Investigating the social-ecological trade-offs between removing and preserving mangroves in New Zealand

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Abstract

How we perceive and interact with the natural world will govern our future in times of great environmental change. In New Zealand, the indigenous mangrove species *Avicennia marina* (subsp.) *australasica* has expanded within estuaries in the North Island at a rapid rate over the past few decades. This has led to polarity in public perceptions and attitudes towards mangrove preservation and removal. Although protected, removal of large areas of mangroves has occurred and continues to take place. This thesis investigates the social-ecological trade-offs between removing and preserving mangroves in New Zealand. The research approach employs a mixed methods Holistic Mangrove Framework, which explores gaps in the social-ecological monitoring of mangroves both nationwide and specifically at four sites of removal in the Manukau Harbour, Auckland. Chapter two's review of the literature on mangrove social-ecology showed that prominent knowledge gaps remain in ecological monitoring of mammals, reptiles, insects and spiders, which is also true globally. In a social context, little is known about the cultural value of mangroves (manawa) to Māori or the intrinsic value of this ecosystem. Chapter three showed the creation of a novel framework to investigate the creeping environmental problem of mangrove expansion in New Zealand. This framework has the capacity to be applied to any social-ecological system for a holistic understanding of interactions between humans and nature. Chapter five's integrated biodiversity assessments revealed that there is much heterogeneity in habitat complexity, species richness and abundance among sites. The study site adjacent to the largest mangrove removal area possesses the greatest abundance of bird species, and richness and abundance of arboreal arthropods compared to all other study sites. This highlights that a site-by-site management approach is required and generalisations about the habitat value of mangroves for wildlife cannot be made in the New Zealand context. Chapter six's exploration into perceptions and attitudes towards mangrove preservation and removal revealed significant disparity in attitude between community groups and conservation organisations. Sediment and nutrient retention properties of mangroves are the highest rated ecosystem services. The desire for reversion of estuaries to a pre-urban state is the greatest issue affecting mangroves. Iwi recommend monitoring of water quality and contaminants in mangrove soils. Based on the findings of this study, it is recommended to look beyond mangroves as an ecosystem which has expanded and replaced other adjacent habitats and start thinking about managing our coastal landscapes in a holistic manner. Embracing connectivity and complexity of coastal landscapes and addressing wider land-based issues of sedimentation and nutrient run-off is a necessity. It is advisable for us to work with and be part of our natural environment in order to create a more sustainable future in Aotearoa New Zealand. This is true for interactions with social-ecological systems globally. This study has added to baseline data on social and ecological information on New Zealand's mangroves and contributes to the international body of work on this coastal ecosystem using a mixed methods approach.

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Attestation of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning

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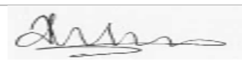
Amrit Dencer-Brown	Concept, data collection, analyses, structure and writing	80%	
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Outputs of research

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Chapter 1

Introduction

"An understanding of the natural world and what's in it is a source of not only a great curiosity but great fulfilment."

Sir David Attenborough

1.1 Background

We are living in a time when human-induced changes to the environment are having a direct impact on our health and well-being and altering the functioning of both faunal and floral communities. This is evident in our everyday lives and in many documented case studies across the world (e.g. Diaz et al., 2006; Hunter., 2007; Alberti et al., 2017). Investigating the relationships and interactions between humans and the environment is imperative to understanding how we can live in a sustainable manner now and in an uncertain future (Miller., 2013; Seymour., 2016).

In New Zealand, land-use change through deforestation, farming and the urbanisation of coastal areas has created a range of environmental issues including contamination and pollution of waterways and reduction of native biodiversity (Taylor et al., 1997). In contrast to the wide-spread reduction of native ecosystems in New Zealand; the grey mangrove *Avicennia marina* subsp. *australasica* (Walp.) J. Everett; has expanded into some estuaries and harbours in North Island. This has created social-ecological issues for some local communities and surrounding coastal landscapes (e.g. Morrisey et al., 2010; De Luca., 2015; Lundquist et al., 2014a). The expansion of this salt-tolerant plant species has called into question its perceived social and ecological value, leading to several applications for the removal of some large areas of mangroves through a variety of mechanical and non-mechanical means (Auckland Council., 2014; Lundquist et al., 2017).

Research into the ecological effects of removal are in progress, however, many knowledge gaps remain. At present, the socio-cultural value of mangroves in New Zealand has not been widely documented in the literature. Previous research on mangrove ecosystems in New Zealand has focussed on either single species studies or one group of organisms, with no attempt to look at integration in ecological studies to cover biodiversity as whole or the socio-cultural elements of a natural ecosystem.

1.2 Rationale and significance of study

Seaward expansion of mangroves in New Zealand is creating local estuarine management issues and polarity in public attitudes towards their conservation (Green et al., 2003; Schwarz, A., 2003; Alfaro et al., 2006; Morrisey et al., 2010; De Luca., 2015). Unlike tropical mangroves, the majority of temperate mangroves are situated in well-developed countries, where direct dependency for subsistence living is of little relevance (Morrisey et al., 2010). This potentially alters positive perceptions towards mangroves as wetlands which should be protected and conserved. In New Zealand, there is a perception amongst some community groups and other members of the public that mangrove expansion is having a negative impact on the surrounding estuarine environment and is reducing the recreational and amenity values of coastal communities (Harty, 2009; Stokes et al., 2009). Regional councils have come under pressure from local societies campaigning for the removal of large areas of mangrove habitat (Harty, 2009). Mangrove removal may detrimentally affect the surrounding estuarine and wider environment in many ways, for example, affecting water quality through release of contaminants and sediments into the waterways, causing habitat loss for a variety of species, as well as compromising the role of mangroves as carbon sinks and buffers against floods and storms (Kaly et al., 1997; Gladstone and Schreider, 2003; Morrisey et al., 2007). Conversely, the expansion of mangroves into adjacent coastal habitats has been viewed as replacing feeding areas for some species of intertidal wading birds and reducing access to the water for recreational and cultural practices such as waka ama (outrigger canoes) (Harty, 2009; de Luca, 2015).

How expansion or removal of mangroves affects coastal ecosystem services has not been investigated in detail in New Zealand mangroves. Due to the increasing number of applications for mangrove removals and lack of information of the impact that removal or preservation is having on the ecology of the areas; there is a pressing need to understand drivers for differing attitudes and perceptions towards mangroves. Exploring these issues and understanding the differences in perception of the intrinsic value of mangroves calls for a social-ecological framework to be employed in order to best assess the current state of play.

This complex issue requires the implementation of a framework which allows for the in-depth investigation into both management decisions around mangrove removal and the existing biodiversity within mangrove ecosystems. There is a substantial body of literature with revised versions of Ostrom's social-ecological systems framework (Ostrom, 2009) to analyse sustainability (e.g. Ban et al., 2013; Hinkel et al., 2014; Leslie et al., 2015). However, these frameworks involve natural resource systems which relate to common pool resources (CPR), such as fishing grounds, irrigation systems and forests (Ostrom, 1990). Mangroves in New Zealand are not utilised in this direct manner, therefore, the development and implementation of a new mixed methods design, which is practical and operatizational for indirectly utilised SES's is developed in this study (chapter three).

It is hoped that the outcomes of this study will provide deeper understanding of ecosystem functioning of temperate mangroves globally and inform policy for their sustainable management. This study will produce outputs for Auckland Council, local community groups, Mana Whenua, individual users of mangrove environments, and the wider scientific community.

1.3 Aims and Objectives

This study has the overall aim to investigate the social-ecological trade-offs between removing and preserving mangroves in New Zealand.

Research objectives of the study are as follows:

1. *To review the literature on social and ecological studies in New Zealand mangroves in order to identify gaps in social-ecological information regarding mangroves*

2. *To create a mixed methods framework based on social-ecological systems in order to address the overall research aim*

3. *To investigate secondary social-ecological data from council resource consents to compile background knowledge on a) the ecological assessments and b) the demographics and opinions towards specific removals of community stakeholders at selected sites*

4. *To understand the perceptions and attitudes towards mangrove removal and preservation through interviewing local community stakeholders*

5. *To conduct integrated biodiversity assessments at the selected sites to provide baseline data for lesser known species occupying mangrove habitats*

6. *To evaluate trade-offs in order to recommend future courses of action with mangrove removal/management in New Zealand*

1.4 Organisation of thesis

The thesis is a PhD by manuscript, which, at the time of submission had two published manuscripts and two in review. Chapters two, three, five and six were submitted for publication (chapter two was published in 2018 and chapter six in 2019). The outline of each chapter is detailed as follows:

1.4.1 Chapter one: Introduction

Chapter one explains the background of the study in a broad context. It then expands upon this with the significance, rationale, aims and objectives of the study. A summary of research objectives, concepts and methods of chapters two-six is in a tabulated form is at the end of this chapter.

1.4.2 Chapter two: Review on biodiversity, ecosystem services and perceptions of New Zealand's mangroves

Chapter two reviews the literature on the ecology of mangroves in New Zealand and the subsequent management of expanded areas. This chapter addresses the knowledge gaps existing in terms of groups of animals lesser surveyed in mangrove ecosystems and the lack of socio-cultural information on the perceived value of mangroves in New Zealand. This manuscript was published in February 2017 in *Resources*.

1.4.3 Chapter three: Coastal Complexity and Mangrove Management

Chapter three explains the issues with mangrove removal and preservation in the context of social-ecological systems. It highlights the complexity when investigating such issues and the concept of using a mixed methods approach in order to effectively address the research aim. Through this approach, the creation of a mixed methods Holistic Mangrove Framework is designed and explained, with descriptions of its implementation at each stage of research. The methodology of this framework is currently in review in the *Journal of Mixed Methods Research*.

1.4.4 Chapter four: Social-ecological monitoring in Manukau mangroves

This chapter investigates the existing ecological and socio-cultural data on the selected sites. It assimilates and integrates the findings from resource consent applications for mangrove removal in order to provide baseline social-ecological knowledge on the sites. It also provides background to the consultation process and stakeholders involved in removal at the sites. This chapter created specific site-based knowledge in order to conduct the primary research chapters five and six.

1.4.5 Chapter five: The Secret Lives of Mangroves

This chapter investigates the biodiversity of mangroves at the four selected sites. It explores biodiversity using integrated assessments to provide a one-off snap-shot of biodiversity at the sites. It highlights the gaps in current ecological monitoring and provides baseline data for lesser known species occupying mangroves. This chapter is in review in the journal *Ocean and Coastal Management.*

1.4.6 Chapter six: Muddied Waters: Investigating attitudes and perceptions towards New Zealand's mangroves

This chapter explores the perceptions and attitudes towards mangrove removal and preservation in New Zealand as a whole and specifically at the four sites in the study area. It investigates the opinions of a wide-range of stakeholders and discusses current management, the value of mangroves in terms of ecosystem services and the issues facing them in New Zealand. This chapter has been published in the journal *Sustainability*.

1.4.7 Chapter seven: Discussion

This chapter discusses, evaluates and concludes the findings from the previous chapters. It shows how each research objective was met in order to address the overall aim of the research. It reveals limitations of this study and provides recommendations and discusses the wider implications of the research. Key reflective findings in this chapter were submitted for publication in the *Journal of Mixed Methods Research* and is in review.

1.5 Research questions and methods

The following table (Table 1) shows the questions asked to address the research objectives of the study for chapters two-six and the methods used in these chapters to conduct the research.

Table 1. Objectives, concepts and methods of chapters two-six

Chapter	Research Objective	Concepts explored in chapter	Methods
Two	To review the literature on social and ecological studies in New Zealand mangroves	• **Investigate biodiversity and ecosystem service information on New Zealand's mangroves** • **Identify knowledge gaps in terms of ecosystem services and potential species occupying New Zealand mangroves** • **Better integrate data for comprehensive and effective management decisions regarding the removal and preservation of mangroves**	Literature review of peer-reviewed journals and personal communication with iwi and ecologists
Three	To create a mixed methods framework based on social-ecological systems	• **Explore facets of coastal complexity and connectivity in relation to both estuarine ecology and local community involvement in management decisions** • **Bridge the disciplinary and epistemological silos typically found in mangrove research** • **Present a more holistic and multi-dimensional approach to social inquiry that integrates multiple perspectives**	Literature review of SES, mixed methods designs and philosophical paradigms
Four	To investigate secondary social-ecological data from resource consents	• **Investigate social-ecological reasons for mangrove removal at the study sites** • **Record ecological monitoring conducted prior to and post-removal at the study sites** • **Explore consultation carried out prior to removal and with whom**	Literature review of council resource consent applications for removal
Five	To conduct integrated biodiversity assessments at the selected sites	• **Effective capture of biodiversity of a wide-range of animal groups in mangrove habitats over a short-term period** • **Investigation into community patterns of abundance and diversity of terrestrial arboreal invertebrates within and between sites** • **Investigation into how connectivity of mangrove habitats affects arthropod biodiversity of the plots sampled** • **Investigation into the kinds of organisms trapped or recorded in different trap types**	Integrated biodiversity assessments at the study sites
Six	To understand the perceptions and attitudes	• **Explore perceptions and attitudes towards preservation and removal of mangroves in New Zealand generally and at the study sites** • **Analyse whether demographics influence responses** • **Evaluate findings from the qualitative and quantitative aspects of the interviews**	Semi-structured interviews

Chapter 2

A review on biodiversity, ecosystem services and perceptions of New Zealand's mangroves: Can we make informed decisions about their removal?

"We abuse land because we regard it as a commodity belonging to us, when we see land as a community to which we belong, we may begin to use it with love and respect".

Aldo Leopold

The proceeding chapter is a comprehensive review of social and ecological peer-reviewed papers on mangroves in New Zealand. It records and collates social-ecological information from 1950's to the present day (2018, at the time of publication). It summarises trends in the data and current knowledge gaps with suggestions for social-ecological monitoring going forward. It seeks to understand the present-day situation in terms of issues with mangrove expansion in New Zealand and how management practices of mangroves are implemented to address these issues.

2.1 Abstract

Mangrove cover is increasing in estuaries and harbours in many areas on North Island, New Zealand. The expansion of mangroves has been attributed to anthropogenic land-use change, including urbanisation and conversion of land to agriculture. Rapid expansion of mangroves in the coastal landscape has created discord in local communities over their importance in terms of the services they deliver to both wildlife and people. Some community groups have been advocates for large-scale removal of mangrove habitat, whilst other local residents oppose removal. This review paper investigated and discussed pertinent biodiversity and ecosystem services studies based in New Zealand mangroves from 1950 to 2017. Results showed that the majority of biodiversity studies have targeted particular species or groups of organisms, with a focus on benthic invertebrate communities. Deficits remain in our knowledge of this expanding forest and shrub ecosystem, notably the terrestrial component of biodiversity, species community-shifts with landscape fragmentation and associated cultural values. It is recommended that broader species assessments and a longer-term approach be applied to biodiversity monitoring in mangroves, coupled with Mātauranga Māori (Māori knowledge) and western science for holistic management of this coastal ecosystem.

Key Words: mangrove; New Zealand; iwi; communities; biodiversity; ecosystem services

2.2 Introduction

The biosphere's ability to provide goods and services to support human populations is being severely compromised by rapid environmental change through anthropogenic impact upon natural ecosystems (McMicheal et al., 2003). Integration of natural and social sciences in order to address complex human-environment interactions has been slowly materialising over time (Mooney et al., 2013). However, studies integrating biodiversity monitoring and ecosystem services of natural ecosystems are few (Harrison et al., 2014). This chapter reviews biodiversity studies and ecosystem services (defined as attributes) within mangroves, as natural systems under pressure from anthropogenic impact. The specific focus of this contribution is on temperate mangroves in New Zealand. Within this body of literature, linkages between (1) biodiversity, (2) ecosystem services and (3) management of New Zealand's mangroves are investigated and the following broad-scale questions are addressed:

What biodiversity and ecosystem service information exists on New Zealand's mangroves?

What are the knowledge gaps in terms of potential species and ecosystem services occupying New Zealand mangroves?

How can we better integrate data for comprehensive and effective management decisions regarding removal and preservation of these ecosystems?

<u>Mangrove ecosystems</u>

Mangroves are forests ecosystems consisting of trees, shrubs and ferns (Tomlinson, 1986) occupying the intertidal zone between the land and sea. There are 73 species of 'true' mangrove and they are mainly located in the tropics and subtropics, ranging between 32°N to 38°S (Quisthoudt et al., 2012). Mangrove latitudinal limits are primarily controlled by climate (Austin et al., 1989). Globally, there have been significant losses in mangrove areas over the past fifty years (Alongi, 2002). Giri et al (2010) estimated the total worldwide mangrove area to be 137,760 km^2, representing a decrease of 35% of the total area from 1980 to 2000 (MEA, 2005). A further 1920 km^2 were lost between 2001-2012. Asia, specifically South-East Asia, contains the largest remaining mangrove area and has suffered the greatest losses with more than 1000 km^2 lost between 2000-2012. The conversion of mangrove forests to aquaculture ponds accounted for 30% reduction in mangrove area. Rice-agriculture expansion and palm oil plantations are also significant drivers for mangrove removal in South-East Asia (Richards & Friess, 2016). In addition to aquaculture and agricultural land conversion, other significant drivers of global mangrove loss are increased urban expansion in coastal areas and infrastructure (resorts) to support coastal tourism development (FAO, 2007).

Mangroves, biodiversity and Ecosystem Services

Biodiversity or biological diversity refers to "the variability among living organisms from all sources, including, inter-alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (CBD, 1992). Loss of biodiversity from natural ecosystems can detrimentally affect both humans and nature (Diaz et al., 2006). Ecosystem services are the contributions to human welfare made by the natural world (Huxham et al., 2017) (p.246) and can be divided into three main categories: regulating, provisioning and cultural, with supporting services underpinning the others (MEA, 2005). The ecosystem services which mangroves provide in the tropics and sub-tropics are widely-recognised (Spaninks & Beukering, 1997; McLeod & Salm, 2006; Kettunen et al., 2010) and considerable emphasis has been placed upon assessing the value of mangrove ecosystem services using environmental economics (Alongi, 2002; MEA, 2005; FAO, 2007). Understanding the relationships between people and nature using an anthropocentric, specifically economic perspective can be both insightful and valuable (Davidson-Hunt et al., 2016) (p.13). Table 2 shows ecosystem goods and services of mangroves with their ecological function and direct, indirect and non-use values (MEA, 2005; Salem & Mercer, 2012; Brander et al., 2012).

Table 2. Services, function and value types of economic goods and services of mangrove ecosystems. Direct use values correspond to physical interaction with mangroves by humans (provisioning services), which result in both consumptive and non-consumptive uses (Salem & Mercer, 2012). Indirect use values relate to regulating services, while non-use or passive values relate to cultural services (Salem & Mercer, 2012). Adapted from Brander et al., 2012, with modifications from Salem & Mercer, 2012 and MEA, 2005.

ECOSYSTEM SERVICE	ECOLOGICAL FUNCTION	ECONOMIC GOODS AND SERVICE	VALUE TYPE
Provisioning	Nursery and habitat for animal and plant species	Commercial & recreational fishing and hunting. Harvesting of natural materials, energy resources	Direct use
Cultural		Recreation, ecotourism	Direct use
Cultural		Existence, bequest and option values	Non-use
Regulating	Carbon sequestration	Reduced global warming	Indirect use
Regulating	Flood and water flow control, storm buffering, sediment retention, water quality maintenance/ nutrient retention	Flood and storm protection, improved water quality and waste disposal	Indirect use

Temperate mangroves

The ways in which temperate and tropical mangroves are utilised by local communities are different (Morrisey et al., 2010). Tropical mangroves exist mainly in developing countries (e.g., India, Thailand, Vietnam, Kenya, and Tanzania). In these countries, subsistence living and local livelihoods are closely linked to utilisation of local environments. This creates co-dependency and potential for Payments for Ecosystem Services (PES) programs in addition to incentives for restoration and conservation of mangrove ecosystems (Huxham et al., 2017) (p.248) Temperate mangroves are generally located in the developed world where dependency on mangrove goods and direct services are much less important to communities thereby affecting the value we place upon such ecosystems. Temperate mangroves occur in parts of the USA, Southern Brazil, South Africa, Japan, Australia and New Zealand (Morrisey et al., 2010). Of the six countries where temperate mangroves are located, four are in the top fifty GDP per capita (USA, Australia, New Zealand and Japan) (Statistics Times, 2016).

2.2.1 New Zealand's mangroves

Mangroves are part of the indigenous flora of Aotearoa (New Zealand) and have been part of the natural environment for approximately 19 million years (Sutherland, 2003). They are the most southerly growing mangrove ecosystem in the world. The only existing mangrove species in New Zealand is *Avicennia marina* subsp. *australasica,* which has existed there for over 11,000 years (Pocknall, 1989) and currently occupies an area of approximately 177 km^2 (data compiled Hume et al., 2007; Carbines et al., 2017). Mangroves range from Cape Reinga in the far North of Northland, to Ohiwa harbour in the Bay of Plenty, on the East Coast and Kawhia harbour on the West coast (Morrisey et al., 2007; Vectors New Zealand, 2017; Land Information New Zealand, 2017) (Figure 1). Prior to the definition of ecosystem services, both (1972) and Dingwall (1984) recognised that there was no direct utilisation of New Zealand's temperate mangrove for fuelwood, charcoal or timber (Kūchler, 1972; Dingwall, 1984). Historically, mangroves or manawa had previous provisioning services for Māori. They were utilised for their tanning properties, as tools for pounding fern-root and as dyes for clothes. Post-colonisation, boat-builders used green mangrove wood for shaping the stern and bow (Crisp et al., 1990) (p. 23).

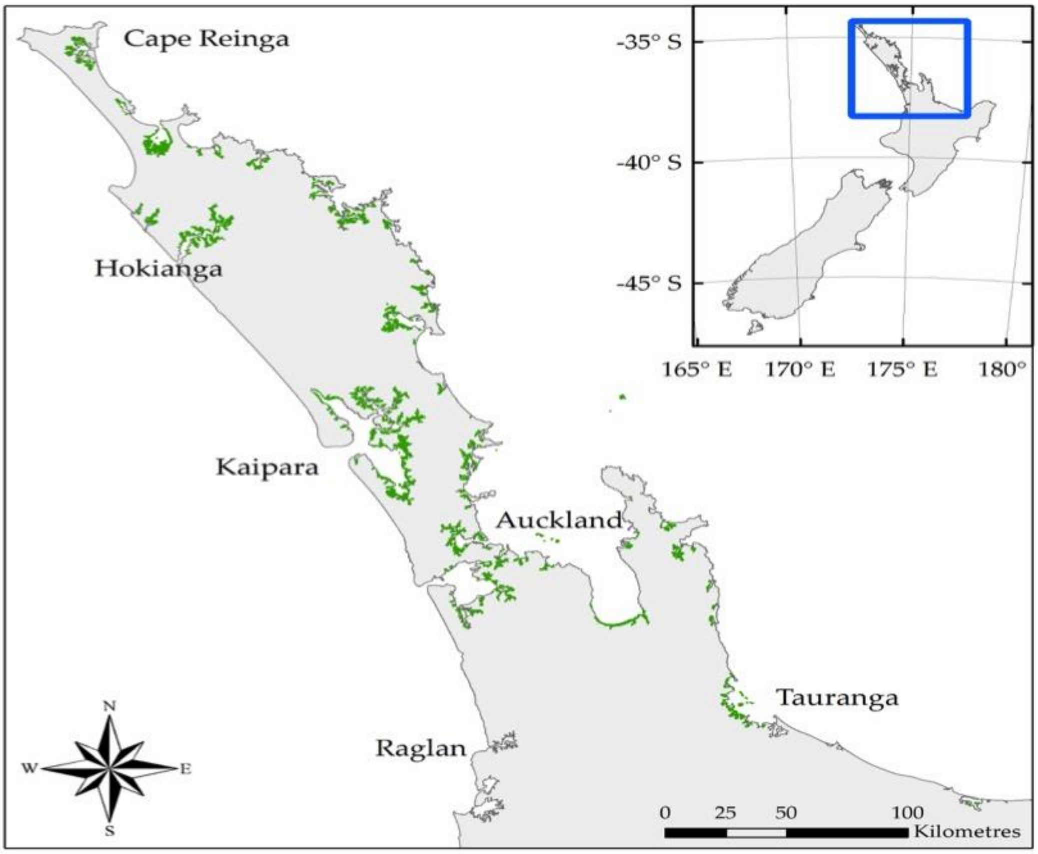


Figure 1. Map of mangrove distribution in New Zealand (green polygons). (Southerly limits below Tauranga). Adapted from Vectors New Zealand, 2017 and Land Information New Zealand, 2017)

Mangroves also provide habitat for species utilised as seafood or kaimoana, such as parore (black fish; *Girella tricuspidata*), tio (Pacific and Rock oysters; *Saccostrea glomerata and Crassostrea glomerulata*), kanae (grey mullet; *Mugil cephalus*) and tuna (eels; Anguillidae spp.) for the local community of Motuti in Panguru, Hokianga, Northland (Crisp et al., 1990) (p. 23). Even though the traditional uses of mangroves are not practiced, they still support both traditional Māori, community and ecological values (Schwarz, 2003). Current harvesting of tio by iwi and hapū (Māori tribes and smaller descent groups) occurs in the pneumatophore (aerial roots) zone of mangroves (seaward fringe), as far South as Tauranga. Previously iwi in this area advocated for mangrove removal. Recently, however, a pro-protection attitude has been adopted by local iwi from the belief that the mangrove fringe in this area supports high abundances of tio (Park, 2017).

2.2.2. Conservation Status and Policy: Treaty of Waitangi and the Resource Management Act

Te Tiriti o Waitangi or Māori version of the Treaty of Waitangi is one of New Zealand's founding documents signed on 6th February, 1840 (Waitangi Tribunal, 2017). In this agreement, tribal proprietary rights over 'taonga' (e.g., traditional language, knowledge and customs, land, water, flora and fauna) are guaranteed as 'te tino rangatiratanga' in Te Tiriti o Waitangi (Article 2). Despite this historic agreement, current legislation does not support Māori proprietary rights over flora and fauna, including mangrove. However, the Resource Management Act (1991) does make provisions for Māori consultation and decision-making over taonga, including mangrove management. The Wai 262 Report (flora and fauna section) also addresses 'ownership' and appropriation of Māori knowledge, customs, and cultural expressions surrounding indigenous flora and fauna, including all products derived from indigenous species (Wai 262, 2011).

Mangrove forests in New Zealand are protected from reclamation and indiscriminate destruction under the Resource Management Act (RMA) 1991 (RMA, 1991). The RMA promotes sustainable management of physical and natural resources (e.g. land, air and water; (RMA, 1991)). In this context, sustainable management refers to "managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while—

sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and *avoiding, remedying, or mitigating any adverse effects of activities on the environment".* (36, *Part 2, section 5*).

Despite the RMA, there is no clear mandate for mangrove conservation in New Zealand. Each regional council has their own policies and plans which relate to mangrove management. The Auckland Unitary Plan states that mangroves may be removed from the following areas; i) the general coastal marine zone, ii) significant ecological areas where ecosystem service values are not from mangroves and iii) significant ecological areas that are wading bird habitats (if they did not exist in these areas prior to 1996). (This was the earliest year where comprehensive aerial photography existed for the Coastal Marine Area (CMA) in the Auckland region) (Auckland Unitary Plan, 2013). In order to effectively achieve the goals of the RMA, any persons managing natural and physical resources must take into account the Treaty of Waitangi (Te Tiriti o Waitangi), 1840.

Under central and regional government policy, iwi (Māori tribes) are recognised as kaitiaki (guardians) and decision-making partners with customary rights. Therefore, iwi should be involved at the start of any decision-making process regarding natural and physical resource management. Overall, current resource planning has failed to fully account for rights and interests of Māori, mainly due to the mainstreaming of planning concepts, which originate from Western cultural concepts (Taiepa, 1999; Selby et al., 2010).

2.2.3. Mangrove expansion and removal

Over the past 150 years, mangrove expansion within estuaries has occurred due to increased sedimentation rates caused by changes in land-use, linked to urban and industrial development and agriculture (Green et al., 2003; Morrisey et al., 2007). Increased soil erosion in the wider catchment area and accelerated estuary infilling has led to expansion of mangroves at a mean rate of 4% per year across New Zealand (Morrisey et al., 2007). This expansion has created local estuarine management issues and polarity in public attitudes towards their conservation (Schwarz, 2003; Green et al., 2003; Morrisey et al., 2010; De Luca, 2015; Alfaro, 2006a).

There is a perception amongst some communities that mangrove expansion has a negative impact on the surrounding estuarine environment and reduces recreational and amenity values of coastal communities (Harty, 2009; Stokes et al., 2009). Boat and fishing access and vistas of the estuary and open water have been identified as important drivers for mangrove management and subsequent removal in New Zealand (De Luca, 2015).

Regional councils have come under pressure from local community groups campaigning for the removal of large areas of mangroves (Harty, 2009) leading to a number of resource consents being granted by regional councils to remove large areas of mangrove habitat from estuarine environments (Lundquist et al., 2014a), following an Assessment of Environmental Effects (RMA, 1991; Morrisey et al., 2007). Mangrove removal may detrimentally affect the surrounding estuarine and wider environment in many ways including declines in water quality through release of contaminants and sediments into waterways. Habitat loss for a variety of species will occur with mangrove removal, in addition to compromising the role of mangroves as carbon sinks and buffers against floods and storms (Morrisey et al., 2007; Kaly et al., 1997; Gladstone & Schreider, 2003).

In New Zealand, there is a strong focus on using citizen science for data collection, especially in the monitoring of biodiversity (New Zealand Landcare Trust, 2016). Incorporating Mātauranga Māori with environmental monitoring in community groups which are undertaking restoration projects (grassroots citizen science) is now being used in order to address socio-cultural needs and wishes (Peters, 2016). Estuary Care Groups have formed across New Zealand in order to 'maintain estuary values' (Bay of Plenty Regional Council, 2016). Mangroves play an integral role in this monitoring due to their expansion. The National Institute for Water and Atmospheric Research (NIWA) has created guidelines for the community-focused ecological monitoring of mangroves, in conjunction with Waikaraka Estuary Managers (Schwarz et al., 2005). The Bay of Plenty Regional Council have also created an environmental monitoring tool kit for estuary care groups to better understand ecosystem recovery and support future consents of mangrove removal (Bay of Plenty Regional Council, 2016).

How ecosystem services are affected by removal of mangroves has not been investigated in detail in New Zealand. Due to the increasing number of mangrove removals and lack of information on the impact this is having on the ecology of the areas, there is a pressing need to understand drivers for differing attitudes and perceptions towards mangroves and how these perceptions influence management decisions. Perception in this context can be thought of as the awareness an individual has towards something because of their practical interrelationships with nature on a daily basis (Ingold, 2000) (p.24). There is a strong pro-removal attitude in New Zealand towards mangroves, which directly influences management decisions. Decisions for large-scale removal will affect biodiversity of remaining mangrove patches and the surrounding coastal landscape (De Luca, 2015; Harty, 2009; Lundquist et al., 2014a).

2.3 Materials and Methods

In this paper, we undertook a thorough review of published, peer-reviewed literature in addition to documenting regional council reports (available online), about New Zealand mangrove ecology and management. This paper looks to build upon the review about the ecology and management of New Zealand's mangroves by Morrisey et al. (2010). Our results and discussion summarises all peer-reviewed published studies and key reports (from 1950), with a strong focus on new research carried out in terms of biodiversity, ecosystem services and economic valuation of mangroves in New Zealand (post 2010). Studies were divided into categories of biomass/abundance/distribution, nutrients, sedimentation, economic valuation, cultural value and management of mangroves. Management papers were also reviewed in order to integrate current knowledge and identify gaps in information with recommendations going forward.

The literature search was conducted using search terms "mangrove*" and "New Zealand" with the search engines Web of Science, Web of Knowledge and Google Scholar. Search terms were intentionally left broad so as to encompass all published peer-reviewed studies and council reports over the time period between January 1950 to July 2017. Whole papers were read, with title, location of study, results and references extracted. Papers and reports were categorised into biodiversity studies or mangrove attributes Results are presented for each field of study and by location and year, with the aim of highlighting knowledge gaps in both ecological and societal connections with mangroves.

2.4 Results

Seventy-seven papers were identified from the literature, (1952 to July 2017). Overall trends (with the exception of the 1960's) show an increase in number and type of study per decade (Figure 2). Biodiversity studies represent the majority per decade (with the exception of 1950's where biomass/abundance/distribution papers are slightly higher).

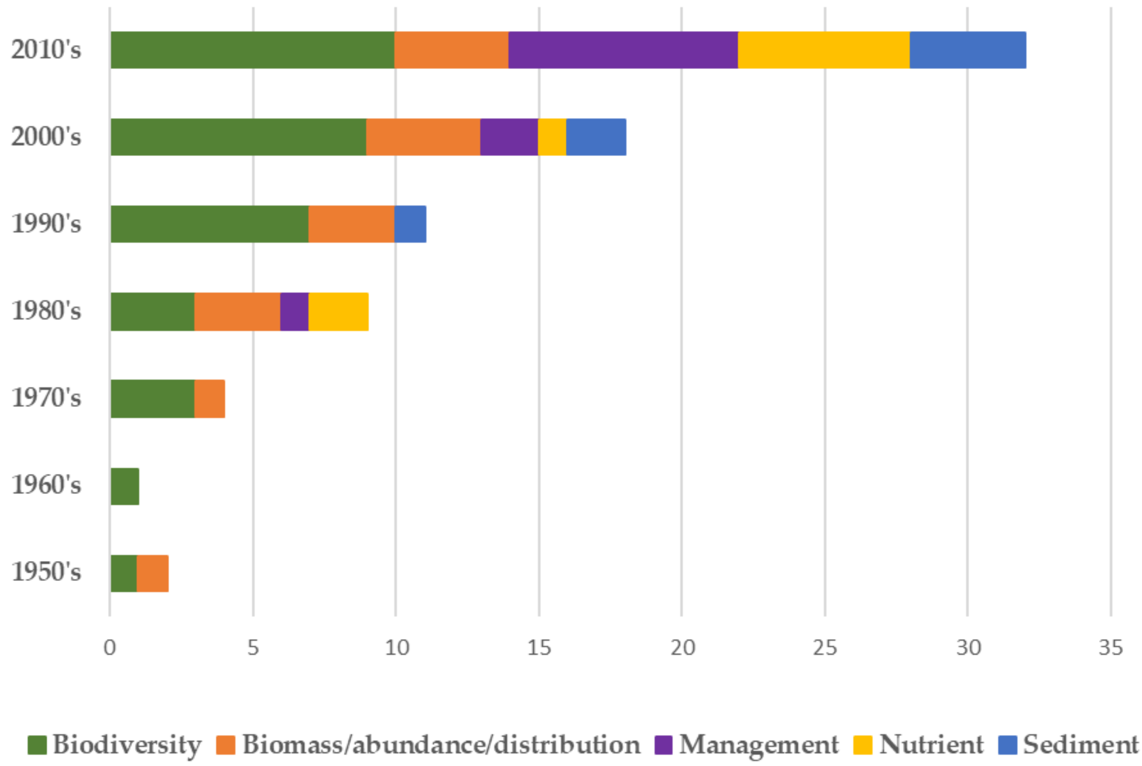


Figure 2. Studies on New Zealand mangrove attribute by decade up to and including 2017 (n=77). Studies identified from the literature were grouped into 5 categories of "biodiversity", "management", "sediment", "biomass/abundance/distribution "and "nutrient" papers and then by decade to document changes over time. (Lamb, 1952; Chapman et al., 1958; Morton & Miller, 1968; Cox, 1977; Henriques, 1980; Taylor, 1980; Gill, 1982; Woodroffe, 1982, 1985; Burns & Ogden, 1985; Dugdale, 1990; Kūchler, 1972; Ritchie, 1976; Dingwall, 1984; Hicks & Silvester, 1985; Dromgoole, 1988; Crisp et al., 1990; Laird, 1990; Miller & Miller, 1991; Blom, 1992; Young & Harvey, 1996; Clapperton et al., 1996; Osunkoya & Creese, 1997; Beauchamp & Paris, 1999; Gao, 1999; ,May, 1999; Nichol et al., 2000; Mildenhall, 2001; Parrish & William, 2001; Robertson & Heather, 2001; Swales et al., 2002; Morrisey et al., 2003; Brejaart & Brownell, 2004; Ellis et al., 2004; Ward & Harris, 2005; Alfaro, 2006a, b; Lovelock et al., 2007; Morrisey et al., 2007, 2010; Stephens et al., 2007; Swales et al., 2007, 2009, 2016; Harty, 2009; Alfaro, 2010; Stokes et al., 2010; Santini et al., 2012; Swales et al., 2015; Stokes & Harris, 2015;; Baird et al., 2013; Ismar, 2013; Lowe, 2013; Murray, 2013; Patterson & Cole, 2013; Yang et al., 2013; Gladstone-Gallagher et al., 2014; Lundquist et al., 2014a; Bulmer, 2017b Lundquist et al., 2014b, 2017, Balke et al., 2015; Bulmer et al., 2015; Doyle, 2015; Ngāti Te Ata Waiohua, 2015; Bulmer et al., 2016a,b ; McBride et al., 2016; Tran et al, 2016; Gritcan et al., 2017; Park, 2017; Pérez et al., 2017; Reynolds et al., 2017).

2.4.1 Biodiversity

A total of thirty-five peer-reviewed studies were classified as biodiversity in mangroves (Figure 3), including one technical report on the impact of removal of mangrove on benthic communities conducted by NIWA on behalf of Auckland Council (Lundquist et al., 2014a). The majority of studies have occurred in the past two decades, dominated by microbenthic invertebrate studies (37%), followed by birds, insects and spiders (both 23% of total studies), 8% of peer-reviewed studies are around fish, 6% on mammals and one single study on lichens in mangroves.

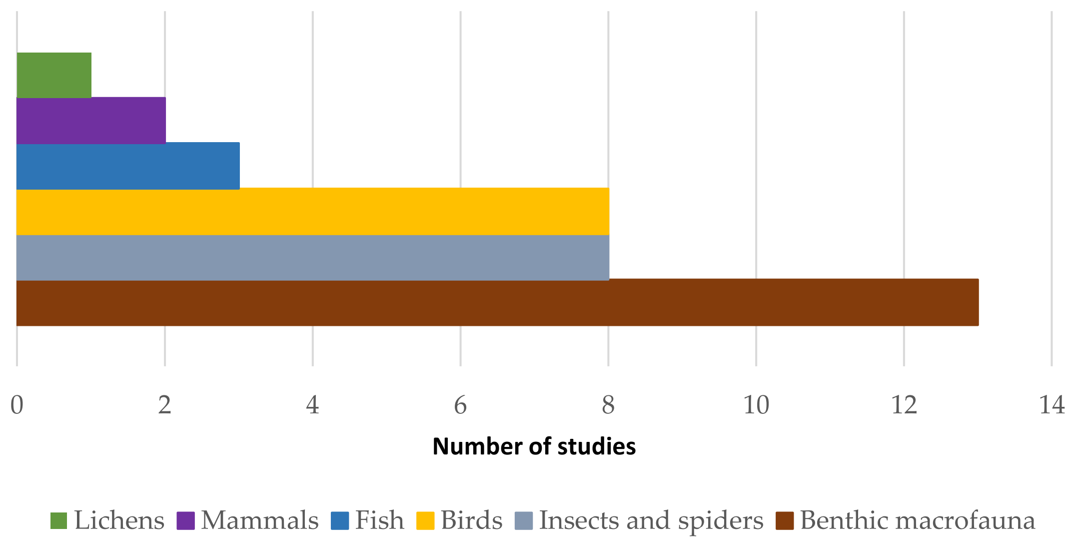


Figure 3. Online published biodiversity studies in New Zealand mangrove (peer-reviewed and technical reports from councils (1950-2017, n=35)). Studies were quantified and separated into type of organism (Lamb, 1952; Morton & Miller, 1968; Ritchie et al., 1976; Cox, 1977; Henriques, 1980; Taylor, 1980; Gill, 1982; Crisp et al., 1990; Dugdale, 1990; Laird, 1990; Miller & Miller, 1991; Blom, 1992; Clapperton et al., 1996; Beauchamp & Paris, 1999; Parrish & Williams, 2001; Robertson & Heather, 2001; Morrisey et al., 2003; Brejaart & Brownell, 2004; Ellis et al., 2004; Ward & Harris, 2005; Alfaro, 2006a,b, 2010; Morrisey et al., 2007; Stephens et al., 2007; Stokes et al., 2010; Baird et al., 2013; Lowe, 2013; Gladstone-Gallagher et al., 2014; Ismar, 2014; Lundquist et al., 2014a; Doyle, 2015; Bulmer, 2017b; Reynolds et al., 2017).

2.4.2. Macrobenthic invertebrate studies

Recent studies (2003-2017) have indicated lower macrobenthic invertebrate abundance associated with mangrove habitat compared to adjacent unvegetated habitats (Alfaro, 2006a; Ellis et al., 2004; Alfaro, 2010), with mature stands of mangrove showing the lowest diversity (Alfaro, 2010) and a greater number of taxa and abundance in young mangrove stands (Morrisey et al., 2003). Focus on the effects of mangrove removal on macrobenthic invertebrate communities has risen over the past decade, to observe whether communities in removed areas are similar to those of mudflat communities over time. Stokes (2010) observed a low diversity of gastropods, polychaetes and decapods in both mudflats and mangroves at three sites in Tauranga Harbour post-removal, with an absence of bivalves at both habitats (Stokes et al., 2010). A shift from filter-feeding to deposit-feeding communities occurred at these sites, which was driven by increased sedimentation and finer sediments within the upper estuaries (Stokes et al., 2010).

There is a considerable amount of variability in the responses of macrobenthic invertebrate communities with mangrove removal. A study on the effects of different methods of mangrove removal on benthic invertebrate communities was carried out at nine locations (twenty plots) in the Auckland region (Lundquist et al., 2014a). Mechanical removal, with biomass left *in situ*, showed less recovery towards sandy habitats and corresponding macrofaunal invertebrate communities. Smaller clearings, using non-mechanical methods with biomass removed were more likely to recover in the direction of macrofaunal invertebrate communities associated with sandy habitats. Seaward edges were more likely to show recovery than centre or landward edges of mangrove removal areas as exhibited by the increasing diversity of benthic invertebrate species from centre to the edge of unvegetated areas (Lundquist et al., 2014a). Bulmer et al. (2017a) also showed that removal method had an effect on reversion of benthic community structure to previous sandflat communities. Hand clearances, sites exposed to greater hydrodynamic forces and removal of above-ground biomass showed the highest chance of transition to adjacent sandflat habitat, although this was unlikely to occur in the first five years after removal (Bulmer et al., 2017a). Macrobenthic invertebrate studies dominate the literature of mangrove biodiversity in New Zealand. Benthic macrofaunal invertebrates respond in a variety of ways depending on the mangrove removal method, location of area removed and the hydrodynamics of the area (Lundquist et al., 2014a; Stokes et al., 2010; Bulmer et al., 2017a). Mature mangrove supports lower macrobenthic invertebrate diversity and abundance than young mangrove and adjacent mudflats (Morrisey et al., 2003; Ellis et al., 2004; Alfaro, 2006a; Alfaro, 2010; Stokes et al., 2010).

2.4.2. Birds

Assessments of birds inhabiting mangroves are sparse, with the most comprehensive assessment by Cox (1977). Twenty-two species of birds were observed and recorded in mangroves at specific sites in Kaipara Harbour, eleven of which showed signs of regular usage (Cox, 1977). Recently, two studies have been published on the nationally threatened New Zealand Fairy Tern *Sternula nereis davisae or* 'tara-iti' in mangrove (Baird et al., 2013; Ismar et al., 2014) in Mangawhai and Kaipara, respectively. Baird et al. (2013) observed Fairy Tern sightings in Kaipara mangroves and Ismar et al. (2014) identified the mangrove-lined highly tidal and shallow mid-estuary and the lagoon on the sand spit as foraging hotspots for breeding populations in Mangawhai. Another species known to frequent mangroves is the Banded Rail (*Gallirallus philippensis*). Recent work on Banded Rail in Mangawhai mangroves has shown their presence within the mangrove and at the edges, with an increase in foraging behaviour on the outer edges (seaward fringe) (Ji, 2017). There has been an increase in the use of trail cameras in the last few years, which have detected both nationally threatened and declining species (Baird et al., 2013; Ismar et al., 2014; Ji, 2017). More research is required on birds occupying New Zealand mangroves, including long-term monitoring of populations of Fairy terns and Banded Rails.

2.4.3 Insects and Spiders

There have been eight peer-reviewed published studies on insects and spiders, including single species studies on endemic obligate tortricid moth (*Planotortrix avicenniae*) (Dugdale, 1990) and the eriophyid mite (*Aceria avicenniae*) (Lamb, 1952). Other studies include presence of the Asian paper wasp (*Polistes chinensis*) (Clapperton et al., 1996), the scale insect (*Ceroplastes sinensis*) (Brejaart & Brownell, 2004), invasive argentine ants (*Linepthima humile*) (Ward & Harris, 2005) and the painted apple moth (*Teia anartoides*) (Stephens et al., 2007).

Personal communication from Dugdale in Morrisey et al (2010) listed the lemon-tree borer beetle (*Oemona hirta)* and ant colonies within tunnels of mangrove stems made by boring insects. In recent years, one study on the diversity of arthropod communities in Firth of Thames mangroves identified 101 species, 44% of which had not been found in any other inland habitat. The author concluded that the terrestrial arthropod community in this area was unique compared to other New Zealand habitats and may include species not present elsewhere (Doyle, 2015). The studies on terrestrial invertebrates in New Zealand mangroves are few. It is imperative that more information is documented on terrestrial invertebrate populations in mangroves.

2.4.4. Fish

Ritchie (1976) identified 30 species of fish which regularly occupy mangroves, including flounder, mullet and eels as permanent residents; snapper, trevally, baracouta and mackerel being frequent visitors and dogfish, shark and red moki occasional users (Ritchie, 1976). A broad-scale study by Morrison et al. sampled mangroves bordering eight estuaries between February-April 2006 (. Nineteen species were recorded, dominated by yellow-eyed mullet *Aldrichetta forsteri* (65.5%), and grey mullet *Mugil cephalus* (17.9%). Short-finned eels were positively related to habitat complexity of mangroves (Morrisey et al., 2007). However, no comparisons were made with adjacent habitats, therefore the importance of mangrove habitat and potential nursery roles could not be assumed. A recent study conducted by Lowe (2013) found grey mullet and pilchard in high abundance in Manukau harbour and Mahurangi respectively. Diversity and abundance of fish species were greatest in seagrass, followed by sandflats, mangroves and mudflats (Lowe, 2013).

Further research is being conducted following Morrison et al. (2010) to understand habitat use of mangrove by fish as explained below from personal communication with Mark Morrison (2017). "There are three species that can be defined as using mangroves as a fisheries habitat, defined as using this habitat disproportionately more than other habitats. On the East Coast, mangroves are a habitat for juvenile parore, on the West Coast they are a habitat for grey mullet juveniles and short-finned eels on both coasts.

It is possible that expansion of mangroves in these areas may mitigate against the loss of freshwater habitat for short-finned eel. However, there are no estimates for this. There were large numbers of very small grey mullet exiting the mangroves in the Manukau as the tide dropped when it was sampled, and it is suspected they use mangroves here to avoid predation (Morrison, 2017). It is likely that the quality of food or amounts of food for mullet are much less in mangrove than intertidal mudflat, which is possibly driving that reduction in growth rate" (Morrison, 2017). Comparisons of fish utilisation between mangrove and adjacent coastal ecosystems are required before we can understand the value of mangrove habitat to different fish species.

2.4.5 Mammals

Two studies have been published on the presence of mammals in New Zealand mangroves to date. Cox (1977) observed rat droppings and footprints at a Kaipara mangrove site and Blom (1992) speaks of the presence of weasels (*Mustela nivalis*) in mangroves. Morrisey et al (2010) stated that it is likely that brush-tailed possum *(Trichosurus vulpecula)* uses mangroves due to its ubiquitous nature in New Zealand. A current study (in progress), looking at mammalian predators in Mangawhai mangroves using camera traps; found rats present at the outer edge and interior of mangrove, along with rats, cats, stoats, hedgehog and ferret footprints at the saltmarsh/mangrove fringe (Ji, 2017). There is limited knowledge on the presence of mammals in mangroves in New Zealand; all studies have identified non-native, invasive mammalian species as occupying mangroves (Cox, 1977; Blom, 1992; Ji, 2017).

2.4.6. Lichens

A recent study has been published regarding the presence of lichen on mangroves (Reynolds, 2017). The authors, sampling 200 trees from 20 mangroves sites throughout North Island documented 106 lichen species from 45 genera, which were correlated with diameter at breast height of mangrove and mean annual rainfall. Two 'Nationally Endangered', five 'Naturally Uncommon' and twenty-seven 'Data Deficient' species were identified, highlighting the importance of mangroves for lichen species. Comparable numbers of lichens have also been found in both tropical and sub-tropical mangroves globally (Reynolds, 2017). This recent study is currently the only published peer-reviewed paper on lichens in mangroves in New Zealand. It is important for monitoring of threatened lichen species to continue as part of mangrove biodiversity knowledge in the future.

2.5 Attributes- Regulating and supporting service studies

Research involving regulating and supporting services of mangroves was identified in thirty-two peer-reviewed published papers, 50% in the last seven years. A strong focus of these recent papers has been on macronutrients (carbon and nitrogen) in mangrove leaves, below-ground biomass (roots) and sediment.

2.5.1. Nutrients

Gritcan et al (2017) investigated levels of nitrogen and phosphorus in mangrove leaves in Mangawhai, Waitemata and Manukau. Results showed significant differences among the areas, with Mangawhai having lower levels of total nitrogen and δ^{15} nitrogen than Manukau (2.2%N and 9.9‰ and 2.0%N and 5.2‰, respectively) and Waitemata having intermediate levels. A decrease in leaf total nitrogen and δ^{15} N in Waitemata mangroves over the past 100 years was documented also. This suggests a decline in anthropogenically derived nitrogen inputs, which may be linked to sewerage system improvements in the harbour over the same period (Gritcan et al., 2017).

A few studies in recent years have focused on carbon allocation of mangroves in above-ground biomass (AGB), below-ground biomass and sediment carbon stocks. Allometric equations produced for AGB, carbon and nitrogen stocks at the southerly distribution of *Avicennia marina australasica* in New Zealand by

Bulmer et al., (2016a). Results showed that carbon and nitrogen stocks accounted for 41.23 ± 0.40% and 1.28 ± 0.03%, respectively, of total above ground biomass. Tree canopy volume was the greatest predictor of all three variables (Bulmer et al., 2016a).

Tran et al., (2016) also looked at carbon allocation in *Avicennia* at Mangawhai and estimated that New Zealand mangroves stored a total of 0.2–1.1 Mt carbon (C) in above ground and 1.06–1.72 Mt C in below-ground biomass (Tran et al., 2016). Carbon and nitrogen stocks in below ground biomass and sediment were also measured at five mangrove sites across North Island (Bulmer et al., 2016b). Results showed that carbon contributed 88 ± 3% of total below ground stocks, and nitrogen contributing 99 ± 0.4% of total stocks.

Sedimentary carbon stocks were affected by mangrove removal, as shown by a recent study by Perez et al., (2017). The authors looked at the effects of mangrove removal on amounts of sediment carbon in Whangamata and found that removed sites of mangroves showed a marked decrease in sedimentary carbon stocks (2,767 ± 580 g m^{-2}) in comparison to the preserved area (6,949 ± 84 g m^{-2}) (Pérez et al., 2017) this was coupled with a decrease in sedimentation rates in removed areas. Total organic carbon concentrations were also markedly higher in areas dominated by mangrove (post-1944) in comparison to areas dominated by salt marsh (pre-1944) (Pérez et al., 2017).

Rates of efflux of CO_2 have also been compared between cleared and intact mangroves in a recent study [80]. Sediment CO_2 efflux rates were 168.5 ± 45.8 mmol m^{-2} d^{-1} and 133.9 ± 37.2 mmol m^{-2} d^{-1} from cleared mangrove forests (Bulmer et al., 2015). The authors stated that these rates are comparable to rates from tropical mangrove forests. These studies showed the importance of mangroves as nutrient sinks, especially for carbon storage.

