Conservation (DoC). (2020). Predator Free New Zealand 2050 Strategy. Department of Conservation, Wellington.

Department of Conservation (DoC). (2022). *Te Ara ki Mua Framework for Adaptive Management of Wild Animals*. https://www.doc.govt.nz/nature/biodiversity/aotearoa-new-zealand-biodiversity-strategy/te-ara-ki-mua-framework/

Department of Conservation (DoC). (2022). Aotea Conservation Park Advisory Committee (ACPAC) Agenda and meeting papers for ACPAC Meeting 25, 25-11-2022.

Department of Conservation (DoC). (2022b). *Te Ara ki Mua: A Framework for Adaptive Management of Wild Goats, Deer, Wild pigs, Tahr and Chamois*. Department of Conservation, Wellington.

Descola, P. (2013). *Beyond Nature and Culture.* Translated by J. Lloyd. University of Chicago Press, Chicago.

Dickson, B., Hutton, J. & Adams, W. M.(2009). *Recreational Hunting, Conservation, and Rural Livelihoods*. Blackwell, Oxford, U.K.

DIISE. (2023). The Database of Island Invasive Species Eradications: developed by Island Conservation, University of California Santa Cruz Coastal Conservation Action Lab, IUCN SSC Invasive Species Specialist Group, University of Auckland and Landcare Research New Zealand. http://diise.islandconservation.org

Dillon, D. (2008). Rural contexts: Islands. In: Ross, J. (Ed.). *Rural Nursing: Aspects of Practice*, pp. 3-18. Rural Health Opportunities, New Zealand.

Doherty, T.S., Glen, A.S., Nimmo, D., Ritchie, E. & Dickman, C.R. (2016). Invasive species and global biodiversity loss. *Proceedings of the National Academy of Sciences* 113(40), 11261-11265.

Donne, T.E. (1924). *The Game Animals of New Zealand: An Account of their Introduction, Acclimatisation, and Development*. John Murray, London.

Doupé, R.G., Mitchell, J., Knott, M.J., Davis, A.M. & Lymbery, A. J. (2010). Efficacy of exclusion fencing to protect ephemeral floodplain lagoon habitats from feral pigs (*Sus scrofa*). *Wetlands Ecology and Management* 18(1), 69-78.

Ducarme, F., Flipo, F. & Couvet, D. (2020). How the diversity of human concepts of nature affects conservation of biodiversity. *Conservation Biology* 35 (3), 1019-1028.

Eason, C., Miller, A., Ogilvie, S., & Fairweather, A. (2011). An updated review of the toxicology and ecotoxicology of sodium fluoroacetate (1080) in relation to its use as a pest control tool in New Zealand. *New Zealand Journal of Ecology 35*(1), 1-20.

Egan, D., Hjerpe, E.E., Abrams, J. (2011). Why people matter in ecological restoration. In: Egan, D., Hjerpe, E.E., Abrams, J. (Eds) *Human Dimensions of Ecological Restoration*. Society for Ecological Restoration, Island Press, Washington DC.

Elledge, A.E., McAlpine, C.A., Murray, P.J. & Gordon, I.J. (2013). Modelling habitat preferences of feral pigs for rooting in lowland rainforest. *Biological Invasions* 15(7), 1523–1535.

Ellis, J. C. (2005). Marine birds on land: A review of plant biomass, species richness, and community composition in seabird colonies. *Plant Ecology* 181(2), 227–241.

Elton, C.S. (1958). *The Ecology of Invasions by Animals and Plants.* University of Chicago Press, Chicago.

Ens, E.J., Daniels, C., Nelson, E., Roy, J. & Dixon, P. (2016). Creating multi-functional landscapes: Using exclusion fences to frame feral ungulate management preferences in remote Aboriginal-owned northern Australia. *Biological Conservation* 197, 235-246,

Esteves, A.M., Franks, D. & Vanclay, F. (2012). Social impact assessment: The state of the art. *Impact Assessment & Project Appraisal* 30(1), 35-44.

Estevez, R.A., Anderson, C.B., Pizarro, J.C. & Burgman, M.A. (2015). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology* 29, 19-30.

Estévez, R.A., Walshe, T., & Burgman, M.A. (2013). Capturing social impacts for decision-making: a multicriteria decision analysis perspective. *Diversity & Distribution* 19, 608-616.

Falla, R.A. (1948). The outlying islands of New Zealand. *New Zealand Geographer* 2(4), 127-154.

Farnworth, M.J., Campbell, J. & Adams, N. (2011) What's in a name? Perceptions of stray and feral cat welfare and control in Aotearoa, New Zealand. *Journal of Applied Animal Welfare Science* 14(3), 269–270.

Farrier, L. (2011). Caring for place: negotiating world heritage on Lord Howe Island. [Bachelor of Science (Honours) thesis]. School of Earth & Environmental Sciences, University of Wollongong, Australia.

Fisher, P., O'Connor, C., Wright, G. & Eason, C.T. (2003). Persistence of four anticoagulants rodenticides in the livers of laboratory rats. *DOC Science Internal Series 139*. Department of Conservation, Wellington.

Flynn, D.O., Frost, L. Latham, A.J.H. (1999). *Pacific Centuries : Pacific and Pacific Rim History Since the Sixteenth Century*. Routledge, London.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S. & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio* 31, 437–440.

Folke, C., Hahn, T., Olsson, P. & Norberg, J. (2005), Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* 30(1), 441-473.

Ford, M.A. & Grace, J.B. (1998). Effects of vertebrate herbivores on soil processes, plant biomass, litter accumulation and soil elevation changes in a coastal marsh. *Journal of Ecology* 86, 974–982.

Gaskin, C. (2014). *New Zealand Seabirds: Important Bird Areas and Conservation.* The Royal Forest & Bird Protection Society of New Zealand, Wellington.

Fowler, P. (2002). World Heritage Cultural Landscapes 1992-2002: A Review and Prospect. *In: Cultural Landscapes: the Challenges of Conservation. World Heritage Papers 7*. Pp. 16-29. UNESCO World Heritage Centre, Paris.

Franckowiak, G.A., Torres-Poché, Z. & Poché, R.M. (2018). Activity patterns by feral hogs in the Texas panhandle. *The American Midland Naturalist* 180(2), 233–245.

Frank, D. M. (2019). Disagreement or denialism? 'Invasive species denialism' and ethical disagreement in science. *Synthese* 198(25), 6085–6113.

Frantz, A.C., Massei, G. & Burke, T. (2012) Genetic evidence for past hybridisation between domestic pigs and English wild boars. Conservation Genetetics 13, 1355–1364.

Fraser, A. (2006). Public attitudes to pest control: A literature review. *DOC Research and Development Series 227*. Department of Conservation, Wellington.

Fraser, K.W. (2000). Status and conservation role of recreational hunting on conservation land. *Science for Conservation 140*. Department of Conservation, Wellington.

Fraser, K. W. & Speedy, C. J. (1997). Hunting pressure, deer populations, and vegetation impacts in the Kaimanawa Recreational Hunting Area. *Science for Conservation* 47. Department of Conservation, Wellington.

Freitas, C.T., Lopes, P.F.M., Campos-Silva, J.V., Noble, M.M., Dyball, R. & Peres, C.A. (2020). Co-management of culturally important species: A tool to promote biodiversity conservation and human well-being. *People and Nature* 2, 61– 81.

Friesen, M.R., Simpkins, C.E., Ross, J., Anderson, S.H., Ismar-Rebitz, S., Tennyson, A., Taylor, G.A., Baird, K.A. & Chris P. Gaskin (2021) New population estimate for an abundant marine indicator species, Rako or Buller's Shearwater (*Ardenna bulleri*). *Emu - Austral Ornithology* 121(3), 231-238.