2.5.2. Sediment accumulation

There has been an increase in the number of papers addressing sediment accumulation rates in the past few years. Of notable interest are three papers around the projected responses of mangrove ecosystems to sea-level rise in New Zealand (Swales et al., 2009; Swales et al., 2016; McBride et al., 2016). Results showed the fate of mangroves depends on sediment elevation rates keeping up with relative sea-level rise (Swales et al., 2009). Current or increasing sediment supply will allow for the maintenance or expansion of mangrove habitat. A rapid increase in mangrove expansion is only likely to occur in smaller estuaries with a high sediment load and limited flushing (Swales et al., 2009). A reduced supply of sediment will result in a large decrease in mangrove upper zones (McBride et al., 2016).

2.5.3. Biomass/abundance/distribution

Many studies have examined the expanding distribution of mangroves over time, from Chapman and Ronaldson's work (1958) on mangrove and salt-marsh flats of the Auckland Isthmus, up to the present day (2018) Focus has shifted to quantification of carbon stores and comparisons with tropical mangroves and adjacent habitats such as seagrass. A recent study of interest compared digital images of mangrove on Motu Manawa, or Pollen Island from 1940 and 2003, finding an increase in mangrove area of 21% (Yang et al., 2013). This expansion was linked to sediment retention and an increase in total organic carbon, with accumulation occurring in the interior of the mangrove as it expanded seaward (Yang et al., 2013). A recent litter production and decomposition study in Whangamata mangroves showed that leaf litter decomposition is an order of magnitude slower than that of tropical mangroves (Gladstone-Gallagher et al., 2014). Litter fall within the forest (older trees) was significantly higher (t-test, $P < 0.05$) than that of younger trees on the edge of the forest, with roughly half of the production. The authors concluded that mangrove detrital production was comparable to seagrass (*Zostera muelleri*) in the Whangamata Harbour (Gladstone-Gallagher et al., 2014). These studies showed that mature mangroves have high levels of total organic carbon and high detrital litter production.

2.6 Attributes-Social and economic studies

Eleven papers addressed social (cultural and management) and economic studies in mangroves, with the majority (ten) having been published in the past decade. The proliferation of management papers has coincided with the increase in removals, which have used a variety of removal techniques

2.6.1. Management

Two general management papers published in recent years highlight the main reasons behind removal. These include a desire to revert mangrove habitats to sandflats existing before mangrove colonisation in the 1950's and to increase recreational and amenity value of open-water spaces, including cultural waka (canoe) access (Lundquist et al., 2014b). Other reasons for removal include restoration of seagrass and shellfish beds, improved functioning of drainage systems and increased flood protection (Lundquist et al., 2017). A study of 40 removal sites indicated the likelihood of reversion to sandflats following removal is rare, often having detrimental effects on the local ecosystem and amenity (sights and smells) instead. Methods of removal impact upon the reversion of the areas to previous sandflats, in addition to wave action and tidal flushing. The authors suggested the following for effective management: If removal of mangrove is to go ahead, seedling removal provides a low impact method of management. However, seedling removal will be continuous due to rapid colonization or recolonization of mangroves. This method will remove additional growth, but not the established mangrove. Mechanical removal creates the most physical disturbance and compression of the seabed, in addition to anoxic conditions created by mulch left in-situ, smothering benthic communities (De Luca, 2015; Lundquist et al., 2017). Smaller areas of mangrove removal recover faster and it is recommended that small strips of mangrove are removed on the seaward boundary of a mangrove stand in order to maximise exposure to wave action and tidal flushing (Lundquist et al., 2017). The authors also highlighted the importance of baseline monitoring pre-removal and comparisons with post-removal data to be made in order to evaluate the achievement of removal objectives and to provide an indication of ecological health of the area (Lundquist et al., 2014b; Lundquist et al., 2017). Mangrove management is a complex topic to be addressed on a site-by-site basis; it is not a one-case-fits-all issue (Lundquist et al., 2014b; Lundquist et al., 2017). Mangrove removal of large areas is not advised before long-term ecological monitoring of a coastal area has been undertaken (Lundquist et al., 2017). Table 2 summarises social and economic studies on New Zealand mangroves between 2013-2017.

Table 2. Management papers on mangroves in New Zealand, categorised by type of paper (E=Economic Valuation, C=Cultural Impact Assessment, M=Management), topic, location in New Zealand, general notes and references (2013-2017).

Type	Topic	Location	Notes
E	Costs of removal	Auckland and Tauranga	Variation of costs ranging from $10,000-$33,000 NZD/Ha for removal Bay of Plenty Regional Council, 2016.
E	Total economic value of land-based ecosystems	New Zealand-wide	Gross value of $144,000,000 NZD for mangroves Patterson & Cole, 2013.
E	Cost-benefit analysis of managing mangroves	Auckland	Projected expenditure 2011 local board plans including mangrove removal Murray, 2013.
C	Cultural impacts of mangrove removal	Auckland	Restoration of mauri of harbour is of most importance Ngāti Te Ata Waiohua, 2015.
M	Management and Planning review	Tauranga	Harbour-wide management of mangroves difficult to achieve. Need site-specific assessments. Bay of Plenty Regional Council, 2016.
M	Managing mangrove expansion	New Zealand-wide	Likelihood of successful restoration rarely considered, minimal information on long-term trends in ecosystem health of removed areas Lundquist et al., 2014b.
M	Management guidelines	General New Zealand	Land-use to reduce sediment loads needs to be better managed, pre-removal baseline data required Lundquist et al., 2017.

2.6.2. Economic valuation and cost of removal

Costs of mangrove removal vary by method, area and timeframe. Auckland Council (2015) provided a list of estimated costs for removals in the Auckland and Bay of Plenty regions. The resource consent costs ranged from $2,500 NZD (Auckland Airport) to $38,000 NZD (notified and full hearing process, Pahurehure Inlet 2). Costs for removal ranged from $10,000 to $33,000 NZD per hectare with monitoring costs ranging from $10,000 for baseline, up to $15,000 for monitoring during and post- removal (Murray, 2013). The largest resource consent for removal in the Auckland area to date was 27 hectares of mangrove in Pahurehure Inlet 2, between 2010 and 2012. This cost $1.5 million NZD [89]. Another current removal is in Waimahia (19.3Ha). Costs are estimated at $880,000 NZD for removal, plus $28,000 for a works management plan and $5,000 for a bird survey. Table 3 shows costs of removal for some of the largest areas in the Auckland region in recent years.

Table 3. Costs of consent process and removals of mangroves in Auckland region (selected recent examples of substantial areas of removal 2010-2017)

Region	Activity	Method	Year	Costs (NZD)
Papakura Auckland	Mangrove and seedling removal over 3 years (27Ha)	Tractor and helicopter to remove AGB, roots left in situ	2010-2012	$1,500,000 Murray, 2013.
Waimahia	Mangrove and seedling removal	Handsaw, loppers	2015	$888,000 (works costs) plus 28k works management plan and 5k bird survey (projected) Bay of Plenty Regional Council, 2016.
Mangere and Waitemata	Consenting process and removal of mangroves in Auckland's two harbours	Hand removal	2011 Local Board Plans	$780,000 Murray, 2013

A nation-wide survey of the total economic value of New Zealand's land-based ecosystems and their services was conducted in 2013, by Patterson and Cole

(2013). Results from this rapid assessment of land-based ecosystems valued mangroves as having the lowest net worth (Figure 4a), with a gross-value of $144 million NZD (2012). This covers the services of disturbance regulation (flood control, storm protection and drought recovery) ($95 million NZD), refugia for wildlife (nurseries, habitat for migratory species, regional habitats for locally harvested species or overwintering grounds) ($8 million NZD) and passive use value (non-use values) ($44 million NZD) (Patterson & Cole, 2013). When considering value per hectare, these figures (Figure 4b), place mangroves at sixth highest total use value ($5,000 NZD/Ha).

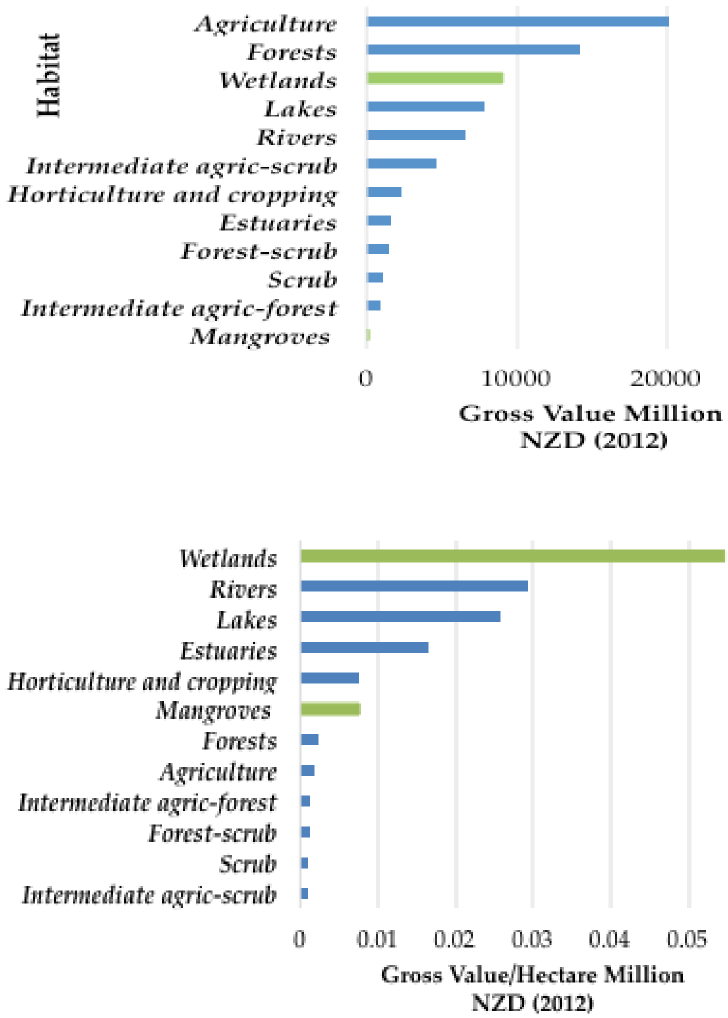


Figure 4a). Gross value (use value + passive value) estimated for New Zealand's land-based ecosystems in 2012 and **4b).** Gross value *(per hectare)* estimated for New Zealand's land-based ecosystems in 2012. Both (a) and (b) are adapted from data extracted from Patterson & Cole (2013).

These studies highlight the expense involved in mangrove removal and the ambiguous information displayed regarding valuation of mangroves in terms of the ecosystem services they provide (mangroves are separated from wetlands in this assessment). More comprehensive information is required to provide accurate estimations of the value of mangroves in New Zealand.

2.6.3. Cultural studies

Only one published study mentions the cultural value of mangroves in New Zealand (Patterson & Cole, 2013). The authors stated that no reliable data could be found for ecosystem service valuation of mangroves and therefore, they placed provisioning and cultural values of mangrove as zero.

Ngāti Te Ata Waiohua (mana whenua of the Mangere-Ōtāhuhu area) carried out a cultural impact assessment in 2015 for Auckland Council for mangrove removal at sites around Mangere in the Manukau, Auckland. This impact assessment was written prior to approval of the resource consent for mangrove removal at four sites (Kiwi Esplanade, Norana Park, Hastie Avenue and Mahunga Drive, totalling 13.5 Ha), it provides an insight into the views of this iwi towards mangrove removal. Ngāti Te Ata Waiohua state that: *"We are not opposed to the removal of mangroves providing that the storm water and other source discharge are of the highest standard and that comprehensive, sufficient research is undertaken to justify their removal"*. Overall, this Iwi's primary objective is to *"restore the mauri* (life-force) *of the harbour so it begins to heal itself"* (Ngāti Te Ata Waiohua, 2015). Very little is known about the cultural value of mangroves to iwi. This is an area which should be explored further.

2.7 Discussion

Despite an increase in the number of studies covering a wide-range of mangrove ecosystem services, or attributes, there are still substantial knowledge gaps in our understanding of mangrove ecology in New Zealand. Of all biodiversity studies on mangrove in New Zealand, the focus and most knowledge gained has been around benthic macrofaunal invertebrate communities and comparisons with adjacent mudflat habitats. Given the ease of sampling and relatively straight-forward identification of species, this kind of monitoring gives fast and informative results. However, valuation of mangrove habitat in terms of abundance and diversity of organisms should not be based on these studies alone.

The role of mangroves in providing habitat for terrestrial species, not just marine and freshwater organisms, has been largely overlooked globally (Meades et al., 2002; Rog et al., 2017). Little information is available for terrestrial vertebrates, such as mammals, reptiles and amphibians (Meades et al., 2002). A recent global review of these groups in mangroves found 464 species of terrestrial vertebrates documented in mangroves worldwide (Rog et al., 2017).

No peer-reviewed published study has been carried out on the presence of reptiles in mangroves. Crisp et al. (1990) referred to Pacific and forest geckos (*Hoplodactylus pacificus* and *H. granulatus* respectively) being found in northern mangroves (Hokianga and Rangaunu) as well as sea snakes (*Laticauda colubrina*, *L. laticordata* and *Pelamis platurus*) (although these are rare). No citations were provided in these descriptions of reptiles (Crisp et al., 1990) (p.37).

Recently, there has been an increase in the use of camera traps or trail cameras in New Zealand mangroves. These have recorded presence of mammalian predators, such as stoats, rats, hedgehogs, cats and ferrets as well as the Banded Rail in Mangawhai and Waitakere mangroves (a nationally declining bird species) (Ji, 2017; Paris, 2017). Another mammal of interest for long-term monitoring is the long-tailed bat (*Chalinolobus tuberculatus*). While there are no records on the activity of this species over brackish water environments. High food availability (flying insects such as moths, beetles, mayflies, mosquitoes and midges) in mangrove areas is likely (Paris, 2017). Long and short-tailed bats are New Zealand's only native land mammals (Carter & Riskin, 2006). Geckos and bats rely on insects as a food source.

Apart from one study on terrestrial arthropod communities in mangrove in the Firth of Thames (Doyle, 2015), no other published study has assessed any form of insect diversity in New Zealand mangroves. A recent review exploring linkages between biodiversity attributes and ecosystem services across multiple natural ecosystems has shown a positive relationship between the two. For example, species level traits such as abundance or number of species is important for pest regulation, pollination and recreation (Harrison et al., 2014). Assessing biodiversity within mangrove ecosystems in New Zealand has not been investigated in any detail across groups of organisms. Establishing baseline data on diversity, densities and distribution of groups of organisms will contribute to ecological knowledge on mangroves and provide insights into linkages between species and the resulting ecosystem function in terms of biodiversity.

As well as an increase in the number of biodiversity studies in New Zealand mangroves, studies on macronutrients, such as carbon and nitrogen, in both above- and below-ground biomass and sediments are also on the rise. Globally, research on the role of mangroves as carbon sinks and mangrove sediment as a store of blue carbon is also underway (McLeod et al., 2011; Pendleton, 2012; Alongi, 2014). Research in this field in New Zealand is beginning (Bulmer et al., 2016 a, b), in addition to studies on sea-level rise and how this may affect mangrove distribution in the future. These studies will provide important information for climate change adaptation and mitigation in New Zealand.

Knowledge gaps include the retention of contaminants in mangroves, such as transitional metals. Recent studies from New Caledonian mangroves showed that nickel, chromium and iron concentrations were substantially higher in mangrove areas sampled than the global average in mangroves (Marchand et al., 2012). The role of mangroves in retaining transitional metals is related to water quality of the surrounding environment and so has both ecological and societal implications in terms of mangrove removal. The objective of all iwi is to restore the mauri, or vitality, of harbours and waterways. Understanding how mangrove removal affects the release of contaminants in the water should be a priority for research. Some kaitiaki (guardians of the environment) state that removal of some areas of mangrove should be stopped until we have information on this (Anonymous iwi, 2017). This is an example of how Māori values and Mātauranga can be integrated with ecological knowledge for sustainable management of estuarine and coastal areas where mangroves are present. Figure 5 summarises ecosystem service studies and process in New Zealand mangroves.

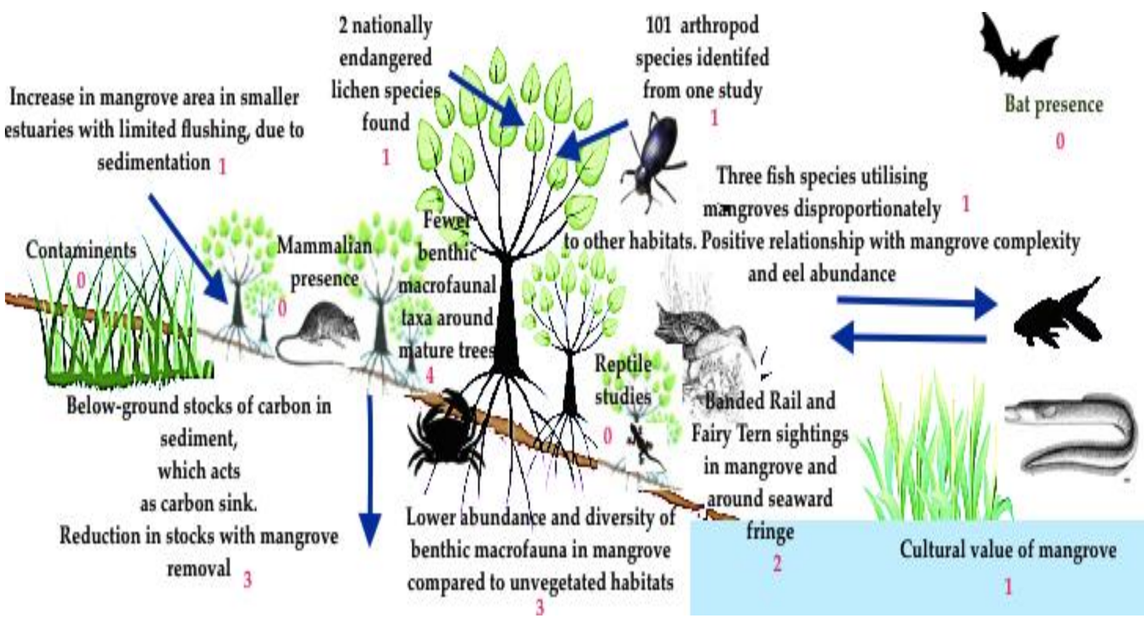


Figure 5. Pertinent biodiversity and mangrove attribute studies in New Zealand mangroves (2010-2017) Pink number refers to the amount of studies since 2010. Images adapted from Fishbase, 2017; Species at Risk Public Registry, 2011; Pixabay, 2018; Huxham et al. 2018; Sibr.com, 2018; Morizu.com, 2018; Clipart Library, 2016.

Economic studies have highlighted the high costs involved in removing mangroves. The costs of lodging a consent application, removal, disposal and on-going ecological monitoring of a site need to be considered. Patterson & Cole (2013) estimated the value of mangroves in New Zealand based only on disturbance, refugia and passive value of mangroves in New Zealand. They also separate mangroves from wetlands in this study, when mangroves are in fact coastal wetlands (Environmental Protection Agency, 2016). The authors identified a lack of available information on valuation of mangrove ecosystems in New Zealand.

The main influence on mangrove presence in New Zealand is human activity and related consents for removal, this is driven by a perception from some people that mangrove expansion has detrimentally affected coastal and estuarine environment, replaced habitat for some species and reduced recreational activities and amenity access. The lack of published data on perceptions and attitudes of local communities (iwi and other community groups), and the limited number of ecologists involved in monitoring these habitats must be addressed. This will create an overall understanding and knowledge or Mātauranga around socio-cultural and ecological values of mangroves at particular sites in New Zealand.

Mangrove management should not just be viewed in terms of seedling and young tree removal as sedimentation loads will allow for continued reestablishment of mangrove propagules in many regions. Wider land-use management which addresses sediment loading in addition to finding a balance between maintaining ecosystem services of value and the wants and needs of local communities is required (Lundquist et al., 2017). The links between mangrove ecosystems and local community aspirations is very strong in some estuaries and harbours in New Zealand where mangrove expansion has occurred rapidly. The system itself is a social-ecological system (SES) and therefore requires an SES framework, which incorporates both societal perceptions and attitudes along with ecological monitoring in order to address coastal sustainability. A mixed methods approach to collecting, analysing and evaluating social-ecological data to address mangrove management is recommended.

2.8 Conclusion

The range of attribute studies and subsequent findings highlight the complexity of mangrove management in New Zealand. A reductionist viewpoint towards biodiversity does not give recognition to how local people interact with and understand nature (Viveiros de Castro, 1994). Indeed, the management of mangroves in New Zealand has been referred to as a 'wicked problem' as it has many causes and non-definitive solutions (Murray, 2013). Currently, we cannot make informed decisions about mangrove removal due to the gaps in ecological and socio-cultural knowledge (including both traditional and current local ecological knowledge), which still exist. The interconnection between ecological and social systems must be considered if we are to address these complex interactions (Davies et al., 2015). An integrated approach to overall estuarine and coastal management, which uses traditional ecological knowledge and engages iwi in long-term monitoring of these dynamic ecosystems is the end goal.

Chapter 3

Holistic Mangrove Research Framework

"One of the best ways to see tree flowers is to climb one of the tallest trees and to get into close, tingling touch with them, and then look broad".

John Muir

The proceeding chapter describes the process of designing and implementing a mixed methods framework for the study in order to address the overall research aim. It includes a background to social-ecological systems (SES), the need to apply a mixed methods framework to address the problem of mangrove management and the research paradigms adopted. This chapter speaks about each phase of the study in terms of design and conduction in a broad sense, which can be applied to other SES's in order to investigate human-nature interactions in a holistic manner. This chapter sets the stage for the study and provides a flexible, adaptable framework on which this research was based.

3.1 Abstract

Social and natural systems are non-linear in nature, cross-scale in both time and space, and evolve dynamically. The complexity of such social-ecological systems (SES) means that there is not a simple solution to problems of sustainability. This chapter describes the development and design of an innovative mixed methods design for investigating the social-ecological trade-offs between preserving and removing temperate mangroves in New Zealand. We outline a "Holistic Mangrove Research Framework" using a new three-phase mixed methods design to generate knowledge and identify social and ecological trade-offs. The creation of this social-ecological framework within the context of temperate mangroves provides a case study approach for local mangrove management and regional coastal sustainability.

Key Words: complexity; social-ecological; mixed methods; mangroves; management

3.2 Introduction

3.2.1. Social-ecology of mangrove ecosystems in New Zealand

Large-scale mangrove removal in New Zealand can be thought of as a "creeping environmental problem" (Glantz, 1994, p.218). This is a problem, which grows gradually, with a time lag between cause and effect, resulting in cumulative and long-term consequences (Glantz, 1994). As such, this problem may also be viewed as "wicked" due to its many causes and non-definitive solutions (Murray, 2013). Donna Mertens calls for researchers to consider new ways to tackle wicked problems: "business as usual will not lead to effective use of research to address wicked problems, problems for which time for solutions is running out" (Mertens, 2015, p. 5).

The New Zealand grey mangrove (*Avicennia marina* subsp. *australasica* (Walp.) J. Everett.) is a native coastal and estuarine tree species, which is protected by law under the Resource Management Act (RMA, 1991). The rapid seaward expansion of mangroves over the past fifty years within estuaries and harbours in the Auckland region, North Island, New Zealand has led to applications of resource consents for removal of mangrove back to 1996 levels (Morrisey et al., 2007; Auckland Council Unitary Plan, 2013). Some of these consents have been granted in the past twenty years with sparse ecological monitoring both pre- and post-removal.

Reasons for removal have centred on the changing coastal landscape over the course of 150 years due to urbanisation, agricultural practices and industrialisation. For example, increased sedimentation caused by anthropogenic activities has led to the expansion of mangroves in these areas (Green et al, 2003; Morrisey et al., 2007). This expansion has led to a polarising debate over their presence, with some supporting the conservation of mangroves at one end of the spectrum and those advocating for complete wholesale removal on the other. The desire for the reversion of estuaries to a pre-mangrove state, in order to facilitate recreation and amenity access in estuaries is a driving force for their removal by local communities (Harty, 2009; Stokes, 2009; De Luca, 2015).

The inter-relationship between humans and mangrove ecosystems can be viewed as a social-ecological system, which is a complex and integrated system whereby humans are part of nature (Berkes & Folke, 1998). This complexity means that there is not a simple solution to address issues of sustainability (Axelrod & Cohen, 1999) and understanding the complex whole requires knowledge about the specific variables and how their component parts are related (Ostrom, 2009). Describing a social-ecological system in a simplistic manner can be both counter-intuitive and unhelpful in comprehending complexity (Johnson & Lidström, 2018). Rather complexity should be embraced (Ostrom, 2009; Evans et al., 2017). This chapter shows the development and design of an original way to investigate mangrove ecosystems, which are not utilised as a common pool resource. This framework has the capacity to be implemented in other social-ecological settings.

3.2.2 Community consultation and engagement

Community involvement in consultation and engagement is widely acknowledged as key for the effective management of natural systems. Indeed, engagement with stakeholders of all types is necessary to navigate complex management processes (Adams and Sandbrook, 2013; Rose et al., 2018). Management decisions will always affect, and be affected by, people in these complex social-ecological systems, and it is important to take these dynamic interactions into account. In doing so, we must move beyond simply improving the communication of management decisions downstream, to building effective processes of knowledge exchange, co-learning, compromise, and co-operation (Beier et al., 2016; Wyborn, 2015).

As such, there are increasing calls for environmental management and conservation processes to become more integrative, interactive, and inclusive (Bennett et al., 2017; Elliott et al., 2018).

Incorporating adequate consultation and engagement in management processes is likely to increase social acceptability and support for different actions, thus increasing the likelihood of effective management (Ives et al., 2015; Jarvis et al., 2018; Rose et al., 2018). It is important to note that any engagement undertaken should be sensitive to cultural context, and the inherent power dynamics of these systems, to ensure the appropriate stakeholders are identified and included (Reed et al., 2017; Sterling et al., 2017). For this reason, there is a need for clear processes that ensure the perspectives, knowledge, and worldviews of different stakeholders are being taken into account (as per Bennett et al., 2017). By building in appropriate engagement processes from the outset, mangrove researchers, decision-makers, and practitioners can develop a social-ecological approach to mangrove systems that better accounts for the dynamic interactions between people and nature. Such an approach is particularly important for navigating complexity in, and building a holistic understanding of, mangrove systems, which can then be used to inform management and decision-making.

Prior to the application of this social-ecological mixed methods framework, there had been no peer-reviewed social research directly relating to mangroves and their removal in New Zealand. There is an imperative need to understand how mangroves and local communities operate and function as a social-ecological system in order to implement policy for a sustainable coastal future.

3.3 Mixed Methods in mangrove management

A mixed methods approach to research design and enquiry can allow for the answering of a broader range of research questions and provide stronger evidence for conclusions through the corroboration and integration of findings. It can also provide novel insights and understanding, which may not be possible by relying on a single method. In addition, mixed methods can provide a more holistic understanding of mangroves across different knowledge systems that can be used to inform both theory and practice, and aid us in navigating the spaces between them (Tengö et al., 2014; Burke Johnson & Onwuegbuzie, 2004).

This mixed methods framework was designed to address the issue of mangrove expansion and subsequent removal. This framework has the following aims:

a) to understand the facets of coastal complexity and connectivity in relation to both estuarine ecology and local community involvement in management decisions

b) to bridge the disciplinary and epistemological silos typically found in mangrove research to date in an effort to move beyond the false dichotomies of qualitative and quantitative research

c) to present a more holistic and multi-dimensional approach to social inquiry that integrates multiple perspectives, ways of knowing, and cultural wisdom in to the management and conservation of these systems.

This research methodology chapter reflects the researchers' paradigmatic stances and visions for research, in addition to outlining the Holistic Mangrove Research Framework and descriptions of integration within and between the phases of research in order to address the research question. Explanations of the developmental process of this social-ecological research are provided, along with how both inferences and meta-inferences are integrated to make conclusions drawn from different strands of the study (Teddlie & Tashakkori, 2009). Furthermore, suggestions of the application of this framework to the management of coastal ecosystems are provided. In this paper, as in the framework itself, we move from the general to the specific and then back to the general, with some future management recommendations for mangroves in New Zealand.

3.4 Research paradigm and visions for research

Paradigms can be defined as "a set of philosophical assumptions that are inherently coherent about the nature of reality and the researcher's role in constructing it that is agreed upon by a community of scholars" (Creamer, 2017, p.43). It is quite rare in mixed-methods studies for the researcher to explicitly state their research paradigms and philosophical viewpoints (Sale et al., 2002). However, our biases and opinions surrounding our research can strongly influence its direction, and in doing so can also affect the outcomes of the study. Therefore, it is not only important to understand how research is approached and undertaken by researcher(s), but it is also important to highlight this self-reflection as an important part of the research process. This is especially important in investigating and understanding contentious issues, such as the one of mangrove removal. This reflection is as an important part of the Holistic Mangrove Research Framework outlined in this study.

3.4.1 Philosophical viewpoints

Issues around mangrove conservation have generated strong public interest in New Zealand, with a polarising of attitudes occurring. Originally, a pragmatic viewpoint was adopted, whereby the outcomes of the research are directly linked to the research question itself (Creswell, 2003). The over-arching question: “What are the social-ecological trade-offs between preserving and removing mangroves?” was approached with a pragmatic axiology in order to produce tangible outcomes, which are both useful and practical in terms of coastal sustainability and management of this ecosystem. However, approaching research in this way risks oversimplifying the complexity of the system, its interactions and all of its components. Embracing complexity in research to help navigate the complex nature of mangrove ecosystems and the social issues surrounding their expansion in estuaries in New Zealand is recommended.

It is commonplace nowadays for mixed methods researchers to adopt a “multi-paradigmatic perspective”, as we move away from single paradigm operation (Burke Johnson, 2017). This is particularly appropriate when engaging with complex social-ecological issues, which can be multi-faceted and interwoven at many levels. Thus, it became clear that dialectical pluralism was the most appropriate approach for this study.

3.4.2 Dialectical pluralism as a paradigm for social-ecological complexity

The paradigm of dialectical pluralism puts diversity at the centre of both human and physical reality (Creamer, 2018). This is an important component of research undertaken in complex social-ecological systems. For example, even though four separate mangrove systems were investigated, each made up of the same species (*Avicennia marina* subsp. *australasica*), within the same harbour; there were both similarities and differences within and between each location. The ecology and biodiversity at these sites, the stakeholders of these systems, and the management approaches proposed and undertaken are separate and also inter-linked. In addition, the contentious nature of mangrove management in New Zealand, and polarised debate around their management, adds further complexity. This is demonstrated by the diversity of people consulted in resource application for mangrove removal and the range of perspectives and perceived knowledge around mangroves they provide. Dialectical pluralism not only embraces, but also accounts for, the interconnections between all of these factors; an important consideration in undertaking a truly social-ecological approach to research. As such, this research approach, and the associated Holistic Mangrove Research Framework put forward in this chapter reflects the ontology of dialectical pluralism.

Methodologically speaking, a dialectically pluralistic approach was taken in the pursuit of missing information about the biodiversity of mangroves. This is highlighted in the review paper (chapter two) and allows the ecological side of the research to highlight missing knowledge and then to conduct assessments to provide baseline data for biodiversity in temperate mangroves.

3.4.3 Visions for research

Coming from a dialectically pluralistic viewpoint allowed this research to present the concepts, ideas and results of the work to a wide range of people. The ecological research also reflected a pluralistic viewpoint as it involved integrated assessments with a variety of techniques and recognised the mangrove ecosystem as operational as both a terrestrial and aquatic habitat, which different species utilise in different ways and at different times of day.

3.5 Holistic Framework construction

3.5.1 Explanation of the Holistic Mangrove Research Framework

In order to understand and address the complexity around preserving and removing mangroves in New Zealand, a multi-phase, sequential approach was adopted, with elements of each phase of research led by the outcomes of earlier phases (Creamer, 2018). This allowed information to be collected, assimilated and integrated within each phase and to be compared and contrasted between phases in order to view coastal complexity and mangrove management holistically. This is vital because previous studies in New Zealand have focused on the ecology of sites, without integrating community perceptions in order to fully understand the issues around the expansion of mangroves at each site. The insights provided, and framework developed, is broadly applicable to any site nation-wide, and other temperate mangrove systems around the world, although some communities and mangroves may be less accessible to researchers than here in New Zealand. The framework was designed to guide the researcher in a systematic fashion so that each phase increased knowledge around what the social-ecological trade-offs are in removing and preserving mangroves. Figure 6 shows the Holistic Mangrove Research Framework.

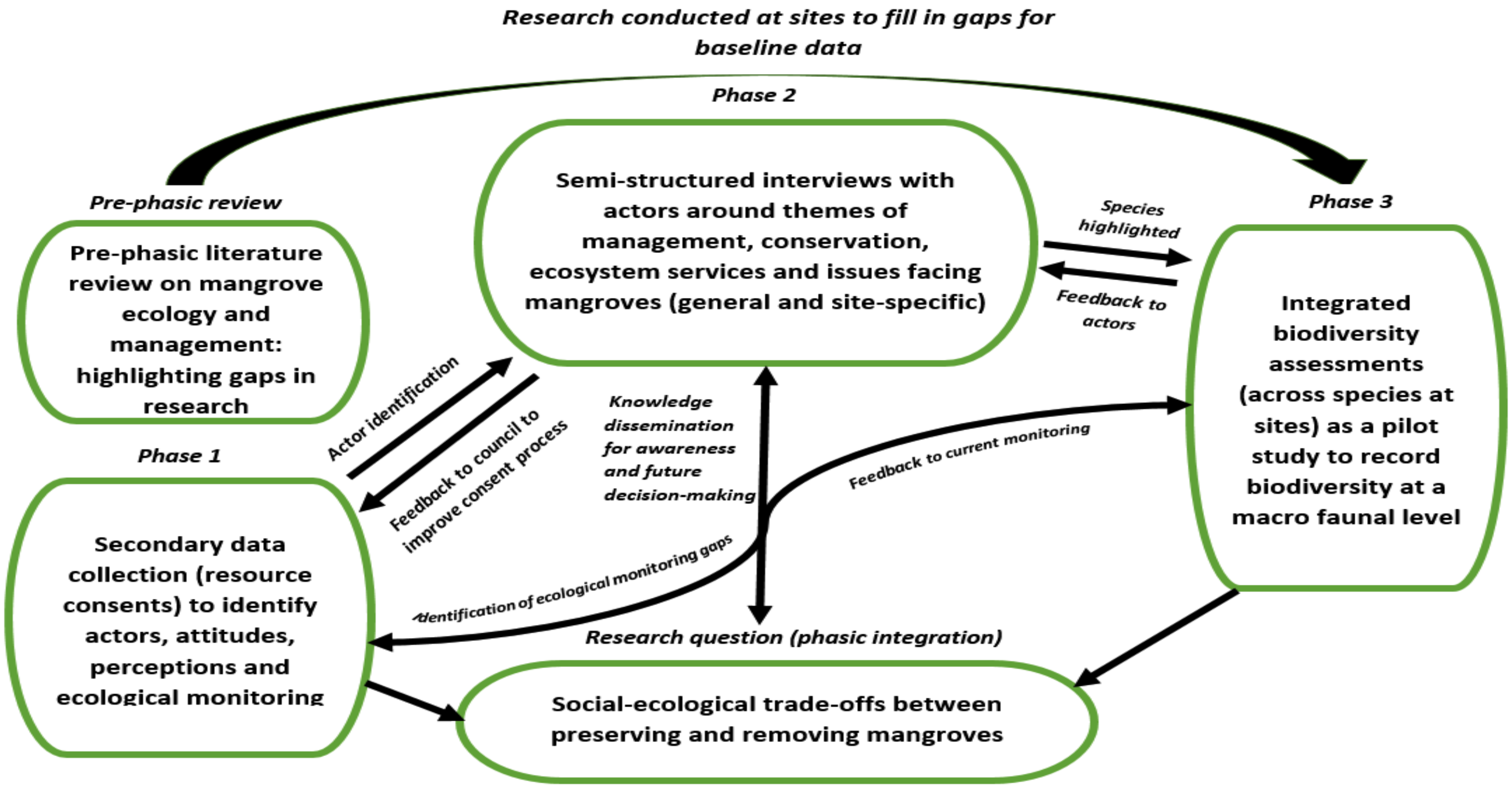


Figure 6. Holistic Mangrove Research Framework for investigating the social-ecological trade-offs between removing and preserving mangroves in New Zealand

3.5.2 Phases of framework

Review

Conduction of an in depth review was required to have a full understanding of current research around mangrove ecology and management. This review (chapter two) built upon a previous review on temperate mangrove ecology, with New Zealand as the focus, by Morrisey et al., 2010. In the nine years since this review was written, a proliferation in the breadth of ecological research and an increase in management papers around best practice mangrove removal has prevailed. Overall, the review was exploratory and inductive, with specific observations recorded around species assessments in New Zealand mangroves, which then allowed for a deductive, explanatory approach in phase three.

Phase One: Comprehension of coastal complexity and current management

Phase one (chapter four) consisted of research into the largest mangrove removals in the Auckland region over the past decade, with the aim of investigating the social-ecological reasons for removal at four different sites within a harbour.

<u>Approach</u>

This phase involved the collection and evaluation of secondary data regarding mangrove removal in an exploratory and inductive way. It was important to begin this research with reading, recording and assimilating the secondary data before any primary data collection was conducted as it provided a baseline for understanding the issues around mangrove removal, policy, the consent process and the people involved.

Collecting secondary social-ecological data on the selected study sites allowed a comparison of the early days of mangrove removal and the evolution of the process of removal, from wholesale removal to a step-by step adaptive management approach. It also provided valuable insights into the perceptions towards mangroves of the local community groups advocating for removal and the conservation organisations vying for preservation. The records and resource consent folders are publicly available as hard copies for viewing at Auckland Council Offices. Table 4 shows the type of information extracted from the resource consents and how it fed into subsequent phases.

Table 4. Secondary data collection and utilisation in subsequent phases of framework

⚜	Site⚜	Timeframe for consent⚜	Reasons and method of removal⚜	Area of proposed patch to be removed⚜	Consultees⚜	Ecological monitoring⚜	Perceptions and attitudes⚜
Data collection⚜	Name of site, g.p.s co-ordinates	Date of granted consent and length of time	Why removal is proposed/ went ahead and by what means	Size of area to be removed/ was removed	Names of people involved in consent process	Type of monitoring, species and results	Recorded data around opinions towards mangroves
Phasic utilisation⚜	Phase 2,3	Phase 2,3	Phase 2	Phase 2	Phase 2	Phase 3	Phase 2

Both societal and ecological information collection in this phase provided the researcher with a strong understanding of the sites and the people involved, including an initial insight into perceptions and attitudes towards mangroves in these locations. This phase did not fully integrate different types of data through analyses, rather it aimed to record, collate and assimilate data to conduct the primary research. This was intentional because forming assumptions about stakeholders based on secondary information could bias both the formulation of questions and inferences made around perceptions and attitudes of people towards mangroves and removal.

Phase Two: Engagement with local community: semi-structured interviews

Phase two was the first stage of primary data collection (detailed in chapter six). Prior to interviews going ahead, a detailed ethics application was submitted to the researcher's institution to promote the conduct of ethical research. The application included knowledge on the stakeholders consulted for each consent and creation of a valid and applicable set of interview questions. The ethics application also included evidence that the researchers had made contact with iwi in the area as a form of pre-engagement. (Appendix 1). Consent forms highlighted that the knowledge shared will remain confidential and the participants will remain anonymous. Stakeholders also had the option of withdrawing from the study at any time. Member checking occurred for each participant to ensure accurate interpretation of the information provided during the interviews.

<u>Approach</u>

The concept behind stakeholder selection was purposive sampling (Black, 2010). The stakeholders to be contacted all have a direct involvement with either the removal sites, or general mangrove management in the area. This selection criteria allowed time required for in-depth interviews and a deeper understanding of the issues around the selected sites. The interview process also provided space to build rapport and trust with local community members. Although somes information was already be gathered and reflected on from phase one, the approach in phase two was also exploratory and inductive (Thomas, 2003). Loose themes around management and consultation such as opinions towards mangrove management at the sites, the consent process and the level of consultation they had during the consent process for removal of mangrove areas was be discussed (chapters six and seven).

As part of the semi-structured interviews, rating of mangrove ecosystem services and issues facing mangroves was conducted by stakeholders, in addition, a Q-sort was carried out by a proportion of participants (chapter six). These two strands of discussion and ratings plus Q methodology created a convergent parallel design within the interview itself. The groups of stakeholders to be interviewed and their potential connectivity are illustrated in Figure 7.

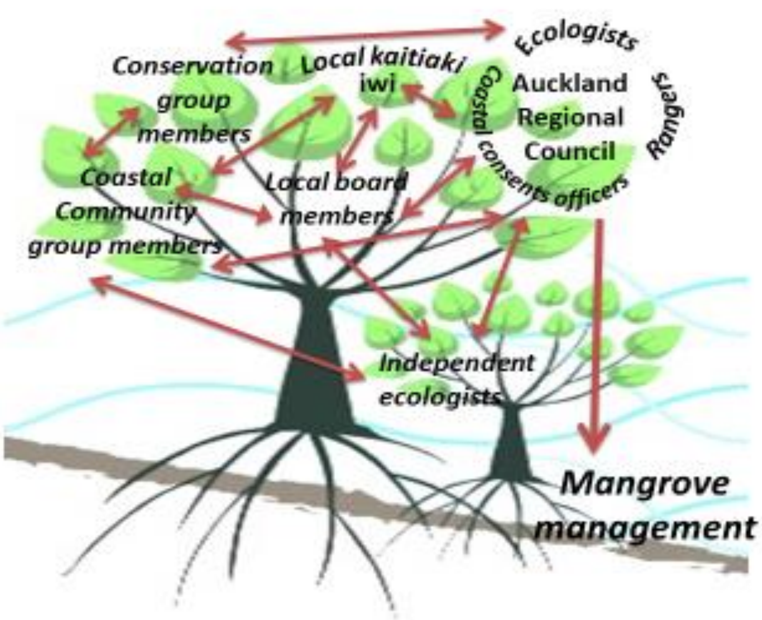


Figure 7. Stakeholders involved in resource consent applications for mangrove removal and connectivity between groups

A different approach was taken in engaging, consulting and talking with local iwi and hapū. A critical issue involving consultation with iwi around land-use and conservation issues is that it is often carried out retrospectively, after work has gone ahead and not from the start (Harmsworth & Atawere, 2013). In any New Zealand based research, it is imperative to contact iwi from the start with the research and the reasons behind it (chapters six and seven).

Phase Three: Biodiversity Assessments

The information evaluated in the review highlighted the type of species assessments within mangrove ecosystems in New Zealand. The majority of these studies have focused on macro-benthic faunal species assessments. Thus, there are distinct knowledge gaps around mammals, reptiles, fish, birds, insects and spiders in mangrove systems (Morrisey et al., 2007). It is therefore important that research is designed to overcome these gaps and better inform mangrove management in New Zealand. Integrated biodiversity assessments were designed and conducted at the four study sites to provide this baseline data (detailed in chapter five).

Approach

The biodiversity assessments at the study sites were innovative, with no known studies of multiple classes of organisms in New Zealand mangroves having been conducted to this point. The integrated assessment was exploratory, both in terms of the lack of knowledge around some groups of organisms and whether they inhabit mangroves in these areas. The assessments were also explanatory, with the recording of physical and environmental variables. For example, relationships were explored between relative abundance, diversity measures and other variables such as canopy cover and salinity. The integrated assessments allowed for the exploration of community abundance and distribution patterns of insects and spiders with intertidal height both within and between mangrove sites. The process of phase three involved detailed planning of the experimental design, pre-assessment of sites for suitability, ordering and purchasing of a wide range of equipment, and testing and collecting data. In addition, logistical planning was important to ensure work was undertaken around tidal inundation at these sites. Figure 8 shows the experimental design of phase three. As well as empirical data collection on groups of organisms at the sites, descriptive observations of particular species which are not able to be counted (e.g. type of flying insects passing through the mangrove) and reptiles at the edges of the patches were recorded.

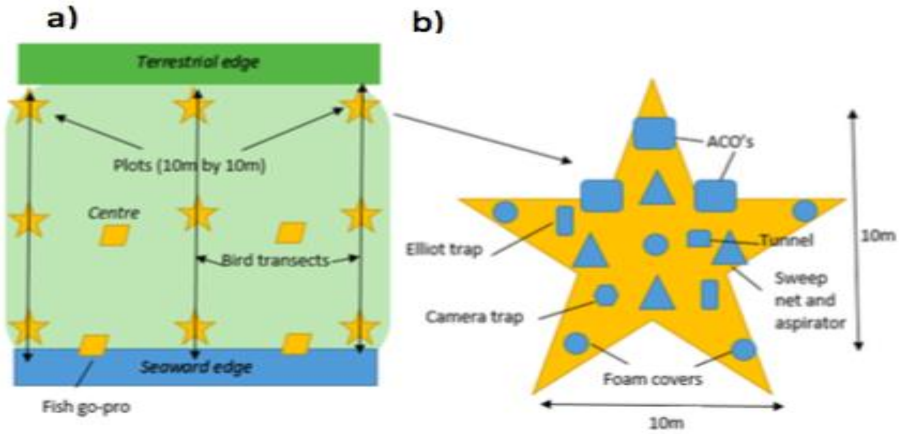


Figure 8. Experimental design for integrated biodiversity assessments a) layout of sampling within mangrove patch b) equipment and location of traps within each plot (*ACO refers to Artificial Cover Objects).

3.6 Implementation recommendations

Although this chapter details a specific framework directed at mangrove management in New Zealand, it has the flexibility to be adapted to any SES, particularly those which are threatened with removal and not utilised directly by people.

Phase one should be carried out separately to inform the following phases. This is imperative to select sites and understand the general issues surrounding an ecosystem in the view of local communities as well as understanding the type and amount of ecological monitoring previously conducted. Phases two and three could be carried out simultaneously, in, a convergent parallel design (Creswell, 2003) or carried out step-wise to inform each other. The step-wise approach adheres to an exploratory sequential design and with both phases of equal priority (Tashakkori & Teddlie, 2003, p. 228). In essence, the Holistic Mangrove Research Framework is flexible and fluid, allowing for adaptation with different contexts, timescales and workforces. The Holistic Mangrove Research Framework was designed to collect social-ecological data in order to address the research aim of investigating the social-ecological trade-offs between removing and preserving mangroves in New Zealand. It has the capacity to be adapted and used in other social-ecological systems. Inferences from each stage aim to be integrated in order to create an overall holistic understanding of coastal complexity and mangrove management. This can improve our relationship as humans, with nature, for a more sustainable future.

Chapter 4

Social-ecological monitoring in Manukau mangroves; secondary data collection

"The Manukau not only belongs to us but we to it. We are a people begotten from within the depths of its waters."

Carmen Kirkwood

The proceeding chapter is a synthesis of the social and ecological information collated from four resource consents for mangrove removal in the Manukau Harbour, Auckland. This chapter consists of background information required for the next two chapters of primary social-ecological data collection. Policies of mangrove protection and removal are outlined and in-depth information on social and ecological reasons for the applications for mangrove removal are collated and discussed in this chapter.

4.1 Abstract

Mangroves are an indigenous flora of New Zealand and are protected under the Resource Management Act (RMA) 1991. Due to proliferation of mangrove habitat into coastal estuaries in many locations in Auckland, regional coastal policy was altered to include the management of mangroves in 2010. Prior to this change, a number of large removals occurred in the region, with a variety of removal techniques, creating different ecological responses such as benthic community compositional change, algal smothering and increased mudflat habitat for wading birds. Over time, ecological monitoring both pre- and post-removal has improved in rigor, however, long-term effects of removal have yet to be fully realised in many locations. This study explores the social and ecological rationale to removal at four sites in the Manukau Harbour Auckland as a pre-assessment to conducting research into the social-ecological trade-offs between removing and preserving mangroves. Resource consent data was accessed at Auckland Council offices as hard copies. Findings show that there have been a wide-range of reasons for removal such as improving navigation of the water, increasing recreational activities in the harbour and restoration of ecosystems to a pre-mangrove state. However, current removal has yet to meet all community aspirations. Ecological monitoring revealed changes in benthic community compositions post-removal, with long-term monitoring recommended. The 'at risk' native bird, the Banded Rail was found in mangroves at all sites, including cleared areas at one site. Some removals are incomplete or have yet to commence, although permits have been granted. This research reveals gaps in pre- and post- removal ecological monitoring at these sites such as assessments of arboreal invertebrates, fish, mammals and reptiles.

4.2 Introduction

Each regional council where mangroves are present in the North Island has their own mangrove management programmes. These are Auckland, Bay of Plenty, Gisbourne, Northland and Waikato regional councils. Overall, mangroves are protected under the Resource Management Act, created in 1991 (Chapter two: 2.2.2).

In order to effectively achieve this act, it is stated that any persons managing natural and physical resources must take into account the Treaty of Waitangi (Te Tiriti o Waitangi) 1840. The Treaty provides a framework for engagement and partnership between Māori and the government. Although there has been controversy and disagreement over the treaty since 1840, the Principles of the Treaty itself have been seen to provide a strong background for decision-making regarding the environment between Māori and the crown as well as other stakeholders (Harmsworth & Atawere, 2013).

4.2.2 Auckland Coastal Plan

Coastal ecosystems are under the greatest pressure of any marine environment in New Zealand (MFE, 2016). Auckland's coastline has undergone a substantial amount of urbanisation in the past fifty years, which has compromised the health of its urban coastal marine areas (Auckland Council, 2009). Mangroves are part of the vegetation in the marine coastal zone. The Auckland Coastal Plan recognises mangroves as an integral component of estuaries, with the ecosystem services of erosion control and shoreline protection. Mangroves are also noted as contributing to the natural aging of estuaries, the raising of the seabed and intertidal flat creation (Auckland Council, 2011). In 2010, Auckland Regional Council altered its policies under the Coastal Plan in order to specifically *"provide a balanced framework for the management of mangroves"* (Auckland

Council, 2010). This was in response to the rapid spread of mangroves in estuaries in the Auckland region. Mangrove expansion into intertidal flats and other adjacent habitats was seen to compromise the biodiversity values of these areas, for example, habitat usage by wading birds (Policy 16.2 Coastal Plan). In addition, expansion "can affect the social, cultural, and economic use and value" of the coastal marine area (Policy 16.2.2 Coastal Plan). As a long-term management solution, it is stated that sediment and nutrient inputs must be reduced as part of an integrated management plan of the wider area (land, riparian and coastal marine areas) (Auckland Council, 2011).

4.2.3 Mangrove removal

Removal of mangrove seedlings in Coastal Protection Area 1 (Okahukura Peninsula volcanic complex) is deemed appropriate in areas which do not have significant values associated with mangroves (Policy 16.4.6.). Mangrove seedlings are defined as those which are 60cm in height or less, consisting of a single "supple" stem, with no evidence of reproductive capacity (possession of propagules or flowers) (Figure 9).

Figure 9. Mangrove seedlings on the banks of Mangere Inlet, March 2018

Removal of mangrove is also considered if colonisation:

- *shows an adverse impact on heritage site value or those of significant ecological, archeological or geological value*
- *obstructs or interferes with public amenity use (e.g. water access, recreation and navigation)*
- *adversely affects identified wading bird roosting and feeding areas*
- *adversely affects maintenance, use and operation of roads, walkways and/or efficient functioning of drainage systems*

or if the proposed removal:

- *is in "overall public benefit"*
- *is in accordance with policy 16.4.8 (consideration of significant disturbance and vegetation removal activities, which recognise the "interconnectedness of land and sea")*

(Policy 16.4.7) (Auckland Council, 2011).

Mangroves can be removed in the Auckland region as a permitted activity, which includes no removal of mature mangroves, removal by hand or non-motorised tools, no disturbance of saltmarsh or seagrass, disposal of vegetation outside of the CMA (coastal marine area) and not in areas where mangroves are providing the service to protect against coastal erosion (Policy 16.5.3) (Auckland Council, 2011).

4.2.4 Mangrove management

Under the Auckland Unitary Plan (2013), the objectives of mangrove management F2.7.2 state that:

(1) The ecological value of mangroves is recognised and mangroves are retained in areas where they have significant ecological value.

(2) Mangroves are retained in areas where they perform an important role in mitigating coastal hazards.

(3) Restore or maintain natural character and ecological values including significant wading bird areas, public access, navigation, riparian access and amenity values.

(4) Sediment deposition within the coastal marine area, that facilitates ongoing mangrove colonisation and spread, is reduced.

(5) Mana Whenua values, Mātauranga and tikanga are recognised and reflected in mangrove management. Removal should be avoided where:

(a) areas having significant ecological or natural character values of which mangroves are an important component, or in other areas where mangroves can provide significant ecological values

(b) areas of active coastal erosion where mangroves have historically provided a buffer against coastal processes causing erosion;

(c) areas where the sediments contain high levels of contaminants at risk of being re-suspended. (Auckland Council, 2013)

Removal of mangroves is allowed in the maintenance, restoration or enhancement of the following social and ecological values (Table 5).

Table 5. Social and ecological values allowing removal of mangroves. Adapted from Auckland Council Unitary Plan, 2013.

Type of Value	Description
Ecological	Natural character, biodiversity, ecological values (such as wading bird habitat) existing prior to the spread of mangroves
Social	Public access to or along the CMA
Social	Connections with reserves or publicly owned land and sea
Social	Public use and amenity values
Social	Public health and safety
Social	Water access for navigation and vessels
Social	Māhinga mataitai, access to traditional use areas and to coast from marae
Social	Historic heritage places
Social	Operation and development of infrastructure

Despite the detailed policies involved in mangrove management, there have been a number of clearances prior to these policies being put in place where large areas of mangrove have been removed by a variety of methods, including mechanical machinery with mangrove debris left in-situ. Some removals have also been illegal (Lundquist et al., 2014a). Recovery of removal areas to previous sand-flats depends upon factors such as wave exposure and sediment characteristics, removal of mangrove debris and method of removal (Lundquist et al., 2014a).

4.2.5 Mangroves in the Manukau Harbour

There is a vast amount of information contained within the resource consent documents, including submissions for and against mangrove removal, expert reviews, ecological assessments and final decisions. This chapter had the following aim:

To investigate secondary social-ecological data from council resource consents for background knowledge on the ecology and communities in the area.

The research objectives are as follows:

- *To investigate the social-ecological reasons for mangrove removal at the study sites*
- *To investigate what ecological monitoring was conducted prior to and post-removal at the study sites*
- *To investigate what consultation was carried out prior to removal and with whom*
- *To identify the social-ecological monitoring gaps which exist at the sites*

4.3 Manukau Harbour History

The Manukau Harbour (37.02°S, 174.42°E**)** is the second largest harbour in New Zealand, formed in a drowned river valley, with a surface water area of 394km^2. It is located to the South and West of Auckland City (Cromarty & Scott, 1995). The harbour is turbid and shallow following approximately 10 million years of sedimentation. It has a substantial tidal range of four metres (McLintock, 1966). Volcanic activity around the Tamaki isthmus over the past 500,000 years has caused the harbour to be sealed off from the Pacific Ocean (except during high sea level periods of time). The harbour contains many shifting sand bars, extensive mudflats and fringing mangroves (McLintock, 1966).

"Manukau" is thought to have the meaning of "Only Birds" in te reo Māori (Simmons, 1980) and to this day is viewed as an important habitat for both local and international wading birds (Scott & Cromarty, 1995). The harbour is an important waterway for Māori, with waka portage still occurring annually It is also used for fishing, outdoor recreation and marine farming. Figure 10 shows the Manukau Harbour with significant terrestrial and coastal ecological areas and wading bird habitat.

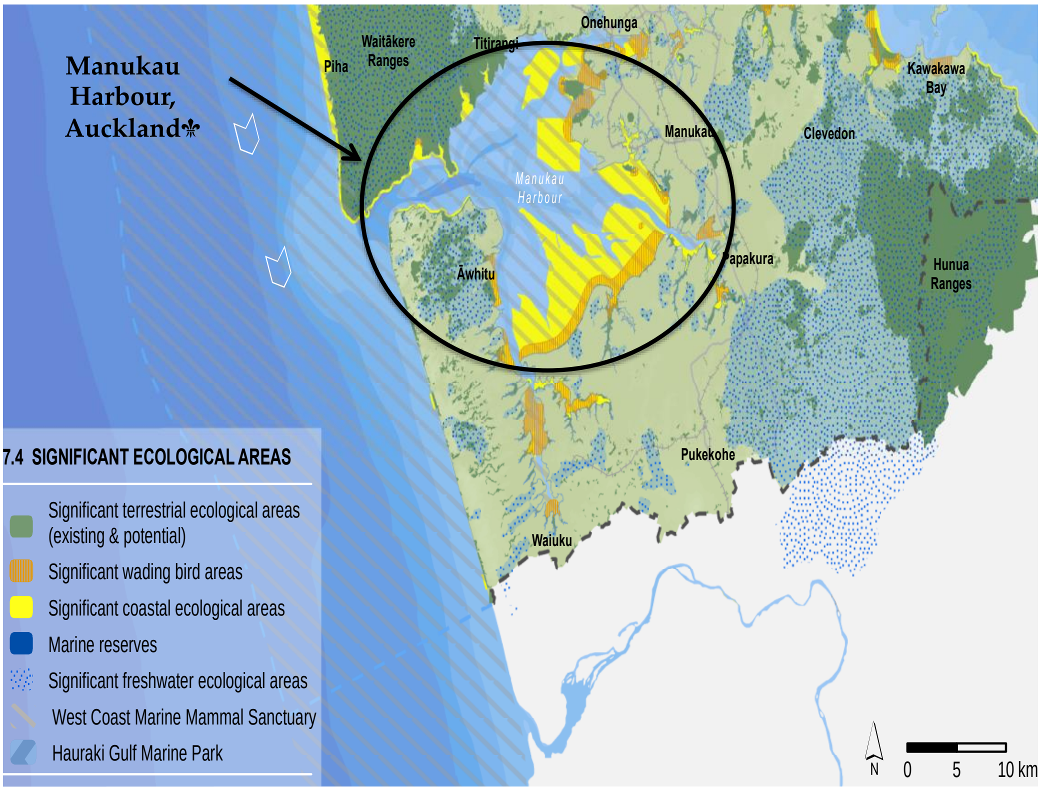


Figure 10. Significant Ecological Areas (SEA) in the Manukau Harbour. Adapted from Auckland Council, 2012.

Intensive modification of the harbour catchment through urbanisation, industrialisation and farming practices has led to a decline in water quality through the release of nutrients and increases in the concentration of suspended sediments (Foley et al., 2018). Although there has been an overall improvement of water quality in the Manukau Harbour over the last decade, suspended sediments and nitrogen concentrations have been recorded to be above the thresholds defined as 'healthy' (Foley et al., 2018). The harbour was recently given an overall environmental health grade of "D"' (ranging from A-F), with Mangere and Pahurehure tidal arms listed as "unhealthy". (Auckland Council, 2018).

4.4 Materials and Methods

Four sites were selected to represent large areas of mangrove removal, which had been completed or were occurring at the time of this study. Information in these publicly accessible files included sites, reasons for removal, area to be removed, chronology and stakeholders who had been consulted prior to the removal. Ecological monitoring of the sites was also recorded. This information was required in order to address the aims of the study and to provide background information prior to conducting interviews and ecological assessments at the sites.

All information was recorded and stored securely on the external hard drive belonging to the primary researcher. Information in this chapter is publicly accessible, however, all comments and view-points recorded are anonymised out of respect and confidentiality of the consultees.

4.5 The Sites

The four sites selected for investigating the social-ecological trade-offs between removing and preserving mangroves were Pahurehure Inlet 2 (consent # 35053), Puhinui and Waimahia inlets (# 41680) and Mangere Inlet (# 46321). These sites represented recent removals of large area of mangrove in the Manukau Harbour for a variety of different reasons.

Table 6 shows the purpose of removal, date issued, expiry date and descriptions of purpose (provided by Auckland Council, 2016).

Table 6. Resource Consent ID, Purpose, Dates, Location and Description of selected mangrove removal sites in the Manukau Harbour, Auckland.

Consent ID	Purpose	Commencement Date	Expiry Date	Site Location	Purpose Description
35053	To authorise the removal of mangrove forest from 27.6 hectares of the Pahurehure Inlet No. 2, Manukau Harbour.	29/01/10	29/01/40	Pahurehure Inlet No. 2 , Tidal Land of Manukau Harbour SO 67474, Pahurehure, Manukau City Manukau Harbour PDC	Mangrove removal as part of Phase 1: Pahurehure Inlet No. 2 rehabilitation Project developed through the Pahurehure Inlet Management Plan (November 2006).
44034	Application to remove mangroves adjacent to Kiwi Esplanade, Mahunga Drive, Hastie Ave and Norana Beach/Norana Park, Mangere.(16.2Ha)	26/03/15	26/03/50	Kiwi Esplanade Mangere Bridge Manukau	Removal of 16.2ha of mangroves from four sites in Mangere Inlet.
41680	Removal of 22.6 hectares of mangroves from within the Puhinui and Waimahia inlets.	19/06/13	30/06/41	Auckland Council Parks Puhinui and Waimahia Inlets Manukau Harbour ACC	Removal of 22.6 hectares of mangroves from within the Puhinui and Waimahia inlets.

4.5.1 Pahurehure Inlet 2

Background and reasons for removal

The construction of the causeway in the 1960's and urbanisation of the surrounding land are the factors thought to have led to mangrove expansion in the inlet. This was viewed by Papakura community as a concern, especially around loss of open water space and sandy beaches for recreational use (PDC, 2007). PDC and ARC commissioned consultants Beca to prepare a management plan for the inlet in 2006.

The strategic goals as listed in the Management Plan for inlet 2 were as follows:

- *To promote and enhance the recreational use and enjoyment of the inlet and its surrounds*
- *To maintain, restore and protect environmental quality and important ecosystems in the inlet*
- *To protect the cultural and heritage areas of importance and improve understanding of these areas*
- *To enhance the amenity of the inlet to create a 'strong sense of place' for the community*

(Inlet Management Plan, 2006)

It was thought that mangrove removal would help in reaching these goals. The total associated costs with removal of mangroves in this area was estimated to have cost 1.5 million NZD (Murray, 2013). Mangrove removal at Inlet 2 was for the removal of 26.7 hectares of mangrove forest in a staged removal, of nine hectares over three years. Consents for removal were lodged from 2002 and were rejected initially. Following this, illegal removals (burning of mangroves) occurred on 11th January 2004. Removal was granted as a restricted discretionary activity in 2010. This was after a local community group campaigned and fought for removal in Inlet 2 for seven years under the jurisdiction of Papakura District Council (File # 16356, Auckland Council Resource Consents). PDC sought to use an adaptive management approach to removal through extraction of mangrove trees by mechanical means and hand felling, with removal of wood offsite. Mangrove roots remained in-situ (Murray, 2013). Figure 11 shows pre- during- and post-removal in Inlet 2.

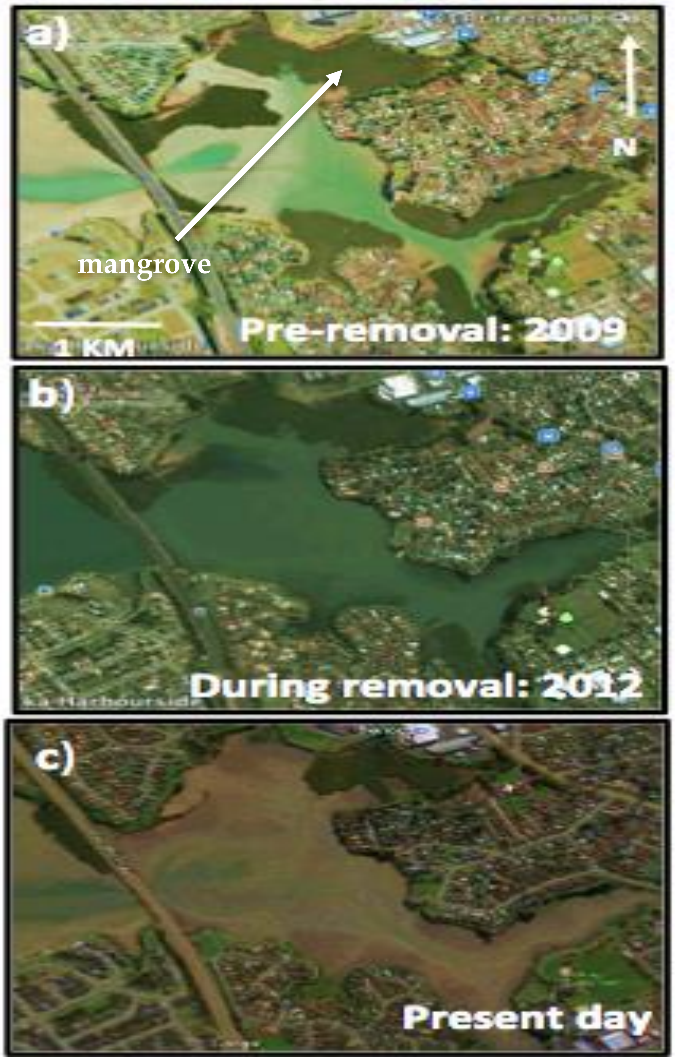


Figure 11. Pahurehure Inlet 2 mangrove removal 2009, 2012 and 2018. Adapted from Google Earth, 2018.

Ecological Monitoring

The ecological monitoring at Inlet 2 for consent 35053 focused on bird surveys carried out by an independent ecologist and an ecological consultancy in 2009 and 2008, 2010, respectively. The majority of results were of the Banded Rail, which was found in both cleared and intact mangroves in 2012, following removal of one trial area, and in all three mangrove areas prior to mechanical removal. Rat footprints belonging to the non-native Norway rat and the native Grey Warbler or 'riroro' and

Fantail or 'piwakaka' were found in all three mangrove areas. Results are compiled and are presented in Table 7.

Table 7. Bird survey results (with incidental rat footprints) in 2008-2010 and 2012 in mangrove areas to be removed in Pahurehure Inlet 2 (Auckland Council resource consent file number 16353).

Species	Area detected	Year recorded	Description
Banded Rail	2/3 mechanical trial areas	2009	Removal of mangroves should be avoided in breeding season (before end Aug), avoid dense shoreline vegetation. Estimated up to ten breeding pairs of rail in the inlet.
Banded Rail	Throughout remaining mangrove areas and cleared areas	2008,2010,2012	Footprints in two mangrove areas to be removed, two adult rails and five chicks found in cleared area (observed in clear and intact areas)
Norway rat	All three areas	2012	Footprints likely belonging to *Rattus norvegicus*
Fantails	All three areas	2009	Assumption that they are breeding in all three areas
Grey Warblers	All three areas	2009	Assumption that they are breeding in all three areas

Ecological monitoring of benthic taxa was also carried out pre- and post-mangrove removal by a range of independent and council ecologists. Conflicting viewpoints on the displacement of some benthic species with removal was revealed by the following statements:

*"**Clearly the habitat for epiphytic taxa are displaced as the mangroves are removed but other taxa associated with open mud flats remain. This information removes any potential concern regarding the potential adverse effects of mangrove removal on benthic community structure**"*.

(IE1, 2008)

"…. whether this (change in benthic community composition) ***constitutes an adverse effect depends on whether the mangrove habitat was considered a result of anthropogenic effects and that the change in benthic habitat from mangrove to intertidal mudflats therefore acceptable".***

(AC1, 2010)

"Further monitoring is required to evaluate the longer-term effects of mangrove removal on benthic community structure".

(IE2, 2012)

Social information

This application was strongly led by a local community group, with members who had seen the inlet change over the past fifty years. Submissions for, neutral and against removal were put in by local people in the application, with 1467 supporting the removal of mangroves, four being neutral and nine opposing removal (Auckland Council resource consent 35053, file # 16535). Table 8 shows a range of statements, which were submitted to ARC with this application, via PDC.

Table 8. Social statements recorded in consent records exemplifying support for, neutral opinions and against mangrove removal

SUPPORT	NEUTRAL	AGAINST
The inlet would be a recreational asset If mangroves were removed and it was returned to pre-motorway conditions	There will be adverse effects to the natural ecosystem, hence a need to proceed with caution	There is no benefit in clearing mangroves
Beaches have been destroyed by mangrove expansion	Monitoring conditions should apply	Mangroves support estuarine life and are important to the food chain
Mangroves do not provide sustenance or nesting places for birds	A compromise would be to remove half of the mangroves in the inlet	The cost to ratepayers over a period of 30 years will be high and better spent elsewhere
The proposal will restore Papakura to its previous state as a harbour side settlement	For every mangrove cut down, a tree should be planted in mitigation	It is too simplistic to say that mangroves are the cause of the inlet silting up. They are a biological response to a changed set of circumstances and will eventually reach equilibrium

Pahurehure Inlet 2 has been the largest removal of mangrove in the Auckland region to date. There has been an application put in to remove the final remaining patch of this mangrove.

4.5.2 Waimahia and Puhinui Inlets

Reasons for removal

The resource consent for the removal of mangroves for Waimahia and Puhinui Inlets under the same application (number 41680) was submitted in 2012 and granted in 2013, lodged by Auckland Council Parks, Sports and Recreation. This was for the total removal of 22.6Ha of mangrove of which 3.2Ha was in Puhinui Inlet and 19.4Ha in Waimahia Inlet. The removal was granted as a discretionary activity under the RMA until 10th June 2048. Removals at these sites were primarily for reasons of waka access from a marae (Māori meeting grounds) and improving general navigation of the creeks, in addition to restoring the natural character of the area prior to the expansion of mangroves. In terms of policy, the removal was thought to satisfy the following stipulations as in Section 104(1) (a) of the NZCPS 2010:

- *Adverse effects seen as less than minor*
- *Proposed removal is likely to have the following positive environmental effects:*
  Improved connection between land and sea
  Restoration of a more pre-urban natural character
- *Improved recreation opportunities*
- *Improved access to the CMA for small vessels*
- *Slowing of estuarine infilling*
- *Better tidal flow and flushing of area within the inlets*
- *Opportunities for beach restoration and*
- *Access to launch waka and better navigation of the channels within the inlets*

The proposal was seen as being consistent with NZCPS because it will enhance the visual amenity of the inlets in the long term (Policy 6 (2) (e)),
in addition to enhancing the recreational activities and public access to the CMA (Policy 6 2(b)) and facilitating restoration of a former natural character (Policy 14)

(Auckland Council, 2011).

Puhinui and Waimahia mangroves are some of the oldest existing in the region. Those in Puhinui are protected under CPA 27c. Mangroves present prior to 1959 were to be retained, whilst some areas of younger mangroves, post 1959, were to be removed (Auckland Council resource consent 41680, file # 23790). Figure 12 shows the proposed removal areas, prior to removal. Older mangroves were defined as “standing well above head height, with a height of 3-4m with a relatively clear understorey” (Coastal Processes Report, Auckland Council Parks, file # 23790.

12a) **12b)**

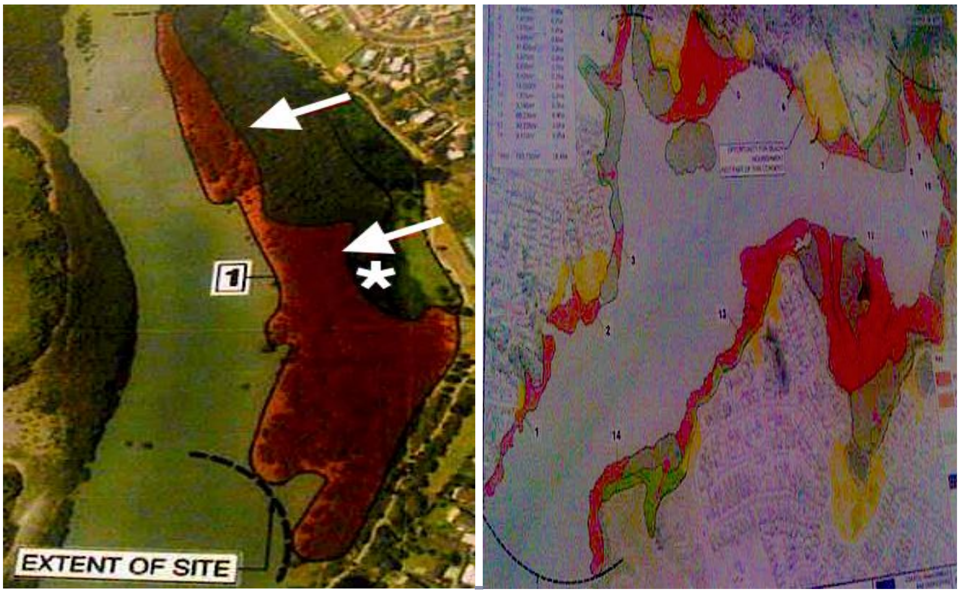


Figure 12. Puhinui inlet designated mangrove removal in red. Arrows indicate ecological sequences from land to sea, * indicates potential Banded Rail habitat, adapted from Davis Coastal Consultants, 2013 and 4b) Waimahia designated mangrove removal in red, remaining areas in green, adapted from Auckland Council Parks, 2013.

Proposed removal was to be by hand-held equipment, using loppers, hand saws or axes, with each individual tree being severed at the base at low tide. Cut trees were to be removed from the CMA and stored on the adjacent esplanade reserve for collection. (Works Management Plan, 2014).

Ecological monitoring

Ecological monitoring was contracted to a firm of independent ecologists based in Auckland. Confirmation that the sites were habitat for Banded Rail within Puhinui inlet and the Eastern parts of Waimahia inlet was recorded. Table 9 shows the species listed as occupying the mangrove sites, potential adverse effects of removal and restoration opportunities (Ecological report, file # 23790).

Table 9. Species present in mangroves, adverse effects of removal and restoration opportunities in Puhinui and Waimahia mangroves.

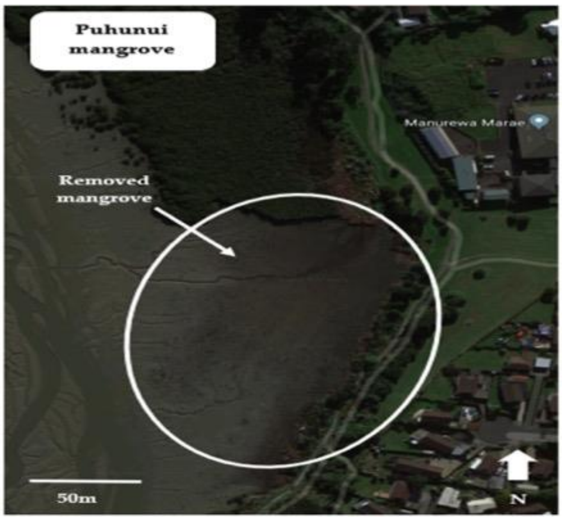
Species	**Banded rail**	**Shellfish beds**	**Fantail, grey warbler, silvereye**
Adverse effects	Reduction of habitat	Potential smothering of beds by mobilisation of sediment through tree removal	Removal of habitat
Restoration	Retain mangroves as feeding habitat where rail known to be present	Method of removal to have the least impact and disturbance of seabed and foreshore	Retain mangroves where ecological sequences of saltmarsh to mangrove to tidal channel exist

Overall, it was agreed that removal of the designated mangrove habitat could go ahead on the proviso that some areas be restored and retained as ecological sequences and indigenous habitats. Auckland Council decided that the ecological effects would be minor.

Social information

The idea behind removal at these sites was to restore some pre-urban character to the area, with a particular cultural benefit for the launch and retrieval of waka by iwi from the local marae. It was also thought that removal would provide the opportunity for more extensive navigation in the inlets. The idea that shellfish beds would be restored by removal of mangrove for kaimoana was also a factor driving removal. No opposition was recorded for this resource consent. There was strong support from the local board and aspirations of iwi for this removal. The consented area of mangrove at Puhinui was removed in 2015. However, at the time of this study, Waimahia mangrove removal had not gone ahead. Figure 13 shows the present mangrove areas at Puhinui (13a) and Waimahia (13b).

13a)



13b)

Figure 9a). Current mangrove removal at Puhinui and **13b).** Current area of mangrove at Waimahia (removal yet to commence). Adapted from Google Earth, 2019.

4.5.3 Mangere Inlet

Reasons for removal

A resource consent for the removal of 13.5 Ha of mangroves (10% of total mangrove area) in Mangere Inlet was granted on 27th January 2015 and expires on 26th March 2050. This tied into policy in the Mangere-Otahuhu Local Plan 2014 as mangrove management being a priority for the area (Mangere-Otahuhu Local Plan, 2014). Under the regional plan: coastal, removal was granted under the following policies:

- *16.5.15: Removal is necessary to maintain or restore the open nature of the significant wading bird areas is a controlled activity.*
- *16.5.20: Mangrove removal in any Coastal Protection Area 2 (CPA 2) is a discretionary activity.*

(Auckland Council, 2011)

The resource consent application was lodged by Auckland Council Parks, Sports and Recreation due to rapid encroachment of mangroves at the sites in the last two decades. The Mangere-Otahuhu coastline has experienced a four-fold increase in mangrove coverage since 1959 (Auckland Council resource consent # P-46321, file # 25339). Rapid expansion of mangrove habitat occurred from 1996 (75.5Ha) to 139.1Ha in 2010 (Auckland Council, 2014). Removal was proposed at twelve locations over four sites (Figure 14a). Removal has gone ahead in the areas outlined in Figure 14b.

14a)

14b)

Figure 10a). Proposed removal of mangrove at four sites and **14b).** Present day (2018) removal of mangrove at the sites in Mangere inlet, Manukau Harbour, Auckland

The expansion of mangroves has led to the reduction in availability and quality of foraging habitat and roosting sites for coastal wading birds due to loss of intertidal mudflats. In addition, all of the sites were identified as possessing recreational and amenity value (Auckland Council Resource Consent P-46321, file # 25339). Table 10 shows each site and perceived social and ecological values.

Table 10. Sites and social-ecological reasons for removal

Site	Social reasons for removal	Ecological reasons for removal
Kiwi Esplanade	Recreational fishing and boating for waka ama activities	Classified as a CPA 1, significant wading bird area (CPA 23b) and significant ecological area (SEA-M1), due to presence of glasswort and other saltmarsh spp. Mangroves not thought to support nationally threatened or 'at risk' bird spp. here as it is a recently established (mangrove) area in small isolated patches
Mahunga Drive	Site of value for Mana Whenua containing archaeology of Māori origin. Enhancement of amenity values associated with sight lines out to the harbour. Proposal for a cycle/walkway between Mahunga Drive and Hastie Avenue.	
Hastie Avenue	Views of the Esplanade Reserve to view the harbour	Part of CPA23a and significant wading bird area SEA M1 23a and SEA M1 23w4. Intertidal mudflats identified as feeding grounds for international migratory birds and national endemic waders including threatened species
Norana Park	Enhancement of amenity, reported by local residents this area was once a beach.	Part of CPA23a and significant wading bird area SEA M1 23a

<u>Ecological monitoring</u>

Baseline monitoring was to occur once prior to removal at each site as and on an annual basis for five years after removal at each site. The information available in the consents only documented that of pre-removal ecological assessments. Mangroves in Mangere Inlet are thought to provide foraging habitat for the pied shag and banded rail. No banded rail footprints were recorded at these two sites by an ecological consultancy in 2014 (Auckland Council, 2014). However, sightings were recorded at two of the sites (Mahunga Drive and Hastie Avenue) by another ecological consultancy in 2015 (Auckland Council Resource Consent P-46321, file # 25339). Potential adverse ecological effects of removal at the sites (listed in 2014) were as follows:

- *Reduction in abundance of non-threatened invertebrates, fish and bird species associated with mangrove habitat*
- *Loss of potential foraging habitat for the banded rail and pied shag*
- *Possible re-suspension of fine sediments*
- *Potential loss of coastal buffering/filtering by mangroves*
- *Disturbance of estuary bed by mangrove removal*
- *Potential increase in shoreline erosion due to an increase in wave action*

It was noted that pied shag also occupy intertidal areas and so adverse effects of removal of mangrove habitat for the shag would not be significant. In addition, as 90% of mangroves in the inlet were to be retained, it was noted that these areas would likely support Banded Rail populations within the inlet.

<u>Social information</u>

There was a large amount of documented consultation in this consent involving local iwi/hapū in the area. Some kaitiaki asked about the risk of releasing contaminants into the harbour if mangroves are removed. The ecologist involved in the consultation explained that cutting mangroves at the base of the stem in order to retain the sediment and to avoid removing mangroves in known areas of contamination are methods used to prevent any contaminants from entering the water (Minutes of meeting, Auckland Council P-46321, file # 25339). There was a preference by some kaitiaki for improving the overall quality of water prior to any mangrove removal. A Cultural Impact Assessment (CIA) was written by one iwi suggesting that due to historic contamination in the inlet, it may be better to leave mangroves until land-use and discharge infrastructure can be improved. Baseline monitoring on contaminated sediments and hydrology was requested, using the Kiwi Esplanade as a baseline site. However, the council said this was not directly related to removal (Cultural Impact Assessment, 2015).

Removal Methods

It was reported that the methodology for mangrove removals would mitigate disturbance and sediment resuspension during works in order to avoid compaction of the foreshore and limit the release of sediments into the Manukau Harbour. Mangroves were to be cut at the base of the stem/trunk below the mudline by hand machinery and roots would breakdown overtime in situ. Stems and trunks were to be taken offsite and mulched (Auckland Council Resource Consent P-46321, file # 25339).

4.6 Discussion

There are a wide-range of reasons why applications for the removal of mangroves are lodged and these consents have a variety of different applicants. Removal is sometimes included as part of local board plans, with community aspirations for the harbour to be a recreational, navigable space. Particular coastal areas have been designated as protected and possess significant ecological value. In these areas, where mangroves have expanded, it is thought better to remove them to retain ecological value. However, the importance of connectivity of mangroves with salt marsh and intertidal mudflats is also recognised.

The most prominent ecological reason for mangrove removal is the protection of intertidal habitat for wading birds. Although mangroves have been recorded at the sites as providing habitat for the 'at risk' Banded Rail and the 'nationally vulnerable' Pied Shag, it is thought that the remaining habitat is enough to support populations. In addition, Pied Shag utilise intertidal mudflats and rail were observed in some cleared areas.

Another ecological reason for removal is in hope of returning Mahinga kai to the harbour, notably kaimoana (shellfish) beds, which have been smothered by sediment. However, there are strong recommendations for contaminant and hydrological monitoring by iwi prior to further mangrove removal. It is the overall aim of iwi at these sites to improve water quality of the harbour and restore its mauri, in addition to protecting cultural heritage sites and access and navigation of the water by waka.

Consultation records provided a range of people to be approached for interview, with some information on the potential participants' occupations and their involvement in the removal process. It also gave some indication of the perceptions and attitudes towards mangroves by particular community groups, planners, conservation organisations and ecologists. Although there was adequate consultation with iwi at these sites, it was apparent that contaminant and hydrology monitoring was not considered a direct issue of mangrove removal and so this was not a priority prior to any removals.

Ecological monitoring focused on birds and benthic species, with little attention paid to fish, reptiles, insects and spiders or mammals. There was also not an indication of much post-clearance monitoring at the sites or whether community aspirations had been met. Due to these removals still being quite recent, it may take more time for the effects to become apparent (Lundquist et al., 2017).

Chapter 5

The Secret Lives of Mangroves: Exploring New Zealand's Mangroves with Integrated Biodiversity Assessments

"The value of biodiversity is that it makes our ecosystems more resilient, which is a prerequisite for stable societies; its wanton destruction is akin to setting fire to our lifeboat".

Johan Rockstrom

The proceeding chapter describes the collection, analyses and evaluation of biodiversity data from integrated biodiversity assessments at the mangrove study sites. It describes the implementation and results of a range of monitoring equipment used to record and capture a wide-range of biodiversity data. It compares biodiversity between sites and focuses on the community abundance and diversity patterns of arboreal arthropod communities.

5.1 Abstract

Integrated biodiversity assessments were conducted at four mangrove sites bordering urban parks in the Manukau Harbour, Auckland, New Zealand. Mangrove habitat complexity was also surveyed. Sites selected were adjacent to areas of mangrove removal between 2010-2018. Assessments were conducted in late summer 2018 and with a duration of one week per site. This study provides a snap-shot of biodiversity within mangroves and a baseline dataset on many species little studied in these habitats. A wide-range of equipment and techniques were used in order to record both terrestrial and marine vertebrates and invertebrates, through the least invasive methods. Forty-nine arboreal arthropod, fifteen bird, six mammalian, two fish, two crab, one shrimp, one gastropod, one jellyfish and one amphipod species were recorded in the study period. Results show much heterogeneity in terms of habitat complexity among sites. Habitat complexity parameters of adult tree density, average crown spread and height of adult trees explained 39% of arboreal arthropod abundance at the sites. Sites with lowest tree density, height and greatest crown spread had the highest relative abundance of arboreal arthropods. There was a significant difference between species richness of arthropods among sites, and sites with lowest adult tree density have the greatest richness. All eleven habitat complexity parameters contributed 34.4% of overall differences in richness among sites. Area of connected mangrove was negatively correlated with both arboreal arthropod abundance ($r^2 = 0.77$) and richness ($r^2 = 0.99$). This research shows that mangroves are important habitats for a wide variety of both native and non-native animal species in New Zealand. Long-term integrated ecological monitoring is required in these habitats and removal of mangrove should be considered on a site-by-site basis.

Key Words: biodiversity; mangrove; habitat complexity; abundance; richness; monitoring.

5.2 Introduction

The accelerated seaward growth of the grey mangrove *Avicennia marina* subsp. *australasica* over the last century has altered the ecology of estuarine and coastal ecosystems throughout the North Island, New Zealand (Morrisey et al., 2007). Expansion of mangroves has created a myriad of social-ecological issues regarding amenity value and cultural access of waterways for local communities and the potential impacts of mangrove forest expansion on New Zealand animal biodiversity and surrounding coastal landscapes. As a result, there have been many applications submitted to regional councils for removal of large areas of mangroves (Green et al., 2003; Harty, 2009). However, the impacts of removal of this indigenous ecosystem are not yet well understood and there are significant knowledge gaps (e.g. Morrisey et al., 2007; Lundquist et al., 2017; Dencer-Brown et al., 2018).

5.2.1 Expansion of mangroves

The grey mangrove *Avicennia marina* subsp. *australasica* is New Zealand's only species of mangroves and has been present in this country for over 11,000 years (Pocknall, 1989). This species is the most southerly mangrove in the world, with a range extending 38°S to 34.3°S and is thought to be limited by both frost (e.g. Chapman & Ronaldson, 1985) and physiological stress (Beard, 2006; Walbert, 2002). Expansion of mangroves has occurred rapidly over the past century due to increased sedimentation linked to land-use changes, such as agriculture, industrialisation and urbanisation of coastal areas (Morrisey et al., 2007; Green et al., 2003). This growth has led to the infilling of estuaries and subsequent resource consents lodged for the removal of large areas (Figure 15).

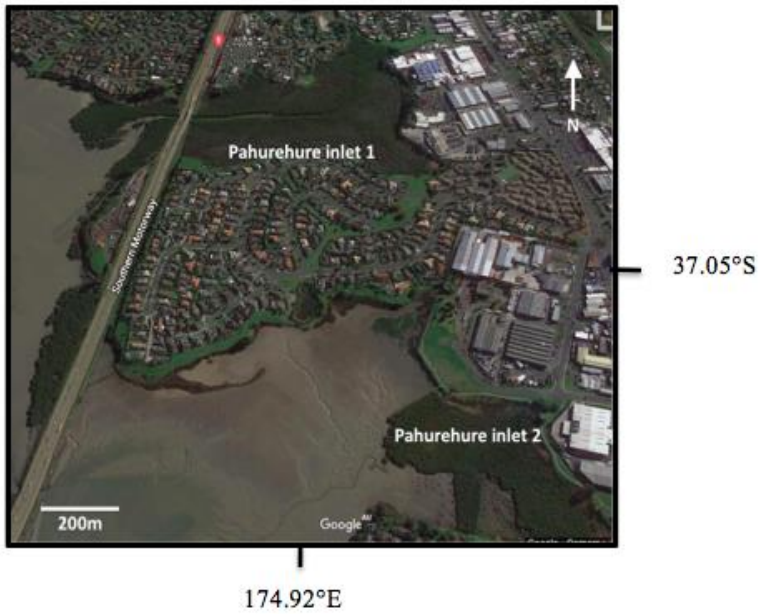


Figure 11. The infilled inlet 1 and remaining patch of inlet 2 mangroves, Pahurehure Inlet 1 & 2, Manukau Harbour, Auckland, New Zealand. Adapted from Google Earth, 2018.

5.2.2 Biodiversity studies

The biodiversity of an ecosystem is strongly linked to both its function and health, which in turn affects the ecosystem services provided by habitats (Sandifer et al. 2015). Therefore, it is important to understand and gather quantitative information on faunal biodiversity within mangrove ecosystems prior to removal of large forest areas and habitat fragmentation. Temperate mangrove ecosystems are less biodiverse than their tropical counterparts (Duke et al., 1998) and there are no unique estuarine or marine organisms in temperate mangroves (Morrisey et al., 2010). In the temperate mangroves of New Zealand, there has been a strong effort to quantify macrobenthic invertebrate community compositional change following mangrove establishment and subsequent removal (Alfaro, 2010; Lundquist et al. 2012). However, there is a lack of long-term monitoring of other groups of organisms, particularly terrestrial vertebrate and invertebrate species. There has been one study in New Zealand documenting the use of mangrove by terrestrial invertebrate biodiversity (Doyle, 2015). This study showed that mangroves support a diverse range of terrestrial arthropod species, almost half of which have not been found in inland habitats (Doyle, 2015).

A recent review paper by Rog et al. (2016) showed that globally, mangroves are utilised by 464 terrestrial vertebrate species, of which nearly half are of conservation concern (Rog et al., 2016). Although New Zealand only has a few terrestrial native vertebrate species, there are no studies on the use of mangrove habitats of these groups. The Department of Conservation (DOC) in New Zealand conducts biodiversity monitoring in a wide range of terrestrial, freshwater and marine habitats throughout the country, however, no integrated biodiversity assessments have been carried out to date in mangroves. This research fits with tier 3 of their monitoring and reporting system (Figure 16).

Figure 12.Biodiversity monitoring and reporting system (Department of Conservation, undated). Retrieved from: https://www.doc.govt.nz/our-work/monitoring-and-reporting-system/

5.2.3 Integrated assessments

Mangroves are notoriously difficult habitats for fieldwork (Heenkenda et al., 2014) and capturing biodiversity within them requires techniques and equipment little trialled in ecological research. There has been one peer-reviewed study of integrated assessments in mangroves to date (Rog et al., 2018 (*unpublished results*)). Rog et al. used a wide range of trapping techniques to survey the terrestrial vertebrate communities in both tropical and temperate

Australian mangroves. Results showed forty-two species of terrestrial vertebrates previously unknown to occupy mangroves in Australia.

A review paper of studies in New Zealand mangroves highlighted the gaps in knowledge around insects and spiders, reptiles, mammals, fish and birds in mangroves (Dencer-Brown et al., 2018). Thus, the present study aims to provide baseline biodiversity data of species that utilise mangrove habitats in New Zealand. In particular, as many non-invasive methods are to be employed as possible. Using non-invasive methods allows for valuable biodiversity data to be collected at low costs (Fateaux et al., 2018). In addition, using such methods creates scope for citizen scientists to repeat observations in order to provide long-term monitoring for threatened ecosystems (Chandler et al., 2016).

This chapter had the following aims:

- To investigate biodiversity at four urban mangrove sites, with a focus on arboreal arthropod community composition
- To investigate mangrove habitat complexity parameters
- To employ a wide range of trapping techniques to record and collect biodiversity data in mangrove habitats as a one-off snapshot of biodiversity

This chapter had the following objectives:

- To successfully capture biodiversity information in mangrove habitats over a short-term period (1 week per site)
- To investigate community patterns of abundance and diversity of terrestrial arboreal invertebrates within and between sites and how these relate to mangrove habitat complexity parameters
- To investigate how connectivity of mangrove habitats affects arthropod biodiversity of the plots sampled
- To investigate what kinds of organisms are trapped or recorded in different trap types

5.3. Materials and Methods

5.3.1 Site selection

All fieldwork was carried out in the late austral summer, between 28th February and 1st April 2018, with the exception of one bird survey; conducted on the 12th April 2018.

The study sites were four mangrove stands (Pahurehure Inlet 2, Waimahia, Puhinui and Mangere Inlet) within the Manukau Harbour, Auckland, New Zealand (37.08°S and 174.80°E) (Figure 17). The Manukau Harbour was selected because of proximity to the researchers' institution and due to it being a region which has undergone a large amount of urbanisation and coastal change in the past few decades.

The Manukau Harbour is New Zealand's second largest harbour (Cromarty & Scott, 1995), with a surface water area of 394 km^2 and tidal range of up to four metres (McLintock, 1966). The harbour has undergone 10 million years of sedimentation, which has continued since the diversion of the Waikato River to the Tasman Sea from the collection of many small rivers and streams, creating a shallow harbour, with shifting sandbars, widespread mudflats and fringing mangroves (McLintock, 1966). The harbour was a prevalent historical waterway for Māori and is popular for recreational activities, such as fishing and boating (McLintock, 1966).

Sites were within areas where mangroves were removed, with the exception of Waimahia, which has not undergone any removal although the consent was granted in 2015. All mangroves sites bordered recreational parks and were close to urban settlements. These four sites included one of the largest and first mangrove removals to be consented by Auckland Regional Council (Pahurehure Inlet 2 in 2010) and one of the largest yet to go ahead (Waimahia).

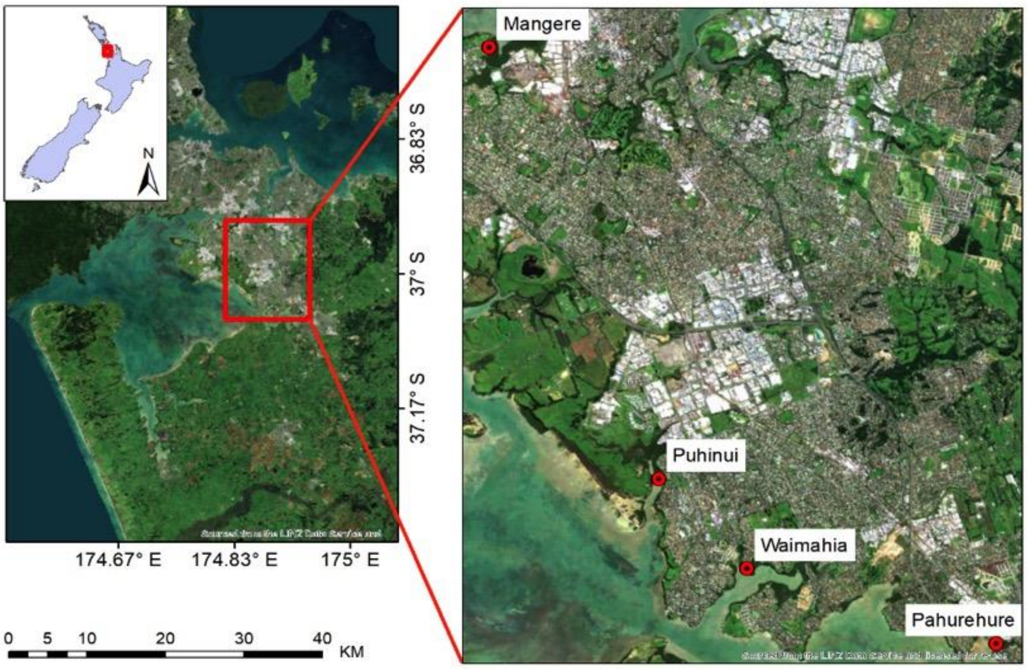


Figure 13. Map of mangrove sites, adapted from LINZ: https://data.linz.govt.nz/layer/88131-northland-04m-rural-aerial-photos-2014-2016/

5.3.2 Study design

In order to investigate differences in relative abundance and diversity of arboreal arthropods with intertidal height, a random stratified sampling design was employed. For each site, a grid overlay, divided into seaward, central and terrestrial zones (using Google Earth) and a random number generator was used to select three plots per zone, giving a total of nine plots per site (Figure 18). Plots of 10 x 10m were measured with a tape measure and the GPS coordinates were recorded with a Garmin Etrex device. Plots were between 50 and 100 metres apart. Five adult trees were selected in each plot and fitted with foam covers to trap any reptiles. Four quadrats of $0.25m^2$ were randomly placed in each plot to count the number of pneumatophores, saplings, seedlings and percentage leaf litter. Within each plot, a holden trap (H) and tracking tunnel (T) were placed down to trap small mammals and track reptiles, respectively.

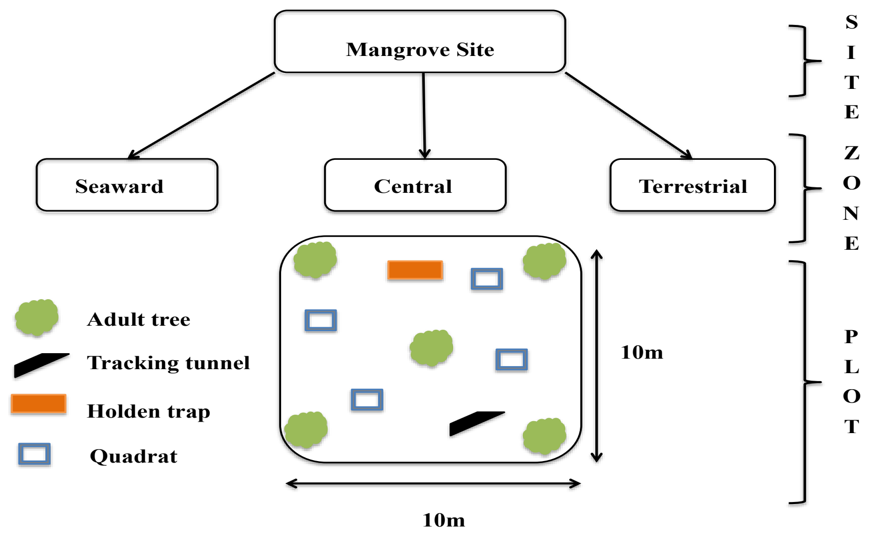


Figure 14. Experimental design, including three mangrove zones (S = seaward, C = centre and T = terrestrial) with three plots per zone. Each plot contained one holden trap for mammals and one tracking tunnel for reptiles. Five adult trees were sampled for insects and spiders using a sweep net and beat sheet. Foam covers were placed around each adult tree to trap any reptiles. Four quadrats of $0.25m^2$ were used to sample number of pneumatophores, saplings, seedlings and percentage leaf litter.

Habitat Complexity

In order to explore differences within and between sites of physical tree characteristics and their relationships to biodiversity data, five adult trees (defined as those with a diameter of >2cm) (e.g. Morrisey et al., 2003; Tran et al., 2016) were selected per plot. These trees were measured (height, length, breadth, girth at 20cm) in order to calculate above-ground biomass (agb). Adult trees which had multiple branches below 20cm were measured separately and the diameters averaged. Percentage canopy cover of each adult tree was calculated and the density of adult trees per plot was determined. Seedlings were defined as mangroves less than 0.5m in height and less than 2.5cm in stem diameter and saplings were defined as those more than 0.5m in height and less than 2.5cm in diameter (Morrisey et al., 2003).

In addition, the connectivity of each site was calculated through calculating the total surrounding connected area of mangrove at each site using Google Earth. Connecting mangrove was defined as a single connected mangrove area within each of the four inlets. Area was logged using the natural logarithm (Ln) and plotted against significant arboreal arthropod indices.

Arboreal arthropod surveys

Arboreal arthropods were caught and collected at each site (five adult trees per plot) by means of a beat sheet and sweep net. Foam covers used to trap reptiles were also expected to trap insects since they were wrapped around the five adult trees in each plot. Two lots of ten beats per tree were conducted in each 10 x 10m plot. Arthropods were counted on a sheet and collected by means of an aspirator or hand-picked and placed into a plastic jar containing 20ml of 95% ethanol. Each jar was labelled with the date and location. Where possible, organisms were identified in the field. Time, date and location with plot number were recorded at each plot. Salinity was measured using a hand-held refractometer (Atago MASTER-S/Mill-alpha, Japan. Air temperature was recorded at each plot using a Weber thermometer instant read 6750. Any butterflies and moths that were caught by sweep net were placed into a jar without ethanol, then frozen for preservation until identification. Observations of flying insects were also made, with the time, date, location and temperature recorded. Arthropods, with the exception of spiders, were identified, labelled and mounted in the lab at Auckland University of Technology, Auckland. Spiders were stored in vials of 95% ethanol and later identified at Landcare Research in Auckland.

Reptiles

In order to assess for the presence of reptiles within mangrove habitats, tracking tunnels were placed on the ground in each plot (one per plot, attached to a tree trunk), with an ink pad baited with a small piece of banana. These were checked on a daily basis between five and seven days per site. Any tracks were noted and photographed. If ink pads were lost due to tidal inundation or had tracks on them, prints were recorded. Then, inkpads were replaced and labelled again. Tunnels were removed after the site survey was completed and re-used for future research. Foam covers were fitted around the diameter of the five adult trees per plot and left for a period of five to seven days and checked on a daily basis for reptiles such as skinks and geckos (Figure 19a). Spotlighting using a handheld torch (Nightsaber 810 lumens) to check for reptiles at night was also conducted twice at each site due to the nocturnal nature of some species of skinks and geckos (Wilson, 2007). In order to create refugia for reptiles, onduline tiles were placed at each site on the terrestrial edges, between rush and mangrove zones. Housing stacks were created with three tiles per housing unit with dowel to create a 1-2cm gap between each tile. Three housing units were placed at each site and left in-situ to provide refugia for reptiles. These were checked on a monthly basis over a period of nine months (Figure 19b).

19a)

19b)

Figure 15a). Foam cover around mangrove adult tree and **19b**). Onduline tile housing on marsh-mangrove edge.

<u>Mammals</u>

In order to check for presence of mammals, Holden traps were baited with a smear of peanut butter and tied to an adult tree in each plot, some distance away from the tracking tunnel baited station. Traps were checked on a daily basis for presence of mammals and if present, they were recorded. After the capture of a mammal in a trap, the trap was removed as this was to detect presence, absence only. Bat surveys with a Magenta Bat 5 heterodyne bat detector were conducted from dusk until nightfall at all sites along the terrestrial edges of each site. Two surveys were conducted per site. The detector was set to 40kHz to detect presence of long-tailed bats and held up over the mangrove canopy. Bat passes, duration of pass and time of pass were recorded. Visual observations of larger mammals were also made at each site throughout the study period.

Fish

Two Hero-5 go-pro's in water-proof housing were placed during tidal inundation at the seaward edges of each site (over 50 metres apart within the mangrove habitats). Each go-pro was tied to a metre-long stick, with fish bait attached to the stick in front. Footage was recorded at 1080 resolution during high tide in a diurnal cycle (between 1.5 and 2 hours). Go-pros were then removed after high tide and data were uploaded and analysed by species present, duration and behaviour.

Birds

Timed bird surveys of ten minutes were carried out in each plot over the time period of five to seven days. Species, relative abundance, behaviour, date, air temperature and location were recorded. Dusk surveys were also conducted at each site over the course of one to two hours from a vantage point which covered all plots at each site. Vantage points were areas next to the mangrove sites on the edge of parks, within a few metres of mangroves and at a higher elevation, in order to observe birds flying to and from the mangroves. Nikon Prostaff 10 x 42 binoculars were used to help identify bird species and relative abundance. Surveys continued until nightfall.

Trail Cameras

Four trail cameras were placed within each site (two on seaward edges, one in the centre and one on the terrestrial edge). No particular group of organisms were targeted here. Cameras were attached above the tidal mark to adult trees and switched on to record photos at 1080 resolution over a period of three to five days. Data were uploaded, and species identified with the date, time, location and behaviour recorded. Figure 20 shows some of the biodiversity capture equipment used in the study.