Fukami, T., Wardle, D.A ., Bellingham, P.J., Mulder, C.P.H ., Towns, D.R., Yeates, G.W., Bonner, K.I., Durrett, M.S., Grant-Hoffman, M.N. & Williamson, W.M. (2006). Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. *Ecology Letters* 9, 1299–1307.

Gadgil, M., Berkes, F, & Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio* 22(2-3), 151-156.

Galetti, M., Camargo, H., Siqueira, T., Keuroghlian, A., Donatti, C. I., Jorge, M.L. & Ribeiro, M. C. (2015). Diet overlap and foraging activity between feral pigs and native peccaries in the Pantanal. *PloS One* 10(11), E0141459.

Gaskin, C. P. & Rayner, M. J. (2017). *Seabirds of the Hauraki Gulf (revised*). Hauraki Gulf Forum, Auckland.

Gentle, M., Speed, J. & Marshall, D. (2015). Consumption of crops by feral pigs (*Sus scrofa*) in a fragmented agricultural landscape. *Australian Mammalogy* 37(2), 194-200.

Gentle, M., Wilson, C., & Cuskelly, J. (2022). Feral pig management in Australia: Implications for disease control. *Australian Veterinary Journal* 100(10), 492-495.

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of Grounded Theory*. Taylor and Francis.

Glen, A.S., Atkinson, R., Campbell, K.J., Hagen, E., Holmes, N.D., Keitt, B.S., Parkes, J.P., Saunders, A., Sawyer, J. & Torres, H. (2013) Eradicating multiple invasive species on inhabited islands: the next big step in island restoration? *Biological Invasions* 15(12), 2589–2603.

Glen, A. S., Pech, R. P., and Byrom, A. E. (2013). Managing invasive species: towards an integrated landscape approach. *Biological Invasions* 15, 2127–2138.

Glen, A.S. & Hoshino, K. (2020). Social and logistical challenges in managing invasive predators: Insights from islands in Japan and New Zealand. *Pacific Conservation Biology* 26(4), 344–352.

Goulet, D. (1993) Biological diversity and ethical development. In Hamilton, L.S. (Ed). *Ethics, Religion and Biodiversity; Relations between Conservation and Cultural Values*, pp. 17–39. White Horse Press, Cambridge, UK.

Green, W. & Rohan, M. (2012) Opposition to aerial 1080 poisoning for control of invasive mammals in New Zealand: Risk perceptions and agency responses. *Journal of the Royal Society of New Zealand* 42(3), 185-213.

Green, W. (2004). The use of 1080 for pest control: A discussion document. Department of Conservation and Animal Health Board, Wellington. 60 p.

Greenaway, A., Hohaia, H., Le Heron, E., Le Heron, R., Grant, A., Diprose, G., Kirk, N., & Allen, W. (2022). Methodological sensitivities for co-producing knowledge through enduring trustful partnerships. Sustainability science 17 (2), 433-447

Grémillet, D. & Boulinier, T. (2009). Spatial ecology and conservation of seabirds facing global climate change: a review. *Marine Ecology Progress Series* 391, 121-137.

Griffiths, R., Bell, E., Campbell, J., Cassey, P., Ewen, J.G., Green, C., Joyce, L., Rayner, M., Toy, R., Towns, D., Wade, L., Walle, R. & Veitch, C.R. (2019). Costs and benefits for biodiversity on Little Barrier Island. In: C.R. Veitch, M.N. Clout, J.C. Russell & C.J. West. (Eds.). *Island Invasives: Scaling Up to Meet the Challenge. Occasional Paper SSC no. 62*. IUCN, Switzerland.

Griffiths, R., Buchanan, F., Broome, K., Neilson, J., Brown, D. & Weakly, M. (2014). Successful eradication of invasive vertebrates from Rangitoto and Motutapu Islands, New Zealand. *Biological Invasions* 17, 1355–1369.

Grydehøj, A. & Hayward, P. (2014). Social and economic effects of spatial distribution in island communities: Comparing the Isles of Scilly and the Isle of Wight, UK. Journal of Marine and Island Cultures 3, 9–19.

Gutiérrez, N. L., Hilborn, R. & Defeo, O. (2011). Leadership, social capital and incentives promote successful fisheries. *Nature* 470, 386–389.

H.M. (1991) France in the Caribbean. In P. Sutton (ed.). *Europe and the Caribbean*, pp. 37–70. Macmillan, London.

Halperin, E. & Tagar, M.R. (2017). Emotions in conflicts: Understanding emotional processes sheds light on the nature and potential resolution of intractable conflicts. *Current Opinion in Psychology* 17, 94-98.

Hansford, D. (2016). *Protecting Paradise: 1080 and the Fight to Save New Zealand's Wildlife*. Potton & Burton, Nelson.

Harmsworth, G.R. & Awatere, S. (2013). Indigenous Māori knowledge and perspectives of ecosystems. In J.R. Dymond (Ed.). Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand. Pp. 274-286.
Hartig, F. (2022). Package 'dHARMA'. Residual diagnostics for hierarchical (multi-level/mixed) regression models. Version 0.4.6.

Hau'ofa, E. (1994). Our sea of islands. *The Contemporary Pacific* 6(1), 147-161. Hawai'i Press, Honalulu.

Hay, P. (2006). A phenomenology of islands. *Island Studies Journal* 1(1), 19–42.

Hay, P. (2013). What the sea portends: a reconsideration of contested island tropes. *Island Studies Journal* 8, 209-232.

Heather, B.& Robertson, H. (1996). *Field Guide to the Birds of New Zealand*. Penguin Books (NZ) Ltd, Auckland. 432 p.

Hegel, C. G. Z., Santos, L. R., Marinho, J. R. & Marini, M. Â. (2019). Is the wild pig the real "big bad wolf"? Negative effects of wild pig on Atlantic forest mammals. *Biological Invasions* 21(12), 3561-3574.

Heinze, G., Wallisch, C. & Dunkler, D. (2018). Variable selection - a review and recommendations for the practicing statistician. *Biometrical Journal* 60(3), 431-449.

Hill, C.M., Priston, N.E.C. & Webber, A.D. (Eds). (2017). *Understanding conflicts about wildlife: A biosocial approach*. Berghahn Books, New York.

Hjort af Ornäs, A. & Svedin, U. (1992). Cultural variation in concepts of nature. *GeoJournal* 26(2), 167-172.

Holloway, J. (1991). Role of commercial harvesting in the management of wild deer. *New Zealand Forestry* 36(1), 3.

Hone, J. (2012). *Applied Population and Community Ecology: The Case of Feral Pigs in Australia.* Wiley, Hoboken.

Horn, S. R. (2022). The next frontier : assessing the feasibility of eradicating mammalian pests from Auckland Island. *New Zealand journal of ecology* 46 (3).

Horsburgh, K.A., Gosling, A.L., Cochrane, E.E., Kirch, P.V., Swift, J.A. & McCoy, M.D. (2022). Origins of Polynesian pigs revealed by mitochondrial whole genome ancient DNA. *Animals* 12(18), 2469.

Hothorn, T. & Mlller, J. (2010). Large-scale reduction of ungulate browsing by managed sport hunting. *Forest Ecology & Management* 260, 1416-1423.

Howie, L. (2008). Rural society and culture. In: Ross, J. (Ed.). *Rural Nursing: Aspects of Practice*, pp. 19-30. Rural Health Opportunities, New Zealand.

Hunter, K.M. (2009). *Hunting: A New Zealand History*. Random House, Auckland.

Huntington, H. P. (2000). Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications* 10, 1270-1274.

Husheer, S.W. & Robertson, A.W. (2005). High-intensity culling increases growth of mountain beech seedlings in New Zealand. *Wildlife Research* 32, 273-280.