Figure 16. Biodiversity capture equipment for mangrove biodiversity surveys used in study.

5.4 Statistical analyses

5.4.1. Tree Ecological indices

Above ground biomass of trees in each plot was calculated using the following allometric equations developed by Tran et al. (2016). These equations were specifically developed for use with *Avicennia marina* var. *australasica* in New Zealand to give an estimate of the total above-ground biomass (agb) using the basal area (ba) at 20cm (Tran et al., 2016).

Equation 1a). Biomass of wood. Equation 1b). Biomass of leaf and 1c).Total agb

a) $Biomass_{wood} = 283.97*ba$

b) $Biomass_{leaf} = 20.43*ba$

c) **Total agb(g) =(283.97*ba) + (20.43*ba)**

Results were converted to agb/kg/m^2. Tree crown spread was calculated by using the following equation: **(Longest spread + Shortest spread)/2** (Blozan, 2004), (Figure 21).

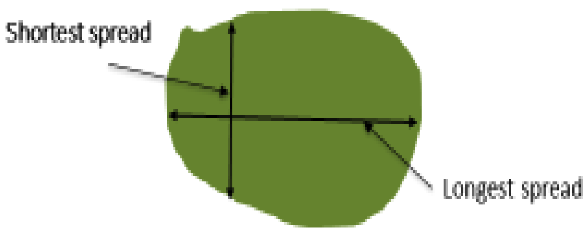


Figure 17. Diagrammatic representation of tree crown spread.

5.4.2 Multivariate Community Analyses

Multivariate community analyses were carried out using PERMANOVA+ (permutational analyses of variance in PRIMER, Plymouth Routines in Multivariate Ecological Research v7). PERMANOVA is a multivariate statistical technique involving geometric partitioning of variation across multivariate data, defined using a chosen measure of dissimilarity, in response to factors in an analysis of variance design (Anderson, 2014). The ecological indices of average pneumatophores, seedlings, saplings, canopy cover, leaf litter, height of adult trees, adult tree density, above-ground biomass, temperature and salinity were compared within and between sites by entering the data as multivariate environmental response data using a nested design of **"Site"** as a random factor and **"Zone"** nested within **"Site"** as a fixed factor.

Draftsman plots were conducted to check for any multicollinearity between ecological indices and data were pre-treated using a square-root transformation and indices normalised. A Principal Component Analysis (PCA) was conducted based on a Euclidean distance matrix and a SIMPER (one-way similarity percentage) plot analysis was used as a post-hoc test to show the ecological indices driving any dissimilarity between zones and sites (Anderson et al., 2008).

The effect of mangrove zone (intertidal height of high, medium and low; where high is the terrestrial edge, medium is the centre of the mangrove and low is the seaward edge) on arboreal arthropod community composition was tested using PERMANOVA+. A nested design of **"Site"** as a random factor and mangrove **"Zone"** as a fixed factor nested within site, with abundance data as the response variable. Abundance data were first square-root transformed to down weight the effect of outliers and dominant taxa and a resemblance matrix based on the Bray-Curtis index of similarity was created (Bray & Curtis, 1957). Non-metric multidimensional scaling (MDS) (Clarke & Ainsworth, 1993) was used to evaluate whether faunal species composition varied between intertidal zones and mangrove sites. A SIMPER was conducted to identify indicator species of arthropods which drove the dissimilarities in community composition between zones and sites (Anderson et al., 2008).

5.4.3. Arthropod Diversity Indices

The diversity of arthropods was also investigated in the nested design. The indices of S (total number of species), d (Margalef's species richness index), P' (Pielou's evenness), H' (Shannon-Weiner) and D (Simpson's Index of diversity) were calculated. Using the DIVERSE function in PRIMER, the diversity indices were treated as environmental variables and draftsman plots conducted to check for co-correlates.

The DistLM routine was used to analyse arthropod diversity indices in response to the continuous environmental variables, using a distance-based regression approach. Initially all ecological indices were run using AICc selection criterion (multivariate analogue to the small-sample-size corrected version of AIC (Akaike's "An Information Criterion)) (Anderson et al., 2008). A step-wise regression approach was used to see which variables contributed most to the overall differences in the data. Ordination and visualisation of the fitted models from the DistLM output were created using the dbRDA (distance-based redundancy analyses) routine.

5.5 Results

5.5.1 Tree ecological indices

The greatest agb, mean canopy cover and mean density of adult trees was found at Mangere (Table 1). The highest adult trees mean crown leaf spread and the lowest canopy cover and density of adult trees were found at Waimahia mangroves. The lowest agb was seen at Pahurehure Inlet 2.

Table 11. Mangrove ecological indices of mean above-ground biomass (agb), canopy cover, density of adult trees, adult tree height and crown leaf cover per 100m^2 at four mangrove sites in the Manukau Harbour, Auckland, New Zealand.

Site	**Mean above-ground biomass +/- S.E. (kg/m^2)**	**Mean canopy cover (%) +/- S.E.**	**Mean density of adult trees +/- S.E.**	**Mean adult tree height (m) +/- S.E.**	**Mean crown leaf spread (m) +/- S.E**
Pahurehure Inlet 2	23.64 +/- 3.78	65.74 +/- 3.61	76.67 +/- 12.37	2.97 +/- 0.23	2.50 +/-0.34
Waimahia	39.34 +/- 5.20	64.56 +/- 4.34	70.78 +/- 8.59	3.98 +/- 0.29	2.84 +/- 0.33
Puhinui	32.91 +/- 5.93	65.28 +/- 5.57	112.67 +/- 28.59	3.39 +/- 0.48	2.09 +/- 0.39
Mangere	42.68 +/- 7.13	73.89 +/- 4.14	162.22 +/- 18.65	3.87 +/- 0.12	2.41 +/- 0.24

The highest abundance of saplings was found at Pahurehure Inlet 2, and the highest mean seedling abundance and leaf litter was found at Puhinui mangroves. The highest mean abundance of pneumatophores was found at Waimahia. Mangere mangrove had the lowest abundance of saplings and percentage leaf litter, with Pahurehure Inlet 2 having the lowest mean seedlings. Puhinui mangroves had the lowest number of pneumatophores (Table 12).

Table 12. Mangrove ecological indices of mean sapling, seedling and pneumatophore abundance and percentage leaf litter per m^2 at four mangrove sites in the Manukau Harbour, Auckland, New Zealand.

Site	**Mean sapling abundance +/- S.E.**	**Mean seedling abundance +/- S.E.**	**Mean pneumatophore abundance +/- S.E.**	**Mean leaf litter (%) +/- S.E.**
Pahurehure Inlet 2	2.11 +/- 1.34	70.11 +/- 13.61	261.56 +/- 35.35	64.31 +/- 3.18
Waimahia	0.89 +/- 0.89	88.11 +/- 16.04	272 +/- 36.93	36.31 +/- 5.93
Puhinui	0.11 +/- 0.11	101.67 +/- 17.99	221 +/- 29.04	67.64 +/- 7.39
Mangere	0	93.44 +/- 8.15	230 +/- 34.56	29.25 +/- 6.12

A draftsman plot showed that no ecological indices were highly correlated to each other. A PERMANOVA was run with "**Site"** as a random factor and **"Zone"** as a fixed factor nested within **"Site"**. Results showed significant differences between sites: $F_{3,35}$=3.71, p=0.001 and significant differences in zone nested within site: 'Zone (Site)': $F_{8, 35}$ = 3.49, p=0.001 (see Appendix 2 for PERMANOVA output). A PCA was conducted to show the differences in ecological indices by site (Figure 22).

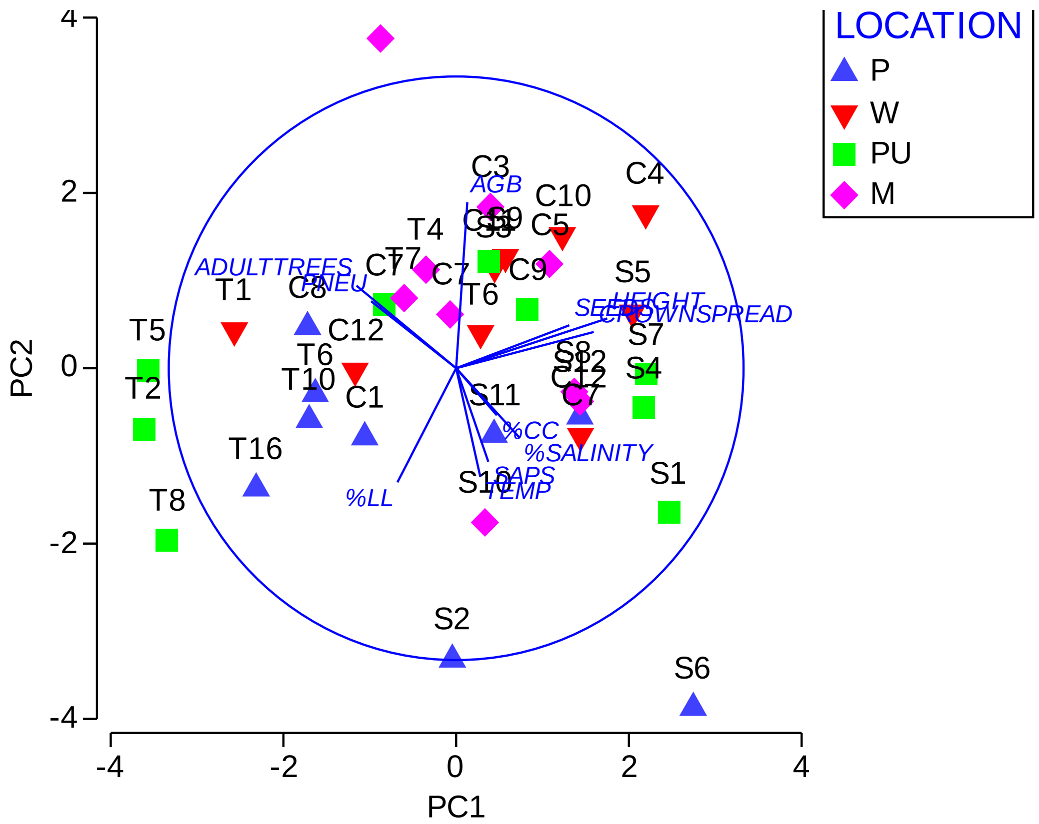


Figure 18. Principal Component analysis of ecological indices (density of adult trees, agb, height of adult trees, salinity, temperature, crown spread, number of saplings, number of seedlings, number of pneumatophores, percentage leaf litter & percentage canopy cover), in four mangrove sites (P=Pahurehure Inlet 2, W=Waimahia, PU=Puhinui and M=Mangere) in the Manukau Harbour, New Zealand.

A SIMPER analyses was conducted to show the average dissimilarity between sites and the ecological indices driving those differences. The greatest difference between sites was between Waimahia and Puhinui (average squared distance = 23.93), with the crown spread and height of the trees contributing 12.82% and 12.80% to the differences respectively. The greatest contribution of an ecological indice was the percentage leaf litter between Puhinui and Mangere, contributing 16.5% of total dissimilarity between these sites. Table 13 shows the site comparisons of ecological indices by contribution of top factors. See Appendix 2 for a full output.

Table 13. Mangrove ecological indices driving differences between sites

Site pair	Ecological indice	Contribution of dissimilarity
Pahurehure Inlet 2, Waimahia	Temperature	16.12%
Pahurehure Inlet 2, Puhinui	Sapling abundance	12.42%
Waimahia, Puhinui	Crown spread, tree height	12.82%, 12.80%
Pahurehure Inlet 2, Waimahia	Leaf litter	13.42%
Waimahia, Mangere	Adult trees	13.40%
Puhinui, Mangere	Leaf litter	16.50%

5.5.2 Arthropod community variables

Arboreal arthropods consisted of four classes: Insecta, Arachnida, Malostraca and Diplopoda with a total of 10 orders, 49 species and 2699 individuals caught through sweep net, beat sheet and foam cover techniques (data pooled). Visual observations at plots of flying insects which were unable to be caught easily were also recorded and included in this data set. For a full list of species see Appendix 2. The most diverse order of arthropods collected were the spiders (order Araneae), with 15 different species from eight different families, followed by the beetles (order Coleoptera), with 12 different species from seven families. The most abundant species across all sites was the ant *Technomyrmex jocosus*, followed by the isopod crustacean *Oniscus asellus* or common woodlouse. Figure 23 shows the total abundance of arboreal arthropods captured within orders by site.

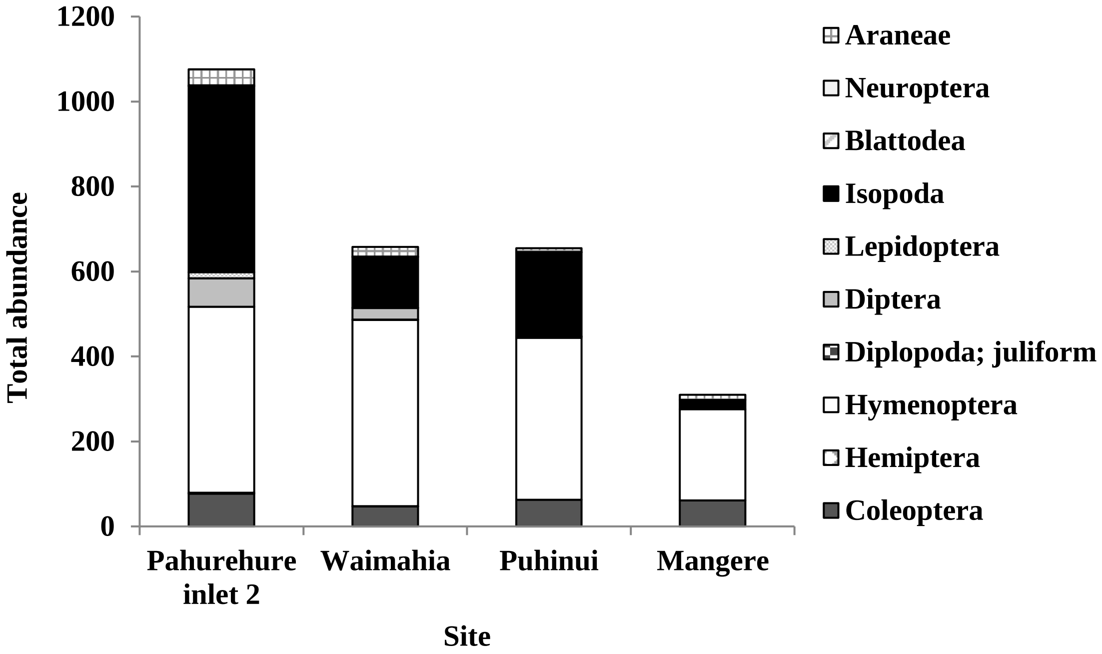


Figure 19. Total arboreal arthropod abundance by order (100m² x 9 plots) at four mangrove sites in the Manukau Harbour, Auckland, New Zealand.

Two orders of arboreal arthropods were found only at one site and in very small numbers: Neuroptera at Pahurehure (n=2) and Diplopoda; juliforms at Waimahia (n=1). Araneae, Isopoda, Hymenoptera and Coleoptera were present at all sites. Figure 24 shows the percentage of each order by site.

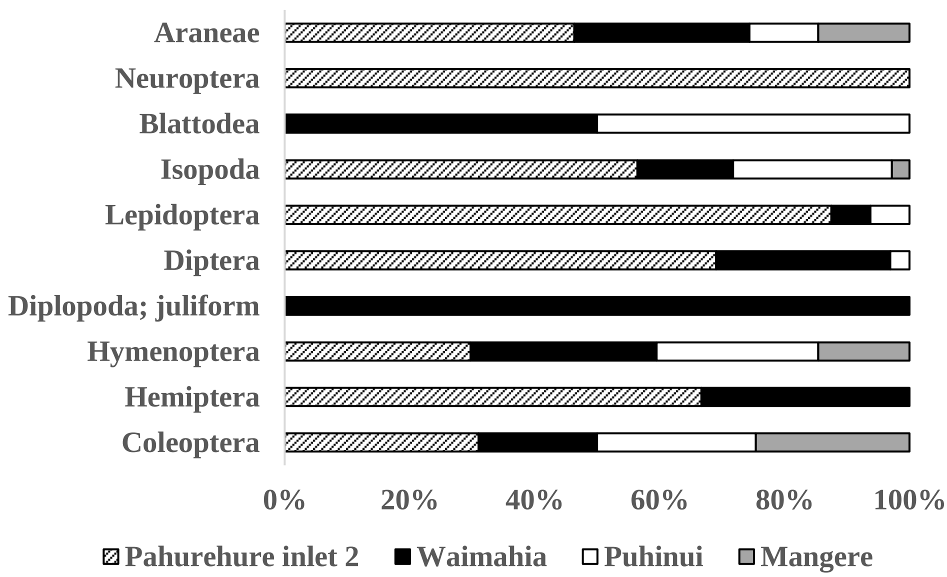


Figure 20. Percentage of each site by order of arboreal arthropod at four mangrove sites in the Manukau Harbour, Auckland, New Zealand.

PERMANOVA results showed a significant difference in arthropod community abundance among sites and zones nested within sites. Site had a significant effect on arthropod abundance at the 0.001 level and zone nested within site has a significant effect at the 0.05 level. There were significant differences in abundance among all sites (see Appendix 2). Figure 25 shows a non-metric multi-dimensional scaling plot of arboreal arthropod community composition at the four mangrove sites.

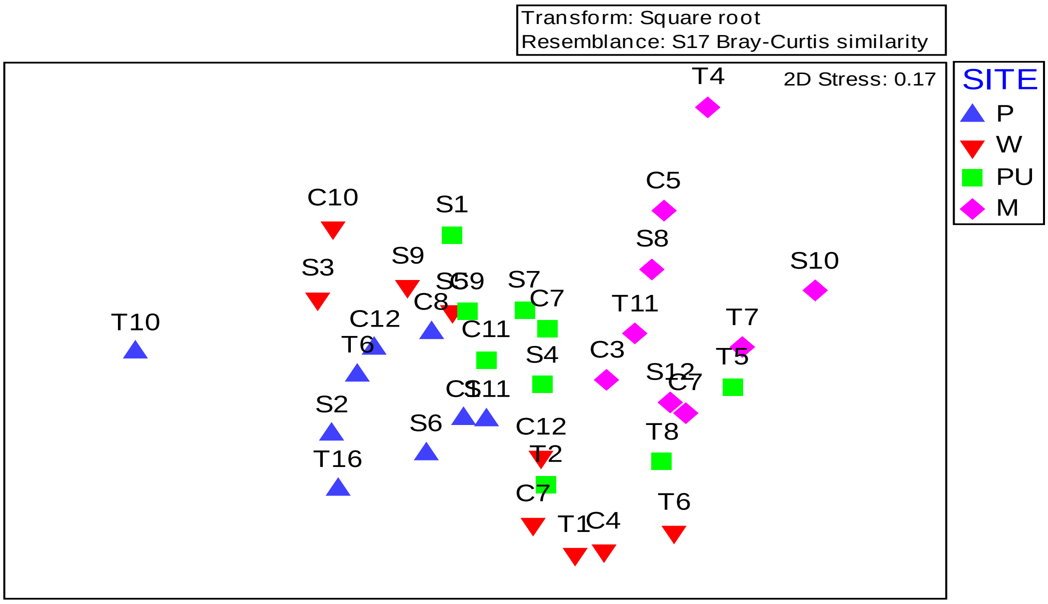
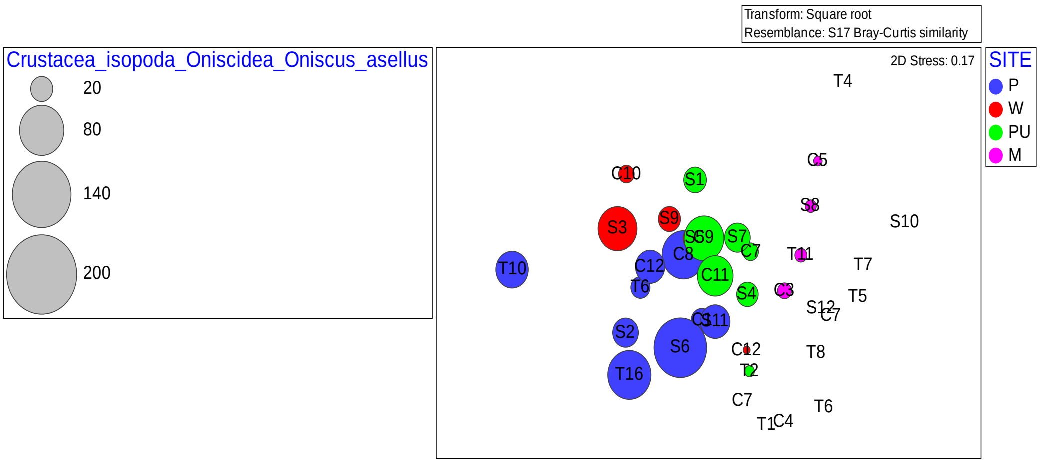


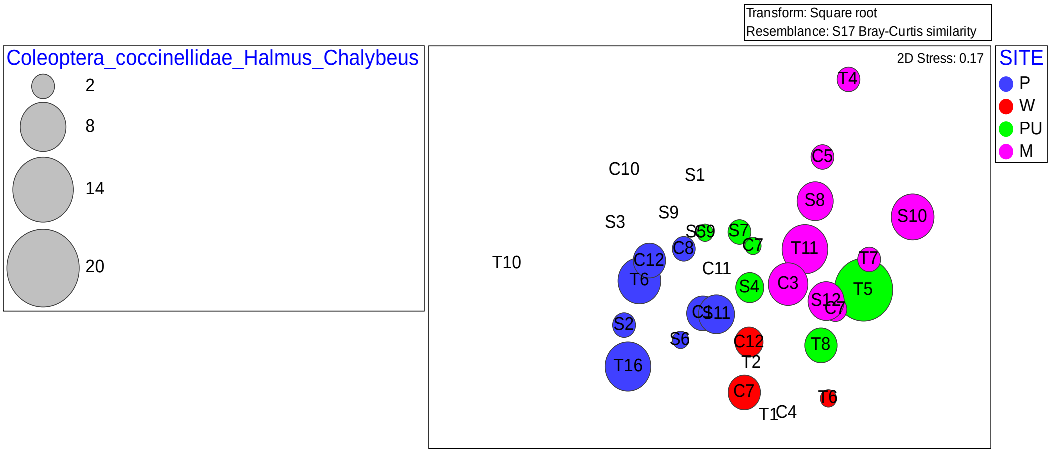
Figure 21. Non-metric MDS plot based on Bray- Curtis index of similarity of community composition patterns of arboreal arthropods (transformed data: square-root transformed) at four mangrove sites (P=Pahurehure inlet 2, W=Waimahia, PU=Puhinui and M=Mangere) in the Manukau Harbour, Auckland, New Zealand.

The greatest dissimilarity between sites was observed between Pahurehure inlet 2 and Mangere (58.40%), with the main species contributing being the isopod crustacean *Oniscus asellus* (18.22%) (Figure 26a). This species was a top contributor of dissimilarity between all pairs of sites. The steel blue beetle *Halymus chabus* (Figure 26b) was also a top contributor of dissimilarity, as was the ant *Technomyrmex jocosus*. (Figure 26c). For a full output of species driving dissimilarity between sites, see Appendix 2.

26a).



26b).



26c).

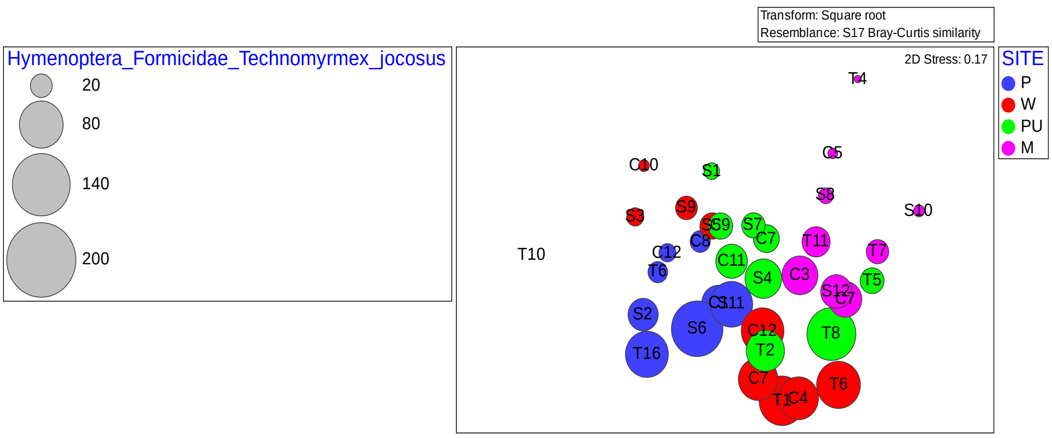


Figure 22.2-dimensional bubble plots based on Bray-Curtis dissimilarity index of arboreal arthropods contributing to the most dissimilarity between mangrove sites (square-root transformed) **a)** Isopoda: *Oniscus asellus*, **b)** Coleoptera: *Halymus chabus* and **c)** Hymenoptera: *Technomyrmex jocosus* at four mangrove sites ((P=Pahurehure Inlet 2, W=Waimahia, PU=Puhinui and M=Mangere) in the Manukau Harbour, New Zealand.

Relationships between arthropod diversity indices and ecological indices

A DistLM in PERMANOVA was run (using AICc). Results show that the ecological indices explained 39% of the arthropod abundance data, and the significant factors which contributed to differences among sites were adult tree density, crown spread and adult tree height ($p < 0.05$) (Table 14).

Table 14. A DistLM of ecological indices correlated with arboreal arthropod community composition. Indices in bold are significant at the 0.05 level.

Variable	R^2	SS (trace)	Pseudo-F	P	Prop.	Cumul.
+%LL	0.045317	2392.3	1.6139	0.148	0.045317	0.045317
+ADULTTREE	**0.12328**	**4115.9**	**2.9347**	**0.013**	**0.077966**	**0.12328**
+CROWNSP	**0.17804**	**2890.6**	**2.1317**	**0.042**	**0.054755**	**0.17804**
+%SALINITY	0.21403	1900.3	1.4197	0.2	0.035995	0.21403
+TEMP	0.24902	1846.8	1.3975	0.206	0.034984	0.24902
+%CC	0.27461	1351.2	1.0233	0.391	0.025595	0.27461
+AGB	0.29207	921.46	0.69037	0.663	0.017455	0.29207
+HEIGHT	**0.34587**	**2840.2**	**2.2207**	**0.049**	**0.0538**	**0.34587**
+PNEU	0.36616	1071.1	0.83229	0.528	0.02029	0.36616
+SAPS	0.37635	538.06	0.40857	0.876	0.010192	0.37635
+SEEDS	0.38788	608.57	0.45198	0.859	0.011528	0.38788

The DistLM procedure was run again using a step-wise regression approach, results showed that the three variables of density of adult trees, crown spread, and height of adult trees contributed to 23.5% of the overall patterns in arthropod abundance. A dbRDA was conducted for visualisation of these ecological variables contributions to differences in arthropod abundance data (Figure 27) (see Appendix 2 for output).

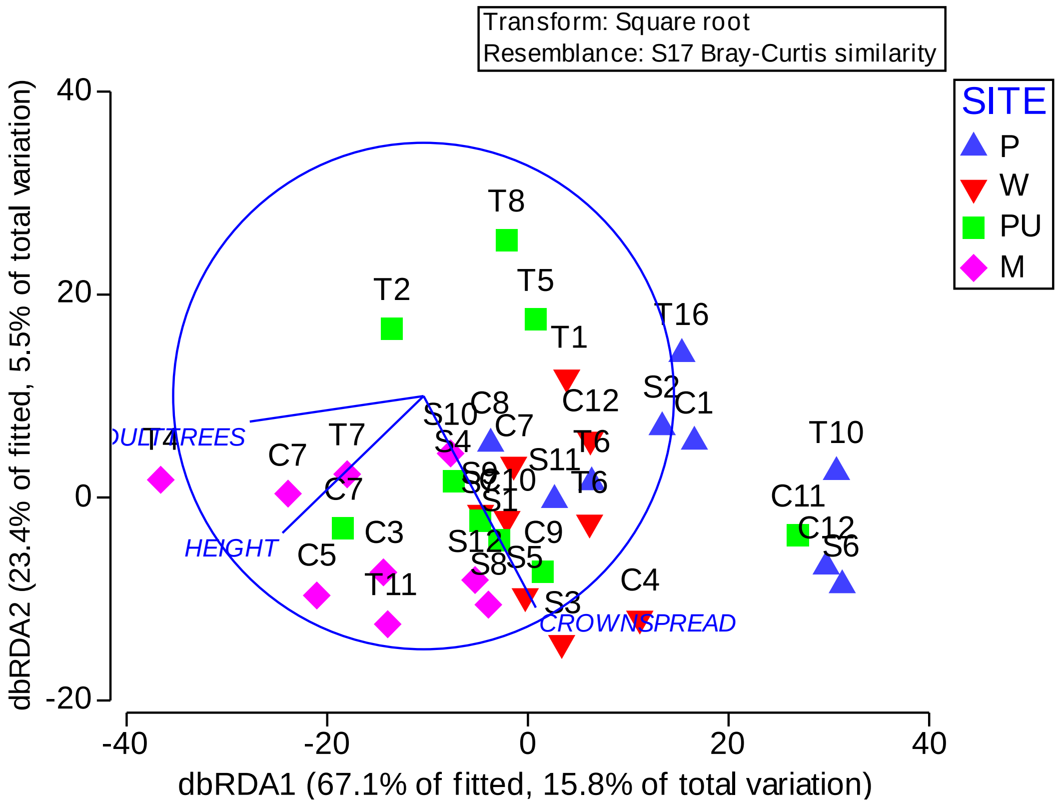


Figure 23. dbRDA of significant ecological indices (density of adult trees, height of adult trees and mean crown spread) driving differences in arboreal arthropod community composition patterns at four mangrove sites (P=Pahurehure inlet 2, W=Waimahia, PU=Puhinui and M=Mangere) in the Manukau Harbour, New Zealand.

Diversity indices of S (total number of species), d (Margalef's species richness index), P' (Pielou's evenness), H' (Shannon-Weiner) and Simpson's Index were calculated using the DIVERSE function in PRIMER. A draftsman plot showed that both total number of species and Margelef's species richness, Shannon-Weiner and Simpson's index of diversity were strongly correlated (0.95) and so total number of species and Shannon-Weiner were removed from the analysis. Using the nested design, Margelef's index of species richness was significant at the 0.05 level, with a pairwise comparison showing differences between Pahurehure and all other sites (greater richness at Pahurehure) (Figure 28). $F_{3, 35}$ =8.45, p = 0.002 Appendix 2). There were no significant differences between zones.

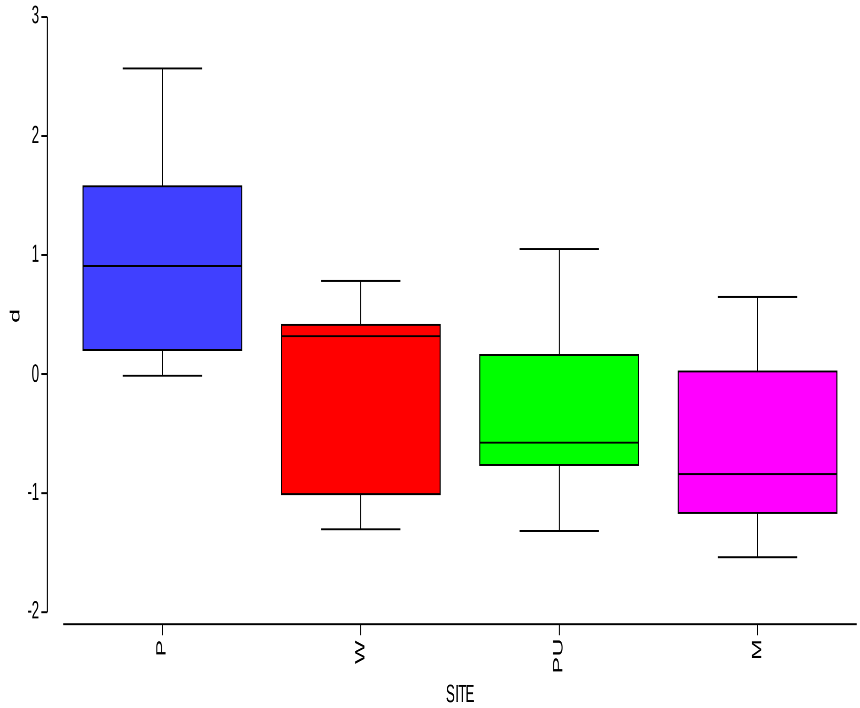


Figure 24. Margelef's species richness by mangrove site (mean values +/- S.E) at four mangrove sites (P=Pahurehure Inlet 2, W=Waimahia, PU=Puhinui and M=Mangere) in the Manukau Harbour, Auckland, New Zealand.

The ecological indices were added into a DistLM to see if any variables contributed to the difference in species richness. All eleven variables contributed to 34.4% of the richness data, with the density of adult trees being significant at the 0.05 level, which composed 12.6% of the overall contribution of environmental variables.

Connectivity of mangrove sites

The connecting area of each mangrove site was calculated and recorded in Table 15. Mangere Inlet had the largest area of connecting mangrove, followed by Puhinui, Waimahia and Pahurehure Inlet 2, which has the smallest area of connecting mangrove.

Table 15. Surrounding connected mangrove area at all four sites, estimated using Google Earth (2018).

Mangrove site	Total connecting area (m^2)	Natural log (Ln) total connecting area (m^2)
Pahurehure inlet 2	50942	10.84
Waimahia	366291	12.81
Puhinui	440336	13.00
Mangere	1072633	13.89

The significant diversity indices of arthropod abundance and species richness were plotted as response variables against the total connected area of each mangrove site in order to assess whether these indices were correlated with mangrove area. Results show a similar trend in both diversity indices (abundance and richness), with a negative correlation between these indices and total connecting mangrove area (Figure 29).

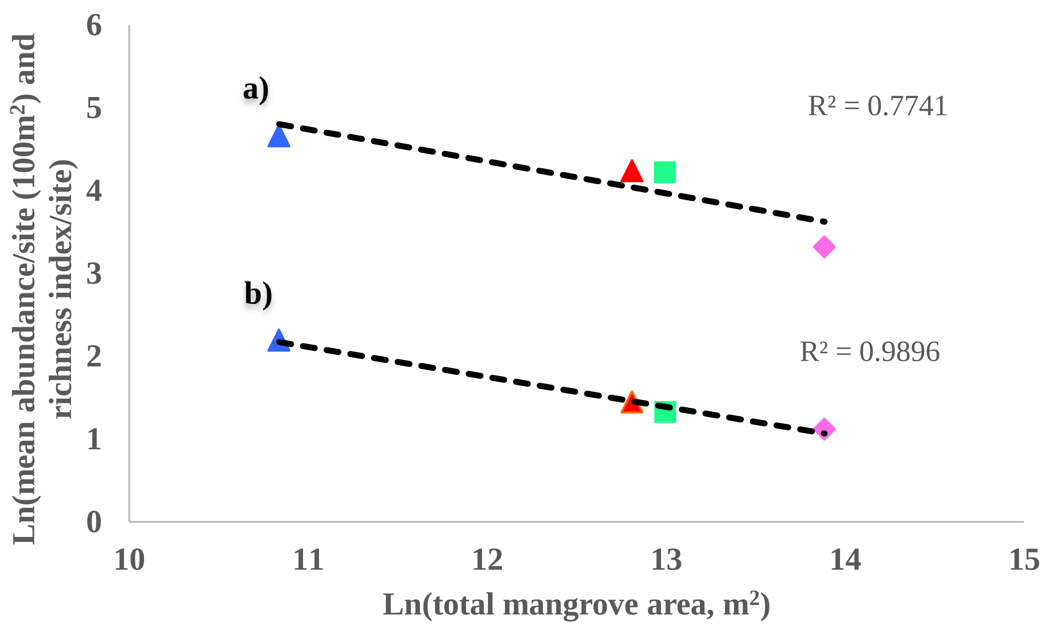


Figure 25. Relationship between natural log (Ln) of total connected mangrove area and arboreal arthropod mean abundance **(a)** and species richness **(b)** at Pahurehure Inlet 2 (blue triangle), Waimahia (red triangle), Puhinui (green square) and Mangere (pink diamond).

5.5.3 Reptiles

No reptiles were observed within mangrove sites during this study from the foam covers or onduline tile trapping techniques. Skink (unidentified spp.) were observed at the marsh edge bordering the mangrove at all sites. Onduline tiles created a refuge for some benthic and arboreal invertebrate fauna, including woodlice (*Onsidia*), gastropod snails (*Amphibola crenata*), crabs (*Helice crassa*) and sandhoppers (*Gammurus*). Table 16 shows the organisms and relative abundance calculated at each site.

Table 16. Onduline tile benthic and terrestrial species counts.

Site	Species	Mean/tile
Pahurehure Inlet 2	*Amphibola crenata*	*50*
	Gammarus spp.	*6*
Waimahia	*Amphibola crenata*	*25*
	Helice Crassa	*0.66*
	Onisidia spp.	*7.66*
Puhinui	*Amphibola crenata*	*8.33*
	Gammarus spp.	*10*
Mangere	*Amphibola crenata*	*15*
	Gammarus spp.	*10*
	Helice Crassa	*0.66*
	Onisidia spp.	*13.33*

5.5.4 Mammals

Mammals were detected at all sites except Mangere mangrove. Holden traps caught Norway rats (*Rattus norvegicus*) in seven traps (19.4%), three of which were at Waimahia mangrove. The tracking tunnels picked up both rat and mice prints in 25% of tunnels over the fieldwork period (Figure 30a and b). Mice (*Mus musculus*) were detected at Puhinui only.

30a) **30b)**

Figure 26a). Rat prints of the Norway rat; *Rattus norvegicus* and **30b).** Mouse prints *Mus musculus* from tracking tunnel prints at mangrove sites in the Manukau Harbour, Auckland, New Zealand.

Two bat passes were recorded at Pahurehure Inlet 2. A domesticated cat, hedgehog and possum were also detected on the edges of the mangrove at Waimahia. Table 17 shows species, location and trapping technique for mammals.

Table 17. Mammalian species recorded at four mangrove sites in the Manukau Harbour, Auckland, New Zealand (Long-tailed bat, detected by bat pass but no visual confirmation, so tentative detection).

Site	Plot	Species	Trap
Pahurehure Inlet 2	S2	Norway rat	Holden
	T16	Norway rat	Holden
	Terrestrial edge	Long-tailed bat*	Bat detector
Waimahia	T1	Norway rat	Tracking tunnel
	T6	Norway rat	Holden
	T6	Norway rat	Tracking tunnel
	T6	Domesticated cat	Visual
	C4	Norway rat	Tracking tunnel
	Adjacent to S3 on grass	European hedgehog	Visual
	S3	Norway rat	Tracking tunnel
	S5	Norway rat	Tracking tunnel
	S9	Norway rat	Tracking tunnel
	End of riparian zone (boardwalk)	Common brushtail possum	Visual
Puhinui	T5	Mouse	Tracking tunnel
	T8	Mouse	Tracking tunnel
	T8	Norway rat	Tracking tunnel
	C7	Norway rat	Holden
	C7	Norway rat	Tracking tunnel
	S4	Norway rat	Holden
Mangere	N/A	No observations	

5.5.5 Fish

Go-pro data recorded the presence of two fish species the yellow eyed mullet (*Aldrichetta forsteri*) and the short-finned eel (*Anguilla Australis*) (Figure 31a and b). The mysid shrimp Tenagomysis and crabs *Austrohelice crassa* and *Macropthalmus spp*. were also recorded.

31a) **31b)**

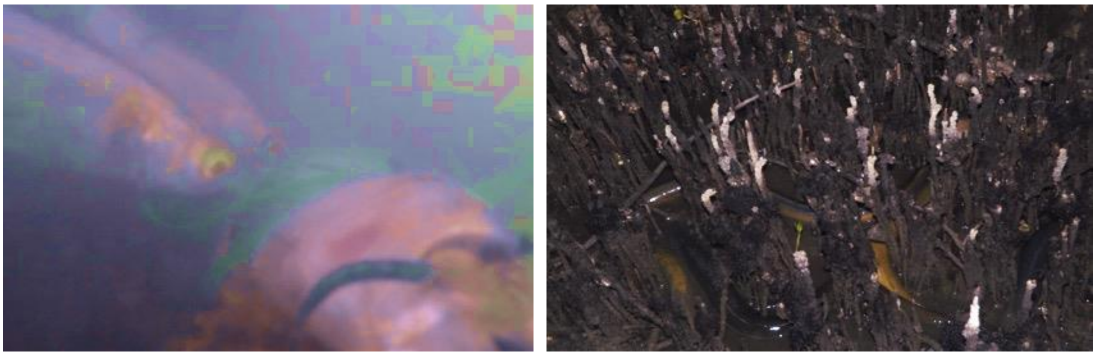
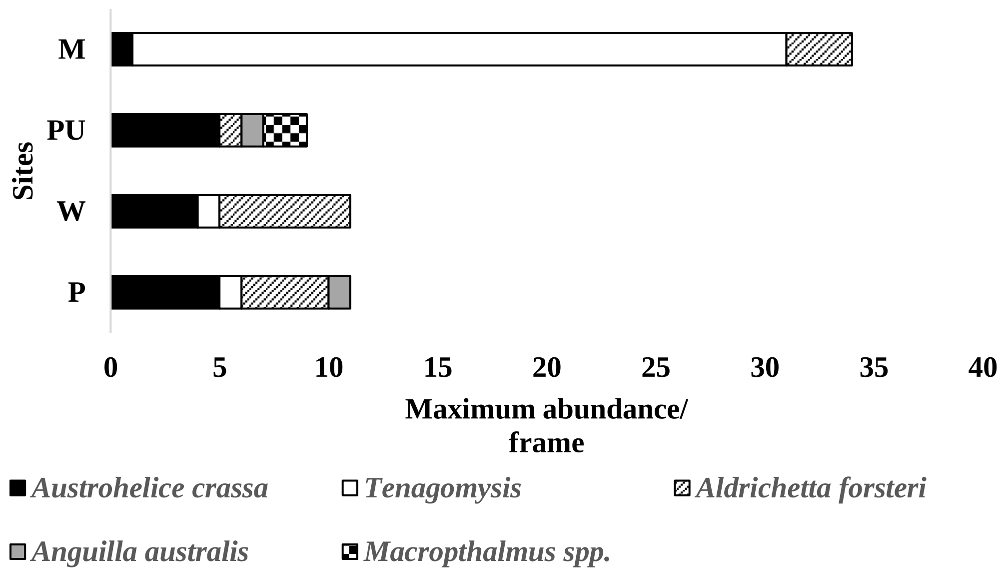


Figure 27a). Yellow-eyed mullet; *Aldrichetta forsteri* and **31b).** short-finned eels *Anguilla australis* recorded by go-pro and visual observations respectively at mangrove sites in the Manukau Harbour, Auckland, New Zealand.

Waimahia mangrove had the greatest abundance of juvenile yellow-eyed mullet (n=6), present throughout the video footage (1.25 hours). It also had the highest abundance of short-finned eels (visual observations only). A permanent channel was found at Waimahia which contained a resident short-finned eel population of approximately five eels per metre squared for a length of twenty metres (abundance estimated at low tide). No eels were detected at this site in the go-pro footage. Mangere mangrove had the greatest number of mysid shrimp (n=30), present in 66.67% of frames. Puhinui mangrove had the least abundance of species (n=9) (Figure 32a and b).

32a)



32b)

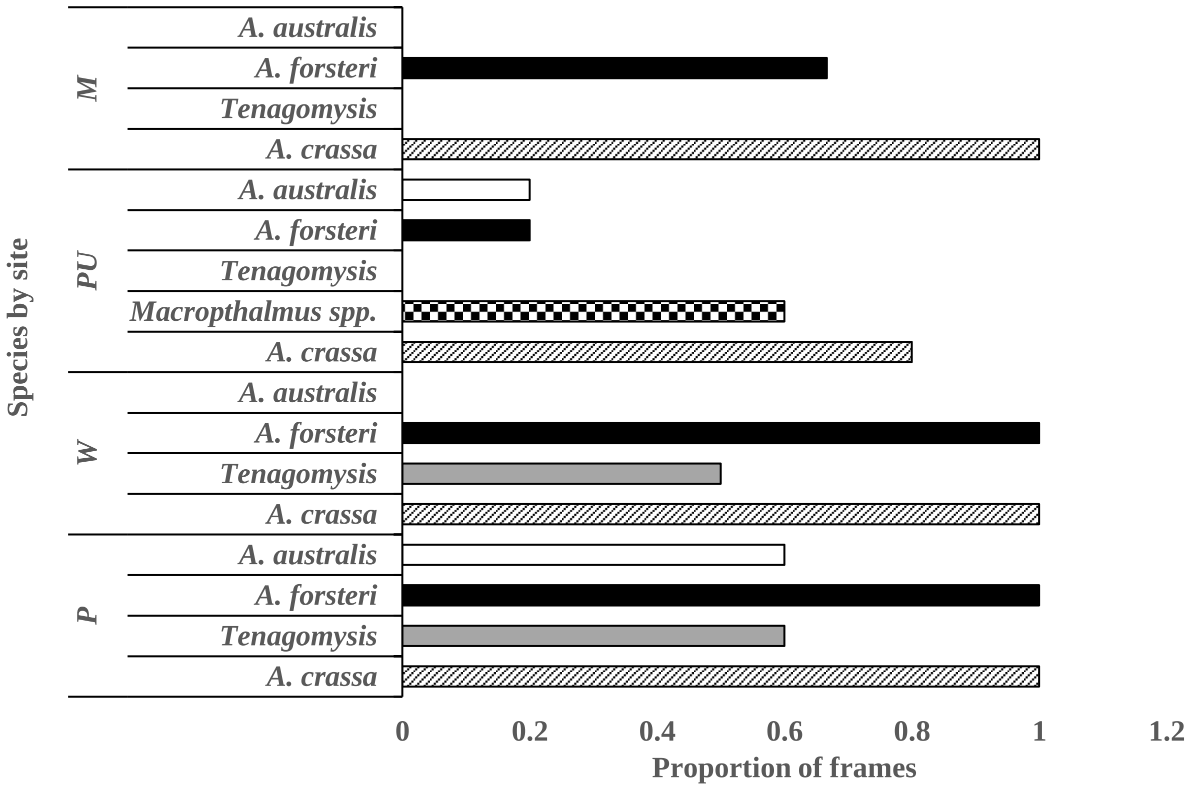
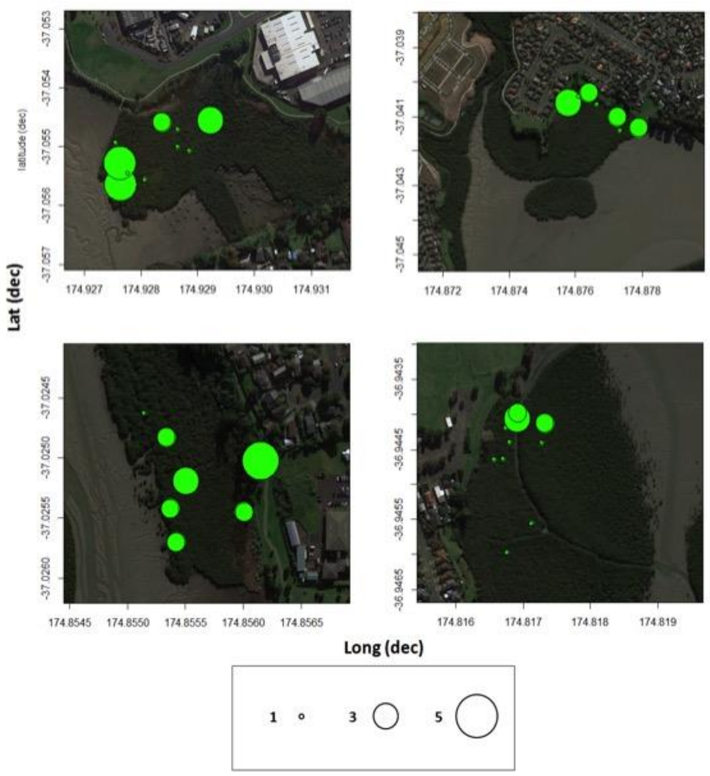


Figure 28a). Maximum abundance observed in any one frame of the go-pro video footage of the four species recorded feeding on the bait and **32b).** Proportion of frames the species were present in by site, where P = Pahurehure Inlet 2, W=Waimahia, PU=Puhinui and M=Mangere.

5.5.6 Birds

A total of 619 birds were recorded at all sites over the period of observation. The highest abundance was recorded at Pahurehure Inlet 2, with a total of 445 birds observed over a one week period (two timed evening surveys and three walked transects), the fewest birds were observed at Waimahia (39 birds). The greatest species richness was observed at both Pahurehure Inlet 2 and Puhinui (9). With the least at both Mangere and Waimahia (6). Figure 33a) and b) shows mds bubble plots of species richness and relative abundance, respectively, at all sites.

33a)



33b)

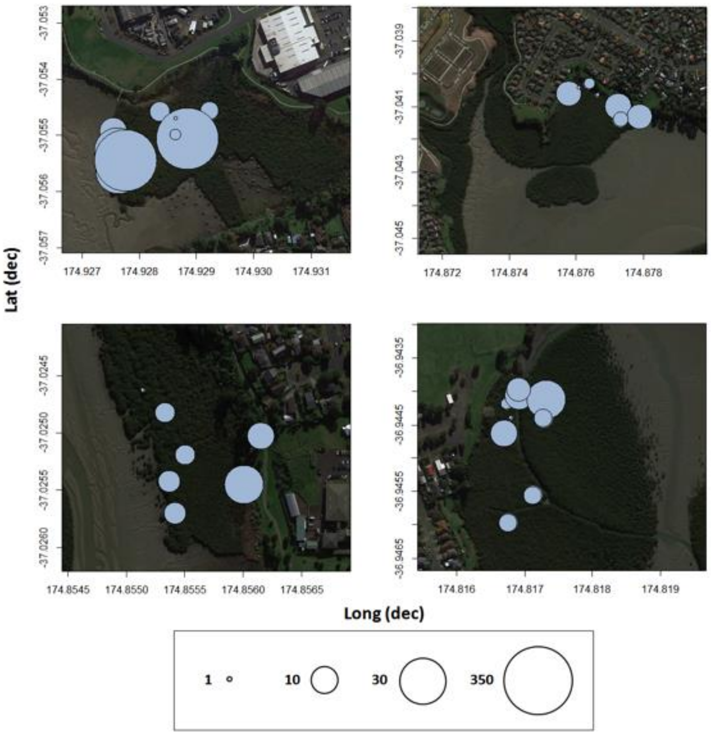


Figure 29a). Species richness and **33b)**. Relative abundance of birds at four mangrove sites as detected from visual surveys at four mangrove sites (top left; Pahurehure Inlet 2, top right; Waimahia, bottom left; Puhinui and bottom right; Mangere) in the Manukau Harbour, Auckland, New Zealand.

The Green Finch (*Chloris chloris*) was the most abundant, with 324 individuals observed at Pahurehure inlet 2 (322) and Puhinui (2). Fantails and blackbirds were present at all sites. Figure 34 shows the relative abundance of birds by species at all four sites.

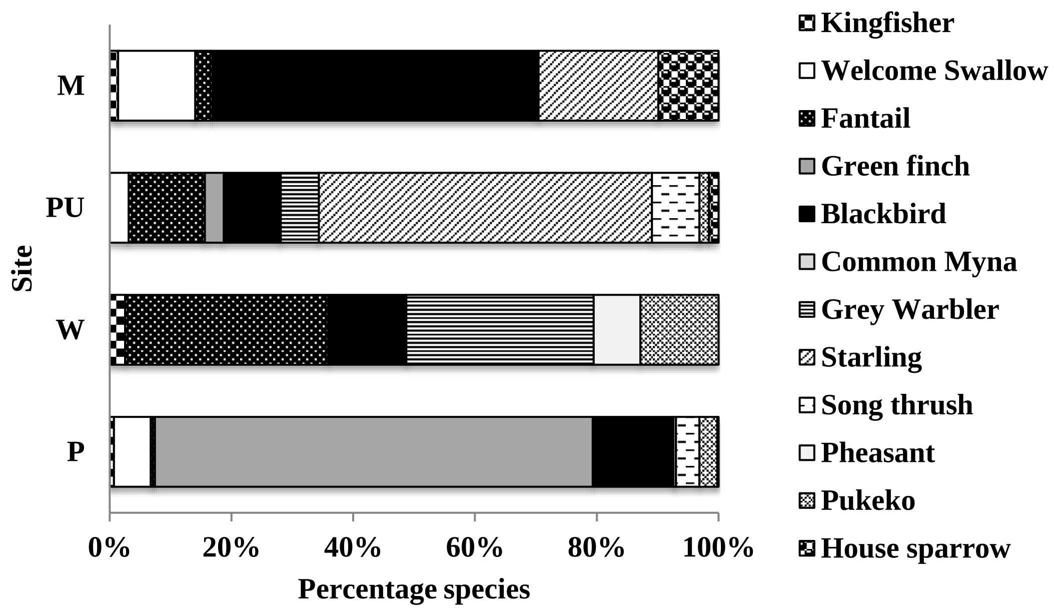


Figure 30. Percentage bird species by site from visual bird surveys where P = Pahurehure Inlet 2, W=Waimahia, PU=Puhinui and M=Mangere.

5.5.7 Trail Camera Data

The trail camera data photographed eight different species of bird, including the threatened native species the Banded Rail, present at both Pahurehure Inlet 2 and Waimahia mangrove. The camera also recorded the Norway rat and jellyfish. Relative abundances could not be ascertained from the trail camera data, however, presence of each species at each site was recorded (Figure 34).

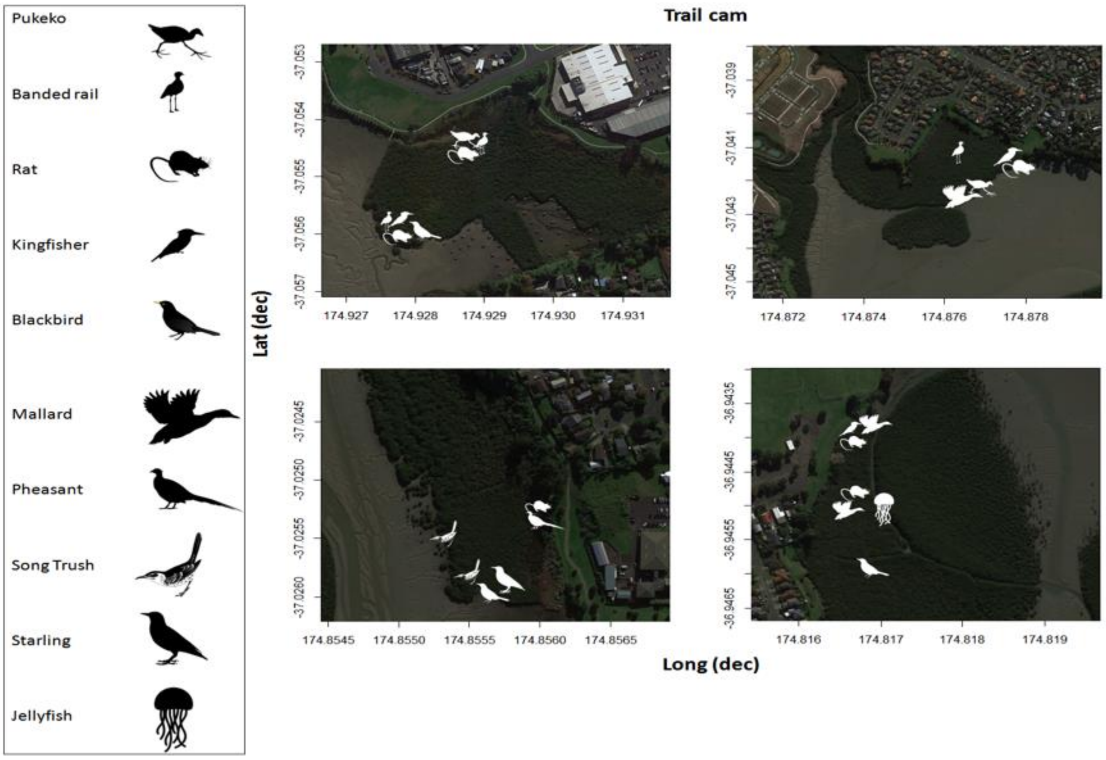


Figure 31. Trail camera species detected at four mangrove sites (top left; Pahurehure Inlet 2, top right; Waimahia, bottom left; Puhinui and bottom right; Mangere) in the Manukau Harbour, Auckland, New Zealand.

The Norway rat was detected in 37.5% of trail cameras (all sites), the least detected species was the pheasant (*Phasianus colchicus*) and the jellyfish (Cnidaria, unknown spp.) 0.06% of cameras (total sites). Figure 36 shows the fraction of cameras each species is present by site.

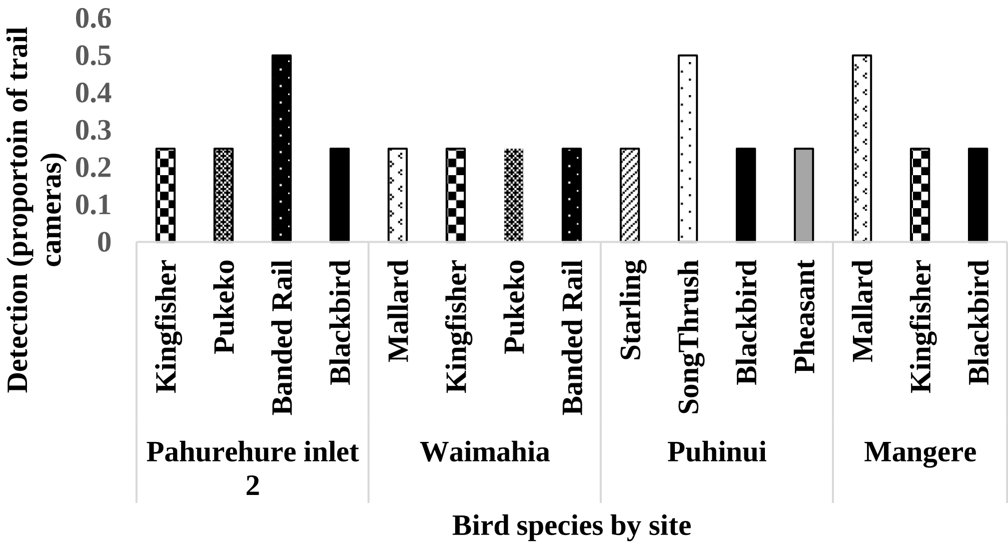


Figure 32. Proportion of trail cameras detecting bird species at four mangrove sites in the Manukau Harbour, Auckland, New Zealand.

5.6 Discussion

Biodiversity measures were taken at four mangrove sites in the Manukau Harbour, New Zealand, through a variety of techniques in order to provide a “snap-shot” assessment of organisms inhabiting mangrove areas. Where previous studies in New Zealand mangroves have focussed on benthic communities in areas pre and post-removal, this study sought to provide baseline data on a wide-range of organisms through integrated assessments. This was important due to the removal activities at these sites, which have taken place (Pahurehure Inlet 2) are ongoing (Puhinui and Mangere) and are to go ahead (Waimahia). It is noted that the majority of techniques were non-invasive and may bias results of what species were recorded. The aims of this study were to provide baseline data of animal groups which have not been frequently investigated by use of simple, low cost yet effective techniques and to trial equipment in an environment which is notoriously difficult to operate in. The methods used in this study can be repeated for use in citizen science and practitioners in order to capture a wide-range of biodiversity in mangroves.

5.6.1 Organisms recorded

A total of forty-nine species of arboreal arthropods, fifteen bird species, six mammalian species, two fish species, two crab species, one shrimp species, one gastropod snail species, one jellyfish species and one amphipod species were recorded in mangrove habitats at four sites in the Manukau Harbour (collectively). As this was a snap-shot, short-term study in late summer, other species which occur at other times of the year may have been missed. However, this was an ideal time for sampling, due to the flowering of *Avicennia marina* in the late summer (Godley, 1979) and peak abundance of arboreal arthropod populations, bat passes or sightings and the presence of many estuarine-based bird species in New Zealand. However, due to time constraints it was not possible to assess for temporal differences in biodiversity throughout the year.

5.6.2 Habitat Complexity

Even though the sites are composed of the same species of mangrove, the results highlight that there is much architectural heterogeneity among patches in terms of tree characteristics. Mangere mangrove stands had the greatest mean agb, canopy cover and density of adult trees and the least saplings and leaf litter. This mangrove site also has the largest connecting area of mangrove out of all the four sites. Pahurehure Inlet 2 had the lowest agb and the highest mean sapling abundance, and this was the least connected mangrove habitat, with a total remaining area of approximately 4.3 Ha post removal. Waimahia mangrove had the largest mean crown spread, the highest trees and the most pneumatophores, whilst Puhinui mangrove had the highest mean seedling abundance and leaf litter, with the least number of pneumatophores.

Arboreal arthropod communities and habitat complexity

The relative abundances of arboreal arthropods were similar to those collected in another study in Thames mangroves, New Zealand by Doyle (2015), through the same collection methods of sweep netting and beating (Doyle, 2015). This was the only other study on arboreal arthropod communities to date in New Zealand. Doyle concluded that half of the arthropod assemblages observed at the mangrove stands in Thames had not been found in other inland habitats. In this present study, all arthropods identified were not unique to mangrove ecosystems. The two endemic mangrove insect species (the mangrove leafroller *Planotortrix avicenniae* and the eriophyid mite *Aceria avicenniae*) were not recorded. However, native insect species, such as the common copper butterfly *Lycaena salustius* (Puhinui mangrove) (Figure 37) and the cicada *Amphipsalta zealandica* (Pahurehure Inlet 2) were recorded.

Figure 33.The native common copper butterfly; *Lycaena salustris*, captured at Puhinui mangrove, March 2018.

The most abundant species was the ant *Technomyrmex jocosus.* This is an Australian generalist scavenger species, which readily exploits both open and forested habitats (Landcare Research, 2018). This species forages in dead trees, leaf litter, on shrubs and trunks and branches of living trees (Bolton, 2007). Ants have been identified as having an important role in protecting mangroves from herbivory of other insects and crab species (Cannicci et al., 2008). The isopod crustacean *Oniscus asellus* also occurred in high number at some sites. This species is also non-native and has colonised almost all habitats around New Zealand (Massey University, 2016). Woodlice such as *Oniscus* spp. feed upon decaying leaf and plant matter and are key regulators of leaf litter decomposition (Van de Weghe, 2016). The ladybird beetle *Halmus chalybeus* was also identified as a common species at the sites. This beetle was introduced from Australia in 1899 for pest control. It is now widespread within the Auckland region and feeds on a large variety of native and non-native insects. It is a likely food source for other predatory insects, spiders and birds (Martin, 2016). The most diverse group of arthropods in this study was the spiders (order Araneae). Spiders are a key component of forest ecosystems and fill a role as both prey for other organisms such as birds and predators of insects (Oxbrough & Ziesche, 2013). The site with the greatest spider abundance and richness of spiders also had the greatest abundance of birds (Pahurehure Inlet 2), supporting the predator/pray relationship between birds and spiders.

There were significant differences in both the abundance and species richness of arthropod communities between sites. Pahurehure Inlet 2, which was the smallest mangrove stand, had the greatest abundance and diversity of arthropod species. Tree characteristics which were correlated with abundance of arthropods were identified as adult tree density, crown spread and height of adult trees, to a slightly lesser extent. Sites with the highest number of individual arthropods had the lowest tree density and the highest crown spread. Species richness was also driven by adult tree density, again with the most richness at sites with the lowest tree density. Highly dense forest habitats can impair landscape navigation by flying insects thereby reducing abundance (Houlihan et al., 2012). Greater crown spread increases surface area for some groups of arboreal arthropods to feed upon (Neves et al., 2013), therefore the balance between space for navigation and area of habitat to utilise can affect patterns of arthropod diversity.

Tree characteristics accounted for approximately one third of arthropod diversity (abundance and species richness) and it became apparent that wider landscape-scale processes may also contribute to community composition of arthropods. The total connected area of the four sites were measured and plotted against arthropod abundance and richness data for each site. There was a strong negative correlation with increasing mangrove area and arthropod diversity indices. This has been found in another study by Su et al. (2015), which looked at insect densities in urban green spaces in Beijing, China. They found that higher insect densities were present in areas smaller than 500 metre squared and connectivity did not increase the density of insects. Bowman et al. (2002) also found a decrease in insect densities with increasing patch size. There may be increased dispersal of some insect species in more connected patches (Su et al, 2015).

The age of the stands was not investigated in this study. Morrisey et al., 2003 hypothesized that increasing maturity of mangrove stands may create a shift in focus from benthic species to terrestrial organisms, such as insects and spiders. As there is seaward growth of mangroves at these sites, it would be expected that terrestrial zones contain greater abundance and richness of insects and spiders than seaward zones, however the effect of zone was not significant in this study. As these sites were adjacent to removed areas, it could be that edges created from mangrove removal have altered the ecology of the mangrove through edge effects (Murcia, 1995). Pahurehure Inlet 2 has just 4.3 Ha remaining of what was over 24 hectares of mangrove (now mudflat). It may be that this remaining, isolated mangrove patch has a high arthropod abundance and richness due to the unavailability of any connecting or nearby patches in comparison to the other sites. In addition, this patch has been modified from its original state, which may have had a direct effect on the spatio-temporal distribution of insect, spider and bird species (Murcia, 1995). It was observed that edges of this site functioned as a bird roost for at least three bird species (the green finch, blackbird and song thrush) as observed from dusk surveys and spotlighting.

5.7 Trapping techniques

5.7.1 Foams, onduline and tunnels

Different trapping techniques targeted and caught different groups of animals. Foam covers, tracking tunnels and onduline tiles (as well as spotlighting at night) aimed to capture the presence of any reptiles such as skinks and geckos within the mangroves. Although skink were observed in the rush marsh bordering all mangrove sites, no reptiles were observed within the mangroves during the study period. As these sites are all bordering urban and/or industrialised areas, with a high level of human disturbance, it was unlikely that reptiles would be found (Hitchmough et al., 2013). It remains that the only account of reptiles in New Zealand mangroves are uncited references in Crisp et al. (1990). Foam covers provided cover for arboreal arthropods (predominantly *Technomyrmex jocosus* and *Oniscus asellus*) and onduline housing created refugia for amphipods, crustaceans and gastropods.

Tracking tunnels picked up both rat and mouse prints and Holden traps captured Norway rats. In addition, a domesticated cat and common brushtail possum were observed at Waimahia mangroves. This site had a high number of non-native mammals in and around the edges. Pahurehure Inlet 2 had two bat passes possibly belonging to the native long-tailed bat (one of two bat species which are the only New Zealand native mammals). It is advised that further monitoring be carried out at these two sites with special regard for mammalian monitoring.

5.7.2 Go-pro's

Juvenile yellow-eyed mullet and short-finned eels were the dominant benthic species picked up by the go-pro footage. Mullet were present at all sites and Waimahia was identified as a site with a permanent resident eel population. This site has been checked multiple times throughout the year to confirm the presence of eels in the channel at this site. Previous studies have reported mullet and short-finned eels as permanent residents or utilising mangrove habitat disproportionately to other habitats in New Zealand mangrove harbours (Ritchie, 1976; Morrisey et al., 2007). Short-finned eel abundance has been correlated with mangrove habitat complexity (saplings, seedlings and number of trees) in New Zealand (Morrisey et al., 2007). Previous studies have identified mangrove areas as being nursery habitats for grey mullet, short-finned eels and parore (Morrisey et al., 2007). This present study observed juvenile yellow-eyed mullet as being the primary species occupying these sites and would suggest mangroves play a nursery role for this species also.

Although all sites had a low diversity of fish species, it was seen from the video footage that mangrove habitats at high tide are an important refuge and feeding ground for these two species, with eels remaining within the shallow channel at low tide. Fish were observed throughout the video footage at all sites. Go-pro footage provided an effective, non-invasive method to observe fish species and visual observations provided additional short-finned eel data.

5.7.3 Bird visual surveys and trail cameras

A combination of visual observations and trail camera footage recorded the presence of a wide variety of bird species (15), five of these species were native (Sacred Kingfisher, Welcome Swallow, Fantail, Pukeko and the Banded Rail). The Banded Rail is a threatened native species of bird in New Zealand, and has been recorded utilising the edges of mangroves before (Ji, 2017. Pers Comm.). In this study, the trail cameras picked up the species foraging in the centre of the mangrove (Waimahia, Figure 38). This provides strong evidence that rails also utilise the interior of mangrove stands for shelter and foraging, not just the edges.

Figure 34. The Banded Rail; *Gallirallus philippensis*, detected by trail camera in centre of Waimahia mangrove, March 2018.

The trail cameras were effective at picking up a wide range of species, from Norway rats to Kingfishers (Figure 39). Although relative abundance measures could not be obtained from this footage, trail cameras are a non-invasive method to observe the diversity of species utilising mangrove habitats.

Figure 35. Norway rat at night and Sacred Kingfisher by day at same location in mangrove, detected by trail camera, March 2018.

5.8 Conclusions

Integrated biodiversity assessments can successfully capture a wide-range of species in a dynamic flooded ecosystem such as mangrove stands. Short-term assessments provide a snap-shot of biodiversity which can aid decisions for removal or preservation of large areas of mangroves. Reasons for removal of this native forest habitat should be considered very carefully and trade-offs understood through comprehensive long-term monitoring. There is much heterogeneity in terms of physical tree characteristics and animal biodiversity in mangrove sites within the same harbour, therefore management should be considered on a site-by-site basis. These integrated assessments provided both baseline data and contributed to current information on a wide-range of species monitoring in mangroves. Little used recording techniques such as trail cameras and go-pro's successfully captured biodiversity at these sites. It is recommended that sites targeted for removal be monitored, for as many groups of species using equipment such as trail cameras and go-pro's, as well as visual observations of birds and mammalian species.

Chapter 6

Muddied Waters: perceptions and attitudes towards mangroves and their removal in New Zealand

"There are things known and there are things unknown, and in between are the doors of perception"

Aldous Huxley

The proceeding chapter describes the findings of the interviews conducted with members of local communities around perceptions and attitudes towards mangroves at the study sites and at a national level. It investigates opinions towards management and policy regarding mangroves and discusses wider coastal ecosystem issues. It shows the implementation of a mixed methods design in order to facilitate a broader holistic understanding of how people view mangrove ecosystems in New Zealand. Recommendations for improving mangrove and general coastal ecosystem management by local community members are included.

6.1 Abstract

Seaward expansion of New Zealand's mangrove *Avicennia marina* (subsp.) *australasica* in estuaries has led to disparity in opinion over their social-ecological value. This study investigated existing stakeholders and interested parties' perceptions and attitudes towards mangroves, focusing on four sites in Auckland. A mixed methods design was used consisting of semi-structured interviews, ratings of importance of mangrove ecosystem services and issues and *Q*-sorts on mangrove social-ecological statements. 29 participants were interviewed in person. Results revealed a disparity in perceptions and attitudes towards mangroves. Community Groups displayed strongly negative opinions towards mangrove preservation and Conservation Organisations' expressed a strongly positive stance. The occupation of participants was a significant factor in the ratings. Overall, sediment and nutrient retention were rated as the most important ecosystem services. The desire for reversion of estuaries to a "pre-mangrove" state is the greatest issue affecting mangroves. *Q*-analysis revealed loading of participants onto two factors representing (1) a pro-preservation attitude towards mangrove and (2) a neutral view. Managing sediment loads and nutrient run-off in the wider catchment were highlighted as ways to reduce mangrove expansion. Improving water quality and the health of the harbour was of utmost priority to kaitiaki (Māori guardians of the environment). This study provides critical insights into the management of mangroves as social-ecological systems.

Keywords: perceptions; attitudes; mangroves; expansion; preservation; mixed methods

6.2 Introduction

Mangrove preservation and removal in New Zealand is a contentious issue. The grey mangrove *Avicennia marina* (subsp.) *australasica* has been present in New Zealand for at least 11,000 years (Pocknall, 1989), however, seaward expansion into estuaries exacerbated by high sediment loads from land-use change have altered the ecology of coastal areas (Green et al., 2003; Harty, 2009; Lundquist et al., 2014b). Viewpoints towards mangroves in New Zealand have shifted over-time. Previously this temperate forest and shrub ecosystem was thought to possess the ecological values of tropical and subtropical mangroves, with a predominantly conservation-based approach to their management (Crisp et al., 1990; Morrisey et al., 2007). In the past twenty years, attitudes towards mangroves have become polarized, with applications for resource consents (official permission to conduct operations which have an environmental impact) to remove expanded areas of mangroves (De Luca, 2015; RMA, 1991). Much of the drive for removal comes from local communities wanting restoration of open-water areas for access and views, with a return to a pre-urbanized coastal setting (De Luca, 2015). However, community aspirations may be unrealistic in certain areas due to reduced tidal flushing and ongoing urbanisation, which creates more sediment loading and nutrient run-off into estuaries (Morrisey et al., 2007). Whilst mangroves are recognised as being part of New Zealand's indigenous flora, and therefore protected under the Resource Management Act (RMA) 1991 (RMA, 1991), they may be removed in particular areas for a range of social and ecological reasons. Each regional council where mangroves are present has their own policies on removal. The Auckland Council Unitary Plan (2013) F2 coastal-General Coastal Marine Zone states that mangrove seedlings may be removed from Significant Ecological Areas- Marine (SEA-M1) where: "mangroves are a minor component, or absent", or specific "wading bird areas". Removal of mangroves is also permitted in "significant wading bird areas" and to "enable the operation, maintenance, use and functioning of existing lawful structures, infrastructure, or to ensure public health and safety in the use or operation of infrastructure" and to allow the maintenance or enhancement of ecological areas or public access (Auckland Council Unitary Plan, 2013). However, large-scale removal (particularly with mechanical machinery) can cause macroalgal blooms and reduced oxygen levels in both the sediment and water, impacting negatively on benthic communities and indirectly on wading birds (Bell & Blaney, 2017).

With applications for removal continuing, there is a need to understand the drivers for removal and how local community perceptions and attitudes can influence alterations of the coastal landscape. A perception can be defined as "the process by which organisms interpret and organize sensation to produce a meaningful experience of the world" (Lindsay & Norman, 1977). Whereas an attitude involves a deeper behavioural insight, defined as "a mind-set or a tendency to act in a particular way due to both an individual's experience and temperament" (Pickens, 2005). These are closely linked and can mutually influence each other (Reibstein et al., 1980).

To investigate and understand how the expansion of mangroves affects aspects of society and culture in Aotearoa New Zealand, it was deemed important to speak with Māori stakeholders and interested parties. A strong element of Māori culture is based on caring for the environment. Guardianship or kaitiakitanga of marine and freshwater environments is a priority for Māori. In particular, listening to the views of kaitiaki (Māori guardians of the environment) through Mātauranga Māori (Māori knowledge and knowing) is imperative to understand the cultural significance of estuarine ecosystems (Clapcott et al., 2018).

Due to the complexity in addressing mangrove management in New Zealand, a mixed methods approach was adopted to provide deep insight from multiple angles. One type of data collection and analysis alone would not allow for the complexity of this social-ecological system and its issues to be fully realized.

The use of mixed methods in social-ecology is becoming more widespread as we understand the holistic nature of human-environment interactions (BenDor et al., 2014; Murray et al., 2016; Liehr et al., 2017).

This study employed the metaparadigm of dialectical pluralism, defined as "an operative process, which is both dialectical and dialogical with the acceptance and expectancy of difference in virtually every realm of inquiry, including reality" (Burke Johnson, 2017). Dialectical pluralism centralizes diversity of both physical and human reality (Creamer, 2018), as this study is around a complex social-ecological system, this axiology was deemed the best fit.

Q-methodology was used as part of this study to explore differences in participant's perceptions and attitudes towards mangroves and their removal. Q is used in a variety of fields ranging from social sciences (Zografos, 2007) through to health sciences (Kufeld, 2004). It is an inductive and exploratory analysis, which can reveal holistic and detailed information about participant's perspectives (McKeown & Thomas, 1988). *Q*-methodology is used to study subjectivity; it can reveal perspectives towards particular issues, which is particularly useful in understanding the opinions of stakeholders (Kufeld, 2004). It was hoped that by employing *Q*-Methodology, areas of distinct polarity and disagreement between stakeholders and interested parties with regards to mangrove preservation and removal would be identified.

In addition to Q-methodology, two points-based scales (Ho, 2016) were constructed for the rating of mangrove ecosystem services and issues facing mangroves. Rating scales are one of the most commonly used methods to measure attitudes towards statements around a topic (Menold & Bogner, 2016) and the extent to which participants feel they are important/agree with them (Burns and Grove, 1997).

This chapter had the following aim:

To investigate the perceptions and attitudes of local communities towards mangrove ecosystems in New Zealand

This chapter had the following objectives:

- To interview previous consultees from resource consents for removal of areas of mangrove in the Manukau Harbour, Auckland
- To explore perceptions and attitudes towards preservation and removal of mangroves in New Zealand and specifically at four removal sites in the Manukau Harbour, Auckland
- To investigate whether demographics such as occupation, age and gender influence responses to the ratings of mangrove ecosystem services and issues facing mangroves
- To integrate findings from the qualitative and quantitative aspects of the interviews in order to understand drivers from a holistic perspective

As part of this research, an ethics application was submitted to the ethics committee at the researchers' University and accepted prior to interviews taking place. This ethics application included interviews with kaitiaki for whom a project kaupapa (principle) was written.

6.3 Materials and Methods

6.3.1 Semi- structured Interviews

Potential participants were identified from Auckland Council resource consents for mangrove removal at four sites in the Manukau Harbour, Auckland (Figure 40). These participants had already been contacted and involved in consultation processes as required before the granting of a resource consent for mangrove removal as a permitted discretionary activity (RMA, 1991). The consent records are publicly available to view as hard copies at Auckland Council Offices (Graham St, Auckland).

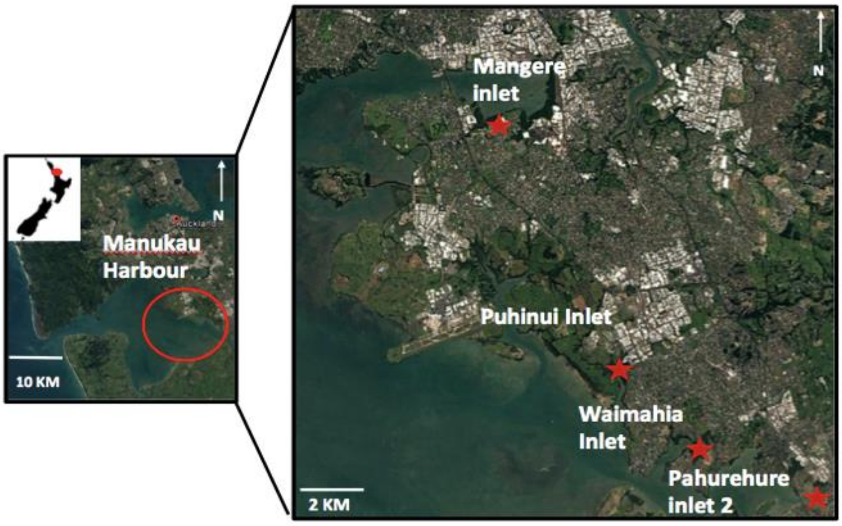


Figure 36. Mangrove removal sites in the Manukau Harbour, Auckland, New Zealand. Adapted from Google Earth, 2018.

Fifty potential participants were identified from the four sites and contacted by email with an invitation to interview. Upon acceptance, an information sheet was provided documenting the background to the study and a confidentiality agreement drawn up for each participant who accepted the invitation to interview. Face-to-face individual semi-structured interviews were held at either the offices of the primary researcher or at the work places and homes of the participants. Interviews lasted between twenty minutes and one hour, depending on the participant's level of engagement. The participant's occupation was listed according to their occupation at the time of mangrove removal, as follows: AC=Auckland council representative, CG=Community Group member, CO=Conservation Organisation member, LB=Local board member, K=Kaitiaki, PR=Park Ranger, IE= Independent ecologist and IP = Independent planner. The views of the participants were their own individual opinions and did not necessarily represent those of their organisations. The interviews consisted of questions on five broad themes related to temperate mangroves in New Zealand:

1. Presence of mangroves
2. Importance of mangroves
3. Expansion of mangroves
4. Current and future consultation process
5. Mangrove management

Questions related to each theme can be found in Appendix 3a. Demographic information of age group, ethnicity, gender, occupation, place of residence and years at residence were also recorded.

6.3.2 Māori participants

As this research involved both the land and water of Aotearoa, it was vital to speak with kaitiaki around the issues of mangrove removal. The kaupapa (principle) of the research was provided to all kaitiaki. The interviews were either carried out kanohi ki te kanohi (face-to-face) following a series of hui (meetings) or on the phone following acceptance of interview by email, with signed consent forms delivered electronically in the case of telephone interviews. The interviews consisted of open-ended questions, focusing on the importance of mangroves in New Zealand and at the specific sites. It was the intention of the primary researcher to ask questions around the past and present state of coastal ecosystems including water quality issues, taonga species (native flora and fauna of special cultural significance), taiao (natural world) and hauora (well-being) in reference to mangroves (manawa) and the wider coastal environment.

6.3.3 Scale-data

Ecosystem services or attributes of mangroves in New Zealand were rated by the participants as being 'very important', 'important', 'neither', 'not important' or 'don't know'. Issues affecting mangroves at the sites were also rated in this way. Ratings were assigned numbers from 4 to 1 (with very important rated 4, in descending order to not important, rated as 1. 'Don't know' was a necessary addition to the 4-point scale as this highlights gaps in knowledge that participants may have towards ecosystem services of temperate mangroves and potential issues facing them. This design was unbalanced, with a skew towards the 'important' ratings. Unbalanced designs can be used when the researcher has an indication that respondents may show a preference to one end of the scale (Naresh, 2006). Extensive research from resource consent applications of the participants consulted indicated that of those who accepted interview, only a minority were staunch opposers of mangrove preservation. Results were converted to scores ranging from 4-1 (with any don't know data removed from the calculations) and averaged for each ecosystem service and issue to investigate which services and issues were rated as most important. 'Don't know' data were viewed separately to ascertain which services and issues were least known about. Table 18 shows the two scale ratings for mangrove ecosystem services a) and b) issues facing mangroves.

Table 18a). Scale ratings of importance of mangrove ecosystem services in New Zealand and **18b).** Magnitude of mangrove-related issues in New Zealand.

18a)

	Rating				
	Very Important	Important	Neither important nor unimportant	Not Important	Don't Know
Mangrove Service					
Aesthetic (visual) value					
Carbon Storage Capacity					
Cultural Value					
Fish Habitat					
Flood and Water Flow Control					
Food Sources					
Medicinal Properties					
Nutrient Retention					
Recreational Value (local)					
Recreational Value (overseas tourists)					
Sediment Retention					
Source of wood/fuel/building materials					
Storm Buffering					
Supporting offshore and near shore fisheries					
Water Quality Maintenance					
Wildlife Habitat					

18b)

	Rating				
	Big issue	Issue	Potential to be an issue	No issue	Don't know
Issues facing mangroves					
Illegal cutting/clearance					
Increased need for access by boats					
Chemical contamination					
Climate change (more severe droughts, floods and storms)					
Coastal erosion					
Dredging of channels					
Dumping rubbish					
Expansion of mangroves impacting negatively on estuaries					
Nutrient pollution					
Sea-level rise					
Sedimentation					
Aesthetics (views of estuaries, the harbour, open water)					
The desire for reversion of estuaries to a pre-mangrove environment					
Coastal development/ urbanisation					

6.3.4 Q-Sort

After the first set of interviews was conducted (n = 10), a Q-sort (McKeown & Thomas, 1988) was constructed around perceptions and attitudes towards mangrove removal based on these interviews and comments recorded from the resource consents. These formed a set of statements, sixteen of which focused on ecological and seventeen on social perceptions and attitudes towards mangroves and removal. In Q methodology, participants are seen as the variables and so a large sample size is not required (McKeown & Thomas, 1988; Brown, 1993). The remainder of participants from the semi-structured interviews (n = 19) was the Q-sample. Table 19a shows the ecological statements and 19b the social statements constructed.

Table 19a). Ecological mangrove statements **19b)** Social statements created from extracting information on resource consents for removal at four sites in the Manukau Harbour, Auckland, New Zealand.

19a)

Mangrove expansion has impacted negatively on surrounding habitats
Mangroves encroach upon saltmarsh in some places which may alter their ecosystem function (saltmarsh)
Mangroves replace wading bird habitat (mudflat) in some areas
Mangroves stabilise mudflats
Maintaining saltmarsh-mangrove ecotones is important
Temperate mangroves have different attributes to tropical mangroves
Not enough research has been conducted regarding how removal of mangroves affects coastal and estuarine ecology
Mangroves should be preserved as much as possible based on their ability to sequester (long-term storage of) carbon
Mangroves are important for a variety of wildlife
Nothing of any ecological value exists in mangroves
Removing mangroves can result in the potential loss of ecological connectivity along shorelines for some species
Removal can result in the potential mobilisation of sediments and effects such as smothering of shellfish beds
Removal can result in better tidal flow and flushing of area within the inlets
Removal can create an improved connection between the land and the sea
We need baseline monitoring (on contaminated sediments and hydrology) to assess improvements to water quality, and information on contaminants
We need to address sedimentation and nutrient run-off from the land to slow the growth of mangroves

19b)

Removal of mangroves can provide improved recreation opportunities
Removal can provide opportunities for beach restoration
I would prefer to see a view of the water instead of mangroves
Mangrove removal is a reversible experiment (if we cut them down, they will grow back anyway)
We should look at improving the water quality of our harbour and monitoring this before we remove any more mangroves
Money is better spent elsewhere
If we decide to remove mangroves, we need to think carefully about the justification for this and select areas accordingly
Removing mangroves is long-term so we need to be able to afford it
Removing mangroves adds value to property
Mangroves have equal value to any other natural habitat
Everyone should have the right to remove mangroves
Beaches have been destroyed by mangrove expansion
Mangrove expansion is due to anthropogenic activities
If removed, this should be in a step-by-step process, monitoring should occur during and post removal to observe changes over time
Removing mangroves can enhance the amenity of an area to create a 'strong sense of place' for the community
People are the issue (with mangrove spread), but we need control over where they are to allow cultural activities to continue
We need to look at putting the environment first before we look after ourselves

The remainder of participants was given the Q-Sort at the beginning of the interview. Participants ranked the statements into three categories: ‘agree’, ‘disagree’ and ‘neutral’. They then placed the statements on the Q-grid (Figure 41), which is divided into 33 squares ranging from -4 (statements disagreed with the most) to +4 (statements agreed with the most), with 0 as neutral opinion towards the statement. A photo was taken for each participant’s Q-sort and the data was entered into Q statistical software PQ Method (Schmolk, 2008) for analysis.'

PQ Method carries out factor analyses on the data, through the correlation matrix, which was manually entered for each participant. The results display the similarities of how participants sorted the statements (Herrington & Coogan, 2011). Participants with similar ranking of statements were loaded onto the same factor. Principal Component Analysis (PCA) with varimax rotation was used. This allowed the researchers to reduce any subjectivity they may have had (Yang & Bliss, 2014).

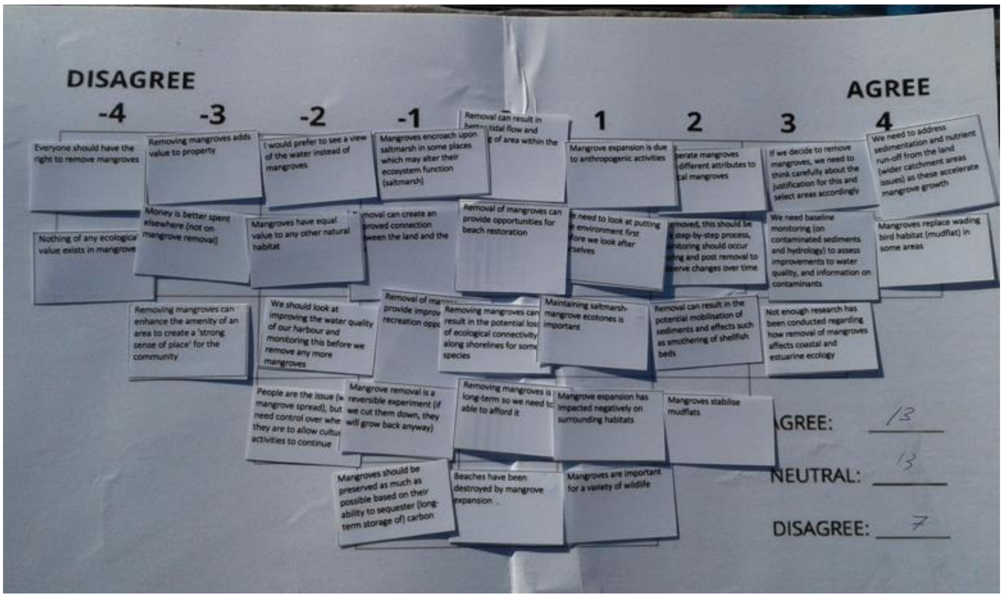


Figure 37. Example of Q-Sort with 33 ecological and social statements ranked from strongly disagree (-4) to strongly agree (+4).

6.4 Statistical analyses

6.4.1 Transcripts

Transcripts were typed out from the audio files by the primary researcher and sent back to each participant for member-checking. Upon acceptance of the final transcript, the documents were uploaded into NVivo 12 software and coded thematically (Braun & Clarke, 2006). Thematic analysis can be used to examine similarities and differences in the perspectives of participants (Braun & Clarke, 2006). Inductive coding was used to both condense the raw data into summary findings and to link research objectives and findings (Thomas, 2006). After initial coding was completed, with a coding framework to define each code, themes and subthemes emerged from the data, which were defined and named (Nowell et al., 2017). Qualitative data was analysed further using the Queries and Classifications procedures in NVivo (QSR International, 2012) in order to look for patterns in responses associated with different demographics (age, gender, occupation). All names were removed following the final coding. Transcripts from kaitiaki were reflexively read and were included in NVivo coding and integrated into themes and sub-themes.

6.4.2 Ecosystem services and issues facing mangroves

Scale-data was analysed through multivariate techniques using Primer-E (Plymouth Routines in Multivariate Ecological Research) software (Clarke & Ainsworth, 1993) to enable a deeper investigation into the factors driving differences in perceptions and attitudes towards mangroves.

PERMANOVA+ (Permutational analyses of variance) was used to analyse differences in participant responses to the rating of mangrove ecosystem services and issues facing mangroves in New Zealand. PERMANOVA is a semi-parametric statistical technique that separates data through geometric partitioning of variation across multivariate data, in response to factors in an ANOVA design (Anderson, 2014). PERMANOVA is becoming more frequently used in social science data analyses and allows for robust quantitative analyses of multivariate response data (Anderson, 2014).

The effect of occupation on response data for both ecosystem services and issues was investigated in the PERMANOVA design of **"Occupation"** as a fixed factor in an unordered design was tested. Age and gender were also tested as factors driving differences in responses of participants towards ecosystem services and issues and interactions between **"Occupation"** with **"Age"**, **"Occupation"** with **"Gender"** and **"Age"** with **"Gender"** were tested for (age and gender as fixed factors). Response data was square-root transformed to down weight the effect of high responses and a resemblance matrix based on

Bray-Curtis index of similarity was created. Non-metric multidimensional scaling (MDS) (Clarke & Ainsworth, 1993) was conducted to represent and visualize the position of responses with significant independent variables in multidimensional space. SIMPER (one-way similarity percentage) analyses were conducted to see which ecosystem services and issues drove dissimilarities and within and between groups (Anderson et al., 2008).

6.3. Results

6.3.1 Semi-structured interviews

A total of 29 participants completed the semi-structured interviews (19 male, 10 female). Five kaitiaki each from a different iwi/hapū (Māori tribes/subtribes) were spoken with kanohi-ki-te-kanohi and on the telephone. Figure 42 shows the breakdown of participants who were part of the semi-structured interviews.

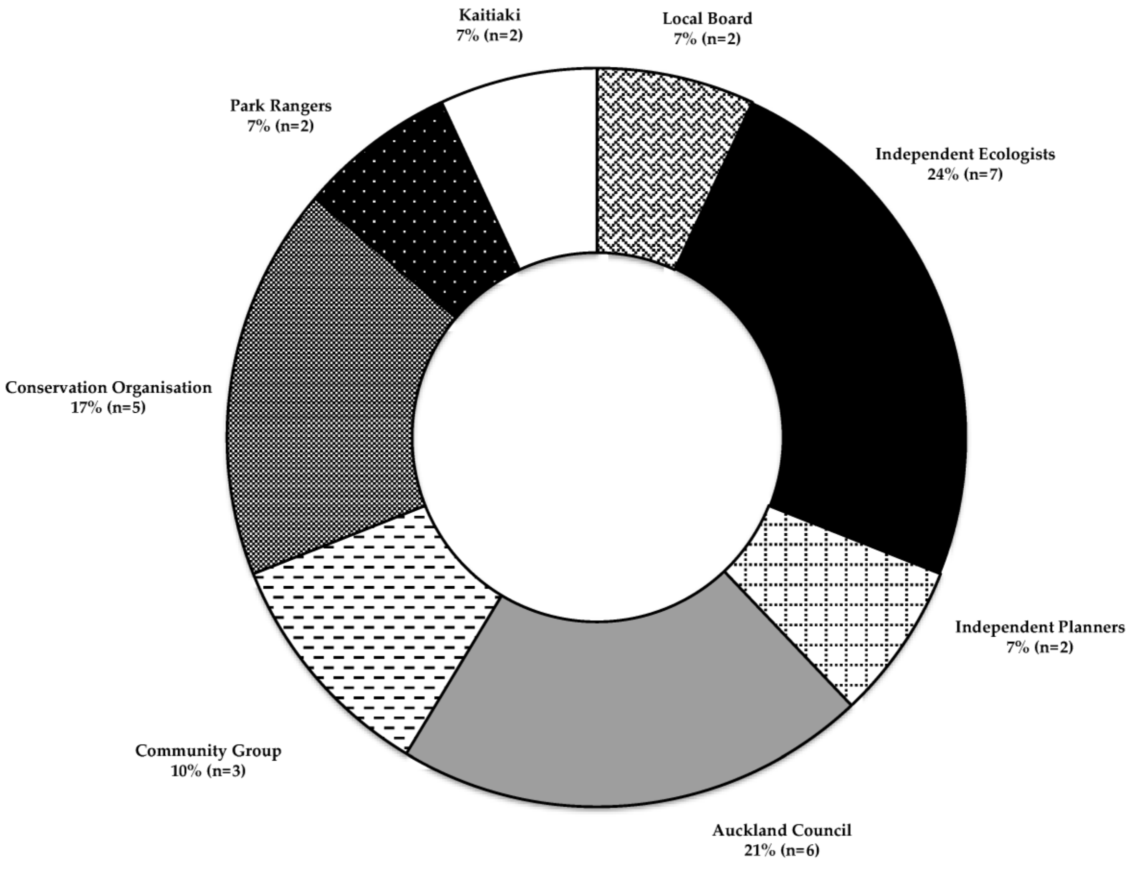


Figure 38. Occupations of participants with percentage contribution to participant pool.

79.3% of participants believed that mangroves performed an important role in coastal ecosystems in New Zealand. 13.8% believed that mangroves do not play an important role and 6.9% had a neutral point of view. Figure 43 shows the percentage of each occupation stating the importance of mangroves in New Zealand.

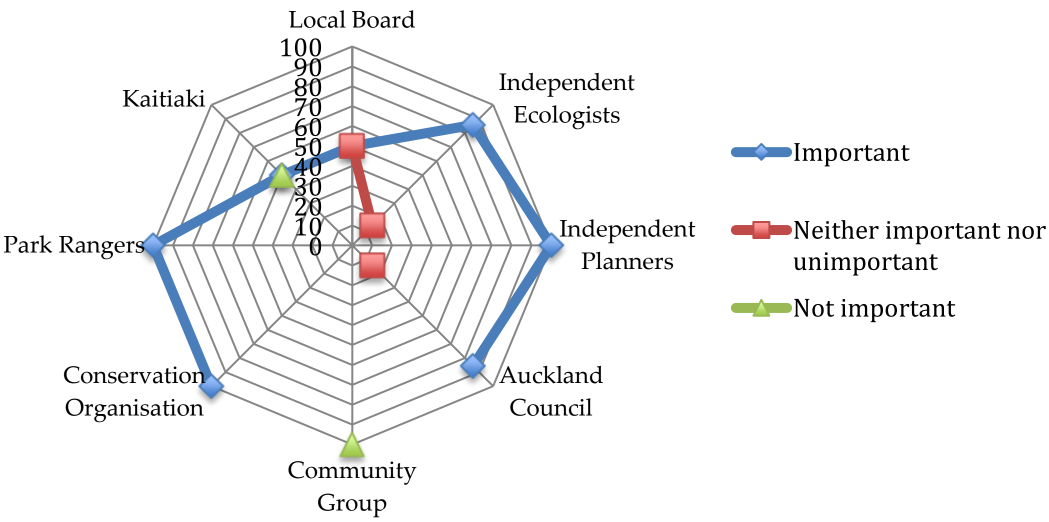


Figure 39. Participant's views on the importance of mangroves in New Zealand's coastal ecology. Stated as "important", "neither important nor unimportant" or "not important" by percentage per occupation.

Participants were asked whether they felt positively, neutrally or negatively towards mangroves at the sites in question. 31.0% felt positively towards the presence of mangroves, 41.4% were neutral and 27.6% felt negatively towards the presence of mangroves at the sites. Figure 44 shows the percentage of each occupation in terms of positive, neutral or negative feeling towards mangroves at the sites.

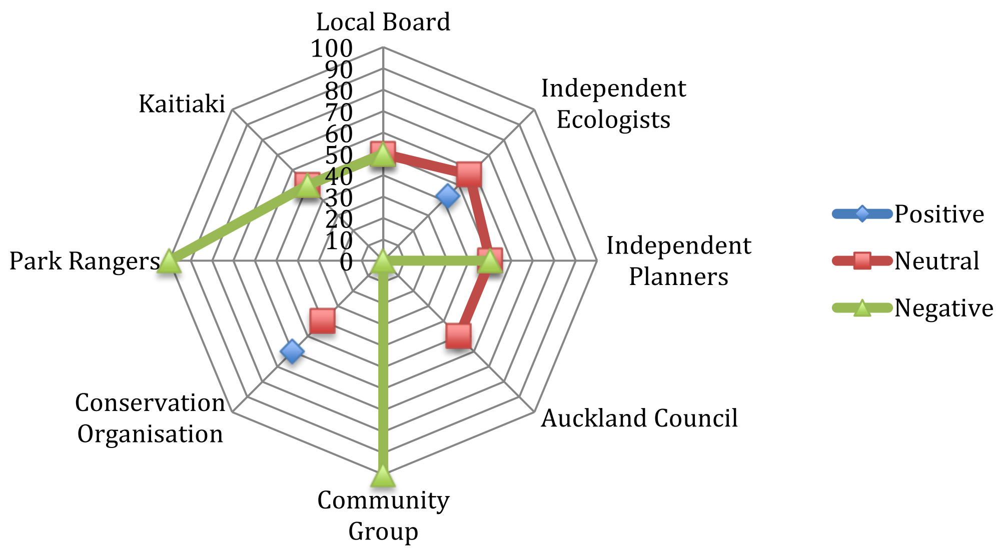


Figure 40. Participant's views on the presence of mangroves at four sites in the Manukau harbour, Auckland, New Zealand. Stated as "positive", "neutral" or "negative" as percentages per occupation.

Overall a diverse range of opinions emerged from the data, with beliefs driven by experience and observations. The qualitative data revealed five broad themes of Sustainable Balance, World-view, Practical Management, Environmental Change and Values. These are discussed and evaluated below. Figure 45 shows the themes and sub-themes emerging from the qualitative data. For a full list of codes and definitions see Appendix 3A (ii).

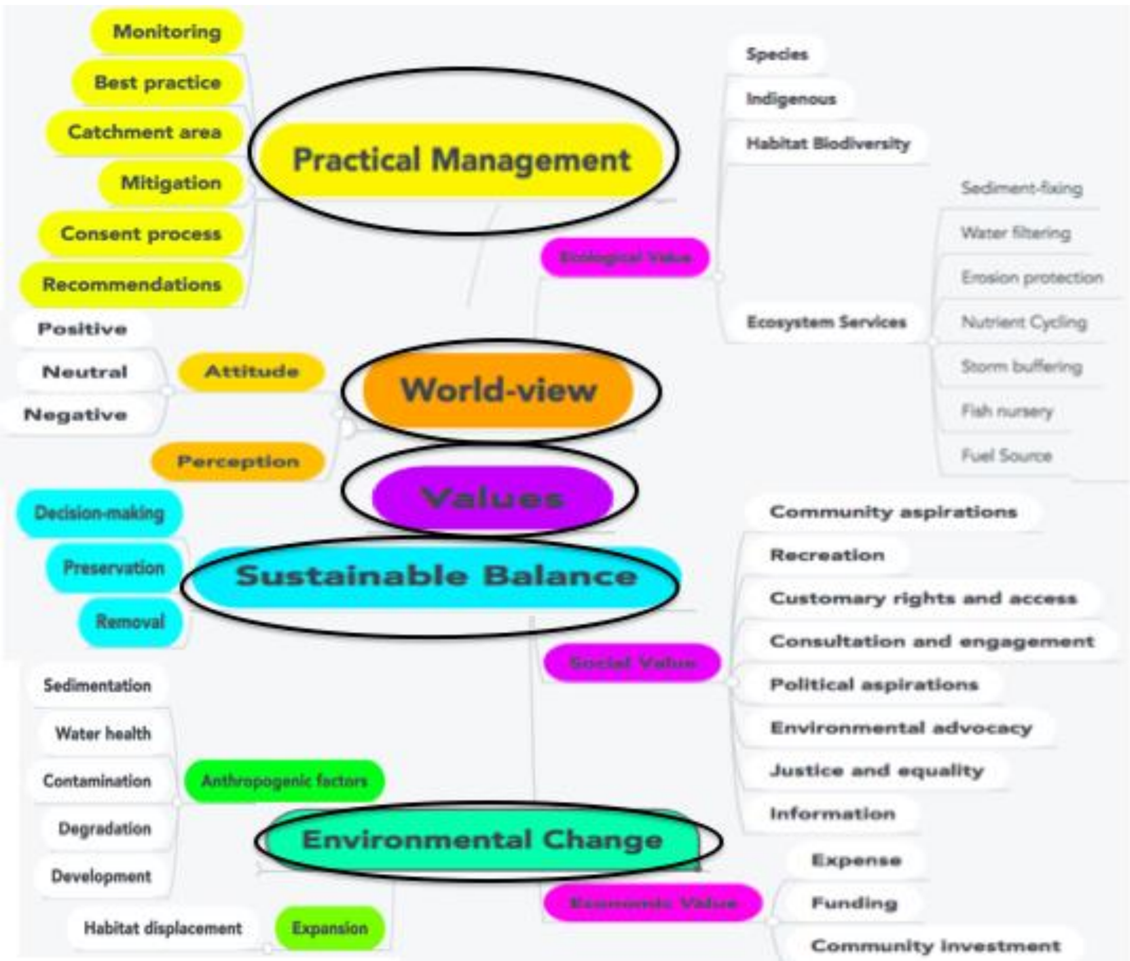


Figure 41. Themes and sub-themes emerging from the semi-structured interviews by inductive coding.

<u>Sustainable Balance</u>

The theme of Sustainable Balance consisted of removal and preservation of mangroves and the decision-making factors involved in this. The balance of use values of the estuaries for people and nature was mentioned. Access to the water for cultural activities such as waka ama (outrigger canoes) and amenities were deemed as important and removal of certain areas should be allowed for these reasons. Aesthetics (views of the water) were not seen by some participants as a valid reason for removal.