Ickes, K., Dewalt, S.J. & Thomas, S.C. (2003). Resprouting of woody saplings following stem snap by wild pigs in a Malaysian rain forest. *Journal of Ecology* 91, 222–233.

Imber, M.J. (1987). Breeding ecology and conservation of the black petrel (*Procellaria parkinsoni*). *Notornis 34,* 19–39.

Imber, M.J., McFadden, I., Bell, E.A. & Schofield, R.P. (2003). Post-fledging migration, age of first return and recruitment, and results of inter-colony translocation of black petrels (Procellaria parkinsoni). *Notornis* 50, 183-90.

Infield, M., Entwistle, A., Anthem, H., Mugisha, A. & Phillips, K. (2018). Reflections on cultural values approaches to conservation: Lessons from 20 years of implementation. *Oryx* 52(2), 220-230.

Innes, J., Warburton, B., Williams, D., Speed, H. & Bradfield, P. (1995). Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. *New Zealand Journal of Ecology* 19, 5–17.

Jacobsen, S.K. & McDuff, M.D. (1998). Training idiot savants: The lack of human dimensions in conservation biology. *Conservation Biology* 12(2), 263-267.

Jolley, D. Ditchkoff, B., Sparklin, S.S., Hanson, B.D., Mitchell, M.S. & Grand, J.B. (2010). Estimate of herpetofauna depredation by a population of wild pigs. *Journal of Mammalogy* 91(2), 519-524.

Jones, H. P, Holmes, N.D., Butchart, Stuart, H.M., Tershy, B.R. & Kappes, P.J. *et al*. (2016). Invasive mammal eradication on islands results in substantial conservation gains. *Proceedings of the National Academy of Sciences* 113, 4033–4038.

Jordan, P. (2014). In Cummings, V., Jordan, Peter, & Zvelebil, Marek. *The Oxford handbook of the archaeology and anthropology of hunter-gatherers* pp. 903-917. Oxford University Press, Oxford.

Judd, D. R. & Witt, S.L. (2015). *Cities, Sagebrush, and Solitude : Urbanization and Cultural Conflict in the Great Basin*. University of Nevada Press, Nevada.

Kannemeyer, R. L. (2013). *Public attitudes to pest control and aerial 1080 use in the Coromandel.* (Doctoral dissertation). University of Auckland, Auckland

Kapa, D. (2003). The eradication of kiore and the fulfilment of Kaitiakitanga obligations. *Te Mata Koi: Auckland University Law Review* 9(4) 1326-1352.

Kidd, C. (2016). The political ontology of conservation. In *Culture and Conservation: Investgating the Linkages Between Biodiversity Protection and Cultural Values and Practices, pp. 6-15*. Arcus Foundation, New York.

Kier, G., Kreft, H., Lee, T.M., Jetz, W., Ibisch, P.L., Nowicki, C., Mutke, J. & Barthlott, W. (2009). A global assessment of endemism and species richness across island and mainland regions. *PNAS* 106, 9322–27

King, C. (2019). Hard lessons in pest management (1976-2019). In King, C. (Ed.). *Invasive Predators in New Zealand: A Disaster on Four Small Paws*, pp. 277-323. Palgrave MacMillan, London.

King, C. M., & Forsyth, D.M. (Eds). (2021). *The Handbook of New Zealand Mammals*. Third edition. Otago University Press Te Whare Tā o Te Wānanga o Ōtākou, Dunedin.

Kirch, P. V. (2014). *Kua'āina Kahiko: Life and Land in Ancient Kahikinui, Maui*. University of

Knight, J. (2012). The anonymity of the hunt: a critique of hunting as sharing. *Current Anthropology* 53(3), 334–355.

Kramer, C.J., Boudreau, M.R., Miller, R.S., Powers, R., VerCauteren, K.C. & Brook, R.K. (2022). Summer habitat use and movements of invasive wild pigs (*Sus scrofa*) in Canadian agro-ecosystems. *Canadian Journal of Zoology* 100(8), 494-506.

Krull, C. R., Choquenot, D., Burns, B. & Stanley, M. (2013b). Feral pigs in a temperate rainforest ecosystem: disturbance and ecological impacts. *Biological invasions* 15(10), 2193–2204.

Krull, C.R., & Egeter, B. (2016). Feral pig (*Sus scrofa*) predation of a green and golden bell frog (*Litoria aurea*). *New Zealand Journal of Ecology* 40(1), 191-195.

Krull, C.R., Waipara, N.W., Choquenot, D., Burns, B.R., Gormley, A. & Stanley, M.C. (2013). Absence of evidence is not evidence of absence: Feral pigs as vectors of soil-borne pathogens. *Austral Ecology* 38(5), 534-542.

Lambert, S., Waipara, N., Black, A., Mark-Shadbolt, M. & Wood, W. (2018). Indigenous biosecurity: Māori responses to kauri dieback and myrtle rust in Aotearoa New Zealand. In: J. Urquhart, M. Marzano, & C. Potter. (Eds). *The Human Dimensions of Forest and Tree Health*, pp. 109-137. Palgrave Macmillan, Web. https://link.springer.com/chapter/10.1007/978-3-319-76956-1_5

Lang, S.D.J, Mann, R.P. & Farine, D.R. (2019). Temporal activity patterns of predators and prey across broad geographic scales. *Behavioral Ecology* 30 (1), 172–180.

Latham, A.D.M. & Yockney, I. (2017). A review of control strategies and tools for feral pigs. *Contract Report LC3699, for Northland Regional Council*. Manaaki Whenua – Landcare Research, New Zealand.

Law, R.G. (1972). Archaeology at Harataonga Bay, Great Barrier Island. *Records of the Auckland Institute and Museum* 9, 81-123.

Leclerc, C., Courchamp, F. & Bellard, C. (2018). Insular threat associations within taxa worldwide. *Scientific Reports* 8, 6393.

Lee, P.C. (2017). People, perceptions and 'pests': Human-wildlife interactions and the politics of conflict. In C.M. Hill, A.D. Webber & N.E.C. Priston (Eds). *Understanding Conflicts About Wildlife: A Biosocial Approach*, pp. 15-35. Berghan Books, Incorporated.

Lemos, M.C., Boyd, E., Tompkins, E., Osbahr, H. & Liverman, D. (2007). Developing adaptation and adapting development. *Ecology & Society* 12, 26.

Leppens, J. (2005). Fishing for tourists: perceptions from the Stewart Island community of the creation of Rakiura National Park [Masters thesis]. Lincoln University, Lincoln, New Zealand.

Lewis, K.S.J., Black, A., Condron, L.M., Waipara, N.W., Scott, P., Williams, N. & O'Callaghan, M. (2019). Land use changes influence the sporulation and survival of *Phytophthora agathidicida*, a lethal pathogen of New Zealand kauri (*Agathis australis*). *Forest Pathology* 49 (2), e12502.

Lincoln, N.K. (2014). Effect of various monotypic forest canopies on earthworm biomass and feral pig rooting in Hawaiian wet forests. *Forest Ecology and Management* 331, 79-84.

Long, M.S., Litton, C.M., Giardina, C.P., Deenik, J., Cole, R.S. & Sparks, J.P. (2017). Impact of nonnative feral pig removal on soil structure and nutrient availability in Hawaiian tropical montane wet forests. *Biological Invasions* 19(3), 749–763.

Lyver, P.O'B., Ruru, J., Scott, N., Tylianakis, J.M., Arnold, J. & Malinen, S.K. *et al.* (2019). Building biocultural approaches into Aotearoa - New Zealand's conservation future. *Journal of the Royal Society of New Zealand 49*(3): 394-411.