"I think that going in to clear mangroves solely for the reason that landowners' views have changed in the last twenty to thirty years is maybe not quite so relevant anymore and we need to stop treating mangroves as the problem".
(IE4)

The idea of wholesale removal of mangroves was generally opposed by participants, the questioning of whether removal was a “sensible” course of action came up. Targeted removal of some areas was seen as appropriate, however, the idea that removal is not a one-off practice was also highlighted.

“Firstly, I don’t have a problem with them being removed in a sensible way”. (CO3)

“So, it’s finding a careful balance, but the fragmentation of that habitat and the effects that it has, balanced with the management feasibility, you start having to ask some serious questions whether it’s a sensible thing to do”.

“What we’ve tried to help communities really understand is that it is never a once-off removal and then nothing comes back”. (AC2)

On-going seedling removal (by hand) was seen as important to maintain the areas which had faced mangrove removal. There was some concern expressed about the long-term nature of investing in removal with community involvement of seedling and sapling removal seen to be an important aspect of maintenance. Long-term buy-in by the community was mentioned. There was the concern that short-term solutions (adding value to property, improving aesthetics) outweighed the long-term effects of removal.

“That concerns me a bit. It’s all very well clearing these areas of mangroves, but you are creating an awful lot of work going forward for somebody and it won’t necessarily be the people who clear them, it will be their children and grandchildren”. (IE6)

“It is not an instant one-off solution to remove mangrove, it’s like mowing a lawn. It needs continued maintenance and management, people are not looking long-term”. (K1).

There was a split in opinion among iwi regarding mangrove removal. Some individual kaitiaki did not oppose removal as long as water quality was not affected. Other’s wanted no more removal until further monitoring was done in terms of contaminants and sediment. It was spoken that ***"a holistic view must be taken when people advocate for the wholesale removal of mangroves".*** (K1)

The purpose of removal and what people are trying to achieve with this was questioned by many participants. The idea of a balance of different ecosystems working together as a mosaic was expressed as was the concept that there may be natural decline of mangrove if the system is left to equilibrate.

World-View

The view-points of participants towards mangrove ecosystems and the perceived value that they have were highly polarised. Community groups had a strong negative perspective and attitude towards the presence of mangroves in New Zealand. They thought that tropical mangroves were ecologically valuable, but that New Zealand's temperate mangroves don't have the same function or value as tropical mangroves.

> ***"…this attitude has misled generations of people since the 1970's when it (temperate mangroves) was imbued with all the qualities of tropical mangals"***. (CG2)

> ***"My instinctive, but uninformed, view would have been that they would have provided a beneficial environment for wildlife, though probably through confusing them with their tropical counterpart, as seen on TV, which has quite a different ecology"***. (CG3)

Community group participants said that the adverse effects of removal have been unjustified. They also expressed that if mangroves were found to have ecological value in New Zealand, removed areas would grow back very fast and so there is not so much of an issue with removal.

> ***"If for some reason, mangrove removal was found to be a horrible thing, you stop, and it will all grow back, and it will grow back very quickly. It's a reversible experiment".*** (CG2)

"The experience from Pahurehure is that the predictions by so-called Council experts of the dire effects of removal have proved completely unfounded". (CG3)

Council representatives and ecologists thought that community perceptions towards mangroves were negative and this was reinforced by the views of community group participants (Table 20).

Table 20. Selected negative perceptions of local communities towards mangroves in New Zealand by Community Groups (CG), Auckland Councils members (AC) and Independent Ecologists (IE).

Community perception towards mangrove	Participant	Quote
No community benefit	CG3	"They are not perceived as having any redeeming community benefit at all. They are certainly highly detrimental to the health of any estuary".
Not good due to expansion	AC5	"The community's perception is that mangroves are not good, that's unfortunate, I don't like that perception, but because of the rapid expansion of mangroves, people think they are everywhere".
Visual improvement with removal	IE2	"So, I'm not convinced that clearing mangroves does anything apart from people having a visual improvement in their minds"
Negative impact on ecology	CG2	"A magnificent tree and incredibly adapted tree with lovely smelling flowers but overall having a negative impact on the ecology in New Zealand".

In comparison to the negative attitudes and perceptions towards mangroves held by some community group participants, there was a positive feeling and attitude characterising some council members, independent ecologists and conservation groups. Mangroves were viewed by some as being "native" and "an important part of estuarine ecosystems". The role of mangroves as coastal buffers and the question of how long it would take to see adverse effects of mangrove removal were commented on. Some spoke strongly against removal, referring to it as a "disaster". One Council representative spoke of a site visit to a recently removed area with local board members from another area in Auckland. Feedback from those who saw the site was negative, with some members being "appalled" by the removal of such a large area of mangroves. There was also a degree of neutrality towards mangroves and their presence in New Zealand. Site specificity was spoken about, with mangroves having an important role in areas transitioning to salt marsh and connecting to upper estuarine regions. Older mangroves (dating back to 1940's/50's and beyond) were perceived to have greater value than those that had recently expanded. There was also the idea of shifting viewpoints and opinions by some participants over time based on personal observations.

"I've changed my opinion of them over the years from positive to back a bit because I've seen encroachment of them on shorebird habitat". (PR1)

An interesting viewpoint was put forward by one kaitiaki who said that it isn't a matter of opinion towards mangrove, but rather a "control argument" in reference to the spread of mangrove. The concept of mitigation by expansion was commented on by an independent planner who stated that some people thought that expansion in urban areas "offsets" the loss of mangrove in rural areas due to farming practices.

Practical Management

The need for more baseline monitoring of mangrove sites including thorough habitat assessments, data collection on contaminants in mangrove soils and water quality monitoring prior to any mangrove removal was spoken about. Some participants thought that managing mangroves should involve wider catchment management in order to identify areas of expansion. Suggestions included that communities should think more about land management control and sedimentation, instead of focusing solely on mangrove removal.

"It's not just a mangrove problem, it's a whole sediment coming down from the catchment problem". (IE2)

"I believe that they are more of a symptom of other issues that are going on within a catchment". (IE4)

An adaptive management plan by the council is implemented in order to understand what conditions may occur post-mangrove removal. However, some council participants said that when an application is lodged to remove an area of mangroves, there is usually not enough information to do an ecological assessment provided by the people who lodge the consents. Site selection and on-going maintenance of the site (seedling removal) were raised as issues faced by council members processing applications. The idea of communicating to the application lodgers about the suitability of removal of mangroves was spoken about, with a clear understanding of what the benefits would be to removal and managing community expectations around this.

"…had been requested by local people and we actually said that from an ecological perspective, there was no benefit to clearing the mangroves". (IE4)

The idea of selecting areas where mangroves provide ecosystem services and keeping them, then removing areas where amenity access is important was suggested in order to create "tapestry of environments". Post-removal monitoring was suggested to ask the question: "What has the improvement been?" This was also emphasized by individual kaitaiki who spoke about the resources themselves being important, not the people. The care of the environment is the utmost priority.

"We need to look at putting the environment first before we look after ourselves". (K5)

General recommendations from participants included the following:

- water quality assessments (incoming and outgoing tides) to ascertain the role of mangroves in filtering the water.
- production of a set of guidelines between regional councils to create clearance options and future predicted outcomes of removal
- keeping mangroves around stormwater outlets until contaminants are removed
- maintaining the removed area free of propagules
- identification of areas of mangrove to be preserved
- no blanket removal of mangroves
- removal of juvenile mangroves without consents being required
- leaving mangroves until natural equilibrium is reached
- designating mangrove reserves in pristine areas
- stopping further encroachment of mangrove through seedling removal
- looking at sediment management and the effects if mangrove were to be removed
- taking responsibility for management

For best practice it was suggested that a clear, strategic feasibility process of removal should be put in place. Thinking long-term about why removal should go ahead, with any removal being small scale and "specific to a purpose" was recommended. Realistic management objectives need to be set in order to "limit the ongoing burden you are putting on future generations".

Environmental Change

All participants agreed that mangroves were expanding at the sites spoken about. Reasons for expansion were thought to be driven by land clearances through urbanisation causing high levels of sediment and nutrient run-off from the land into estuaries of the Manukau Harbour. Farming practices increasing sediment loads were also mentioned as a contributing factor prior to urbanisation. Sea-level rise caused by climate change was mentioned as a potential future factor limiting growth of mangrove.

__"They'll get to some limit and potentially are balanced by things like sea-level increase".__ (AC2)

The idea of intense industrialisation and urbanisation, including building of motorways, causeways and housing developments over the past fifty years were thought of as contributing factors to the colonisation and rapid growth of mangroves in these areas. Figure 46 shows potential causes of expansion and reduction of mangrove habitat as voiced by participants.

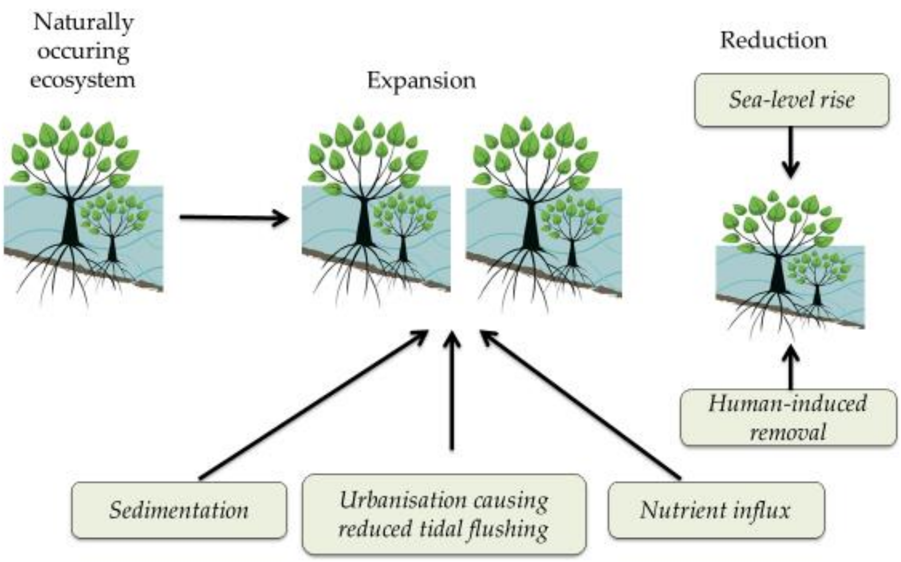


Figure 42. Causes of mangrove expansion and reduction in New Zealand spoken about by participants.

The expansion of mangroves was seen by some participants as a "natural response" to human-induced changes to the environment. Some participants thought that for this reason that they should be removed or at least managed to some extent. Others saw the benefit in expansion as a way of buffering the waters against the large sediment loadings and stormwater contaminants which mangrove contained.

"I'd prefer to have sediment stabilised rather than washing backwards and forwards in the ecosystem". (CO1)

"I think there's still a massive amount of storm water contamination that's not being picked up and to a degree mangroves sequester that. They tie it up and stop it getting into the food chain". (CO3)

"…. they will bind sediments, so they have the potential to sequester contaminants and various other bits and pieces and for sediments in contaminated areas, that's not such a bad thing". (AC1)

In terms of addressing expansion, many participants saw that reducing sedimentation input from the land as a key factor. The idea of improving storm-water outlets and addressing contaminated sediments before mangrove removal was seen as important by some participants. The notion of placing water quality above aesthetics to improve the overall health of the harbour was put forward by kaitiaki. They also advocated for removal of the causeway to increase tidal flushing at one site.

"Aesthetics are not important, it's the quality of the water".

"We also advocated for the removal of the causeway in order to improve the flow of water in the inlet and potential restoration of the harbour overtime, but consultation occurred too late" (K1).

Values

Social, economic and ecological values in relation to mangroves were spoken about in the interviews. The social values of communities and expectations from removal of mangroves to restore areas back to pre-urbanised environments were viewed as unrealistic by some participants. A strong drive to improve the recreation and amenity value of the harbour came across.

"Generally, people think that if you remove mangroves, you end up with nice white sandy beaches, which may have shown up in black and white photographs from 1952. That's not going to happen, those days are gone, so that's an unreasonable expectation". (AC1)

"Reasons for removal there were recreational, so opening up navigable space for the community and the views. People want things to go back to yester year". (AC3)

The current situation of localised, community-driven removal was viewed as "haphazard" by some and successful by others. The removal of an area of mangrove for waka launching and retrieval at one site through balancing "recreational, cultural, landscape and ecological constraints" was achieved by consultation with iwi and council. Achieving the balance of community aspirations and what is perceived as best for the environment was seen as the best way to benefit humans and nature.

"I think it really has to be balanced with what's best for the ecology and the motivation for removal". (LB1)

The cost of removing and subsequently maintaining removed areas of mangroves was a key issue for participants. The idea of obligation to provide on-going funding by the applicant and to think long-term about costs was a key issue by Auckland Council participants. Concerns by community groups that local boards will not always have the funding for removal and repopulation of seedlings in removed areas was mentioned. This was also mentioned by independent ecologists and suggested that in some cases, money is better spent in other areas of the harbour in terms of improving coastal ecology.

The ecological value of mangroves revealed a range of opinions with regards to different species utilising mangroves and the roles mangroves play in coastal ecology. The Banded Rail *(Gallirallus philippensis)* was mentioned frequently as occupying mangroves, although some participants questioned whether they utilised only the edges of the mangrove or the interior. The role of mangroves as a fish nursery was debated, with a general consensus that they are occupied by some fish species, however, not comparably to tropical mangroves and only during high tide.

The erosion-buffering, sediment-fixing and water-filtering roles of mangrove were mentioned by a wide-range of participants. The idea that the expansion of mangroves has reduced area for wading birds was also mentioned. Table 21 shows the perceived ecological values in terms of ecosystem services and species inhabiting mangroves described by participants.

Table 21. Ecological value of mangroves in terms of ecosystem services and species inhabiting mangroves as spoken about by participants; AC = Auckland Council, CG = Community Group, IE = Independent Ecologist, CO= Conservation Organisation.

Ecology	Sentiment	Quote	Participant
Banded Rail	Mangroves as habitat	"…it's probable or possible that the increase in mangrove habitat has actually formed a very good bastion for Banded Rail"	AC1
		"…so Banded Rail use mangroves as cover when they are foraging, and they breed at the interface of mangroves and saltmarsh"	AC2
Fish	Not important	"They provide a different ecosystem service and we are not seeing them as important for fish nurseries"	AC2
	Temporary habitat	*"There are some fish species that use the mangroves as a temporary nursery habitat, if that was the case, it's only going to be for at a very small part of the tide"*	CG1
Erosion	Buffer against erosion	"in terms of erosion management to create a buffer along those coastlines".	AC3
		"There had been mangroves along that shoreline. No doubt they would have prevented the erosion".	CG3
Sediment	Sediment-fixing	"…roles that I see are fixing sediment."	CO3
		"I think they have a role in trapping sediment"	IE1
Water quality	Improving water quality	*"If we take all of those mangroves away, then we are taking the water and flushing it straight into the harbour with no improvement in water quality in between"*.	CO5

6.3.2 Ecosystem services and issues of New Zealand's mangroves

Ecosystem Services

Results of ratings of ecosystem services were averaged (scale of 1-4), with any don't know responses removed. The highest rated ecosystem service of mangroves was nutrient retention and sediment retention

The lowest rated ecosystem service of mangroves was as a source of wood, fuel or building material. Figure 47 shows the mean rating of each mangrove ecosystem service by participants.

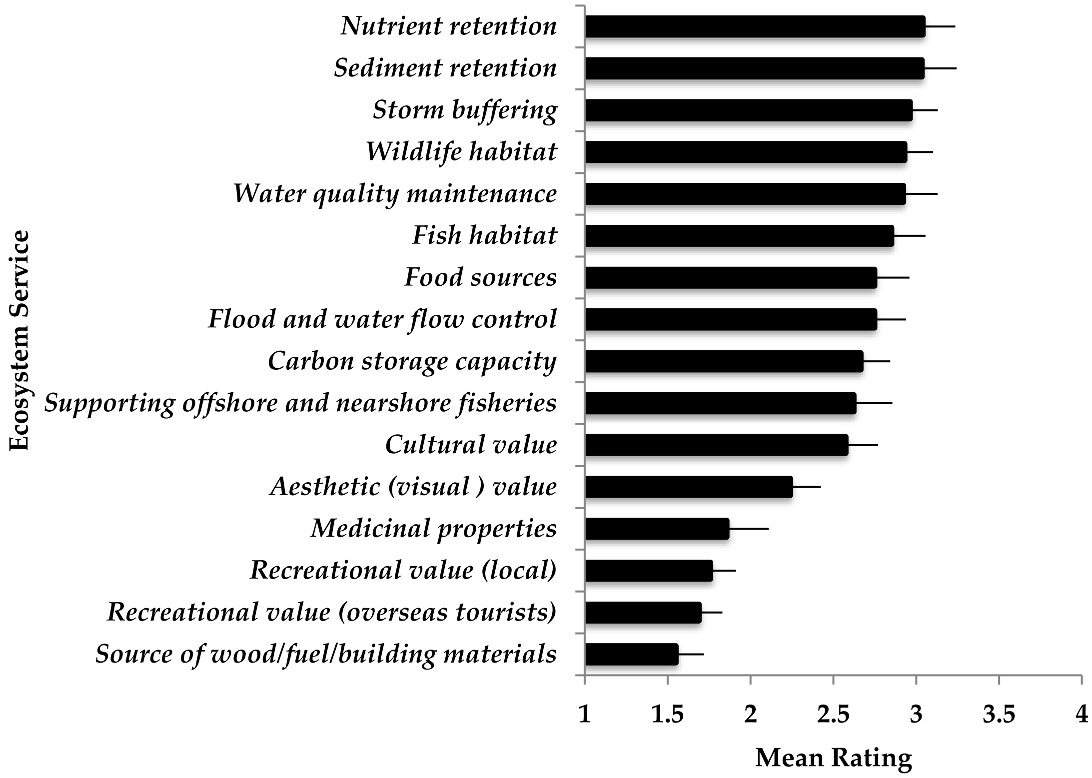


Figure 43. Mean rating of mangrove ecosystem services as ranked by participants on a scale of 1-4, 1= not important, 2= Neither important nor unimportant, 3= Important, 4=Very important.

Almost half (48.3%) of participants rated medicinal properties as 'don't know', this was followed by mangroves as a source of wood/fuel/building materials (31.0%). 'Don't know' responses were entered as 'missing data' in PRIMER-e and PERMANOVA designs were created and run. The outcomes in terms of significant factors were compared with entering 'don't know' data as 'zero'. There were no significant differences in the outcome of which factors were significant and so in order to do post-hoc tests (SIMPER), treating 'don't know' data as zero was decided upon. This allowed for pairwise comparisons between different groups (which was not possible with entering data as 'missing').

There was a significant difference between the responses of participants towards the importance of mangrove ecosystem services with occupation. PERMANOVA; $F_{7, 28} = 2.64$, $p<0.05$. Table 22 shows the significant pairwise comparisons between groups (for a full output see Appendix B1). Significant differences lay between the participants listed as independent ecologists (IE) with Community Groups (CG), Conservation Organisations (CO) and Local Board (LB). Community Groups (CG) differed significantly in responses compared to Auckland Council (AC) and Conservation Organisations (CO). Auckland Council participants had significantly different responses in the rating of mangrove ecosystem services to Conservation Organisations and Local Board (LB).

Table 22. Significant pairwise comparisons between participants of different occupations with mangrove ecosystem services, with t value, p value and unique permutations by occupation pairs where IE = Independent Ecologist, CG = Community Group, CO = Conservation Organisation, AC = Auckland Council, LB = Local Board.

Occupation	t	p (PERM)	Unique perms
IE, CG	2.94	0.01	120
IE, CO	1.51	0.023	547
CG, AC	3.18	0.014	84
CG, CO	2.3	0.016	56
AC, CO	1.49	0.011	408
IE, LB	2.14	0.03	36
AC, LB	2.24	0.035	28

SIMPER analyses showed that the greatest differences between groups were those between Community Groups and Conservation Organisations (34.86%). The nMDS plot shows the differences between groups in multidimensional space (Figure 48).

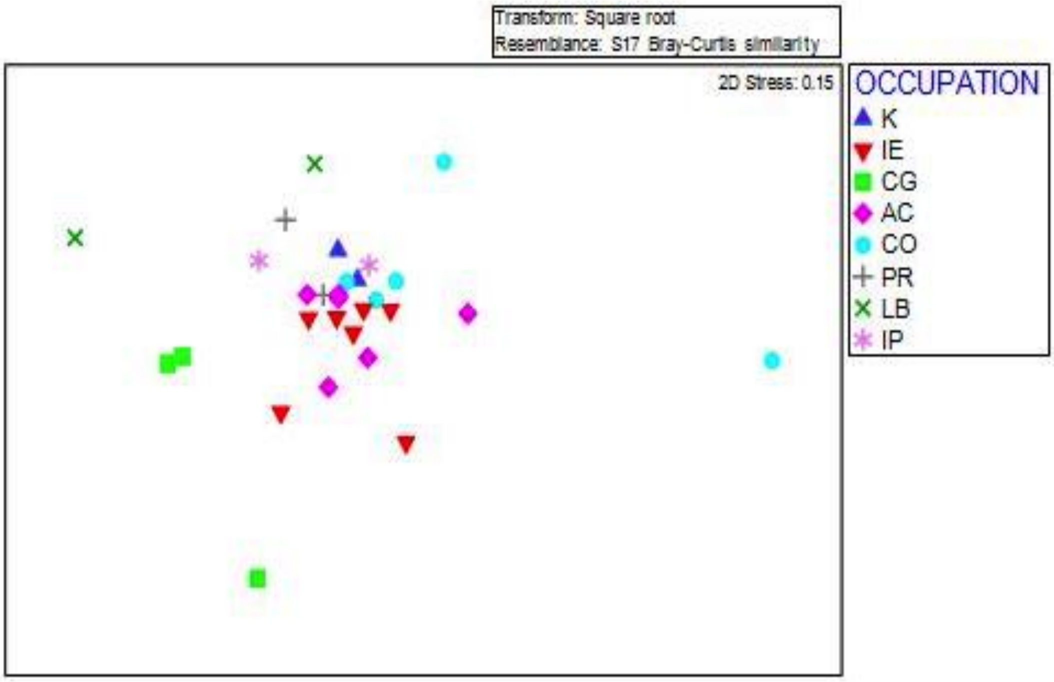


Figure 44. Non-metric multidimensional scaling based on Bray-Curtis of rating of ecosystem services of mangrove in New Zealand by different occupations. K = Kaitiaki, IE = Independent Ecologist, CG = Community Group, AC = Auckland Council, CO = Conservation Organisation, PR= Park Ranger, LB = Local Board and IP = Independent Planner.

Sediment retention was the top factor in contributing to dissimilarities in these two groups (7.83%) (Figure 49), with Conservation Organisations rating sediment retention more highly than Community Groups a service of mangroves. The second largest dissimilarities were seen between Local Board and Auckland Council (27.59%). The top factor driving dissimilarities was carbon storage capacity (15.61%). Auckland Council ranked carbon storage capacity as being more important than Local Boards did.

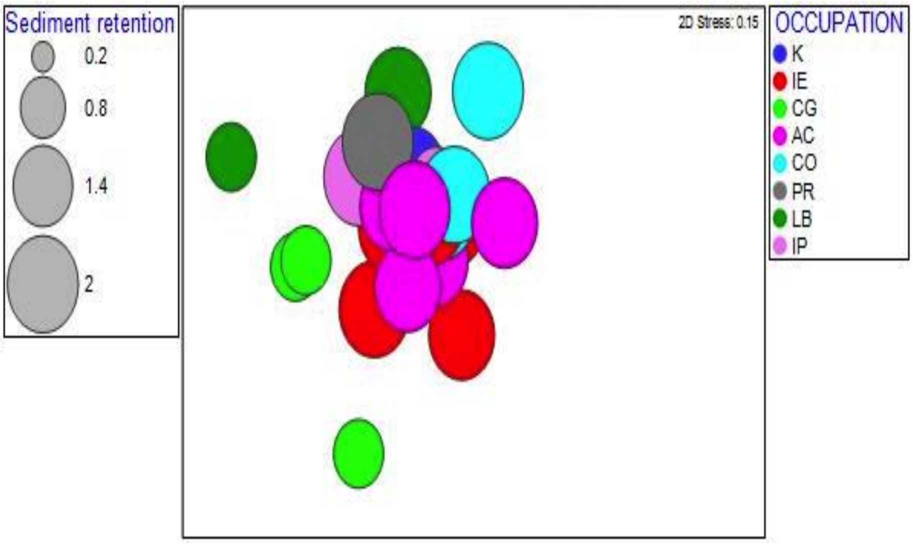


Figure 45. 2-D Bubble Plot based on Bray-Curtis similarity matrix showing occupations rating of sediment retention as an ecosystem service of mangroves in New Zealand.

Table 23 shows the significant pairwise differences, and contribution of dissimilarities of all significant groups, with the top two factors for each pair. For a full output, see Appendix B2. There were no significant differences between participant responses and age or gender or interactions of all three factors ("Occupation", "Gender" and "Age".

Table 23. Top two ecosystem services for significant pairwise comparisons between occupations (occupation with higher rating in brackets), with overall dissimilarity, percentage contribution and cumulative contribution.

Occupation	Overall dissimilarity	Ecosystem Service	%	Cumulative %
CG, CO	34.86	*Sediment retention (CO)*	7.83	7.83
		Nutrient retention (CO)	7.81	15.64
AC, LB	27.59	*Carbon storage capacity (AC)*	15.61	15.61
		Water quality maintenance (AC)	9.28	24.89
CG, AC	27.33	*Nutrient retention (AC)*	8.20	8.20
		Cultural value (AC)	8.13	16.33
IE, LB	26.90	*Carbon storage capacity (IE)*	15.03	15.03
		Medicinal properties (LB)	10.72	25.75
IE, CG	25.65	*Medicinal value (CG)*	9.47	9.47
		Cultural value (IE)	8.75	18.23
AC, CO	23.74	*Water quality (AC)*	9.42	9.42
		Carbon storage capacity (AC)	9.26	18.68
IE, CO	20.03	*Water quality (IE)*	11.05	11.05
		Nutrient retention (IE)	10.83	21.88

Issues affecting New Zealand's mangroves

The highest rated issue facing mangroves was the desire for reversion of estuaries to a pre-mangrove state. This was followed by coastal development/urbanization, illegal cutting and clearance. The lowest rated issue facing mangroves was the dredging of channels. 7% of participants listed the issues of mangroves in New Zealand facing chemical contamination, climate change and sea-level rise as "Don't know". Figure 50 shows the mean ranking of issues facing mangroves in New Zealand.

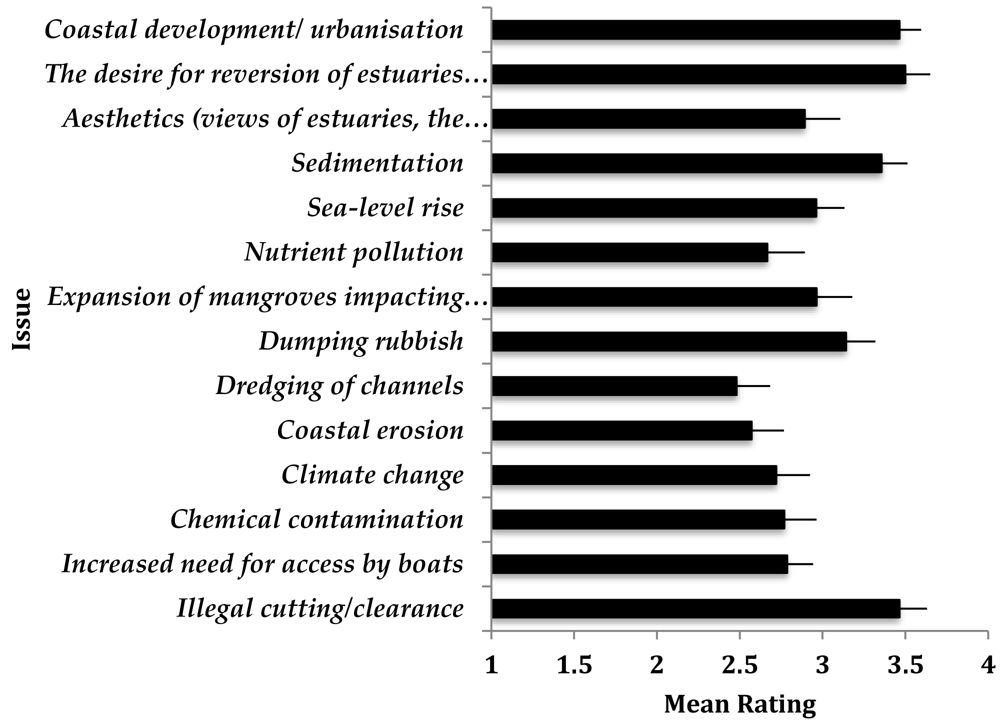


Figure 46. Mean rating of issues facing mangroves in New Zealand as rated by participants (don't know data removed).

There were significant differences between occupations and the rating of issues affecting mangroves in New Zealand. PERMANOVA "Occupation", $F_{7, 27}$= 2.009, p<0.05. Pair-wise comparisons showed that responses between Independent Ecologists with Community Groups, Auckland Council and Conservation Organisations were significantly different in their rating of issues. There were also significant differences between Community Groups with Auckland Council and Conservation Organisations and that of Auckland Council with Conservation Organisations. Table 7 shows groups with significantly different responses. For a full output, see Appendix 3b.

Table 24. Significant pairwise differences between occupations with T-values and p-values.

Occupation	T-value	P-value
IE, CG	1.90	0.019
IE, AC	1.76	0.005
CG, AC	2.58	0.011
CG, CO	2.15	0.019
AC, CO	1.44	0.044
AC, LB	1.79	0.036

SIMPER analysis showed that the greatest dissimilarity between groups lay between Community Groups and Conservation Organisations (18.55%) with the second most between Community Groups and Independent Ecologists (13.77%). The nMDS shows the spatial differences between groups in terms of ranking issues affecting mangroves (Figure 51).

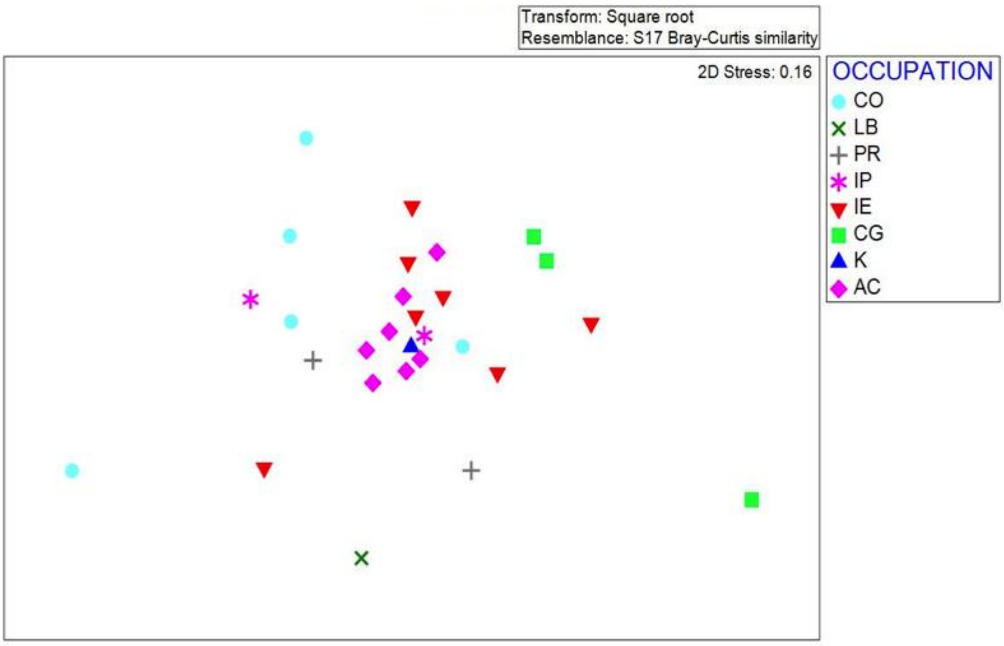


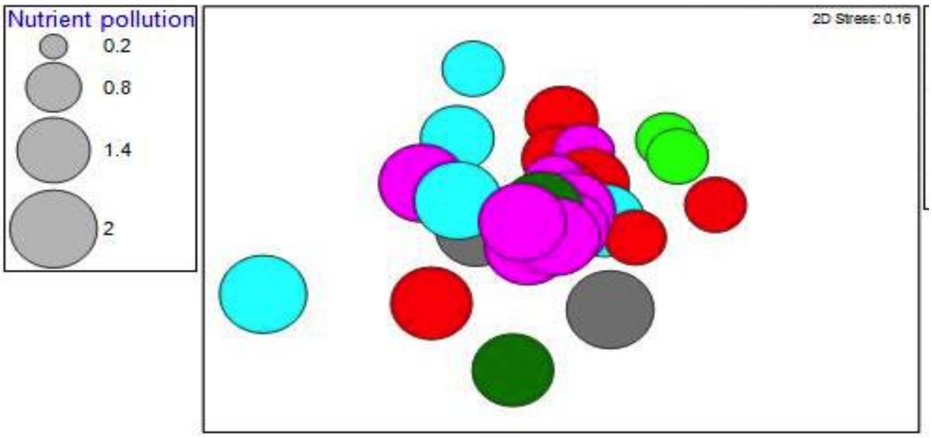
Figure 47. nMDS based on Bray-Curtis similarity showing differences between occupations on the issues facing mangroves in New Zealand

Table 25 shows pairwise differences, and contribution of dissimilarities of all significant groups, with the top two factors for each pair. For a full output, see Appendix 3b.

Table 25. Top two Issues facing mangroves as rated by participants, with significant differences between groups, in descending order of dissimilarity.

Occupation	Overall Dissimilarity	Issue	Percentage Contribution	Cumulative Percentage
CG, CO	18.55	Nutrient Pollution (CO) Chemical Contamination (CO)	12.24 10.95	12.24 23.18
IE, CG	13.77	Nutrient Pollution (IE) Sea-Level Rise (IE)	13.32 12.03	13.32 25.36
CG, AC	13.68	Nutrient Pollution (AC) Chemical Contamination (AC)	15.28 13.21	15.28 28.49
AC, CO	11.42	Expansion of mangroves (AC) Aesthetics (AC)	13.18 10.83	13.52 24.00
IE, AC	9.77	Climate Change (AC) Nutrient Pollution (AC)	11.93 7.93	11.93 21.66
LB, AC	9.51	Sea-level rise (AC) Climate Change (AC)	24.33 22.31	24.33 46.64

MDS bubble plots show the distribution of two of the top factors driving dissimilarities between groups of a) nutrient pollution and b) chemical contamination (Figure 52a) and b)).



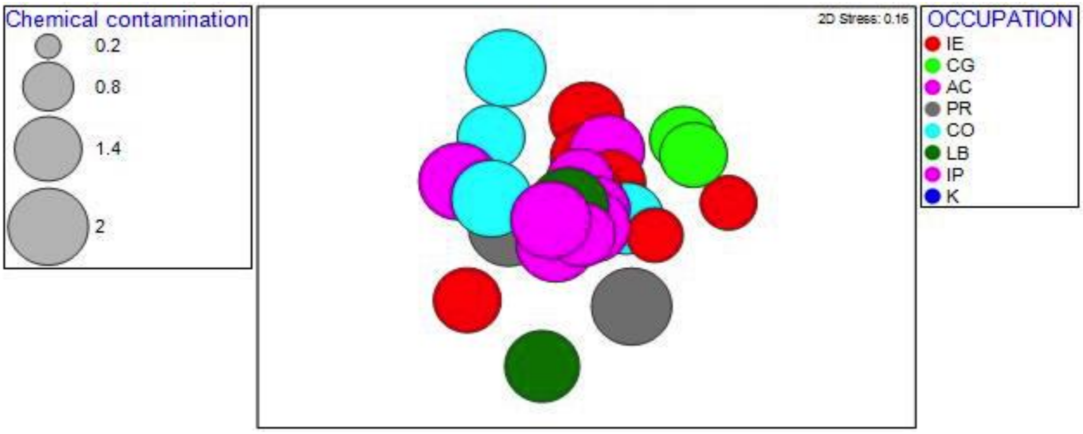


Figure 48a). 2-D bubble plot based on Bray-Curtis similarity for nutrient pollution and **52b).** chemical contamination ranking by participants.

6.4 Q-Sort

Two factors were found after Varimax rotation for significant subject loadings. Factor 1 explained 35% of the variance and Factor 2 explained 19%. Giving a total of 54% of total variance explained. Table 26a) shows Factor 1 extreme statements with high and low Z Scores and 26b) shows Factor 2 extreme statements.

Table 26a). Factor 1 statements about mangroves with highest and lowest Z-Scores and **26b)**. Factor 2 extreme statements about mangroves with high and low Z-Scores.

26a)

Number	Statement	Z-Scores
9	**Mangroves are important for a variety of wildlife**	**1.735**
16	**We need to address sedimentation and nutrient run-off from the wider catchment….**	**1.697**
23	**If we decide to remove mangroves, we need to think carefully about the justification for this and select areas accordingly**	**1.451**
30	**If removed this should be a step by step process**	**1.004**
1	**Mangrove expansion has impacted negatively on surrounding habitats**	**-1.134**
19	**I would prefer to see a view of the water instead of mangroves**	**-1.447**
27	**Everyone should have the right to remove mangroves**	**-2.258**
10	**Nothing of any ecological value exists in mangroves**	**-2.296**

26b)

Statement Number	Statement	Z-Scores
16	**We need to address sedimentation and nutrient run-off from the land to slow the growth of mangroves**	**1.774**
15	**We need baseline monitoring (on contaminated sediments and hydrology) to assess improvements to water quality, and information on contaminants**	**1.717**
23	**If we decide to remove mangroves, we need to think carefully about the justification for this and select areas accordingly**	**1.649**
29	**Mangrove expansion is due to anthropogenic activities**	**1.231**
3	**Mangroves replace wading bird habitat (mudflat) in some areas**	**1.110**
25	**Removing mangroves adds value to property**	**-1.472**
8	**Mangroves should be preserved as much as possible based on their ability to sequester (long-term storage of) carbon**	**-1.326**
10	**Nothing of any ecological value exists in mangroves**	**-1.843**
27	**Everyone should have the right to remove mangroves**	**-2.483**

Factor 1 exhibited a pro-protection attitude towards mangroves. Ten participants loaded positively onto this factor. They agree strongly that mangroves are important for a variety of wildlife and that sedimentation and wider catchment issues need to be addressed before we remove mangroves. They did not think that expansion of mangroves has created a negative impact. They strongly disagree that mangroves do not have any ecological value. One participant loaded strongly negatively onto this factor, they do not agree with any of these statements.

Factor 2 exhibited more of a neutral view towards mangroves. Of the six participants loading onto this factor, all agreed that sedimentation and nutrient run-off should be addressed to slow the growth of mangroves. They wanted more monitoring on contaminants and water quality, but also thought that mangroves do replace mudflat in some areas. Participants disagreed that mangroves should be preserved as much as possible for carbon storage. They also disagreed that nothing of any ecological value lives in a mangrove.

Participants loading highly onto the factors were linked to their occupations to see if any patterns existed with attitude and perception and occupation. The majority of participants who loaded strongly onto factor one were the Conservation Organisation members (n=4), followed by the Independent Ecologists (n=3). Two members from Auckland Council and one local board member also loaded significantly onto this factor. One Conservation Group member loaded onto this factor, strongly negatively (Figure 53a). Factor 2 participants were fewer (n=6), from a wider range of occupations. Two Independent Ecologists, one Kaitiaki, one Park Ranger, one Independent Planner and one Auckland Council employee. The Independent Planner and Auckland Council employee loaded the highest onto factor 2 (Figure 53b).

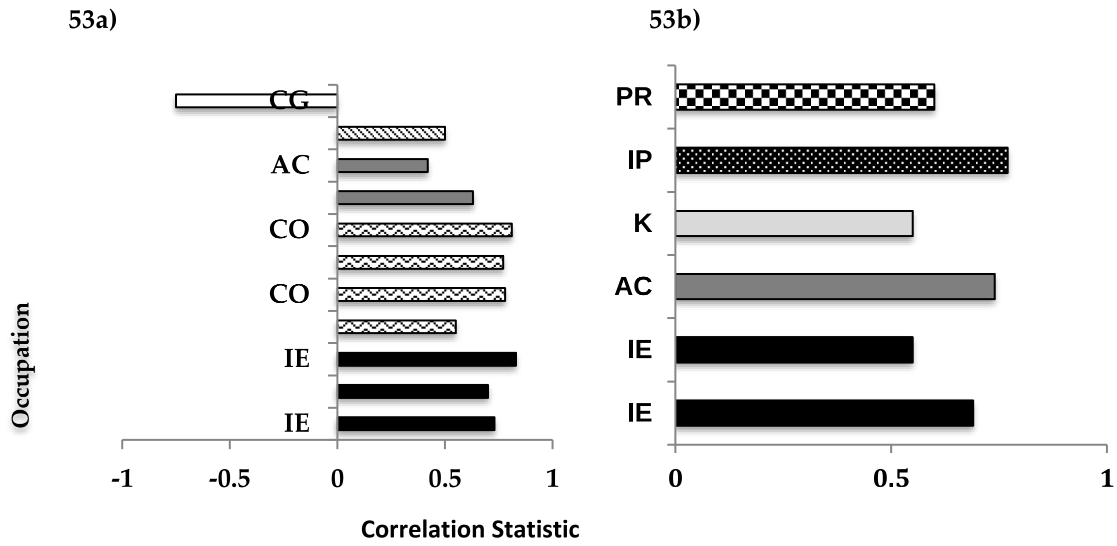


Figure 49a). Factor one loadings and **53b).** Factor two loadings by Occupation

6.5 Discussion

The results from the mixed methods analyses revealed many differences and similarities between the perceptions and attitudes of participants towards mangroves. It was known previously that polarity existed on the issue of preserving or removing mangroves in New Zealand (De Luca, 2015). This study reinforces the idea that considerable disparity exists in the perspectives of stakeholders in local communities. It also highlights that many people are aligned in some of their opinions, possessing more of a neutral point of view to the issues of mangrove preservation and removal, in addition to the two extremes.

6.5.1 Polarity in perceptions and attitudes

It became apparent that the largest differences in perceptions and attitudes were between the Community Groups, who are generally advocates of mangrove removal, and the Conservation Organisations, who wanted mangroves preserved. Community Groups were of the mind-set that mangroves in New Zealand do not possess the ecosystem services which mangroves elsewhere possess. Indeed, temperate mangroves have lower diversity in terms of tree species and no organisms are obligate inhabitants of temperate mangroves (Morrisey et al., 2010), however, their importance as part of coastal ecosystems should not be overlooked. The perceived value of New Zealand's mangroves held by these two groups contrasted dramatically. Community groups held other habitats in higher regard than mangroves, seeing them as having very little benefit to humans or nature.

> ***"Their presence has only been detrimental"***. (CG3)

Conversely, Conservation Organisations viewed mangroves in New Zealand as having a plethora of positive roles in coastal ecosystems.

"Yes, there's no question that mangroves are beneficial, they offer so many benefits …". (CO5)

In addition to the transcripts revealing such a contrast between these two groups, SIMPER analyses of both ecosystem services and issues facing mangroves exemplified differences between these two groups. The importance of sediment retention properties of mangroves in New Zealand was the biggest dissimilarity in ecosystem service raised between these groups. This was reinforced by the transcript data, where the Conservation Organisations widely-accepted sedimentation as the main reason for mangrove expansion at the four sites, seen as a positive service due to mangrove roots holding the sediment in place. One Community Group member did not accept that mangrove expansion was due to sedimentation caused by human-induced land-changes, however, this was the general consensus from all other participants and in the literature (Green et al., 2003; Harty, 2009; Lundquist et al., 2014b). Nutrient retention as a service and nutrient pollution as an issue facing mangroves also drove dissimilarities between Community Groups and Conservation Organisations. Nutrient retention, along with sediment retention was rated the highest ecosystem services of mangroves in New Zealand as averaged by all groups. New Zealand mangrove sediments store considerable amounts of nitrogen, with removal likely to result in significant alterations in coastal nitrogen stocks (Bulmer et al., 2016b). However, there is considerable heterogeneity between sites. A recent study by Gritcan et al (2017) showed that nitrogen and phosphorous levels were significantly higher in mangroves in Manukau Harbour, Auckland, New Zealand than at two other mangrove sites (Mangawhai and Waitemata) (Gritcan et al., 2017).

All Conservation Organisation participants who were part of the Q-sort loaded significantly (and positively) onto Factor 1 in the Q-analyses. This Factor was identified as a "Pro-preservationist' attitude, with high importance placed on the habitat value for a variety of species and a strong disagreement with any aesthetic reason for removal or lack of ecological value. All Conservation Group members (n=1) who conducted the Q-Sort loaded significantly (and negatively) on this factor, strongly disagreeing with statements in this group. This further demonstrated the disparity between these two groups. Table 27 shows a joint display of disparity between Community Groups and Conservation Organisations from all aspects of this study.

Table 27. Mixed method joint display of interviews, scale data and Q-sort to show polarity between Community Groups (CG) and Conservation Organisations (CO).

Method	Analyses	Evaluation
Semi-structured interviews	Queries and Classifications matrix coding query (CG and CO) with all nodes	Greater perceived value and positive attitude towards mangroves by CO, highlighted in themes of world-view, sustainable balance, environmental change, values and practical management
Scale rating of ecosystem services and issues	PERMANOVA with "Occupation" as fixed factor, Bray-Curtis similarity matrix	Significant differences between groups p<0.05. Greatest dissimilarity of all groups for both ecosystem services and issues. Driven by ranking of sediment and nutrient retention as services and nutrient pollution and chemical contamination as issues facing mangroves, CO ranking these higher than CG.
Q-Sort	Sorting of 33 social and ecological statements	Loading of all CO's onto "pro-protectionist" attitude, only CG in sort loading negatively onto this factor.

6.5.2 Role of mangroves in New Zealand and at sites

Over two-thirds of participants saw mangroves as playing an important role in the coastal ecology of New Zealand. Reasons for importance included mangroves being an "important part of estuarine ecosystems" and "providing an important ecological role". Mangroves were described as "native" to New Zealand by some participants, however others saw them as "invasive" and "choking up estuaries". Mangroves are indigenous to New Zealand (Morrisey et al., 2007), however, their expansion into estuaries where they did not exist previously has created issues (Lundquist et al., 2014b). All participants agreed that expansion had occurred at the four sites (prior to any removals). This shifted the opinion of mangroves for some, from positive to neutral or negative. The modification of these areas through urbanisation and industrial practices was seen as a cause of expansion, which in turn has changed the character of some coastal areas, affecting navigation and recreational usage. The value of all habitats was recognized by many participants. ***"I think that all habitats have their own values and I value all of them"*** (AC1). The idea of connectivity between habitats such as saltmarsh, mudflat and mangrove, to create a mosaic of landscapes, instead of wholesale removal of any one habitat was seen as important to sustain the health of coastal ecosystems.

6.5.3 Social divides

The rapid change in landscape through human-induced land alterations in the Manukau Harbour, over one generation, is at the core of the community drive to remove mangroves. ***"The Manukau Harbour is the area where we get the most complaints about mangroves"*** (AC1). Coastal development/urbanization and desire for the reversion of estuaries to a pre-mangrove state were ranked the top issues facing mangroves overall. Expectations that mangrove removal will result in the reversion to previous beaches is unrealistic in many cases, as recovery towards a sand flat environment can take over a decade and is dependent on geophysical factors such as tidal flushing, rates of sedimentation and erosion (Lundquist et al., 2014a). Removing mangroves for aesthetic reasons alone was not seen as a viable reason by the majority of participants, however a few thought that people would "rather see a view of the water than mangroves" (CG1, CG2).

Launching of waka was viewed as a legitimate reason for mangrove removal by participants. Recommendations included that removal should be small scale and specific to a purpose. Much of the issue with removal was the long-term investment required to keep mangroves from re-establishing, community buy-in and realistic expectations were seen as imperative to applications for removal. Due to removal being an on-going practice, a cost-benefit analyses is recommended to be conducted for each proposed removal site (Murray, 2013).

6.5.4 Ecological divides

Ecological values of mangroves were diverse, from sediment retention properties, to providing a habitat for wildlife. Factor 1 participants in the Q-analysis strongly agreed that mangroves are important for a variety of wildlife. The trade-off between mangroves providing habitat for bird species requiring cover, such as the Banded Rail, versus mudflats as a habitat for wading birds was spoken about by all groups. ***"You've got a competition issue if you've got mangrove habitat, you don't have wading birds ... so there's a balance there"*** (AC1).

Carbon storage capacity was a key service rated by Auckland Council participants and Independent Ecologists. In the Q-analysis, the preservation of mangroves based on the ability to sequester large amounts of carbon was disagreed with by Factor 2 participants, who adopted more a neutral view towards mangrove preservation. The ability of mangrove sediments to store large amounts of carbon is becoming widely recognized internationally (Pendleton et al., 2012; Alongi, 2014) and studies in New Zealand mangroves have shown that this is an important ecosystem service (Bulmer et al., 2016 a, b). The ecosystem services little known about were the medicinal properties of the New Zealand grey mangrove and whether it can be used as a source of wood/fuel/building materials. *Avicennia marina* leaves are used in some traditional medicines in the treatment of small pox, ulcers and rheumatism across the world (Bandaranayake, 1998). There has been no direct utilization of the subspecies in New Zealand for fuelwood, charcoal or timber (Küchler, 1972; Dingwall, 1984) however, it has been documented that boat-builders used the wood for shaping of the bow and stern post-colonisation in New Zealand (Crisp et al., 1990).

6.6 Kaitiaki

Kaitiaki saw the issue of mangrove expansion and subsequent removal from an all-encompassing, holistic perspective. The long-term nature of removal was spoken about, recognizing that continued maintenance and management are required. Expansion was seen as a "natural response to an unnatural situation". Some kaitiaki strongly objected to further removal of one site, until further monitoring on sediment flushing and contaminants held in mangrove sediments. Chemical contamination was a driving factor for dissimilarity between other participants, with Auckland Council and Conservation Organisations ranking this as an important issue affecting mangroves. Kaitiaki strongly disagreed that aesthetics was an important reason for removal.

"The resource should be the priority, not the person".

Priority for kaitiaki was water quality, restoring kaimoana (seafood) habitat and waka access. Tipping points in terms of pollution affecting biodiversity of fish and harming wairua (spirit) of the harbour was spoken about. Some thought that there were bigger issues at hand to deal with than removing mangroves. Overall restoration of the degraded environments surrounding the coast of the Manukau was an important goal, as well as recognizing that mangrove expansion was a wider problem, related to land-use change including rural practices and industrialization. This is a view reflected in the literature as part of kaitiakitanga (guardianship); the responsibility to maintain both the well-being of humans and natural resources (Clapcott et al., 2018).

6.7 Design, recommendations and future directions

This innovative mixed methods design allowed for an in-depth evaluation of perceptions and attitudes towards mangroves in New Zealand, with a specific focus on sites in the Manukau Harbour, Auckland. Combining semi-structured interviews with scale ratings and Q-methodology could be applied to the investigation of many social-ecological systems. Each method revealed specific information, which was reinforced and triangulated with the results of the others. Although the sample size of participants was small, it was adequate to investigate social-ecological trade-offs between removing and preserving mangroves at these four sites and reinforced existing knowledge on disparity in communities over mangrove removal (Green et al., 2003; Harty, 2009; Murray, 2013; De Luca, 2015). The nature of conducting such research is that sample size is not guaranteed, however it should be determined by the aims of the research (Marshall, 1996), which was justified.

Recommendations arising from this chapter are that more communication is required between all stakeholders when an application for mangrove removal is lodged. Knowledge based on research, with realistic expectations after removal, investment from the community and long-term ecological monitoring is a necessity for coastal sustainability. Increased awareness and a holistic understanding of wider catchment area issues is required prior to any application for mangrove removal. There will always be trade-offs in the removal of an ecosystem. Balancing social and ecological aspirations to benefit both humans and nature is imperative for future livelihoods.

Chapter 7

Discussion

"One of the first conditions of happiness is that the link between man and nature shall not be broken"

Leo Tolstoy

7.1 Introduction

This study has the overall aim to investigate the social-ecological trade-offs between removing and preserving mangroves in New Zealand. This was investigated through the design and application of a Holistic Mangrove Research Framework at four mangrove sites in the Manukau Harbour, Auckland. The need to understand how humans and nature interact and how we can better understand our environment through viewing things differently, or in this case, pluralistically, drove this research. It is through understanding the perceptions and attitudes of those around us and the environment in which we live in that we can make smart decisions which benefit not just us as humans, but all nature (Russell et al., 2013). The complexity of this research was embraced in the paradigm of dialectical pluralism (Johnson, 2017), reflected in both the plethora of viewpoints of participants and diversity of species at the sites. Using an equal-priority mixed methods approach allowed access to new ways of knowing and observing the ecosystems and communities involved as a complex whole. Overall, the process of planning, designing and conducting the research was successful in terms of addressing the aim of the research and very fulfilling for the researcher.

This final chapter discusses, integrates and evaluates the findings from the previous chapters to address the overall research aim. The chapter includes future recommendations, a review of limitations and reflections on the research itself.

7.2 Holistic mangrove research framework

Research objective one:

To create a mixed methods framework based on social-ecological systems in order to address the overall research aim

The framework developed provides guidance on undertaking equal-priority mixed methods research, whereby no particular emphasis is put on the qualitative or quantitative aspects of the research (Creamer, 2017). This allowed for a truly balanced comprehension of the social-ecological trade-offs between removing and preserving mangroves. Many SES frameworks neglect the ecological aspects of the system and do not integrate social-ecological data in ways that embrace complexity instead of simplifying it (Ostrom, 2009; Vogt et al., 2015; Evans et al., 2017; Johnson & Lidström, 2018). Such an approach is very important for equal weighting, generating a more holistic understanding of mangrove systems, and navigating the complexities of SES research. Interpretive efficacy (Teddlie & Tashakkori, 2009) was maintained through intra- and inter-phase mixing, which provided inferences and meta-inferences around the issues of mangrove removal in the area.

Limitations of framework

The framework allowed for an in-depth exploration of local community attitudes and a snap-shot of biodiversity, in addition to creating space for understanding the background to the sites. Application of the framework took time and no knowledge in any SES can be complete as it is continually evolving (Biggs et al., 2015). Information gathered from the framework may change over time as we gather more knowledge on the social-ecological trade-offs between removing and preserving mangroves in New Zealand and elsewhere.

The social-ecological framework constructed in this study was designed to provide researchers with guidance and structure when conducting their mixed methods research in complex systems. The framework is flexible and adaptive and can be tailored to different timeframes and contexts. This is especially important as many factors may be unknown at the outset of this and similar studies and will be discovered during different phases of the research process.

Reflections and Recommendations arising from framework

Information from each phase showed that mangrove management in local areas is in fact a wider catchment area issue and that for effective and sustainable coastal practices, transparency, consultation, engagement with local communities and transfer of ecological and socio-cultural knowledge is required. This issue has been mentioned in previous regional studies (e.g. Murray, 2013; Lundquist et al., 2014a; 2017), however, it has not been investigated in this mixed methods, integrative manner previously. Such an approach is an important shift in how we embrace the complexity of social-ecological problems in order to value difference and promote respect for dialogue. The implications of this study for conservation education are to create a deeper understanding of mangroves as a biodiverse coastal ecosystem, which is strongly linked to surrounding habitats. It is important in any social-ecological research to allow for the sharing of knowledge with stakeholders (Sterling et al., 2017).

In this study, findings have been shared with local community groups, conservation organisations, Auckland Council, and all participants. Knowledge gathered in this study has also been presented to undergraduates and postgraduates at the researchers' institution, nationally and internationally through lectures, symposia and conferences. It is hoped that the outcomes of sharing this research will improve knowledge dissemination, navigate trade-offs in management, and improve conservation and community outcomes.

Figure 54 shows a conceptual diagram of the interlinking between integrated biodiversity assessments, local coastal management and regional sustainability.

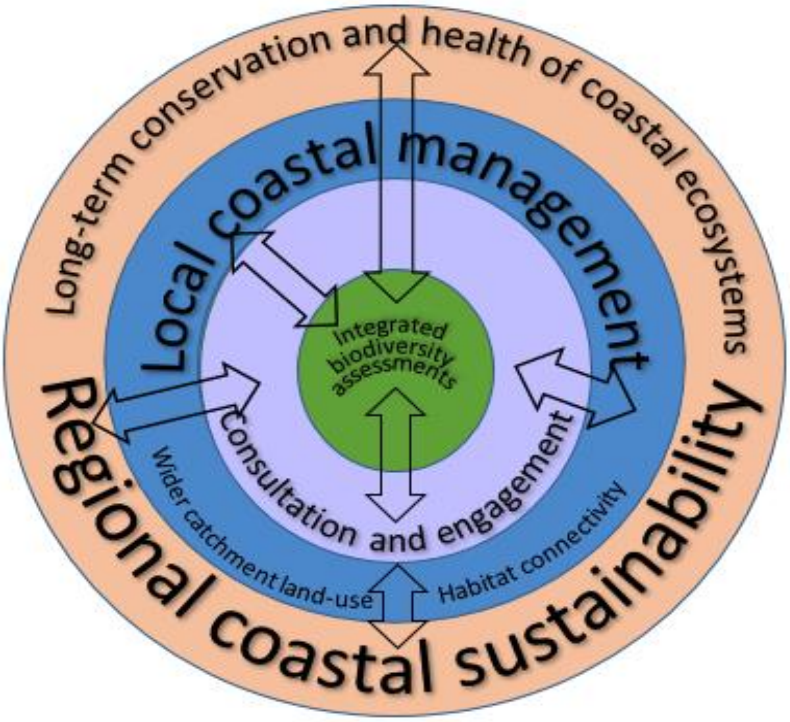


Figure 50. Conceptual diagram of the interlinking between site-specific social-ecological assessments, local coastal management and regional coastal sustainability.

7.3 Review of New Zealand mangrove ecosystems

Research objective two:

To review the literature on social and ecological studies of New Zealand mangrove ecosystems in order to identify gaps in social-ecological information

This objective was achieved in chapter three and published in 2017. Results of the literature review revealed that the majority of studies on New Zealand mangroves were of benthic invertebrate communities. How benthic communities changed following the removal of mangrove areas depended upon three main factors as follows:

- method of removal (hand clearances improving likelihood of community shifts towards sandflat communities)
- removal of above ground biomass offsite
- removal in areas with strong tidal flushing (Bulmer et al., 2016a)

The literature shows that a decrease in benthic abundance was observed in mature mangroves versus young stands (Alfaro, 2010), and was low in both mudflats and mangroves at selected sites (Stokes et al., 2010). In addition, the location of removal within the mangroves affected reversion towards a sandier habitat, with seaward edges showing greater recovery than removal in the centre of a patch or terrestrial edges (Lundquist et al., 2014a). Therefore, removing mangroves and expecting reversion to a sandy beach or mudflat with thriving benthic communities is not always realistic and can take up to a decade to recover (Lundquist et al., 2014a, Bulmer et al., 2016a). This has direct implications for community aspirations including restoration of kaimoana for iwi. Consent applications showed a lack of monitoring of reptiles, insects and spiders and mammals. No studies showed integration of any biodiversity monitoring, which is a more holistic way to understand the habitat value of mangroves to a wide variety of organisms. The review also highlighted a lack of published socio-cultural knowledge surrounding mangroves in New Zealand. Of the one published cultural impact assessment, iwi expressed the wish for monitoring of contaminants in mangrove sediments and surrounding water quality (Ngāti Te Ata Waiohua, 2015). Since this review was conducted, a PhD thesis on 'Reconciling Legislative Provisions and Outcomes for Māori' was published (Kennedy, 2017). This thesis includes a chapter on the value of mangroves (manawa) to their iwi. This iwi, in the Thames region of New Zealand promotes the protection of mangroves as a habitat for juvenile kaimoana and value mangrove roots and stems as substrate for the snail *Amphibola crenata* (titiko) and oysters (tio) (Kennedy, 2017). This recent piece of literature is invaluable in realising the cultural value of mangroves to some iwi, however there is still a deficit in this area of research in New Zealand mangroves.

Limitations of review

This review highlighted knowledge gaps in social-ecological research into mangrove ecosystems in New Zealand. Gathering and assimilating such a large amount of social-ecological information from studies over 50 years was time consuming and complex. However, this was integral for the research to go ahead. The review allowed the researcher to ascertain the species to be monitored for baseline data and the socio-cultural information to be explored. It also highlighted the complexity of the ecosystem and reiterated the need for a mixed methods study in order to understand this SES. However, it only included peer-reviewed published material. Some unpublished literature for example from Masters theses could have been missed in this review.

Reflections and Future recommendations

This review chapter showed that the terrestrial component of mangrove ecosystems is widely overlooked, both in New Zealand and internationally. Prior to this research, only one published study shows the implementation of integrated assessments to investigate biodiversity in mangrove ecosystems which focused on vertebrate communities (Rog, 2017). Important groups of organisms, which contribute to the health and functioning of mangroves such as insects and spiders need to be monitored prior to any removal (Macintosh & Ashton, 2002).

Understanding community aspirations for removal and whether these are realistic need more visibility for the general public. More research on the potential cultural value of mangroves for Māori in New Zealand needs to be carried out.

7.3 Secondary social-ecological data collection

Research objective three:

To investigate secondary social-ecological data from council resource consents for background knowledge on the ecology and communities in the area

There has been a large amount of industrialisation and urbanisation in and around the Manukau (Pritchard et al., 2008). Reasons for removal of mangroves at the four study sites were predominantly socio-cultural and included: *enhancement of the amenity value of the harbour, navigation of water for waka, recreational boating and fishing and views of the harbour.* Ecological reasons for removal at the sites included *creating more intertidal flat habitat for at risk and threatened wading bird species* and *restoration of kaimoana beds* (also a socio-cultural reason). Policy in the NZCPS states that mangroves may be removed where it will help restore the area to its "natural character" (Auckland Council, 2011) and communities believe that removal will help revert the areas back to a pre-mangrove, pre-urban state. The concept that removal of mangroves brings a reversion of the area to a pre-mangrove state is inaccurate at certain sites (Lundquist et al., 2017), particularly given the continued urbanisation and development in the Manukau Harbour.

There is a strong push to prevent further expansion of mangroves around ecologically significant areas such as the Kiwi Esplanade (Mangere resource consent #46321), which is home to a vast range of national and international migratory wading birds (Auckland Council, 2018b). This may be a valid reason to remove mangroves that have expanded in the area, as long as other adjacent areas of mangrove habitats are kept, along with saltmarsh and eelgrass habitats for connectivity and wildlife corridors. Maintaining the connectivity of coastal habitats is recommended by independent ecologists interviewed who have researched the sites.

Restoration of kaimoana beds for iwi may also be a valid reason for removal at certain sites, but may not be successful if continued sedimentation occurs, causing smothering of macrobenthic species residing in the sediment (Thrush et al., 2004; Lundquist et al., 2014a; Robertson et al., 2015; Bulmer et al., 2016a). Whilst some iwi believe that removing mangroves will restore shellfish beds, others see mangroves as a habitat for other kaimoana, such as juvenile mullet, tio and titiko (Kennedy, 2017). These values are in direct conflict with each other. Each site of mangrove removal will require monitoring to see whether restoration of beds occur, and adjacent shellfish beds are not detrimentally affected by removal activities (Lundquist et al., 2017).

In the Manukau, the restoration of the harbour is of utmost priority for local communities. With such strong community voices, it is important that the value of mangroves is fully understood, not only in terms of biodiversity, but other ecosystem services, such as carbon storage and flood protection, which this system offers (Bulmer et al, 2016a, b).

Limitations of data collection

The initial collection of resource consent data took three months (five days per week). This time was required to conduct rigorous and complete social-ecological data collection on each site. Whilst labour- and time-intensive; the data obtained created an important and solid foundation for the rest of the study. This data could then be referred to throughout the other phases of the study in order to identify any additional gaps between the research as it was being undertaken and the consent process itself. Recording and collating such a large amount of information, although done systematically, means that some information may have been missed. It was not apparent through this data collection that removal had not gone ahead at Waimahia mangrove. As the other three selected sites all had removed sections of mangroves, it might have been better to select another site of known removal in order to be consistent in terms of study design. The biodiversity assessments at the sites took place almost a year after this stage. It was hoped that some removal would have gone ahead at Waimahia during this time, however, this did not occur.

Reflections and Future recommendations

Reasons for removal must be carefully thought out and researched by those applying for resource consents. Aesthetic values for removing mangroves such as improving sightlines and views of the harbour are not valid reasons as this directly compromises ecosystem services of mangroves. Mangroves should also remain in areas of known chemical contamination and coastal erosion (Auckland Council, 2013).

Removing large areas of mangroves and leaving above ground biomass in-situ is not ecologically sound, such as in Pahurehure Inlet 2 (Figure 55a). Mechanical means to remove mangroves can create compaction of sediments and algal smothering, which detrimentally affects benthic communities and their consumers such as birds and fish (Lundquist et al., 2014a) (Figure 55b). We require long-term ecological monitoring and investigations into the social implications of mangrove removal in order to fully comprehend its effects (Lundquist, 2017; Schmitt & Duke, 2015).

Figure 51a). Pahurehure Inlet 2 removal area with mangrove wood left in–situ and **55b)** Algal smothering in pneumatophore zone with remaining seaward fringe of mangroves.

7.5 Perceptions and attitudes

Research objective four:

To understand the perceptions and attitudes towards mangrove removal and preservation through interviews with local community stakeholders

The selection of stakeholders encompassed a diverse a range of viewpoints. Stakeholders with extreme points of view were contacted and interviewed, as well as those with less polar viewpoints, to allow for a deep understanding of perceived knowledge across a wide-range of people, as reflected within local communities. Allowing for this range of viewpoints created an axiological stance that respected different viewpoints and ways of knowing. This was particularly important when engaging and consulting with Māori.

Expansion of mangroves in New Zealand is viewed as anthropogenic or "a natural response to an unnatural situation". Removal to pre-1996 levels is usually used as a baseline (the time when aerial photographs were reliable), which is reflected in current policy. A driving force of removal is the desire to return estuaries to a pre-urban environment (Lundquist et al., 2014a). The Manukau was still heavily urbanised at this time, so cutting back to 1996 levels is not going to create a pre-urban space. The majority of participants saw mangroves as providing an important role in coastal ecology. However, in some cases, the expansion of mangroves was viewed as detrimental. Although the ecosystem services of sediment and nutrient retention were rated as the top services of mangroves, the desire for reversion of estuaries was the top issue facing mangroves. If communities understand the provisioning value of mangroves, they should see that removing them severely compromises the ability of mangroves to carry out these roles. This shows dissonance and mismatch, perhaps a lack of understanding of the effects of removal, of which there is still much to learn.

There was convergence in the outcomes of Q-sort which showed that both the pro-preservationist group and the neutral group ranked sedimentation and nutrient run-off from the land as a top-ranking issue affecting mangrove ecosystems. The disparity in the rating of ecosystem services and issues was most prominent between Community Groups and Conservation Organisations. Chemical contamination and nutrient pollution in mangroves ranked as the biggest issues by Conservation Organisations and the least important by Community Groups.

Some participants saw mangroves as invasive, even non-native, although this species *Avicennia marina* has existed in New Zealand for at least 9,000 years (Pocknall, 1989). It is true that mangroves are expanding seawards in areas in North Island and therefore now exist in areas where they may not have previously. However, ecological reasons as to why they have proliferated need to be considered. For the areas of mangroves where valid reasons are upheld to remove them, long-term buy-in from communities is a necessity. Currently, many applicants are only thinking short-term, with no on-going funding for maintenance of removed areas. Some sites have not been removed, even though consents have been granted, due to a lack of funds.

Limitations of interviews

Epistemologically speaking, it was noted that the researcher could not stand entirely separately and independently of the participants involved in the study. Therefore, it is important to consider the value and means of active engagement with participants during the interview process and in the follow up, with published articles around the research given to participants for their interests and for transparency. It was vital that engagement and consultation was made from the outset, with transparency about the outcomes of the research and the role stakeholders would play. The ethics process, planning the semi-structured interview questions, creating and testing the Q-sort and making initial contact with iwi took almost six months. This set the stage for trustworthiness and validity of the study.

The interview process itself proved lengthy. Some stakeholders were hard to reach, some became unavailable, some agreed to be interviewed without committing to dates, and a small number of stakeholders refused to participate outright. As a consequence, it was difficult to predict the total number of stakeholders participating initially. The small sample size of stakeholders was a limitation to the study, a greater sample size would have provided a more robust statistical analysis and stronger general conclusions. However, the richness of the data provided was considered sufficient to allow for a deep understanding of the issues around mangrove management. Time was also a limiting factor to the study. It is important to consider the time taken for the process of contacting, meeting and interviewing stakeholders. This took three months of intense work and did not include any of the analytical stages of the chapter.

Reflections and Future recommendations

It was clear from the interviews that there are multiple ways of knowing and of perceived knowledge, where each participant has their own truth about the issues resulting from mangrove expansion in their local areas or as a regional problem. The dissonance between Community Groups and Conservation Organisations highlights the need for more monitoring to be done in New Zealand mangroves by ecologists in order to provide awareness for the general public, before applications for removal are lodged.

It is through the understanding of local communities' wishes and realistic aspirations that local boards and regional councils can work together in a transparent way with ecologists to understand how removal impacts upon biodiversity within a mangrove habitat and what the solutions are to meet realistic community aspirations and maintaining ecological integrity.

7.6 Biodiversity of mangroves

Research objective five:

To conduct integrated biodiversity assessments at the selected sites to provide baseline data for lesser known species occupying mangroves

The collection of biological data at the sites provided a wealth of information on local biodiversity of mangrove ecosystems. The sense of place was realised at each site, with different times of day supporting different groups of organisms (for example, fish at high tide and birds roosting at night). This one-off snapshot of data provided valuable information about how to record the presence of multiple groups of organisms in a relatively simplistic way to allow the complexity of these systems to be investigated.

Findings from the biodiversity data show that the most isolated patch of mangroves (Pahurehure Inlet 2) had the greatest richness and abundance of insect and spider species and the greatest bird abundance of all the sites. It was thought prior to the study that this site would possibly contain the least amount of species due to such a large removal of the surrounding mangroves. This shows that we cannot assume that a small patch of mangrove will not have high biodiversity, indeed, a lack of connectivity of surrounding mangrove may have created a higher dependency of species to occupy what is left of this habitat.

There was a large amount of heterogeneity in habitat complexity parameters between the sites, which contributed to approximately a third of differences in arboreal arthropod community composition. Further studies are needed to see whether it is complexity parameters and/or connectivity to surrounding mangroves that drives patterns in arboreal arthropod community composition.

This study provided baseline data on these communities at the four sites, in addition to adding to existing data on fish, mammal and bird species in mangroves. It also highlighted the lack of reptiles such as geckos and skinks at these sites. However, skinks were observed in saltmarsh adjacent to mangroves at all study sites.

The outcomes of this chapter provided feedback in terms of written reports and email contact to both Auckland and Waikato regional councils and the Department of Conservation. It also provided baseline biodiversity monitoring data for independent ecologists in order to improve ecological assessments currently conducted in mangroves pre- and post- removal.

This information was also given to the stakeholders interviewed by email to increase local knowledge around these sites. A community talk with a conservation group and knowledge exchange with the Department of Conservation, Auckland Council and independent ecologists also occurred throughout the planning, implementation and results of this phase of the study.

Limitations of research

It was vital to consider the seasons and how this may impact research design and the results of the biodiversity surveys. In this study, biodiversity research was conducted in mid- late summer, where a peak in species is expected and flowering of the mangrove occurs (Morrisey et al., 2007). Surveying the sites as a one-off snapshot of biodiversity does not show any seasonal variation. In addition, the methods used were predominantly non-invasive and may have not been as effective at capturing biodiversity as more invasive techniques.

It is also important to plan for any research permits that might be required and account for the time taken for any approval processes. For example, the permit to conduct research from the Department of Conservation had to be processed, which also required acceptance of the research on behalf of DoC by iwi in the area. The process of submitting the application for a wildlife permit and receiving it took three months.

Reflections and Future recommendations

The wildlife value of mangroves in New Zealand is sometimes discounted as non-important as no animal depends solely on mangroves (Morrisey et al., 2007). The concept that an ecosystem is only important if there are obligate species relying on it is inaccurate. Each species has its role and ecological niche; which contribute to the overall health and functioning of the ecosystem itself and the wider coastal landscape (Laureto et al., 2015). It is recommended that each site have seasonal monitoring carried out, with integrated assessments to cover a range of organisms inhabiting mangroves. In addition, use of connecting habitats such as salt marsh should be monitored for terrestrial invertebrate species. Recommendations for each site surveyed are as follows:

Pahurehure Inlet 2 and Waimahia mangrove sites

This study has shown that there are differences in the biodiversity of mangrove sites. The most fragmented mangrove patch (Pahurehure Inlet 2) had the greatest abundance and diversity of arboreal arthropods and birds. This site is recommended to be preserved, with continual annual long-term monitoring, especially for banded rail and arboreal arthropod species. Waimahia mangrove is the second richest and most abundant site in terms of arboreal arthropods and the richest site for short-finned eels. The banded rail was also recorded at this site. The site surveyed is due for removal (resource consent #41680) as part of total of 19.4 Ha to be removed (Auckland Council Resource Consent Records). Based on these assessments, it would not be recommended to be removed. However, there was a large amount of non-native mammals at this site and so Holden traps or other pest traps should be installed within and around the mangroves, in order to preserve the bird life at this site. In 2017, a boardwalk was built through a section of Waimahia mangrove, connecting two housing areas to each other. This boardwalk highlighted anthropogenic pollution within the mangroves at this site (Figures 56a, b, c).

Figure 52a). Waimahia mangrove boardwalk, **56b).** Point source pollution from drain and **56c).** Algal smothering in the mangroves.

<u>Puhinui and Mangere mangrove sites</u>

Puhinui mangrove had the highest diversity of bird species and supports native insect diversity such as the common copper butterfly *Lycaena salustris*. This site has already had a patch of mangrove removed for waka (Māori canoe) access, but the removal area has not been maintained and seedlings are growing back (Figure 57a). It is also heavily polluted with tyres, polystyrene blocks and other rubbish (visual observations) (Figure 57b). It is recommended that this site is cleaned up and that sapling maintenance continues by the local community for cultural reasons.

Figure 53a). Removed area of mangrove at Puhinui, showing re-growth of saplings and cut edge of mangrove and **57b).** Pollution in the mangroves

Mangere Inlet mangroves

Areas of Mangere mangrove were removed to increase wading bird access, and the Kiwi Esplanade is a noted area for wading bird species (Auckland Council, 2018b). This area was also highly polluted and had the least amount of arboreal arthropod species. It is recommended for this site to be cleaned up and that further monitoring of all groups of organisms be carried out here before any further removal. However, the value of the site for wading birds is important. Due to the extensive expansion of mangroves in Mangere Inlet, removal of some areas is not considered so detrimental to the coastal ecology of the area.

When planning biodiversity research, it is important to consider the equipment required, and when this will need to be ordered for it to arrive before the biodiversity surveys are planned to be conducted. The experimental design still had to be slightly altered to allow for delays in equipment delivery. Despite this, desired monitoring of a wide-range of species was still achieved across all sites. This experience taught the researcher how important it is to be flexible and adaptable when conducting ecological research. A plan can be well-conceived; however, the practice of ecology is never perfect.

7.7 Wider issues and holistic management

The New Zealand Coastal Policy Statement 2010 (policy 11) aims to:
' protect indigenous biological diversity in the coastal environment' including a) avoiding adverse effects of activities on '*indigenous taxa that are listed as threatened or at risk*' and to b) 'avoid, remedy or mitigate other adverse effects of activities on *indigenous ecosystems and habitats that are only found in the coastal environment and are particularly vulnerable to modification e.g. estuaries, coastal wetlands, intertidal zones…..*' (NZCPS, 2010).

This policy covers protection for the 'at risk' Banded Rail and mangroves themselves as an 'indigenous ecosystem particularly vulnerable to modification'. However, it also covers intertidal zones and would include at risk or threatened wading birds occupying intertidal flats. Therefore, there is ambiguity and conflict within the coastal policy itself between protecting mangroves and protecting surrounding habitats from mangrove encroachment. Expansion of mangroves is seen by some to displace other habitats. This is true in the case of seaward growth of mangroves into intertidal flats. However, to what level does this encroachment compromise the ecosystem services of surrounding habitats? Does expansion of mangroves have a detrimental effect on the overall coastal health and functioning? These questions remain unanswered. Instead of focusing on comparisons of habitats and species within them, the importance of connectivity between different adjacent habitats such as saltmarsh-mangrove-seagrass-intertidal flat should be a top priority in coastal conservation, both in New Zealand and globally. It emerged from all chapters of this study that addressing the underlying issues of mangrove expansion is key to satisfying the goals of local communities in terms of some form of restoration of the harbour. Holistic restoration of the harbour is a priority for iwi in the area. This was observed through reading cultural impact assessments, having hui and investigating consultation carried out prior to removal at the sites. The issue of water quality was exemplified in Ngāti Tamaoho Trust's CIA for further urban development in the Manukau Harbour:

"The quality of water determines the relationship that the tribe has with its waters. Environmental degradation, at a national level, has occurred at a large cost and the physical, chemical, and biological quality of water has deteriorated….. As a result, human impacts such uses as farming/agriculture, wastewater treatment, damming, horticulture, urban development, stormwater, and forestry conversions have modified natural water flows and the degree of contaminants that a water body receives, resulting in a decrease in water quality".

(Ngāti Tamaoho Cultural Impact Assessment, 2015)

Although stormwater treatment and drainage has improved, the overall water quality of the harbour was ranked "D" or poor, with the ecological health described as "unhealthy" for Mangere and Pahurehure inlet in 2016 (Auckland Council, 2018a). Consultation and interviews showed that some iwi wanted testing of water quality and further evaluation of the role that mangroves play at the sites in terms of filtering the water and retention of contaminants. Iwi also see expansion as a wider issue caused by sedimentation through urbanisation and farming. Monitoring of water quality and contaminants such as heavy metals should be a priority for regional councils across New Zealand when considering applications for the removal of mangroves.

A Ngāti Tamaoho tupuna said:

"…leave the Manukau Harbour and its estuaries alone and it will heal itself. Stop reclaiming the tidal foreshores and building motorways over the feeding grounds of our fisheries and destroying our shellfish beds and elements of the spawning grounds."

(Ngāti Tamaoho Cultural Impact Assessment, 2015)

7.8 Reflections and outcomes of study

The intended outcomes of this study were to understand what trade-offs exist both for local human and animal communities when society removes mangroves or allows them to proliferate and what the best path of action might be moving into an unpredictable future.

We may view ecosystem service trade-offs in a variety of ways, which can be visualised as frontier shapes whereby we can maximise service value for an ecosystem-based management (ebm) approach (Lester et al., 2013). Removing one native ecosystem in place of another could be viewed as a direct trade-off (Lester et al., 2013). For example, removing mangroves for mudflat creation or reversion to a beaches. However, it is unlikely that the services each system provides will be compensated in this direct manner. This is particulary true in the case of mangrove removal in areas where there has been substantial urban development. Sediment loads are still increasing in the Manukau Harbour (Foley et al., 2018). This, coupled with reduced tidal flushing make it unlikely that reversion of an estuary or harbour to a pre-mangrove state will occur quickly, if at all (Lundquist et al., 2017).

There is complexity around the ecosystem services mangroves and adjacent systems provide and we still have many gaps in our knowledge of the provisioning, regulating and cultural services of temperate mangrove ecosystems in New Zealand, therefore modelling trade-offs in order to maximise service value may not be accurate enough to make ebm decisions.

In the past, only limited ecological monitoring was conducted at removal sites and of particular species. In addition, the perceptions and attitudes of communities living around these areas have been considered primarily from the perspective of those who have pushed for removal, not conservation. The applications for removal of mangrove highlight the reasons why people want them removed, not why they want them preserved. The polarity of attitudes towards mangroves calls for multidimensional dialecticism, which allows for community engagement, comprehension of the complexity and connectivity of the coastal environment and a well-thought out, flexible and adaptive approach to the management of estuarine ecosystems where mangroves exist.

This study has sought to encourage a dialectically pluralistic axiology amongst local communities who have a direct impact upon mangrove removal. This was achieved through triangulation between biodiversity research at the sites and direct feedback to stakeholders around these findings, as well as provision of feedback to participants about the overall findings around perceptions and attitudes towards mangroves. Outreach to parts of the local community (Birds NZ) also occurred post assessments with a talk on the results of bird surveys at the sites. Information has also been provided to the Department of Conservation and Auckland Council on sightings of 'at risk' species during this time. This transfer of knowledge was carried out for the purposes of transparency and in the hope that if local community groups are presented with a wide-range of social and ecological information about mangroves. This may make way for more informed decisions to be made when considering lodging applications for mangrove removal in these areas.

A major limitation of this study was the timeframe, meaning that only four mangrove removal sites could be investigated. Resources to expand this area and interview more stakeholders were not available. However, this framework has the potential to be implemented for long-term social-ecological monitoring in coastal ecosystems. The study has allowed for the biodiversity results of the study to be communicated to scientists, undergraduates, iwi/hapū (Māori tribe/subtribe), members of conservation organisations and local estuary care groups within New Zealand. It has also allowed the researcher to communicate the research internationally. The facets of coastal complexity and connectivity were investigated throughout the stages of the research.

The dynamic evolution of mangrove ecological research and an increasing understanding of the ecosystem values of this habitat, alongside shifting views and policies reflects the complexity of this social-ecological system in a changing world. Investigating mangrove removal case studies within a harbour highlighted both connections with local communities and similarities and differences in the ecology of the sites. It was clear that the coastal landscape and human interactions with said landscape are both connected and complex.

Importantly, the feedback provided to stakeholders allowed for knowledge transfer and exchange between the researcher and the people involved in mangrove management in the area. The process itself was constantly evolving and fluid in construction and approach. The researcher had to remain flexible in thought-process and design implementation at all stages of research. Taking a step-wise approach and integrating at each stage allowed the researcher to be objective throughout the process and gain a holistic perspective on mangrove management and wider coastal sustainability issues.

This framework could be applied to similar social-ecological contexts at local, regional, and national scales. In the collection of data, integration occurred at all phases of the research and inferences were drawn. Knowledge was gained at each stage in an incremental process around what the social-ecological trade-offs between removing and preserving mangroves were. With the knowledge gained, meta-inferences could be made about trade-offs and the complexity of the mangrove system along with local community aspirations and wishes. Whether this research has a direct impact on the management of mangroves in New Zealand remains to be seen. However, it is hoped that the contribution of this study to the pool of social-ecological knowledge on mangroves and its potential applications to other SES is worthy. Table 28 summarises trade-offs based on the sites and knowledge acquired from each stage of the research.

Table 28. Social and ecological trade-offs between removing and preserving mangroves with conclusions based on this study

Trade-off	Issue	Evidence	Conclusions
Ecological	Removal increases intertidal habitat for wading birds but reduces cover for other native species such as banded rail, kingfisher, grey warbler, fantail	Chapters three-six	Trading off mangroves and intertidal flats for birds requires long-term monitoring on populations of nationally at risk and threatened bird species in order to assess the size of mangrove to be removed and the likelihood of success to a healthy intertidal flat habitat which supports other birdlife
Social-ecological	Value of mangrove as a fisheries habitat and nursery for juvenile fish species	Chapters three, five and six	New Zealand mangroves are not a nursery habitat for many fish species as in the tropics. This study showed juvenile mullet present at all sites at high tide and a permanent eel channel at one site. Site by site recommendations needed after long-term monitoring pre- and post- removal
Social-ecological	Restoration of kaimoana beds	Chapters three-five	Dependent upon tidal flushing, area removed (seaward/centre/terrestrial), if agb is left in situ, methods of removal. On-going sedimentation can smother shellfish beds, contaminants in sediments also need to be monitored.
Ecological	Terrestrial species overlooked, value of mangrove focuses marine species and comparison with intertidal habitats	Chapters three-four, six	Biodiversity monitoring of mangroves should include arboreal insects and spiders as a terrestrial component. Other connecting habitats for arboreal arthropod species need to be considered prior to removal of mangroves
Social	Removal improves amenity access and navigation of the waterways	Chapters three-five	A driving factor for removal of mangroves. On-going non-mechanical removal of saplings and seedlings (<60cm) required to maintain areas. Long-term community buy-in required.
Social	Removal improves sightlines and aesthetics	Chapters four-five	Should not be a reason for removal. There is no benefit in removal for ecology of area based on this rationale.
Social-ecological	Removal leads to increased sedimentation and nutrient input into estuaries	Chapters three-five	Top issues facing coastal areas. These ecosystem services of mangroves are listed as most important. Keeping roots in place after removal reduces sediment loads, however, more monitoring into below ground carbon in sediments and heavy metal contaminants is required

7.9 Conclusions

This study has shown how policy makers can integrate both biodiversity knowledge of mangrove sites and societal aspirations of coastal communities to provide a more sustainable future. In order for an integrated, holistic understanding into any social-ecological system, the complexity of the system and the connection of humans to nature must be realised. Perceptions and attitudes towards mangrove ecosystems are not necessarily set in stone, nor is ecological knowledge. It is with continuous engagement of local community members, feedback and transparency of ecological monitoring and taking each case on a site-by-site basis, that a truly sustainable future for coastal communities (of both humans and nature) can be realised.

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Glossary of terms

Axiology- ***'The philosophical study of value'.***

Retrieved from: https://www.dictionary.com/browse/axiology

Epistemology- ***'The study of the nature and grounds of knowledge'.***

Retrieved from: https://www.merriam-webster.com/dictionary/epistemology

Hauora-***Well-being.***

Retrieved from: http://health.tki.org.nz/Teaching-in-HPE/Health-and-PE-in-the-NZC/Health-and-PE-in-the-NZC-1999/Underlying-concepts/Well-being-hauora

Hapū- ***Māori subtribe/clan/descent group***.

Retrieved from: https://teara.govt.nz/en/tribal-organisation/page-1

Holistic (ecology)- ***'views humans and the environment as a single system'***

Retrieved from: https://www.merriam-webster.com/dictionary/holistic

Hui- ***social gathering/assembly.***

Dictionary of New Zealand English. Oxford University Press. ISBN 0-19-558347-7.

Iwi- ***Māori tribe.*** Retrieved from: https://teara.govt.nz/en/tribal-organisation/page-1

Kaimoana-***seafood/shellfish.***

Retrieved from: https://maoridictionary.co.nz/word/1968

Kaitiaki- ***guardian/steward*** (of the environment).

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Kaitiaki

Kanohi-ki-te-kanohi-face-to-face

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=kanohi+ki+te+kanohi

Kaupapa-principle/policy

Retrieved from: https://maoridictionary.co.nz/word/2439

Kaitiakitanga-guardianship

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=kaitiakitanga

Mahinga kai- ***food-gathering place.***

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=mahinga+kai

Mahinga mātaitai –***shellfish bed/customary seafood gathering place***.

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=M%C4%81hinga+mataitai+

Manawa- ***Mangroves.***

McLintock, A.H. (1966). Retrieved from: https://teara.govt.nz/en/1966/mangrove-or-manawa

Mana Whenua-*Territorial rights*.

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Mana+Whenua

Marae-*Area where formal greetings and discussions take place*.

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=marae

Mātauranga Māori- *Māori knowledge*.

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=M%C4%81tauranga+M%C4%81ori

Mauri- *'life force'*. Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Mauri

Ontology- *'The study of being'*.

Retrieved from: https://philosophyterms.com/ontology/

Taiao-*Natural World*.

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=taiao

Taonga-***anything prized, including socially and culturally valuable objects.***

Retrieved from: https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Taonga

Te reo Māori- ***Māori language.***

Retrieved from: https://www.tpk.govt.nz/en/whakamahia/te-reo-maori

'Te tino rangatiratanga' – *'absolute sovereignty'*.

Orange, C. (2012). Treaty of Waitangi. Retrieved from: https://teara.govt.nz/en/treaty-of-waitangi/page-1

Te Tiriti o Waitangi-*Treaty of Waitangi*.

Orange, C. (2012). Treaty of Waitangi. Retrieved from: https://teara.govt.nz/en/treaty-of-waitangi/page-1

Tikanga-*Custom/lore/habit*.

Retrieved from:
https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Tikanga

Waka ama-*Outrigger canoe.*

Retrieved from:
https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=Waka+ama

Wairua- *spirit*

Retrieved from:
https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=wairua

List of abbreviations

AGB: Above-Ground Biomass

CIA-Cultural Impact Assessment

CPA-Coastal Protection Area

CPR-Common Pool Resource

EBM-Ecosystem-Based Management

GDP-Gross Domestic Product

PES-Payment for Ecosystem Services

RMA-Resource Management Act

SEA-Significant Ecological Area

SES-Social-Ecological System

Appendices

APPENDIX 1: Ethics Application

Auckland University of Technology Ethics Committee (AUTEC)

For AUTEC Secretariat Use only

________/________

EA1

Application for Ethics Approval by AUTEC

Please print this application single sided in greyscale and do not staple. Once this application has been completed and signed, please read the notes at the end of the form for information about submission of the application for review.

Notes about Completion

- ❖ Ethics review is a community review of the ethical aspects of a research proposal. Responses should use clear everyday language with appropriate definitions being provided should the use of technical or academic jargon be necessary.
- ❖ The AUTEC Secretariat and your AUTEC Faculty Representative are able to provide you with assistance and guidance with the completion of this application which may help expedite the granting of ethics approval.
- ❖ The information in this application needs to be clearly stated and to contain sufficient details to enable AUTEC to make an informed decision about the ethical quality of the research. Responses that do not provide sufficient information may delay approval because further information will be sought. Overly long responses may also delay approval when unnecessary information hinders clarity. In general, each response should not exceed 100 words.
- ❖ AUTEC reserves the right not to consider applications that are incomplete or inadequate. Please do not alter the formatting or numbering of the form in any way or remove any of the help text.
- ❖ Comprehensive information about ethics approval and what may be required is available online at http://aut.ac.nz/researchethics
- ❖ The information provided in this application will be used for the purposes of granting ethics approval. It may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.
- ❖ The Form is focussed around AUTEC's ethical principles, which are in accordance with the *Guidelines for the approval of ethics committees* in New Zealand.

To respond to a question, please place your cursor in the space following the question and its notes and begin typing.

A. Project Information

A.1. *What is the title of the research?*

What are the social-ecological trade-offs of removing and preserving mangroves in New Zealand?

A.2. *Is this application for research that is being undertaken in stages?*

If the answer is 'Yes' please answer A.2.1 and the following sections, otherwise please answer A.3 and continue from there.

A.2.1. Does this application cover all the stages of the research?

Yes.Click here to enter text.

A.3. *Who is the applicant?*

Professor Andrea AlfaroClick here to enter text.

A.4. *Further information about the applicant.*

A.4.1. In which faculty, directorate, or research centre is the applicant located?

School of Science, Institute for Applied Ecology, Faculty of Health and Environmental Sciences

A.4.2. What are the applicant's qualifications?

BSc, MSc (Hons), PhD (Auckland)

A.4.3. What is the applicant's email address?

Andrea.alfaro@aut.ac.nz

A.4.4. At which telephone numbers can the applicant be contacted during the day?

Phone: +64 9 921 9999 ext 8197

A.5. *Research Instruments*

A.5.1. Which of the following does the research use:

☒ a written or electronic questionnaire or survey ☒ focus groups ☒ interviews
☐ observation ☐ participant observation ☐ ethnography ☐ photographs
☐ videos ☐ other visual recordings ☐ a creative, artistic, or design process
☐ performance tests
☐ some other research instrument (please specify)

Click here to enter text.

Please attach to this application form all the relevant research protocols. These may include: Indicative questions (for interviews or focus groups); a copy of the finalised questionnaire or survey in the format that it will be presented to participants (for a written or electronic questionnaire or survey); a protocol indicating how the data will be recorded (e.g. audiotape, videotape, note-taking) for focus groups or interviews (Note: when focus groups are being recorded, you will need to make sure there is provision for explicit consent on the Consent Form and attach to this Application Form examples of indicative questions or the full focus group schedule. Please note that there are specific confidentiality issues associated with focus groups that need to be addressed); a copy of the observation protocol that will be used (for observations); full information about the use of visual recordings of any sort, including appropriate protocols and consent processes; protocols for any creative, artistic, or design process; a copy of the protocols for the instruments and the instruments that will be used to record results if you will use some other research instrument.

A.5.2. Who will be transcribing or recording the data?

If someone other than the applicant or primary researcher will be transcribing the interview or focus group records or taking the notes, you will need to provide a confidentiality agreement with this Application Form.

Amrit Dencer-Brown (Primary Researcher)

Click here to enter text.

A.6. *Please provide a brief plain English summary of the research (300 words maximum).*

New Zealand mangroves are expanding seaward in some areas and are creating estuarine management issues. Polarity exists on attitudes towards this wetland ecosystem. The aim is to investigate the social-ecological trade-offs of removing and preserving mangroves in New Zealand. This is to be carried out in three stages. 1) Assimilation of existing social and ecological data on accepted resource consents in the Manukau (council records). 2) Semi-structured interviews with ecologists, iwi and community group members who have been previously consulted on the specific consents. 3. Rapid ecological assessments in removed and remaining mangroves to be compared with previous ecological assessments.

A.7. *Additional Research Information*

A.7.1. Is this research an intervention study?

NO

Is this Health and Disability Research? Yes ☒ No

NO

A.7.2. Does this research involve people in their capacity as consumers of health or disability support services, or in their capacity as relatives or caregivers of consumers of health or disability support services, or as volunteers in clinical trials (including, for the avoidance of doubt, bioequivalence and bioavailability studies)?

NO

B. The Ethical Principle of Research Adequacy

AUTEC recognises that different research paradigms may inform the conception and design of projects. It adopts the following minimal criteria of adequacy: the project must have clear research goals; its design must make it possible to meet those goals; and the project should not be trivial but should potentially contribute to the advancement of knowledge to an extent that warrants any cost or risk to participants.

B.1. *Is the applicant the person doing most of the research (the primary researcher)?*

NO

B.1.1. What is the name of the primary researcher if it is someone other than the applicant?

Amrit Dencer-Brown

B.1.2. What are the primary researcher's completed qualifications?

BSc (hons) Zoology, MSc Marine Biology

B.1.3. What is the primary researcher's email address?

An email address at which the primary researcher can be contacted is essential.

amritrules@hotmail.com

B.1.4. At which telephone numbers can the primary researcher be contacted during the day?

0274285236

B.2. *Is the primary researcher*

☐ an AUT staff member ☒ an AUT student

If the primary researcher is an AUT staff member, please answer B.2.1 and the following sections, otherwise please answer B.3 and continue from there.

B.2.1. In which faculty, directorate, or research centre is the primary researcher employed?

If the response to this section is the same as that already given to section A.4.1 above, please skip this section and go to section B.2.2.

Same as A.4.1

B.2.2. In which school or department is the primary researcher employed?

School of Science

B.3. *When the primary researcher is a student:*

B.3.1. What is their Student ID Number?

16910224

B.3.2. In which faculty are they enrolled?

Faculty of Health and Environmental Sciences

B.3.3. In which school, department, or Research Centre are they enrolled?

School of Science, Institute for Applied Ecology

B.4. *What is the primary researcher's experience or expertise in this area of research?*

Where the primary researcher is a student at AUT, please identify the applicant's experience or expertise in this area of research as well.

Amrit has a background in Marine Biology, her Master's thesis was conducted in the mangroves of Zanzibar and was primarily ecologically-based research. She has been working as a social science researcher in the UK prior to commencing her PhD at AUT. She has co-authored on a chapter regarding mangrove ecosystem services and has two papers at the review stage for social science journals involving pedagogical research. In her social science research, she worked closely with academics and students' alike conducting focus groups and interviews, transcribing data and disseminating results for reports for the University.

B.5. *Who is in charge of data collection?*

Amrit Dencer-Brown

B.6. *Who will interact with the participants?*

Amrit Dencer-Brown

B.7. *Is this research being undertaken as part of a qualification?*

YES

B.7.1. What is the name of the qualification?

PhD

B.7.2. In which institution will the qualification be undertaken?

AUT

B.8. *Details of Other Researchers or Investigators*

B.8.1. Will any other people be involved as researchers, co- investigators, or supervisors?

YES

B.8.1.1 What are the names of any other people involved as researchers, investigators, or supervisors?

Professor Simon Milne

B.8.1.2 Where do they work?

School of Hospitality and Tourism

B.8.1.3 What will their roles be in the research?

Secondary supervisor

B.8.1.4 What are their completed qualifications?

PhD Economic Geography

B.8.2. Will any research organisation or other organisation be involved in the research?

YES

B.8.2.1 What are the names of the organisations?

Auckland Council, Department of Conservation (DOC), Manukau Harbour Restoration Society, Forest and Bird, Ngāti Tamaoho Trust, Mangere-Otahu local board.

B.8.2.2 Where are they located?

Auckland Council, DOC and Forest and Bird (city branch) are based in Auckland city centre, MHRS in Onehunga, Mangere-Otahu local board in Mangere, Ngāti Tamaoho in Papakura (all Auckland region).

B.8.2.3 What will their roles be in the research?

Individuals of the organisations and trusts above who were involved in the resource consent hearings at Mangere Bridge, Pahurehure and Puhinui inlets will be identified from the resource consents and invited to attend a semi-structured interview regarding the consultation process of mangrove removals for these areas.

B.9. *Why are you doing this research and what is its aim and background?*

There are a lot of issues regarding the management of estuaries and coastal habitats in New Zealand, which have affected local communities as well as biodiversity of these ecosystems. Regional councils have come under pressure from local societies campaigning for the removal of large areas of mangrove habitat. How the ecology of particular sites is affected by different methods of tree removal has not been investigated in much detail in New Zealand (Auckland Regional Council, 2012).
There is a pressing need to understand the drivers for differing perceptions of mangrove ecosystems in New Zealand and how these drivers affect management decisions as well as subsequent consequences for the health of surrounding estuarine systems.

Overall Aim: This study aims to address the issues regarding mangrove expansion and removals by asking the research question: **What are the social-ecological trade-offs between removing and preserving mangroves in New Zealand?**
This research question will be addressed through the following aims and objectives:

AIM 1: To investigate societal views towards mangroves

Objective:

1. To conduct ethno-historic research on management practices of mangrove removal in Auckland, New Zealand, including qualitative information on perceptions and attitudes of removals through data gathering of resource consents.

This objective is to be addressed by conducting a systematic review and meta-ethnography through data gathering and processing of the current resource consent information held by Auckland Council. These records are publicly accessible and contain all of the reports, statements, court hearings and ecological assessments which were conducted in order for the resource consents to be granted. The following research questions will be asked for this aim:

- **What are the current consented removals (location, area to be removed) and what are the reasons behind each removal?**
- **What ecological assessments have been conducted prior to- and post- removal and what are the results of these?**
- **What stakeholders were involved with the resource consents and what opinions do they have on the removal?**

<u>AIM 2: To assess the current effectiveness of the consultation process for mangrove removal</u>

<u>Objectives:</u>

2. To interview ecologists, community group members and other individuals who have previously been spoken with and were present at resource consent hearings to assess how effective the consultation process was.

3. To ascertain what ecosystem services of mangroves are deemed important and the reasons why.

4. To identify knowledge gaps and actions to improve future consultation processes.

Upon completion of the data gathering and processing, semi-structured interviews will be carried out with the participants of the resource consents who were previously consulted. This is in order to assess whether the consultation process was effective and to ascertain the opinions of ecologists, community group members, local iwi and other individuals who were consulted. **Only the people who were previously consulted will be approached in order to retrospectively gather information on the removals which are taking place**. This is because the scope of the research must be manageable in the time period allowed. The following research questions will be addressed in this section:

- **What was the level of consultation and were opinions accurately portrayed?**
- **What ecosystem services are deemed as important and why?**
- **What else needed to be considered for an effective consultation process?**
- **What recommendations are there for future consents?**

<u>AIM 3: To assess the ecology of intact and recently removed areas of mangroves through conducting broad-based rapid ecological assessments</u>

<u>Objectives:</u>

5. To gather and quantify data from mangrove ecological assessments as provided by council resource consents prior to- and post- removal of mangroves.

6. To conduct ecological surveys and analyse data on biodiversity of mangrove sites (undisturbed and recently removed) and to draw comparisons with any previous ecological assessments conducted as indicated from resource consents.

7. To highlight gaps in current assessments and ecological monitoring to better inform sustainable management of coastal ecosystems.

The following research questions will be addressed in this section:

- **What ecological data was gathered prior to- and post- removal?**
- **What ecological data is missing?**
- **What are the relative abundances and richness of species in the mangroves at the sites?**
- **What needs to be monitored in the future?**

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B.10. *What are the potential benefits of this research to the participants, the researcher, and the wider community?*

Discussion about mangrove expansion will lead to a greater understanding about current estuarine management issues and has the potential for policy to be altered in order to improve the overall health of estuarine ecosystems in New Zealand. Understanding and presenting societal views on current mangrove management with the combination of ecological studies will promote the sustainable management of New Zealand's coastal ecosystems.

This research also allows for engagement with local Iwi who have been involved in recent consents for removal. The opinions and knowledge of previously consulted iwi regarding the value of mangroves has yet to be explored in the literature and is of utmost importance for New Zealand and indigenous communities world-wide.

B.11. *What are the theoretical frameworks or methodological approaches being used?*

The main framework will be loosely based on Ostrom's social-ecological systems (SES) framework (Ostrom, 2005, 2009; McGuiness & Ostrom, 2014). A mixed methods (Creswell, 2003) approach will be adopted throughout this study in order to obtain a holistic view which encompasses ecology, society and management. The first stage will be carried out using a parallel convergent design (Creswell, 2003). The collection of both qualitative and quantitative secondary data on recent mangrove resource consents will be obtained from publicly accessible council records. The second stage will be semi-structured interviews and will feed into the qualitative data collection. Qualitative data will be investigated and analysed using a general inductive approach (Thomas, 2006).Quantitative primary ecological data will be collected using standard biodiversity sampling techniques.

B.12. *How will data be gathered and processed?*

1. Secondary data will be gathered from the existing resource consents which are available at Auckland Council offices. These are publicly accessible records which the primary researcher has already had a brief look at and will be able to return and gather the data at any time. Qualitative data regarding perceptions and attitudes of individual ecologists, community group members and others will be taken down in excel and then imported into NVivo for thematic analysis. Quantitative ecological data from the resource consents will be recorded in excel also and then processed for statistical analysis in SPSS.

2. Semi-structured interviews will be conducted through gathering contact details of individuals consulted in resource consents and inviting them to attend a semi-structured interview. Interviews will be audio-recorded and transcripts typed out and then processed in NVivo for thematic analysis. The information here will be added to the already gathered secondary qualitative data from stage 1. All interviewees information will remain confidential and transcripts delivered back before the publication of any results.

3. Ecological data to be collected in the field does not require an ethical application. Land is public property and open access to everyone.

B.13. *How will the data be analysed?*

Please provide the statistical (for quantitative research) or methodological (for qualitative or other research) justification for analysing the data in this way.

Descriptive statistics will be generated for secondary quantitative data. Univariate statistical analysis will be carried out using IBM SPSS software and multi-variate analysis through PRIMER-e.

Qualitative data will be analysed through thematic coding, with a general inductive approach (Thomas, 2006). Coding will be inductive and thematic analysis is likely to be from a contextualist angle; which acknowledges the ways in which individuals make meaning of their experiences (with mangroves) and how the broader social context (leading to management decisions of removing mangroves) is related to those meanings (Braun & Clarke., 2006).

By examining the outcomes of the quantitative and qualitative results, explanations to particular statistically significant results have the potential to be explained/backed-up through the qualitative outcomes. Using a range of techniques will allow for a broader analysis of results, resulting in a holistic perspective to the research.