Lyver, P. O'B. & Tylianakis, J.M. (2017). Indigenous peoples: Conservation paradox. *Science* 357(6437), 141

MacArthur, R.H. & Wilson, E.O. (1967). *The Theory of Island Biogeography*. Princeton University Press, New Jersey.

Mace, G.M. (2014). Whose conservation? *Science* 345(6204), 1558-1660.

Macleay R. (2013). Heritage weeds in Latte Land. In: *On, in, from, over Bellingen*. North Bank Institute of Independent Studies, Australia.

Madden, R. (2017). *Being Ethnographic: A Guide to the Theory and Practice of Ethnography*. (Second edition). Sage Publications, London.

Malcouronne, P. & Morton, C. (2018). *Aotea: Great Barrier*. Out The Media, Auckland.

Manfredo, M.J. (1989). Human dimensions to wildlife management. *Wildlife Society Bulletin* 17, 447-449.

Manfredo, M.J. (2009). *Who cares about wildlife? Social science concepts for exploring human-wildlife relationships*. Springer, New York.

Marchant, S. & Higgins, P.J. (Eds.). (1990). *Handbook of Australian, New Zealand and Antarctic Birds. (Volume 1 Ratites to Ducks: Part A Ratites to Petrels)*. Oxford University Press, Melbourne.

Marlowe, F.W. (2007). Hunting and gathering. *Cross-Cultural Research : Official Journal of the Society for Cross-Cultural Research* 41(2), 170-195.

Marvin, G. (2005). Sensing Nature: Encountering the World in Hunting. *Etnofoor* 18(1), 15-26.

McBurney, P. (2009). *Mahurangi and Gulf Islands District Collective: Traditional History Report*. Mahurangi and Gulf Islands Collective Commitee, Auckland.

McCall, G. (1994). Nissology: a proposal for consideration. *Journal of the Pacific Society* 17, 1–14.

McCall, G. (1996). Clearing confusion in a disembedded world: the case for nissology. *Geographische Zeitschrift* 84(2), 74-85.

McClanahan, T.R. & Cinner, J. (2012). *Adapting to a changing environment: Confronting the consequences of climate change*. Oxford University Press, New York.

McClanahan, T. R., Marnane, M. J., Cinner, J. E. & Kiene, W. E. (2006). A comparison of marine protected areas and alternative approaches to coral-reef management. *Current Biology* 16, 1408–1413.

McEntee, M. & Johnson, S. (2015). Enabling an ecological vision for Aotea Great Barrier Island: understanding community perspectives and aspirations. *Phase One Report*. Prepared for Great Barrier Island Local Board & Auckland Council. Aranovus Limited, Auckland.

McIlroy, J.C. & Nugent, G. (2021). Chapter 12: Family Suidae. In C.M.King & D.M. Forsyth. (Eds). *The Handbook of New Zealand Mammals*. Otago University Press, Dunedin. Pp. 379-391.

McIlroy, J.C. (1989). Aspects of the ecology of feral pigs (*Sus scrofa*) in the Murchison area, New Zealand. *New Zealand Journal of Ecology* 12, 11-22.

McIlroy, J.C. (2001) Advances in New Zealand mammalogy 1990–2000: Feral pig. *Journal of the Royal Society of New Zealand* 31(1), 225-23.

Medway, D. G. (2002). An historic record of black petrels (*Procellaria parkinsoni*) nesting in south Westland. *Notornis* 49(1), 51-52.

Melstrom, R.T. (2014). Managing apparent competition between the feral pigs and native foxes of Santa Cruz Island. *Ecological Economics* 107, 157-162.

Microsoft Corporation. (2023). Microsoft® Excel® for Microsoft 365 MSO (Version 2304 Build 16.0.16327.20200) 32-bit.

Milne, S., Deuchar, C. & Histen, S. (2018). Visitor Strategy Aotea Great Barrier Island. Aotea Great Barrier Local Board.

Ministry of Agriculture and Forestry (MAF). (2010). How humane are our pest control tools? *MAF Biosecurity New Zealand Technical Paper No: 2011/01*. Ministry of Agriculture and Forestry, Wellington.

Ministry of Education. (2023). Education Counts 2023. https://www.educationcounts.govt.nz/statistics/school-rolls

Miskelly CM. (2014). Legal protection of New Zealand's indigenous terrestrial fauna – an historical review. *Tuhinga* 25, 25–101.

Miskelly, C., McLaughlin, L., & De Graaf, A. (2022). New Zealand falcons (*Falco novaeseelandiae*) hunting petrels at night and underground during the day. Notornis 69(1), 37-44.

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M., Gascon, C. (2011). Global biodiversity conservation: The critical role of hotspots. In: F. Zachos & J. Habel (Eds.) *Biodiversity Hotspots*. Springer, Berlin.

Moller, H. (1996). Customary use of indigenous wildlife – towards a bicultural approach to conserving New Zealand's biodiversity. In: B. McFagen, P. Simpson. (Eds). *Biodiversity: Papers from a Seminar Series on Biodiversity*, pp. 89–125. Department of Conservation, Wellington.

Moloney, P.D., Forsyth, D.M., Ramsey, D.S., Perry, M., McKay, M., Gormley, A.M., Kappers, B., Wright, E.F. (2021). Occupancy and relative abundances of introduced ungulates on New Zealand's public conservation land 2012-2018. *New Zealand Journal of Ecology* 45.

Moore, M. & Westley, F. (2011). Surmountable chasms: networks and social innovation for resilient systems. *Ecology & Society* 16, 5.

Moore, P. (2004). Geology. In: Armitage D (Ed.). *Great Barrier Island.* (Revised edition). Canterbury University Press, Christchurch. Pp. 40-51.

Mori, E., Lazzeri, L., Ferretti, F., Gordigiani, L. & Rubolini, D. (2021). The wild boar Sus scrofa as a threat to ground-nesting bird species: an artificial nest experiment. *Journal of Zoology* 314(4), 311-320.

Morris, B. (2021). The occupation. *New Zealand Geographic* 169. https://www.nzgeo.com/stories/the-occupation/

Morris, S. P. (2010). *On Hunting: A Philosophical Case Study in Animal Sports* [Doctoral dissertation] Ohio State University. http://rave.ohiolink.edu/etdc/view?acc_num=osu1281447236

Mortimer, R., Sharp, B. & Craig, J. (1996). Assessing the conservation of New Zealand's offshore islands. *Conservation Biology* 10(1), 25-29.

Morton, J. & Neilson, M. (2018, December 11). 1080 madness: DoC ranger slept with gun under his bed. https://www.nzherald.co.nz/nz/1080-madness-doc-ranger-slept-with-gun-under-his-bed/2HLXW77BMFFSOYJRQN53WMLWNI/

Mulder, C. P. H., Anderson, W.B., Towns, D. & Bellingham, P.J. (Eds.). (2011). *Seabird Islands: Ecology, Invasion, and Restoration*. Oxford University Press, New York.

Murphy, E. C., Russell, J. C., Broome, K. G., Ryan, G. J., & Dowding, J. E. (2019). Conserving New Zealand's native fauna: a review of tools being developed for the Predator Free 2050 programme. *Journal of Ornithology* 160(3), 883-892.

Murray, T.E.; Bartle, J.A.; Kalish, S.R.; Taylor, P.R. (1993): Incidental capture of seabirds by Japanese southern bluefin tuna long-line vessels in New Zealand waters, 1988–1992. *Bird Conservation International* 3(3): 181–210.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* 403.6772, 853–858.

National Pest Control Agencies. (2018). *Feral pigs: a review of monitoring and control techniques*. National Pest Control Agencies, Wellington. www.bionet.nz/library

Nelson, F., Kerasote, T; King, R.J.H., Bateson, P., Eves, H. E., Wolf, C.M. & Yaich, S.C. (2005). The ethics of hunting. *Frontiers in Ecology and the Environment* 3(7), 392-397.

New Zealand Conservation Authority. (1997). Maori customary use of native birds, plants and other traditional materials. *Interim Report and Discussion Paper ISBN 0-9583301-6-6*. New Zealand Conservation Authority, Wellington.

New Zealand Game Animal Council. (2020). *Hunters for Conservation.* NZ Game Animal Council Media Statement 16 August, 2020. https://nzgameanimalcouncil.org.nz/wp-content/uploads/2020/08/Hunters-for-conservation.pdf

New Zealand Government. (2016). Ngāti Rehua Ngātiwai ki Aotea Deed of Settlement. https://www.govt.nz/browse/history-culture-and-heritage/treaty-settlements/find-a-treaty-settlement/ngati-rehua-ngatiwai-ki-aotea/

New Zealand Government. (2016b). Ngāti Rehua Ngātiwai ki Aotea Deed of Settlement. Schedule of Property Redress. https://www.govt.nz/assets/Documents/OTS/Ngati-Rehua-Ngatiwai-ki-Aotea/Ngati-Rehua-Ngatiwai-ki-Aotea-Deed-of-Settlement-Schedule-Property-Redress.pdf

New Zealand Tahr Foundation. (2022). *New Zealand Tahr Foundation Annual Report 2022*. https://www.nztf.org.nz/sites/default/files/2022-09/NZ_Tahr_Foundation-Annual-Report-2022.pdf

Ngāti Rehua Ngātiwai ki Aotea (NRNWKA). (2016). Hapū Management Plan. Aotea (Great Barrier Island), New Zealand. https://ngatirehua.com/wp-content/uploads/2016/04/hapu_

Nimmo, D.G., Watson, S.J., Forsyth, D.M., Bradshaw, C.J.A., & Frair, J. (2015). Dingoes can help conserve wildlife and our methods can tell. *Journal of Applied Ecology* 52(2), 281-285.

Norton, D. A., Young, L.M., Byrom, A.E., Clarkson, B.D., Lyver, PO'B., McGlone, M.S. & Waipara, N.W. (2016). How do we restore New Zealand's biological heritage by 2050? *Ecological Management & Restoration* 17(3), 170–179.

Nottingham, K.M., Glen, A.S. & Stanley, M.C. (2019). Proactive development of invasive species damage functions prior to species reintroduction. *Global Ecology and Conservation* 17, 2019.

Norbury, G.L.; Price, C.J.; Latham, M.C.; Brown, S.J.; Latham, D.M.; Brownstein, G.E.; Ricardo, H.C.; McArthur, N.J. & Banks, P.B. (2021). Misinformation tactics protect rare birds from problem predators. *Science Advances* 7: eabe4164.

Noy, Chaim. (2008). Sampling Knowledge: The Hermeneutics of Snowball Sampling in Qualitative Research. International Journal of Social Research Methodology, 11(4), 327-344.

Nugent, G. & Fraser, K.W. (1993). Pests of valued resources? Conflicts in management of deer. *New Zealand Journal of Zoology* 20, 361-366.

Nugent, G., Reddiex, B., Whitford, J. & Yockney, I. (2003). Pigs as hosts of bovine tuberculosis in New Zealand – a review. *Landcare Research Contract Report: LC0203/098.* Landcare Research, Lincoln, New Zealand.

O'Bryan, C.J., Patton, N.R., Hone, J., Lewis, J.S., Berdejo-Espinola, V., Risch, Derek R., Holden, M.W. & McDonald-Madden, E. (2022). Unrecognized threat to global soil carbon by a widespread invasive species. *Global Change Biology* 28(3), 877-882.

Ogborn, M. (2003). Semi-structured interviews and focus groups. In N.J. Clifford, S. French & G. Valentine. (Eds). *Key Methods in Geography*. Sage Publications, London.

Ogden, J. & Gilbert, J. (2009). Prospects for the eradication of rats from a large inhabited island: Community based ecosystem studies on Great Barrier Island, New Zealand. *Biological invasions* 11(17), 1705–1717.

Ogden, J. & Gilbert, J. (2011). Running the gauntlet: advocating rat and feral cat eradication on an inhabited island – Great Barrier Island, New Zealand. In: C.R. Veitch, M.N. Clout & D.R. Towns. (Eds.). *Island Invasives: Eradication and Management*, pp. 467–471. IUCN SSC Invasive Species Specialist Group, Switzerland.

Ogden, J. (2004). Major ecosystems. In: Armitage D (Ed.). *Great Barrier Island.* (Revised edition). Canterbury University Press, Christchurch. Pp. 52-81.

Ogden, J. (2006). Sequential impacts of polynesian and European settlement on vegetation and environmental processes recorded in sediments at Whangapoua Estuary, Great Barrier Island, New Zealand. *Regional Environmental Change* 6(1-2), 25-40.

Olson, M.K. & Schafer, J.L. (2001). T two-part random effects model for semicontinuous longitudinal data. *Journal of the American Statistical Association* 96(454), 730-745.

Oppel, S., Beaven, B. M., Bolton, M., Vickery, J., & Bodey, T. W. (2011). Eradication of invasive mammals on islands inhabited by humans and domestic animals. *Conservation Biology* 25(2), 232-240.

P. M. Pavlov. (1981). Feral pigs – ungulate predators. *New Zealand Journal of Ecology* 4, 132-133.

Palmer, A. (2022). The small British cat debate: Conservation non-issues and the (im)mobility of wildlife controversies. *Conservation and Society* 20 (3), 211-221.

Palmer, M.S., Gaynor, K.M., Abraham, J.O. & Pringle, R.M. (2023). The role of humans in dynamic landscapes of fear. *Trends in Ecology & Evolution* 38(3), 217–218.

Park, T. (2020). Behavioural insights for conservation and sustainability. In Sutherland, W.J., Brotherton, P.N.M., Davies, Z.G., Ockendon, N., Pettorelli, N. & Vickery, J.A. (Eds). *Conservation Research, Policy and Practice*. Cambridge University Press, UK.

Parkes, J.P. (1989). Eradication or sustained control by sustained harvests: which option for thar? (Abstract) In Norton, D. 1989 (ed). Annual conference 1988: proceedings of the New Zealand Ecological Society 36th Annual Conference, Dunedin. *New Zealand Journal of Ecology* 12, 126-136.

Parkes, J.P. (1996). Integrating the management of introduced mammal pests of conservation values in New Zealand. *Wildlife Biology* 2(3), 179–184.

Parkes, J.P., Byrom, A.E. & Edge, K.A. (2017). Eradicating mammals on New Zealand island reserves: what is left to do? *New Zealand Journal of Ecology* 41(2), 263-270.

Parkes, J.P., Easdale, T.A., Williamson, W.M., & Forsyth, D.M. (2015). Causes and consequences of ground disturbance by feral pigs (*Sus scrofa*) in a lowland New Zealand conifer–angiosperm forest. *New Zealand Journal of Ecology* 39(1), 34-42.

Parkes, J.P., Nugent, G., & Warburton, B. (1996). Commercial exploitation as a pest control tool for introduced mammals in New Zealand. *Wildlife Biology* 2, 171–177.

Parkes, J.P., Robley, A., Forsyth, D.M. & Choquenot, D. (2006). Adaptive management experiments in vertebrate pest control in New Zealand and Australia. *Wildlife Society Bulletin* 34 (1), 229-239.

Pascal, M., Lorvelec, O., Bretagnolle, V. & Culioli, J-M. (2008). Improving the breeding success of a colonial seabird: a cost-benefit comparison of the eradication and control of its rat predator. *Endangered Species Research* 4 (3), 267-276.

Pauley, J.A. (2003). The value of hunting. *The Journal of Value Inquiry* 37 (2), 233–244.

Peart, R. & Woodhouse, C. (2020). *Protecting the Hauraki Gulf Islands*. Hauraki Environmental Defence Society (EDS), Auckland.

Péron, F. (2004). The contemporary lure of the island. *Tijdschrift Voor Economische en Sociale Geografie* 95 (3), 326-339.

Perry, G., Ogden, J., Enright, N., Davy, L., & Perry, GLW. (2010). Vegetation patterns and trajectories in disturbed landscapes, Great Barrier Island, northern New Zealand. *New Zealand Journal of Ecology*, 34(3), 311-323.

Peterson, M.N., Chen, A., Von Essen, E., & Hansen, H.P. (2020). Evaluating how Swedish hunters determine which species belong in nature. *European Journal of Wildlife Research* 66(5),

Peterson, M. N., Hansen, H. P., Peterson, M. J., & Peterson, T. R. (2011). How hunting strengthens social awareness of coupled human-natural systems. *Wildlife Biology in Practice*, 6(2), 127-143.

Petrie, H. (2006). *Chiefs of Industry: Maori Tribal Enterprise in Early Colonial New Zealand*. Auckland University Press, Auckland.

Petrie, H. (2008). Kai Pākehā – introduced foods. Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/kai-pakeha-introduced-foods/print (accessed 20 May 2023)

Petzold, J. (2018). Social adaptability in ecotones: sea-level rise in Flushing and the Isles of Scilly, UK. *Island Studies Journal* 13(1), 101-118.

Pollard, C.R.J., Redpath, S., Bussière, L.C., Keane, A., Thompson, D.B.A., Young, J., Bunnefeld, N. & Lee, T.M. (2019). The impact of uncertainty on cooperation intent in a conservation conflict. *The Journal of Applied Ecology* 56(5), 1278-1288.

Predator Free 2050 Limited. (2021, December 23). D'Urville Island project withdrawal. [Media statement]. https://pf2050.co.nz/news/media-statement-durville-island-project-withdrawal/

Predator Free New Zealand. (2023). Large predator control projects: Auckland projects. https://predatorfreenz.org/about-us/predator-free-2050/large-predator-control-projects/auckland-projects/

Prenzel, P. V., Vanclay, F. (2014) . How Social Impact Assessment Can Contribute to Conflict Management. *Environmental impact assessment review* 45, 30–37

Pungetti, G. (2012). Island, culture, landscape and seascape. *Journal of Marine & Island Cultures* 1, 51-54.

QSR International Pty. 2020. NVivo Version 13 (released March 2020). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Quiñones, J., Calderon, J., Mayaute, L. & Bell, E. (2020). Black petrel (*Procellaria parkinsoni*) congregations at sea off Perú during the Austral summer. *Notornis* 67(3), 573-576.

Radio New Zealand. (2021, December 28). Forest and Bird raises concerns over pigs and deer in Waitākere Ranges and wetland. https://www.rnz.co.nz/news/environment/458736/forest-and-bird-raises-concerns-over-deer-and-pigs-in-waitakere-ranges-and-wetland

Raine, A.F., Driskill, S., Vynne, M., Harvey, D. & Pias, K. (2020) Managing the effects of introduced predators on Hawaiian endangered seabirds. *The Journal of Wildlife Management* 84(3), 425–435.

Redpath, S., Young, J., Evely, A., Adams, W.A., & Sutherland, W.J. *et al*. (2013). Understanding and managing conservation conflicts. *Trends in Ecology & Evolution* 28(2): 100-109.

Reeves, S. (2011). *Environmental Law in New Zealand*. Kluwer Law International, Netherlands.

Reis, A.C. (2009). More than the kill: hunters relationships with landscape and prey. *Current Issues in Tourism* 12(5-6), 573-587.

Reis, A.C. (2014). Hunting the exotic: practices, discourses, and narratives of hunting in New Zealand. *Society & Animal*s 22(3), 289-308.

Reis, A. & Hayward, R. (2013). Pronounced particularity: a comparison of governance structures on Lord Howe Island and Fernando de Noronha. *Island Studies Journal* 8(2), 285-298.

Rewi, S.T. (2022). Seabirds as tohu of ocean state: tohu informed kaitiakitanga. (Master's thesis). University of Auckland, Auckland.

Richard, Y.; Abraham, E.; Berkenbusch, K. (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report* 237. 57 p.

Riley, S. (2013). 'Buffalo belong here, as long as he doesn't do too much damage': Indigenous perspectives on the place of alien species in Australia. *The Australasian Journal of Natural Resources Law and Policy* 16(2), 157-196.

Risch, D.R. (2019). *Quantifying the impact of wild pigs on global biodiversity and the spatiotemporal ecology of feral pigs on Maui, Hawai'i*. (Thesis). University of Hawai'i, Mānoa.

Risch, D.R., Ringma, J. & Price, M.R. (2021) The global impact of wild pigs (*Sus scrofa*) on terrestrial biodiversity. *Scientific Reports* ***11***, 13256.

Robertson, H.A.; Baird, K.A.; Elliott, G.P.; Hitchmough, R.A.; McArthur, N.J.; Makan, T.D.; Miskelly, C.M.; O'Donnell, C.F.J.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A.; Michel, P. (2021). Conservation status of birds in Aotearoa New Zealand. *New Zealand Threat Classification Series 36*. Department of Conservation, Wellington. 43 p

Rose, D. B. (2007). What Do We Mean By Wild? In Dudley, N. & Stolton, S. (Eds) *Defining Protected Areas: An international conference in Almeria, Spain, May 2007*. IUCN, Seville, Spain.

Ross, J. & Eason, C. (2021). Sodium fluoroacetate (1080) in relation to it's use in New Zealand revisited: a 2021 review. *Lincoln University Wildlife Management Report* 74, 77p. Department of Pest Management and Conservation, Lincoln University, New Zealand.

Rouco, C., De Toore-Ceijas, R., Martin-Collado, D. & Byrom, A. (2017). New Zealand shouldn't ignore feral cats. *Bioscience* 67(8), 686.

Royle, S.A. (2014). *Islands: Nature and Culture*. Reaktion Books Ltd, UK.

RStudio Team (2022). RStudio: Integrated Development Environment for R. Version 2022.7.2.576. RStudio, PBC, Boston, MA. URL http://www.rstudio.com/.

Ruru J. (2004). Managing our treasured home: The conservation estate and the principles of the Treaty of Waitangi. *New Zealand Journal of Environmental Law* 8, 243–266.

Russell, J.C. (2011). Indirect effects of introduced predators on seabird islands. In: C.P. H. Mulder, W.B. Anderson., D.R. Towns & P.J. Bellingham. (Eds.). *Seabird Islands: Ecology, Invasion, and Restoration*. Oxford Academic Books, pp. 261-280.

Russell, J.C. (2014). A comparison of attitudes towards introduced wildlife in New Zealand in 1994 and 2012. *Journal of the Royal Society of New Zealand* 44, 136–151.

Russell, J.C. & Broome, K. (2016). Fifty years of rodent eradications in New Zealand. *New Zealand Journal of Ecology* 40(2), 197-204.

Russell, J.C., Horn, S.R., Miskelly, C.M., Sagar, R.L. & Taylor, R.H. (2020). Introduced land mammals and their impacts on the birds of the subantarctic Auckland Islands. *Notornis* 67(1), 247–268.

Russell, J.C., Innes, J.G., Brown, P.H. & Byrom, A.E. (2015). Predator-Free New Zealand: conservation country. *Bioscience* 65(5), 520–525.

Russell, J. & Kueffer, C. (2019). Island biodiversity in the Anthropocene. *Annual Review of Environment and Resources* 44, 31-60.

Russell, J. C., Meyer, J.-Y., Holmes, N. D. & Pagad, S. (2017*a*). Invasive alien species on islands: impacts, distribution, interactions and management. *Environmental Conservation* 44, 359–370.

Russell, J.C. & Stanley, M.C. (2018). An overview of introduced predator management in inhabited landscapes. *Pacific Conservation Biology* 24(4), 371-378.

Russell, J.C., Taylor, C.N. & Aley, J.P. (2018). Social assessment of inhabited islands for wildlife management and eradication. *Australasian Journal of Environmental Management* 25(1), 24-42.

Russell, K.J., Taylor, C.N., Balanovic, J.X., Aley, J.P., Harbrow, M.A. & Russell, J.C. (2017). Predator Free Rakiura Social Impact Assessment. A report for the Department of Conservation. University of Auckland, Auckland.

Salmond, A. (1991). *Two Worlds: First Meetings Between Maori and Europeans 1642-1772*. Viking Press, Penguin Books (NZ) Ltd, New Zealand.

Salmond, A. (1997). *Between Worlds: Early Exchanges Between Maori and Europeans*. Viking Press, Penguin Books (NZ) Ltd, New Zealand.

Sand, J. (2021). People, animals, and island encounters: A pig's history of the Pacific. *Journal of Global History*, 2021, 1-19. doi:10.1017/S1740022821000383

Sand, J. (2021). People, animals, and island encounters: A pig's history of the Pacific. *Journal of Global History 17*(3), 355-373.

Sandbrook, C. (2015). What is conservation? *Oryx* 49(4), 565-566.

Sanders, H.N., Hewitt, D.G., Perotto-Baldivieso, H.L., Vercauteren, K.C., & Snow, N.P. (2020). Opportunistic predation of wild turkey nests by wild pigs. *The Journal of Wildlife Management* 84(2), 293-300.

Saunders, A., Towns, D., Broome, K., Horn, S., Neureuter, S., Conomos, K., Corson, P., Galbraith, M., Gilbert, J., Ogden, J. & Waterhouse, K. (2021). Social dimensions in island restoration: Some case studies from Aotearoa – New Zealand. *Pacific Conservation Biology* 28(4), 341-354.

Schelhas, J. (2021). Social and cultural dynamics of non-native invasive species. In Poland T.M., Patel-Weynand, T., Finch, D.M., Miniat, C.F., Hayes, D.C . & Lopez, V.M. (Eds). *Invasive Species in Forests and Rangelands of the United States*, pp.267-291. Springer, Swizerland.

Schultz, C. (2022, February 5). It's not a well-kept secret anymore: Is Great Barrier set to become the new Waiheke? New Zealand Herald, Auckland.

Secretariat of the Pacific Community. (2007). The importance of the pig in Pacific Island culture: An annotated bibliography. Secretariat of the Pacific Community, Suva, Fiji.

Selby, R., Moore, P., & Mulholland, M. (2010). *Māori and the environment: Kaitiaki*. Huia, Wellington.

Selin, H. & Arne, K. (2003). *Nature Across cultures : Views of Nature and the Environment in non-Western Cultures*. Kluwer Academic Publishers, Boston.

Shackleton, R.T., Walters, G., Bluwstein, J., Djoudi, H., Fritz, L. de Micheaux, F.L., Loloum, T., Nguyen, V.T.H., Andriamahefazafy, M.R., Sithole, S.S. & Ku, C.A. (2023). Navigating power in conservation. *Conservation Science and Practice* 5(3), 17p.

Simberloff, D., Martin, J.-L., Genovesi, P., Maris, V., Wardle, D. A. & Aronson, J. *et al*. (2013). Impacts of biological invasions: what's what and the way forward. *Trends in Ecology & Evolution* 28(1), 58-66.

Singers, N., Osborne, B., Lovegrove, T., Jamieson, A., Boow, J., Sawyer, J., Hill, K., Andrews, J., Hill, S. & Webb, C. (2017). *Indigenous terrestrial and wetland ecosystems of Auckland.* Auckland Council, Auckland.

Soule, M. E. (1985). What is conservation biology? *Bioscience* 35(11), 727–734.

Sparklin, B.D., Mitchell, M.S., Hanson, L.B., Jolley, D.B. & Ditchkoff, S.S. (2009). Territoriality of feral pigs in a highly persecuted population on Fort Benning, Georgia. The Journal of wildlife management 73 (4), 497-502.

Spatz, D.R., Holmes, N.D., Will, D.J., Hein, S., Carter, Z.T., Fewster, R.M., Bradford, K., Genovesi, P., Samaniego, A., Croll, D.A., Tershy, B.R. & Russell, J.C. (2022). The global contribution of invasive vertebrate eradication as a key island restoration tool. *Nature Scientific Reports* 12(1), 13391-13391.

Sport New Zealand. (2022). *Active NZ Changes in Participation: The New Zealand Participation Survey 2021*. (Main data tables). Sport New Zealand, Wellington. https://sportnz.org.nz/resources/active-nz-changes-in-participation/

Statistics New Zealand. (2013). *2013 Census*. https://cdm20045.contentdm.oclc.org/digital/collection/
Statistics New Zealand. (2018). *2018 Census*. https://www.stats.govt.nz/tools/2018-census-place-summaries/

Stewart, W.P., Kruger, L.E. & Williams, D.R. (2013). *Place-based Conservation: Perspectives from the Social Sciences*. Springer, Netherlands.

Taiepa, T., Lyver, P., Horsley, P., Davis, J., Brag, M. & Moller, H. (1997). Co-Management of New Zealand's conservation estate by Maori and Pakeha: A review. *Environmental conservation* 24 (3), 236–250.

Tatton, K. (1994). *Aotea: Nga unahi me nga taratara o Te Ika Roa a Maui (The scales and spines of Maui's fish: The settlement archaeology of Aotea*). (Thesis). University of Auckland, Auckland.

Taylor, C.N. & Mackay, M. (2016). Social impact assessment and change in New Zealand: Legacy and change. *New Zealand Sociology* 13(3), 230-246.

Taylor, C.N. (2019). The challenges of a new biodiversity strategy for social impact assessment. *Impact Connector 8.* New Zealand Association of Impact Assessment. https://www.nzaia.org.nz/nicktaylor.html

Taylor, C.N., Bryan, C.H. & Goodrich, C.G. (2004). Social Assessment: Theory, Process and Techniques. Social Ecology Press, Middleton, Wisconsin, USA.

Te Urewera Act 2014. https://www.legislation.govt.nz/act/public/2014/0051/latest/DLM6183705

Terrell, John E. (1988). *Prehistory in the Pacific Islands*. Cambridge University Press.

Tershy, B. R., Shen, K.-W., Newton, K. M., Holmes, N. D., and Croll, D. A. (2015). The importance of islands for the protection of biological and linguistic diversity. *BioScience* 65, 592–597.

Thornberg, R. & Keane, E. 2022. Designing grounded theory studies. In Flick, U. (Ed). *The SAGE Handbook of Qualitative Research Design* (Vol. 2), pp. 452-466. Sage Publications, London.

Tickle, L. & von Essen, E. (2020). The seven sins of hunting tourism. *Annals of Tourism Research* 84, 102996.

Torkar, G. & McGregor, S.L.T. (2012). Reframing the concept of nature conservation management by transdisciplinary methodology: From stakeholders to stakesharers. *Journal for Nature Conservation* 20, 65-71.

Towns, D. Bellingham, P.J., Mulder, C.H. & Lyver, P. O'B. (2012). A research strategy for biodiversity conservation on New Zealand's offshore islands. *New Zealand Journal of Ecology* 36(1), 1-20.

Towns, D.R., Byrd, G.V., Jones, H.P., Rauzon, M.J. & Wilcox, C. (2011). Impacts of introduced predators on seabirds. In: C.P. H. Mulder and others (Eds.). *Seabird Islands: Ecology, Invasion, and Restoration*. Oxford Academic Books.

Towns, D.R., Munoz, A., Kress, S.W., Hodum, P.J., Burbidge, A.A. & Saunders, A. (2011). The social dimension - public involvement in seabird island restoration. In Mulder, C. P. H., Anderson, W.B., Towns, D. & Bellingham, P.J. (Eds.). *Seabird Islands: Ecology, Invasion and Restoration*. Oxford University Press, New York.

Towns, D., West, C. & Broome, K. (2013). Purposes, outcomes and challenges of eradicating invasive mammals from New Zealand islands: an historical perspective. *Wildlife Research* 40(2), 94-107.

Turbott, E. (2002). *Year away : Wartime coastwatching on the Auckland Islands, 1944*. Department of Conservation, Wellington.

Van Ee, B.C., Nickerson, Z.L., & Atkinson, C.L. (2020). Picky pigs prefer pigtoes: Evidence for species-selective feral pig predation on freshwater mussels. *Freshwater Mollusk Biology and Conservation 23*(2), 92-98.

Vanclay, F. (2003). International principles for social impact assessment. *Impact Assessment & Project Appraisal* 21(1), 5-11.

Veblen, T.T. & Stewart, G.H. (1982). The effects of wild introduced animals on New Zealand forests. *Annals of the American Association of Geographers* 72(3), 372-397.

Venuto, D. (2022, October 6). The front page: Why feral and roaming dogs in Northland are causing havoc. *New Zealand Herald*. https://www.nzherald.co.nz/nz/the-front-page-why-feral-and-roaming-dogs-are-causing-havoc-in-northland/QFANG43TRMGF2VLN6QY2J33YVY/

Višak, T., Garner, R. & Singer, P. (2015). *The Ethics of Killing Animals*. Oxford University Press.

Von Essen, E. & Hansen, H.P. (2015). How stakeholder co-management reproduces conservation conflicts: Revealing rationality problems in Swedish wolf conservation. *Conservation & Society* 13(4), 332-344.

Von Essen, E., Allen, M. & Hansen, H.P. (2017). Hunters, crowns, nobles, and conservation elites: Class antagonism over the ownership of common fauna. *International Journal of Cultural Property* 24(2), 161-186.

Von Essen, E., van Heijgen, E. & Geiser, T. (2019). Hunting communities of practice: Factors behind the social differentiation of hunters in modernity. *Journal of Rural Studies* 68, 13-21.

Vtorov, I.P. (1993). Feral pig removal: Effects on soil microarthropods in a Hawaiian rain forest. *Journal of Wildlife Management* 57, 875–880.

Waikato Times. (2009, January 31). Hunters get way but say pig of process cost deerly. https://www.stuff.co.nz/waikato-times/news/672235/Hunters-get-way-but-say-pig-of-process-cost-deerly

Wald, D.M., Jacobson, S.K. & Levy, J.K. (2013). Outdoor cats: Identifying differences between stakeholder beliefs, perceived impacts, risk and management. *Biological Conservation* 167, 414–424.

Warburton, B., Eason, C., Fisher, P., Hancox, N., Hopkins, B., Nugent, G., Ogilve, S., Prowse, T.A.A., Ross, J. & Cowan, P.E. (2022). Alternatives for mammal pest control in New Zealand in the context of concerns about 1080 toxicant (sodium fluoroacetate). *New Zealand Journal of Zoology* 49(2), 79-121.

Wardle, J. (1984). The New Zealand beeches: ecology, utilisation, and management. New Zealand Forest Service, Wellington, New Zealand.

Warham, J. (1996). *The Behaviours, Population Biology and Physiology of the Petrels*. Academic Press, London.

Warwick, D. (2010). The titi project, traditional ecological knowledge and science: A critique. *Journal of the Royal Society of New Zealand* 40 (3), 39-43.

Wehi, P.M. & Lord, J. (2017). Importance of cultural practices in ecological restoration. *Conservation Biology* 31, 1109-1118.

Wehr, N., Hess, S.C. & Litton, C. (2018). Biology and impacts of Pacific invasive species. 14: *Sus scrofa* the feral pig (Artiodactyla: Suidae). *Pacific Science* 72(2), 177-198.

Wehr, N.H., Kinney, K.M., Nguyen, N.H., Jiardina, C.P. Litton, C.M. (2019). Changes in soil bacterial community diversity following the removal of invasive feral pigs from a Hawai'ian tropical montane wet forest. *Scientific Reports* 9(1), 14681–9.

Wehr, N.H., Litton, C.M., Lincoln, N.K., Hess, S.C. (2020). Relationships between soil macroinvertebrates and nonnative feral pigs (*Sus Scrofa*) in Hawaiian tropical montane wet forests. *Biological Invasions* 22(2), 577–586.

Weitenberg, C. (2022, May 31). This tiny New Zealand island is completely off-the-grid but doesn't want you to know about it. SBS News, Australia. https://www.sbs.com.au/news/dateline/article/this-tiny-new-zealand-island-is-completely-off-the-grid-but-it-doesnt-want-you-to-know-about-it/8kmbjwemf (accessed 20 May, 2023).

West, P. (2008). *Assessing Invasive Animals in Australia*. National Land and Water Resources Audit & Invasive Animals Cooperative Research Centre, Canberra.

White, Sam. (2011). From globalized pig breeds to capitalist pigs: A study in animal cultures and evolutionary history. *Environmental History* 16(1), 94-120.

Wickham, H., Chang, W., Henry, L., Takahashi, K., Wilke, K., Woo, K., Yutani, H. & Dunnington, D. (2023). Package 'ggplot2'. Version 3.4.1. February 10, 2023. Available at: https://cran.r-project.org/web/packages/ggplot2/index.html

Wilcox, J.T, & Van Vuren, D.H. (2009). Wild pigs as predators in oak woodlands of California. *Journal of Mammalogy* 90(1), 114-118.

Wilshusen, Peter R., Brechin, Steven R., Fortwangler, Crystal L., & West, Patrick C. (2002). reinventing a square wheel: critique of a resurgent "protection paradigm" in international biodiversity conservation. *Society & Natural Resources, 15*(1), 17-40.

Winter, K., and McClatchey, W. (2009). The quantum co-evolution unit: an example of 'Awa (Kava—*Piper methysticum* G. Foster) in Hawai'ian culture. *Economic Botany* 63, 353.

Wittmer, H., Anton, V., Gruber, M., Ireland, L., Linklater, W., Russell, J. & Shanahan, D. (2018). Conservation and restoration in peopled landscapes in Oceania: Opportunities and challenges. *Pacific Conservation Biology 24*(4), 409-416.

Wright, A. E., & Cameron, E. K. (1985). Botanical features of northeastern Great Barrier Island, Hauraki Gulf, New Zealand. *Journal of the Royal Society of New Zealand* 15(3), 251-278.

Young, D. (2004). *Our Islands, Our Selves: A History of Conservation in New Zealand*. Otago University Press, Dunedin.

Young, J. C., Searle, K., Butler, A., Simmons, P., Watt, A. D., & Jordan, A. (2016b). The role of trust in the resolution of conservation conflicts. *Biological Conservation*195, 196-202.

Young, J.C., Thompson, D.B.A., Moore, P., MacGugan, A., Watt, A. & Redpath, S.M. (2016a). A conflict management tool for conservation agencies. *Journal of Applied Ecology* 53(3), 705-71.