B.14. *Has any peer review taken place?*

YES

☐ AUT Competitive Grant ☐ External Competitive Research Grant
☐ PGR1 ☒ PGR2 ☒ PGR9 ☐ Independent Peer Review*

Optional exemplars for evidencing peer review are available from the Ministry of Health (HDEC) website (http://ethics.health.govt.nz/) or from the Forms section of the Research Ethics website ([http://aut.ac.nz/researchethics)](http://aut.ac.nz/researchethics)

C. General Project Details

C.1. *Likely Research Output*

C.1.1. What are the likely outputs of this research?

☒ a thesis ☐ a dissertation ☒ a research paper ☒ a journal article
☐ a book ☒ conference paper ☐ a documentary ☐ an exhibition
☐ a film ☐ some other artwork ☒ other academic publications or presentations
☐ Some other output, please specify

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C.2. *Research Location and Duration*

C.2.1. In which countries and cities/localities will the data collection occur?

All research will be conducted in New Zealand, specifically Auckland through Auckland Council and within three regions of the Manukau: Pahurehure, Mangere and Puhinui.

C.2.1.1 Exactly where will any face to face data collection occur?

Interviews with ecologists are likely to take place at either Auckland Council or AUT in a meeting room the primary researcher will book in advance. Other interviews with individuals from community groups will take place at local library meeting rooms, again booked in advance.

C.2.2. In which countries and cities/localities will the data analysis occur?

All data analysis will occur at The Institute for Applied Ecology, WU Building, Wakefield Street, Auckland.

C.2.3. When is the data collection scheduled to commence?

After the submission and acceptance of the primary researcher's PGR9 application (November 2016).

Secondary data collection to commence February 2017, primary data collection, March 2017.

C.3. *Research Participants*

C.3.1. Who are the participants?

Participants are members of local restoration groups, members of The Department of Conservation, Environmental consultants and ecologists for Auckland council, Forest and Bird, Auckland Park Rangers and individual iwi who have already been consulted on mangrove removals. Participants are to be identified from accessing council consents for recent (last 5 years) mangrove removals.

C.3.2. How many participants are being recruited for this research?

This depends upon the number of individuals who were consulted previously, likely 10 per resource consent, so approximately 30. (N.B. The qualitative data collection for this research has been scaled back and is now a small but important part of the overall study).

C.3.3. What criteria will be used to choose who to invite as participants?

People who have been actively involved in the resource consents (ecologists, iwi, community groups) will be contacted.

C.3.3.1 How will you select participants from those recruited if more people than you need for the study agree to participate?

This will not be an issue, only a small number of people from a variety of organisations will be participating as it is retrospective.

C.3.4. Will any people be excluded from participating in the study?

Exclusion criteria apply only to potential participants who meet the inclusion criteria. An exclusion criterion is any characteristic that ought to disqualify any potential participant from recruitment into the study. Consider exclusion criteria when there are heightened risks due to power differences in the relationship, recent injury, or other characteristics that might place potential participants at unreasonable risk of harms.

If the answer to this question is 'Yes' please answer C.3.4.1 and the following sections, otherwise please answer C.3.5 and continue from there.

C.3.4.1 What criteria will be used to exclude people from the study?

No-one under the age of 18 will be included in this process, therefore no permission from parents will be required.

C.3.4.2 Why is this exclusion necessary for this study?

This is not a survey to ascertain the wider public view on mangroves, therefore under 18's are not required for the research.

C.3.5. Recruitment of participants.

Please describe in detail the recruitment processes that will be used. If you will be recruiting by advertisement or email, please attach a copy to this Application Form

C.3.5.1 How will the initial contact with potential participants occur?

Through emailing and phoning the identified individuals from the resource consents, followed by a face-to-face meeting. As the resource consents are publicly available documents and the majority of individuals belong to organisations which are actively involved in mangrove management, for example Manukau Harbour Restoration Society, it is hoped that they will be interested in participation.

C.3.5.2 How will the contact details of potential participants be collected and by whom?

Through the council website, through contacts made already, through the resource consents all by the primary researcher, Amrit Dencer-Brown

C.3.5.3 How will potential participants be invited to participate?

Through email contact

C.3.5.4 How much time will potential participants have to consider the invitation?

One month

C.3.5.5 How will potential participants respond to the invitation?

Interviews will be arranged by email/telephone and then meeting in person.

C.3.5.6 How will potential participants give consent?

Signed consent form at interview

C.3.5.7 How and when will the inclusion criteria and exclusion criteria given in sections C.3.2 and C.3.3 be applied?

N/A

C.3.5.8 Will there be any follow up invitations for potential participants?

No, unless they are not happy with the transcript and would like to meet further to discuss.

D. Partnership, Participation and Protection

D.1. *How does the design and practice of this research implement the principle of Partnership in the interaction between the researcher and other participants?*

How will your research design and practice encourage a mutual respect and benefit and participant autonomy and ownership? How will you ensure that participants and researchers will act honourably and with good faith towards each other? Are the outcomes designed to benefit the participants and/or their social or cultural group? How will the information and knowledge provided by the participants be acknowledged?

Transparency from the outset is integral to the research. It is hoped that the outputs of this research will lead to effective catchment management decisions aimed at restoring health of coastal environments for the benefit of all communities within New Zealand. As all participation is voluntary, participants can drop out at any stage. Kai and koha will be provided at any meetings. All transcripts will be given back to participants until they are happy with the way their sentiments have been expressed. Nothing will be taken out of context or used to present individuals in particular ways. The researcher will remain respectful, unbias and honourable at all times. All information and knowledge will be acknowledged as deep gratitude in the thesis and any publications, posters and presentations. Invitations to attend any presentations will be offered and the researcher will remain in touch with all interviewees throughout the research process.

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D.2. ***How does the design and practice of this research implement the principle of Participation in the interaction between the researcher and other participants?***

What is the actual role of participants in your research project? Will participants be asked to inform or influence the nature of the research, its aims, or its methodology? Will participants be involved in conducting the research or is their principal involvement one of sharing information or data? Do participants have a formal role as stakeholders e.g. as the funders and/or beneficiaries of the research? What role will participants have in the research outputs (e.g. will they be asked to approve transcripts or drafts)?

The role of the participants is to speak about the existing consultation process involving the removal of mangroves in order to see how effective the current process is, and what things need to be improved. It is also for participants to identify which ecosystem services they believe mangroves have as a way to ascertain the perceptions of their ecological value. As the majority of people involved will be ecologists, there will be a large amount of ecological knowledge which has the opportunity to be recorded. In combination with the existing secondary ecological data and the primary data collection, the ecological value of mangroves will be assessed.

D.3. ***How does the design and practice of this research implement the principle of Protection in the interaction between the researcher and other participants?***

How will you actively protect participants from deceit, harm and coercion through the design and practice of your research? How will the privacy of participants and researchers be protected? How will any power imbalances inherent in the relationships between the participants and researchers be managed? How will any cultural or other diversity be respected?

The consent forms will clearly set out the research protocol and the intended outcomes of the research. Clarity and transparency will be maintained throughout the process, there will be no deceit, harm or coercion at any point and all participants have the option of withdrawing from the research at any stage, no data will be published without the consent of individuals involved. There is just the one primary researcher, however, all participants will remain anonymous unless they explicitly state otherwise. The researcher does not profess to know everything about the subject area and will approach the research process with humility, respect and honour towards all participants involved. Advice and consultation has been sought by advisors at AUT (Margaret Williams, Catherine Redmond and John Perrott) for how best to proceed in conversation with iwi who have been previously consulted.

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E. Social and Cultural Sensitivity (including the obligations of the Treaty of Waitangi)

E.1. *What familiarity does the researcher have with the social and cultural context of the participants?*

The researcher is in the midst of an in depth study of the history of Tamaki Makaurau to better understand the background of the people of New Zealand. In depth discussions have taken place with John Perrott and Margaret Williams about how to proceed with humility and respect. The researcher is very aware of social and cultural issues surrounding the management of the environment and what the Treaty of Waitangi says. The researcher is an ecologist and has been in contact with ecologists at the council regarding the study.

E.2. *What consultation has occurred?*

Research procedures should be appropriate to the participants. Researchers have a responsibility to inform themselves of, and take the steps necessary to respect the values, practices, and beliefs of the cultures and social groups of all participants. This usually requires consultation or discussion with appropriate people or groups to ensure that the language and research approaches being used are relevant and effective. Consultation should begin as early as possible when designing the project and should continue throughout its duration.

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members which is able to be accessed through the Research Ethics website. Researchers may also find Te Kaahui Maangai a directory of Iwi and Maaori organisations to be helpful. This may be accessed via the Te Puni Kookiri website (http://www.tkm.govt.nz/). As well as these documents, the Health Research Council has published Pacific Health Research Guidelines, and Guidelines on research involving children. (see http://www.hrc.govt.nz). There are also guidelines by various organisations about researching with other populations that researchers will find helpful.

Consultation with Maori Liaison at AUT, discussion face-to-face hui with a Makaurau Marae Maori Trust Kaitiaki and members of Ngati Tamaoho Trust, contact with Manakau Harbour Restoration Society, email exchanges with council board members, meeting organised with park rangers at Mangere.

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E.2.1. With whom has the consultation occurred?

Please provide written evidence that the consultation has occurred.

Kowhai Olsen:- Makaurau Maori Trust

Lucille Rutherfurd, Dennis Kirkwood, Gordan Katipa:- Ngati Tamaoho Trust

Janine Nilleson:- Ambury Park

E.2.2. How has this consultation affected the design and practice of this research?

The consultation has helped greatly with the way to approach iwi and explain research with humility and how best to proceed. The design is still the same, but setting up consultation from the beginning has really helped with the approach.

E.3. *Does this research target Māori participants?*

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members

If your answer is 'No', please go to section E.4 and continue from there. If you answered 'Yes', please answer the next question.

E.3.1. Which iwi or hapu are involved?

Initial contact has been made with Auckland kaitiaki from Mangere-Otahuhu at the recent Manukau Harbour Symposium. Kaitiaki from the hapu Ngati Tamoho (Lucie Rutherfurd) and Te Ahiwaru Waiohua (Kowhai Olsen) have said they would be willing to talk about the research study and have met the primary researcher in person. Contact details have been exchanged and kanohi ke ti kanohi have been arranged for November.

E.4. *Does this research target participants of particular cultures or social groups?*

AUTEC defines the phrase 'specific cultures or social groups' broadly. In section 2.5 of Applying for Ethics Approval: Guidelines and Procedures it uses the examples of Chinese mothers and paraplegics. This is to identify their distinctiveness, the first as a cultural group, the second as a social group. Other examples of cultural groups may be Korean students, Samoan husbands, Cook Islanders etc., while other examples of social groups may be nurse aides, accountants, rugby players, rough sleepers (homeless people who sleep in public places) etc. Please refer to Section 2.5 of AUTEC's Applying for Ethics Approval: Guidelines and Procedures (accessible in the Ethics Knowledge Base online via http://www.aut.ac.nz/about/ethics) and to the relevant Frequently Asked Questions section in the Ethics Knowledge Base.

If your answer is 'No', please go to section E.5 and continue from there. If you answered 'Yes', please answer the next question.

E.4.1. Which cultures or social groups are involved?

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E.5. *Does this research focus on an area of research that involves Treaty obligations?*

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members.

If your answer is 'No', please go to section E.6 and continue from there. If you answered 'Yes', please answer the next question.

E.5.1. Which treaty obligations are involved?

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E.6. *Will the findings of this study be of particular interest to specific cultures or social groups?*

If the answer is 'Yes' please answer E.6.1 and the following sections, otherwise please answer F.1 and continue from there.

E.6.1. To which iwi, hapū, culture or social groups will the findings be of interest?

As only those previously consulted on resource consents are to be approached, this research does not assume that the views recorded speak for all iwi in any way whatsoever. The information which will be discussed is regarding the current consultation process. It does not aim to interpret any worldview.

E.6.2. How will the findings be made available to these groups?

Iwi directly involved in the research will be kept in constant contact with throughout the research process through email, phone calls and kanohi ke ti kanohi. Any transcripts will be sent back for approval and any papers written will also be made available to all through the researcher. Presentations on findings will also be offered if people would like to attend.

F. Respect for the Vulnerability of Some Participants

"Vulnerable persons are those who are relatively (or absolutely) incapable of protecting their own interests. More formally, they may have insufficient power, intelligence, education, resources, strength, or other needed attributes to protect their own interests. Individuals whose willingness to volunteer in a research study may be unduly influenced by the expectation, whether justified or not, of benefits associated with participation, or of a retaliatory response from senior members of a hierarchy in case of refusal to participate may also be considered vulnerable." (Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants, World Health Organisation).

F.1. *Will your research involve any of the following groups of participants?*

If your research involves any of these groups of participants, please clearly indicate which ones and then answer F.2 and the following section, otherwise please answer G.1 and continue from there.

☐ people unable to give informed consent? ☐ your (or your supervisor's) own students?
☐ preschool children? ☐ children aged between five and sixteen years?
☐ legal minors aged between sixteen and twenty years?
☐ People lacking the mental capacity for consent?
☐ people in a dependent situation (e.g. people with a disability, or residents of a hospital, nursing home or prison or patients highly dependent on medical care)?
☐ people who are vulnerable for some other reason (e.g. the elderly, persons who have suffered abuse, persons who are not competent in English, new immigrants)? – please specify

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F.2. *How is respect for the vulnerability of these participants reflected in the design and practice of your research?*

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F.3. *What consultation has occurred to ensure that this will be effective?*

Please provide evidence of the consultation that has occurred.

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G. Informed and Voluntary Consent

G.1. *How will information about the project be given to potential participants?*

Consent forms as attached. Written consent in person for interviews.

G.2. *How will the consent of participants be obtained and evidenced?*

AUTEC requires consent to be obtained and usually evidenced in writing. A copy of the Consent Form which will be used is to be attached to this application. If this will not be the case, please provide a justification for the alternative approach and details of the alternative consent process. Please note that consent must be obtained from any participant aged 16 years or older. Participants under 16 years of age are unable to give consent, which needs to be given by their parent or legal guardian. AUTEC requires that participants under the age of 16 assent to their participation. When the nature of the research requires it, AUTEC may also require that consent be sought from parents or legal guardians for participants aged between 16 and

twenty years. For further information please refer to AUTEC's Applying for Ethics Approval: Guidelines and Procedures.

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G.3. *Will any of the participants have difficulty giving informed consent on their own behalf?*

Please consider physical or mental condition, age, language, legal status, or other barriers.

If the answer is 'Yes' please answer G.3.1 and the following sections, otherwise please answer G.4 and continue from there.

G.3.1. If participants are not competent to give fully informed consent, who will consent on their behalf?

Researchers are advised that the circumstances in which consent is legally able to be given by a person on behalf of another are very constrained. Generally speaking, only parents or legal guardians may give consent on behalf of a legal minor and only a person with an enduring power of attorney may give consent on behalf of an adult who lacks capacity.

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G.3.2. How will these participants be asked to provide assent to participation?

Whenever consent by another person is possible and legally acceptable, it is still necessary to take the wishes of the participant into account, taking into consideration any limitations they may have in understanding or communicating them.

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G.4. *Is there a need for translation or interpreting?*

If your answer is 'Yes', please provide copies of any translations with this application and any Confidentiality Agreement required for translators or interpreters.

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H. Respect for Rights of Privacy and Confidentiality

H.1. *How will the privacy and confidentiality of participants be protected?*

Please note that anonymity and confidentiality are different. For AUTEC's purposes, 'Anonymity' means that the researcher is unable to identify who the participant is in any given case. If the participants will be anonymous, please state how, otherwise, if the researcher will know who the participants are, please describe how the participants' privacy issues and the confidentiality of their information will be managed.

Interviews with members of iwi, community groups and ecologists will be kanohi ke ti kanohi however all interviewees will remain anonymous in the final report, unless they have explicitly indicated that they would like to be mentioned by name. All information about participants will remain confidential.

H.2. *How will individuals or groups be identified in the final report?*

If participants or groups will be identified, please state how this will happen, why, and how the participants will give consent.

Individuals and groups will not be identified specifically, only as 'ecologists', 'community members' and individuals belonging to iwi/hapu.

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H.3. *What information on the participants will be obtained from third parties?*

This includes use of third parties, such as employers or professional organisations, in recruitment.

None

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H.4. *How will potential participants' contact details be obtained for the purposes of recruitment?*

Publicly accessible information on resource consents available from the Auckland Council.

H.5. *What identifiable information on the participants will be given to third parties?*

None.

H.6. *Who will have access to the data during the data collection and analysis stages?*

The primary researcher only.

H.7. *Who will have access to the data after the findings have been produced?*

The primary researcher only and data will be kept then destroyed after a period of time (6 years as per AUT guidelines).

H.8. *Are there any plans for the future use of the data beyond those already described?*

NO.

H.8.1.1 If data will be stored in a database, who will have access to that information, how will it be used, for what will it be used, and how have participants consented to this?

No database storage.

H.8.1.2 Will any contact details be stored for future use and if so, who will have access to them, how will they be used, for what will they be used, and how have participants consented to this?

Only contact details of interviewees will be kept by the primary researcher to keep the participants informed of any publications and to remain in contact with them throughout the research process for transparency.

H.9. *Where will the data be stored once the analysis is complete?*

Please provide the exact storage location. AUTEC normally requires that the data be stored securely on AUT premises in a location separate from the consent forms. Electronic data should be downloaded to an external storage device (e.g. an external hard drive, a memory stick etc.) and securely stored. If you are proposing an alternative arrangement, please explain why.

Data and consent forms will be stored at the office of the applicant, WU building, AUT.

H.9.1. For how long will the data be stored after completion of analysis?

AUTEC normally requires that the data be stored securely for a minimum of six years, or ten years for health data. If you are proposing an alternative arrangement, please explain why.

6 years as per AUT guidelines

H.9.2. How will the data be destroyed?

If the data will not be destroyed, please explain why, identify how it will be safely maintained, and provide appropriate informed consent protocols.

Deleted off USB stick and the stick will be scrubbed also.

H.10. *Who will have access to the Consent Forms?*

The primary researcher and the applicant.

H.11. *Where will the completed Consent Forms be stored?*

Please provide the exact storage location. AUTEC normally requires that the Consent Forms be stored securely on AUT premises in a location separate from the data. If you are proposing an alternative arrangement, please explain why.

Office of applicantClick here to enter text.

H.11.1. For how long will the completed Consent Forms be stored?

AUTEC normally requires that the Consent Forms be stored securely for a minimum of six years, or ten years in the case of research involving health data. If you are proposing an alternative arrangement, please explain why.

6 years

H.11.2. How will the Consent Forms be destroyed?

If the Consent Forms will not be destroyed, please explain why.

The consent forms will be shredded after a time period and disposed of on AUT premises.

H.12. *Does your project involve the use of previously collected information or biological samples for which there was no explicit consent for this research?*

NO.

H.12.1. Who collected the data originally?

H.12.1.1 Why was the information originally collected?

H.12.1.2 For what purposes was consent originally given when the information was collected?

H.12.2. How will the data be accessed?

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H.13. *Does your project involve any research about organisational practices where information of a personal or sensitive nature may be collected and / or where participants may be identified?*

NO.

H.13.1. How will organisational permission be obtained and recorded?

H.13.2. Will the organisation know who the participants are?

H.13.3. How will the identity of the participants be kept confidential?

Click here to enter text.

I. Minimisation of risk

I.1. *Risks to Participants*

Please consider the possibility of moral, physical, psychological or emotional risks to participants, including issues of confidentiality and privacy, from the perspective of the participants, and not only from the perspective of someone familiar with the subject matter and research practices involved. Please clearly state what is likely to be an issue, how probable it is, and how this will be minimised or mitigated (e.g. participants do not need to answer a question that they find embarrassing, or they may terminate an interview, or there may be a qualified counsellor present in the interview, or the findings will be reported in a way that ensures that participants cannot be individually identified, etc.) Possible risks and their mitigation should be fully described in the Information Sheets for participants.

I.1.1. How much time will participants be required to give to the project?

Approximately thirty minutes for interviews.

I.1.2. What level of discomfort or embarrassment may participants be likely to experience?

Very minimal/none

I.1.3. In what ways might participants be at risk in this research?

No ways

I.1.4. In what ways are the participants likely to experience risk or discomfort as a result of cultural, employment, financial or similar pressures?

No ways

I.1.5. Will your project involve processes that are potentially disadvantageous to a person or group, such as the collection of information, images etc. which may expose that person/group to discrimination, criticism, or loss of privacy?

NO.

Click here to enter text.

I.1.6. Will your research involve collection of information about illegal behaviour(s) which could place the participants at current or future risk of criminal or civil liability or be damaging to their financial standing, employability, professional or personal relationships?

NO.

I.1.7. If the participants are likely to experience any significant discomfort, embarrassment, incapacity, or psychological disturbance, please state what consideration you have given to the provision of counselling or post-interview support, at no cost to the participants, should it be required.

N/AClick here to enter text.

I.1.8. Will any use of human remains, tissue or body fluids which does not require submission to a Health and Disability Ethics Committee occur in the research?

NO.

Click here to enter text.

I.1.9. Will this research involve potentially hazardous substances?

NO.

Click here to enter text.

I.2. *Risks to Researchers*

If this project will involve interviewing participants in private homes, undertaking research overseas, in unfamiliar cultural contexts, or going into similarly vulnerable situations, then a Researcher Safety protocol should be designed and appended to this application. This should identify simple and effective processes for keeping someone informed of the researcher's whereabouts and provide for appropriate levels of assistance.

I.2.1. Are the researchers likely to be at risk?

NO.

I.2.1.1 In what ways might the researchers be at risk and how will this be managed?

Click here to enter text.

I.3. *Risks to AUT*

I.3.1. Is AUT or its reputation likely to be at risk because of this research?

NO.

Click here to enter text.

I.3.2. Are AUT staff and/or students likely to encounter physical hazards during this project?

NO.

Click here to enter text.

J. Truthfulness and limitation of deception

J.1. *How will feedback on or a summary of the research findings be disseminated to participants (individuals or groups)?*

Please ensure that this information is included in the Information Sheet.

As in information sheets.

Click here to enter text.

J.2. *Does your research include any deception of the participants, such as non-disclosure of aims or use of control groups, concealment, or covert observations?*

NO.

J.2.1. Why is this deception necessary?

Click here to enter text.

J.2.2. How will disclosure and informed consent be managed?

Click here to enter text.

J.3. *Will this research involve use of a control group?*

NO.

J.3.1. How will the Control Group be managed?

Click here to enter text.

J.3.2. What percentage of participants will be involved in the control group?

Click here to enter text.

J.3.3. What information about the use of a control group will be given to the participants and when?

Click here to enter text.

K. Avoidance of Conflict of Interest

Researchers have a responsibility to ensure that any conflict between their responsibilities as a researcher and other duties or responsibilities they have towards participants or others is adequately managed. For example, academic staff members who propose to involve their students as participants in research need to ensure that no conflict arises between their roles as teacher and researcher, particularly in view of the dependent relationship between student and teacher, and of the need to preserve integrity in assessment processes. Likewise researchers have a responsibility to ensure that any conflict of interest between participants is adequately managed for example, managers participating in the same research as their staff.

K.1. *What conflicts of interest are likely to arise as a consequence of the researchers' professional, social, financial, or cultural relationships?*

No conflict of interest.

K.2. *What possibly coercive influences or power imbalances are there in the professional, social, financial, or cultural relationships between the researchers and the participants or between participants (e.g. dependent relationships such as teacher/student; parent/child; employer/employee; pastor/congregation etc.)?*

None.

K.3. *How will these conflicts of interest, coercive influences or power imbalances be managed through the research's design and practice and how will any adverse effects that may arise from them be mitigated?*

N/A

K.4. *Does your project involve payments or other financial inducements (including koha, reasonable contribution towards travel expenses or time, or entry into a modest prize draw) to participants?*

K.4.1. What form will the payment, inducement, or koha take?

Koha in the form of a gift voucher.

K.4.2. Of what value will any payment, gift or koha be?

30 dollars per person.

K.4.3. Will potential participants be informed about any payment, gift or koha as part of the recruitment process, and if so, why and how?

No, but koha will be given following interviews.

K.5. *Have any applications for financial support for this project been (or will be) made to a source external to*

NO.

K.5.1. Who is the external funder?

Click here to enter text.

K.5.2. What is the amount of financial support involved?

Click here to enter text.

K.5.3. How is/are the funder/s involved in the design and management of the research?

Click here to enter text.

K.6. ***Have any applications been (or will be) submitted to an AUT Faculty Research Grants Committee or other AUT funding entity?***

NO.

K.6.1. What financial support for this project is being provided (or will be provided) by an AUT Faculty Research Grants Committee or other AUT funding entity?

Click here to enter text.

K.6.2. What is the amount of financial support involved?

Click here to enter text.

K.6.3. How is/are the funder/s involved in the design and management of the research?

Click here to enter text.

K.7. ***Is funding already available, or is it awaiting decision?***

Click here to enter text.

K.8. ***Do the applicant or the researchers, investigators or research organisations mentioned in Part B of this application have any financial interests in the outcome of this project?***

NO. ***Are the participants expected to pay in any way for any services associated with this research?*** **NO.**

Click here to enter text.

L. Respect for Property

Researchers must ensure that processes do not violate or infringe legal or culturally determined property rights. These may include factors such as land and goods, works of art and craft, spiritual treasures and information.

L.1. ***Will this research impact upon property owned by someone other than the researcher?***

NO.

L.2. ***How do contexts to which copyright or Intellectual Property apply (e.g. social media, virtual worlds etc.) affect this research and how will this be managed?***

Particular attention should be paid to the legal and ethical dimensions of intellectual property. Care must be taken to acknowledge and reference the ideas of all contributors and others and to obtain any necessary permissions to use the intellectual property of others. Teachers and researchers are referred to AUT's Intellectual Property Policy for further guidance.

All people will be acknowledged in papers and addressed however they choose to be. All people will be thanked for their input and participation in the research process.

M. References

Please include any references relating to your responses in this application in the standard format used in your discipline.

Click here to enter text.

- Auckland Regional Council (2012). New Zealand's Mangroves. (Online). Available from: http://www.whaurivet.org.nz/wpcontent/uploads/2012/05/new_zealands_mangroves_summary.pdf Accessed on 9/05/16
- Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, 3 (2). pp. 77-101. ISSN 1478-0887 Available from: http://eprints.uwe.ac.uk/11735
- Chambers, R. (1981). Rapid rural appraisal: rationale and repertoire. *Public administration and development*, *1*(2), 95-106.
- Creswell, J. W. (2003). RESEARCH DESIGN.
- McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. *Ecology and Society*, *19*(2), 30.
- Ostrom, E. (2005). *Understanding Institutional Diversity*. Princeton Univ. Press, Princeton, NJ,
- Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419-422.
- Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American journal of evaluation*, *27*(2), 237-246.

N. Checklist

Please ensure all applicable sections of this form have been completed and all appropriate documentation is attached as incomplete applications will not be considered by AUTEC.

Have you discussed this application with your AUTEC Faculty Representative, the Executive Secretary, or the Ethics Coordinator?	***☒ Yes ☐ No***
Is this application related to an earlier ethics application? If yes, please provide the application number of the earlier application.	***☐ Yes ☒ No***
Are you seeking ethics approval from another ethics committee for this research? If yes, please identify the other committee.	☐ Yes ☒ No

Section A	Project information provided	☒
Section B	Research Adequacy information provided	☒
Section C	Project details provided	☒
Section D	Three Principles information provided	☒
Section E	Social and Cultural Sensitivity information provided	☒
Section F	Vulnerability information provided	☒
Section G	Consent information provided	☒
Section H	Privacy information provided	☒
Section I	Risk information provided	☒
Section J	Truthfulness information provided	☒
Section K	Conflict of Interest information provided	☒
Section L	Respect for Property information provided	☒
Section M	References provided	☒
Section N	Checklists completed	☒
Section O.1	Applicant and student declarations signed	☒

and 2	and dated	
Section O.3	Authorising signature provided	☒

Spelling and Grammar Check (please note that a high standard of spelling and grammar is required in documents that are issued with AUTEC approval)

Attached Documents (where applicable)

Participant Information Sheet(s)	☒
Consent Form(s)	☒
Questionnaire(s)	☐
Indicative Questions for Interviews or Focus Groups	☒
Observation Protocols	☐
Recording Protocols for Tests	☐
Advertisement(s)	☐
Researcher Safety Protocol	☐
Hazardous Substance Management Plan	☐
Any Confidentiality Agreement(s)	☐
Any translations that are needed	☐
Other Documentation	☐

O. Declarations

O.1. *Declaration by Applicant*

Please tick the boxes below.

☒ *The information in this application is complete and accurate to the best of my knowledge and belief. I take full responsibility for it.*

☒ *In conducting this study, I agree to abide by established ethical standards, contained in AUTEC's Applying for Ethics Approval: Guidelines and Procedures and internationally recognised codes of ethics.*

☒ *I will continue to comply with AUTEC's Applying for Ethics Approval: Guidelines and Procedures, including its requirements for the submission of annual progress reports, amendments to the research protocols before they are used, and completion reports.*

☒ *I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.*

16.01.17

Signature *Date*

O.2. *Declaration by Student Researcher*

Please tick the boxes below.

☒ *The information in this application is complete and accurate to the best of my knowledge and belief.*

☒ *In conducting this study, I agree to abide by established ethical standards, contained in AUTEC's Applying for Ethics Approval: Guidelines and Procedures and internationally recognised codes of ethics.*

☒ *I will continue to comply with AUTEC's Applying for Ethics Approval: Guidelines and Procedures, including its requirements for the submission of annual progress reports, amendments to the research protocols before they are used, and completion reports.*

☒ *I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.*

13/01/17

Signature *Date*

O.3. *Authorisation by Head of Faculty/School/Programme/Centre*

Please tick the boxes below.

☒*The information in this application is complete and accurate to the best of my knowledge and belief.*

☒ *In authorising this study, I declare that the applicant is adequately qualified to undertake or supervise this research and that to the best of my knowledge and belief adequate resources are available for this research.*

☒*I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's in rs for purposes relating to AUT's interests.*

Signature

____

____

I *Date* 2/2/17

Notes for submitting the completed application for review by AUTEC

- Please ensure that you are using the current version of this form before submitting your application.
- Please ensure that all questions on the form have been answered and that no part of the form has been deleted.
- Please provide ***one*** printed, single sided, A4, and signed copy of the application and all related documents.
- Please deliver or post to the AUTEC Secretariat, room WU406, fourth floor, WU Building, City Campus. The internal mail code is D-88. The courier address is 46 Wakefield Street, Auckland 1010. Alternatively, please hand the application to the Research Ethics Advisor in person at one of the DropIn sessions at any of the four campuses (http://www.aut.ac.nz/researchethics/resources/workshops-and-drop-inns).
- Applications should be submitted once they have been finalised. For a particular meeting it needs to have been received in the AUTEC Secretariat by 4 pm on the relevant agenda closing day [AUTEC's meeting dates are listed in the website at http://www.aut.ac.nz/researchethics]
- If sending applications by internal mail, please post them at least two days earlier to allow for any delay that may occur.
- Late applications will be placed on the agenda for the following meeting.

MINIMAL RISK CHECKLIST

Your application may be appropriate for an expedited review if it poses no more than minimal risk of harm to participants. To assist AUTEC's Secretariat to screen the application for assignment to the correct review pathway, please complete the following checklist:

Does the research involve any of the following?

ANONYMOUS SURVEY ASSESSMENT

		Yes	No
1	The collection of anonymous and non-sensitive survey/questionnaire data only. *(If YES is checked, the application may receive an expedited review if the data is from adults and poses no foreseeable risks to participants OR where any foreseeable risk is no more than inconvenience – no further questions on this checklist need be answered.)*	☐	☒

MINIMAL RISK ASSESSMENT[1]

		Yes	No
2	Participants who are unable to give informed consent (including children under 16 years old), or who are particularly vulnerable or in a dependent situation, (e.g. people with learning difficulties, over-researched groups, people in care facilities, or patients highly dependent on medical care)?	☐	☒
3	A reasonable expectation of causing participants physical pain beyond mild discomfort, or that experienced by the participants on an every-day basis, or any emotional discomfort, embarrassment, or psychological or spiritual harm, (e.g. asking participants to recall upsetting events)?	☐	☒
4	Research processes which may elicit information about any participant's involvement in illegal activities, or activities that represent a risk to themselves or others, (e.g. drug use or professional misconduct)?	☐	☒
5	Collection of any human tissue, blood or other samples, or invasive or intrusive physical examination or testing?	☐	☒
6	The administration of any drugs, medicines, supplements, placebo or non-food substances?	☐	☒
7	An intervention of any form of exercise, or other physical regime that is different to the participants' normal activities (e.g. dietary, sleep)?	☐	☒
8	Participants who are being asked to give information of a personal nature about their colleagues, employers, teachers, or coaches (or any other person who is in a power relationship with them), and where the identity of participants or their organisation may be inferred?	☐	☒
9	Any situation which may put the researcher at risk of harm? (E.g. gathering data in private homes)?	☐	☒
10	The use of previously collected biological samples or identifiable personal information for which there was no explicit consent for this research?	☐	☒
11	Any matters of commercially sensitive information?	☐	☒
12	Any financial interest in the outcome of the research by any member(s) of the research team?	☐	☒
13	People who are not giving consent to be part of the study, or the use of any deception, concealment or covert observations in non-public places, including social media?	☐	☒
14	Participants who are in a dependent or unequal relationship with any member(s) of the research team (e.g. where the researcher is a lecturer/ teacher/ health care provider/ coach/ employer/ manager/ or relative etc.) of any of the participants?	☐	☒

[1] If "No" is checked to all items 2-14, the application's status as Minimal Risk will be checked by the Secretariat, and may be forwarded to expedited review. Applications with more than Minimal Risk (any one "yes" to questions 2-14 above), and applications where the checklist is not completed will appear on AUTEC's next agenda.

9 March 2017

Andrea Alfaro
Faculty of Health and Environmental Sciences

Dear Andrea

Re Ethics Application: **17/34 What are the social-ecological trade-offs between removing and preserving mangroves in New Zealand**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 9 March 2020.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 9 March 2020;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 9 March 2020 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: amritrules@hotmail.com; Simon Milne

APPENDIX 2: Biodiversity data

Table 1a. PERMANOVA table of results showing significant differences of ecological indices within and between sites

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
SI	3	67.969	22.656	3.7085	**0.001**	996
ZO(SI)	8	170.41	21.301	3.4866	**0.001**	997
Res	24	146.62	6.1093			
Total	35	385				

Table 1b. SIMPER output of dissimilarity of abiotic variables between sites

Groups P & W
Average squared distance = 22.87

Variable	Group P Av.Value	Group W Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
TEMP	0.631	-0.688	3.69	0.82	16.12	16.12
SAPS	0.642	-0.00716	3.55	0.63	15.50	31.63
SEEDS	-0.419	-0.049	2.24	0.91	9.78	41.41
AGB	-0.676	0.317	2.19	0.79	9.56	50.97
HEIGHT	-0.556	0.432	2.1	0.91	9.17	60.14
PNEU	0.126	0.232	2.03	0.80	8.88	69.02
%LL	0.649	-0.485	1.92	1.03	8.39	77.41

Groups P & PU
Average squared distance = 23.56

Variable	Group P Av.Value	Group PU Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
SAPS	0.642	-0.251	2.93	0.55	12.42	12.42
CROWNSP	0.0686	-0.46	2.67	0.74	11.34	23.76
TEMP	0.631	-0.28	2.66	0.74	11.28	35.04
HEIGHT	-0.556	-0.24	2.59	1.02	10.98	46.02
SEEDS	-0.419	0.265	2.48	0.87	10.53	56.55
ADULTTREE	-0.432	0.0389	2.21	0.77	9.37	65.92
PNEU	0.126	-0.298	1.96	0.73	8.33	74.25

Groups W & PU
Average squared distance = 23.93

Variable	Group W Av.Value	Group PU Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
CROWNSP	0.378	-0.46	3.07	0.75	12.82	12.82
HEIGHT	0.432	-0.24	3.06	0.84	12.80	25.62
SEEDS	-0.049	0.265	2.62	0.75	10.95	36.57
%LL	-0.485	0.697	2.56	1.06	10.68	47.25
PNEU	0.232	-0.298	2.18	0.80	9.09	56.35
%CC	-0.223	-0.17	2.06	0.84	8.59	64.94
ADULTTREE	-0.487	0.0389	1.95	0.80	8.15	73.09

Groups P & M
Average squared distance = 23.30

Variable	Group P Av.Value	Group M Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
%LL	0.649	-0.861	3.13	1.09	13.42	13.42
SAPS	0.642	-0.384	3.04	0.55	13.05	26.47
AGB	-0.676	0.444	2.96	0.78	12.69	39.16
ADULTTREE	-0.432	0.88	2.74	0.89	11.74	50.90
%SALINITY	-0.3	0.275	2.13	0.85	9.15	60.05
%CC	-0.114	0.506	1.87	0.86	8.04	68.09
PNEU	0.126	-0.0592	1.87	0.74	8.01	76.10

Groups W & M
Average squared distance = 19.19

Variable	Group W Av.Value	Group M Av.Value	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
ADULTTREE	-0.487	0.88	2.57	1.11	13.40	13.40
%CC	-0.223	0.506	2.33	0.85	12.12	25.52
%SALINITY	-0.0613	0.275	2.09	0.67	10.92	36.44
TEMP	-0.688	0.337	2.05	1.18	10.68	47.11
PNEU	0.232	-0.0592	2.03	0.81	10.57	57.68
AGB	0.317	0.444	1.76	0.75	9.18	66.87
SEEDS	-0.049	0.203	1.65	0.74	8.59	75.45

Groups PU & M
Average squared distance = 23.04

Variable	Group PU Av.Value	Group M	Av.Sq.Dist	Sq.Dist/SD	Contrib%	Cum.%
%LL	0.697	-0.861	3.8	1.08	16.50	16.50
ADULTTREE	0.0389	0.88	2.64	1.00	11.47	27.97
%SALINITY	0.086	0.275	2.56	0.68	11.11	39.09
HEIGHT	-0.24	0.364	2.45	0.89	10.62	49.71
%CC	-0.17	0.506	2.35	0.87	10.19	59.90
CROWNSP	-0.46	0.0137	2.35	0.80	10.18	70.08

Table 2a. PERMANOVA output of arthropod community differences within and between mangrove sites.

Source	df	SS	MS	Pseudo-F	P(perm)	perms	P(MC)
SI	3	18569	6189.6	7.2948	**0.001**	999	0.001
ZO(SI)	8	13931	1741.4	2.0523	**0.002**	998	0.002
Res	24	20364	848.5				
Total	35	52864					

Table 2b. SIMPER output of arthropod abundance by sites

Groups P & W
Average dissimilarity = 51.83

Species	Group P Av.Abund	Group W Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	6.28	3.21	9.28	1.41	17.90	17.90
Hymenoptera_Formicidae_Technomyrmex_jocosus	5.25	7.45	7.12	1.31	13.74	31.64
Coleoptera_coccinellidae_Halmus_Chalybeus	1.70	0.56	3.11	1.53	6.00	37.63
Coleptera_curculionidae_Alloprocas_niger	1.43	1.58	2.96	1.31	5.71	43.34
Diptera_Tipulidae_A	1.34	1.59	2.72	1.40	5.25	48.59
Hymenoptera_Vespidae_Vespula_vulgaris	1.13	0.00	2.55	1.63	4.91	53.50
Araneae_Salticidae_tritespp.	1.47	0.95	2.53	1.46	4.89	58.39
Hymenoptera_Apidae_Apis_mellifera	1.12	0.00	2.35	0.78	4.53	62.92
Diptera_Calliphoridae_Lucilia_sericata	1.08	0.00	2.22	0.68	4.28	67.20
Coleptera_tenebrionidae_artystonaspp	0.52	0.81	1.67	1.04	3.22	70.42

Groups P & PU
Average dissimilarity = 48.90

Species	Group P Av.Abund	Group PU	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	6.28	4.54	6.72	1.15	13.75	13.75
Hymenoptera_Formicidae_Technomyrmex_jocosus	5.25	7.19	5.79	1.13	11.84	25.59
Coleoptera_coccinellidae_Halmus_Chalybeus	1.70	1.53	3.23	1.13	6.61	32.20
Diptera_Tipulidae_A	1.34	0.00	3.02	1.37	6.17	38.37
Araneae_Salticidae_tritespp.	1.47	0.46	2.67	1.58	5.45	43.82
Hymenoptera_Vespidae_Vespula_vulgaris	1.13	0.00	2.55	1.63	5.21	49.03
Hymenoptera_Apidae_Apis_mellifera	1.12	0.00	2.35	0.78	4.80	53.83
Diptera_Calliphoridae_Lucilia_sericata	1.08	0.00	2.22	0.68	4.54	58.37
Coleoptera_cerambycidae_A	0.31	1.07	2.22	1.12	4.53	62.90
Coleptera_curculionidae_Alloprocas_niger	1.43	1.48	2.10	1.42	4.30	67.20
Coleptera_tenebrionidae_artystonaspp	0.52	0.24	1.38	1.10	2.83	70.03

Groups W & PU
Average dissimilarity = 48.79

Species	Group W Av.Abund	Group PU Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%

Crustacea_isopoda_Oniscidea_Oniscus_asellus	3.21	4.54	9.84	1.27	20.17	20.17
Hymenoptera_Formicidae_Technomyrmex_jocosus	7.45	7.19	5.77	1.43	11.82	31.99
Diptera_Tipulidae_A	1.59	0.00	3.90	1.47	8.00	39.99
Coleoptera_coccinellidae_Halmus_Chalybeus	0.56	1.53	3.72	0.92	7.62	47.61
Coleptera_curculionidae_Alloprocas_niger	1.58	1.48	3.01	1.67	6.18	53.79
Coleoptera_cerambycidae_A	0.24	1.07	2.72	1.03	5.57	59.36
Araneae_Salticidae_tritespp.	0.95	0.46	2.39	1.02	4.89	64.25
Coleptera_tenebrionidae_artystonaspp	0.81	0.24	2.18	1.00	4.47	68.72
Coleoptera_curculionidae_Adel_crenatus	0.00	0.62	1.49	0.87	3.05	71.77

Groups P & M

Average dissimilarity = 58.40

Species	Group P Av.Abund	Group M Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	6.28	1.81	10.64	1.65	18.22	18.22
Hymenoptera_Formicidae_Technomyrmex_jocosus	5.25	7.11	6.83	1.27	11.70	29.92
Coleoptera_cerambycidae_A	0.31	2.66	5.27	2.71	9.02	38.94
Coleoptera_coccinellidae_Halmus_Chalybeus	1.70	3.62	4.68	1.23	8.01	46.95
Diptera_Tipulidae_A	1.34	0.00	3.09	1.37	5.29	52.24
Coleptera_curculionidae_Alloprocas_niger	1.43	0.17	3.05	1.35	5.22	57.46
Araneae_Salticidae_tritespp.	1.47	0.64	2.87	1.77	4.92	62.38
Lepidoptera_Crambidae_Orocrambus_flexuosellus	0.32	0.98	2.70	0.45	4.62	67.00
Hymenoptera_Vespidae_Vespula_vulgaris	1.13	0.00	2.61	1.64	4.46	71.46

Groups W & M

Average dissimilarity = 56.53

Species	Group W Av.Abund	Group M Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	3.21	1.81	8.47	1.18	14.99	14.99
Coleoptera_coccinellidae_Halmus_Chalybeus	0.56	3.62	8.04	1.79	14.22	29.21
Hymenoptera_Formicidae_Technomyrmex_jocosus	7.45	7.11	6.48	1.25	11.47	40.68
Coleoptera_cerambycidae_A	0.24	2.66	6.44	2.40	11.40	52.07
Diptera_Tipulidae_A	1.59	0.00	4.00	1.48	7.08	59.15
Coleptera_curculionidae_Alloprocas_niger	1.58	0.17	3.86	1.24	6.83	65.98
Araneae_Salticidae_tritespp.	0.95	0.64	2.77	1.11	4.90	70.88

Groups PU & M

Average dissimilarity = 47.44

Species	Group PU Av.Abund	Group M Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	4.54	1.81	9.93	1.35	20.94	20.94
Coleoptera_coccinellidae_Halmus_Chalybeus	1.53	3.62	6.75	1.56	14.22	35.16
Hymenoptera_Formicidae_Technomyrmex_jocosus	7.19	7.11	5.66	1.28	11.94	47.10
Coleoptera_cerambycidae_A	1.07	2.66	4.86	1.62	10.24	57.34
Coleptera_curculionidae_Alloprocas_niger	1.48	0.17	3.57	2.56	7.53	64.87
Lepidoptera_Crambidae_Orocrambus_flexuosellus	0.00	0.98	2.48	0.35	5.24	70.11

Table 2c. SIMPER output of arthropod abundance dissimilarity by mangrove zone

Groups 1 & 2
Average dissimilarity = 52.51

Species	Group 1 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	2.17	4.55	9.79	1.31	18.64	18.64
Hymenoptera_Formicidae_Technomyrmex_jocosus	7.03	6.74	7.13	1.31	13.58	32.22
Coleoptera_coccinellidae_Halmus_Chalybeus	2.04	1.62	3.99	1.22	7.60	39.82
Coleoptera_cerambycidae_A	0.74	1.04	3.14	1.02	5.98	45.81
Diptera_Tipulidae_A	0.51	1.16	2.93	1.10	5.57	51.38
Coleptera_curculionidae_Alloprocas_niger	1.15	1.30	2.87	1.35	5.47	56.85
Araneae_Salticidae_tritespp.	0.80	1.12	2.84	1.25	5.40	62.25
Lepidoptera_Crambidae_Orocrambus_flexuosellus	0.74	0.10	2.00	0.33	3.81	66.06
Hymenoptera_Apidae_Apis_mellifera	0.76	0.00	1.57	0.56	2.99	69.06
Coleptera_tenebrionidae_artystonaspp	0.25	0.54	1.46	0.76	2.78	71.84

Groups 1 & 3
Average dissimilarity = 53.33

Species	Group 1 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	2.17	5.16	10.14	1.47	19.02	19.02
Hymenoptera_Formicidae_Technomyrmex_jocosus	7.03	6.49	6.86	1.48	12.87	31.88
Coleoptera_coccinellidae_Halmus_Chalybeus	2.04	1.89	5.10	1.13	9.56	41.44

Coleoptera_cerambycidae_A	0.74	1.44	3.57	1.19	6.69	48.13
Coleptera_curculionidae_Alloprocas_niger	1.15	1.05	2.76	1.22	5.18	53.31
Lepidoptera_Crambidae_Orocrambus_flexuosellus	0.74	0.14	2.01	0.34	3.77	57.08
Araneae_Salticidae_tritespp.	0.80	0.73	1.87	1.24	3.50	60.58
Diptera_Tipulidae_A	0.51	0.53	1.74	0.97	3.27	63.84
Hymenoptera_Apidae_Apis_mellifera	0.76	0.08	1.63	0.61	3.06	66.90
Diptera_Calliphoridae_Lucilia_sericata	0.45	0.36	1.50	0.53	2.81	69.71
Araneae_Desidae_harpona (harpona not recognised)	0.30	0.34	1.33	0.64	2.50	72.21

Groups 2 & 3
Average dissimilarity = 44.46

Species	Group 2 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Crustacea_isopoda_Oniscidea_Oniscus_asellus	4.55	5.16	7.75	1.17	17.43	17.43
Hymenoptera_Formicidae_Technomyrmex_jocosus	6.74	6.49	4.96	1.49	11.16	28.59
Coleoptera_coccinellidae_Halmus_Chalybeus	1.62	1.89	4.51	1.09	10.15	38.73
Coleoptera_cerambycidae_A	1.04	1.44	3.44	1.29	7.73	46.47
Coleptera_curculionidae_Alloprocas_niger	1.30	1.05	2.93	1.25	6.58	53.05
Diptera_Tipulidae_A	1.16	0.53	2.87	1.05	6.45	59.50
Araneae_Salticidae_tritespp.	1.12	0.73	2.71	1.27	6.09	65.59
Coleptera_tenebrionidae_artystonaspp	0.54	0.39	1.58	0.83	3.56	69.15
Araneae_Desidae_harpona (harpona not recognised)	0.21	0.34	1.22	0.58	2.73	71.88

Table 2d. Arthropod abundance post-hoc tests between sites

Groups	t	P(perm)	perms	P(MC)
P, W	2.2042	0.002	999	0.004
P, PU	2.5688	0.001	997	0.001
P, M	3.5221	0.001	999	0.001
W, PU	1.9052	0.011	999	0.013
W, M	3.0191	0.001	998	0.001
PU, M	2.4624	0.001	999	0.001

Table 3a. Step-wise regression DistLM output for ecological indices driving arboreal arthropod community composition patterns.

Variable	AICc	SS(trace)	Pseudo-F	P	Prop.	Cumul.	res.df
+ADULTTREE	263.57	4556.9	3.2121	0.008	0.086319	0.086319	
+HEIGHT	262.51	4404.9	3.3165	0.006	0.08344	0.16976	
+CROWNSP	262.09	3468.7	2.7501	0.013	0.065705	0.23546	

BEST SOLUTION

AICc	R^2	RSS	No.Vars	Selections
262.09	0.23546	40361	3	6-8

Table 3b. Margelef's species richness differences between mangrove sites.

Diversity indice	***P value***	***Pairwise comparisons and t value***
Species Richness Index	0.008	P,W (t=2.97)
	0.005	P,PU (t=3.92)
	0.004	P,M (t=4.16)

Table 4. List of insect and spider species identified and presence at sites (coloured cells)

	Wai	Pahure	Puh	Mang
Coleoptera_cerambycidae_A	■	■	■	■
Coleoptera_cerambycidae_B	■			
Coleoptera_coccinellidae_Halmus_Chalybeus	■	■	■	■
Coleoptera_coccinellidae_B	■	■		
Coleptera_tenebrionidae_artystonaspp	■	■	■	
Coleoptera_tenebrionidae_amargymusspp	■	■		
Coleptera_curculionidae_Alloprocas_niger	■	■	■	■
Coleoptera_curculionidae_Alloprochus_B	■		■	
Coleoptera_curculionidae_Adel_crenatus			■	
Coleoptera_anthribidae_Androporus_discedens			■	
Coleoptera_oedemeridae_Parisopalpus_nigronotatus		■		
Coleoptera_Elateridae_Conoderus_exsul		■		
Hemiptera_coccidae_Ceroplastes_sinensis	■	■		
Hemiptera_cicadidae_Amphisalta_zealandica		■		
Hymenoptera_Formicidae_Technomyrmex_jocosus	■	■	■	■
Hymenoptera_Formicidae_Mariella_abstinens			■	
Hymenoptera_Vespidae_Polistes_chinensis			■	
Hymenoptera_icheumonidaespp	■			
Hymenoptera_Apidae_Apis_mellifera		■		
Hymenoptera_Vespidae_Vespula_vulgaris	■	■		
Hymenoptera_Apidae_Bombus_terrestris		■		
Diptera_Tipulidae_A	■	■	■	
Diptera_Tipulidae_B			■	
Diptera_Chironimidae_Chironimus_Zealandicus	■	■		
Diptera_Calliphoridae_Lucilia_sericata		■		
Diptera_Sarcophagidae_Janita_crassipalpis			■	
Diptera_Culicidae_culexspp		■		
Lepidoptera_Crambidae_Orocrambus_flexuosellus		■		
Lepidoptera_Pieridae_Pieris_rapae	■	■		
Lepidoptera_Lycaena_salustius			■	
Diplopoda_unknownspp.	■			
Crustacea_isopoda_Oniscidea_Oniscus_asellus	■	■	■	■
Blattodea_Blattoidea_Blattidaespp	■		■	
Neuroptera_Coniopteryginae_Crytoscenea_australiensis		■		
Araneae_Desidae_Badumna_longinqua		■		
Araneae_Salticidae_a(imm)	■	■	■	
Araneae_Theridiidae_a(imm)	■		■	■
Araneae_Pisauridae_Dolomedes_minor		■		
Araneae_Salticidae_tritespp.	■	■	■	■
Araneae_Salticidae_b	■			

Araneae_Linyphiidae_a				
Araneae_Araneidae_Eriophora_pustulosa				
Araneae_Theridiidae_Phoroncidiaspp				
Araneae_Araneidae_Celaenia_excavata				
Araneae_Theridiidae_Cryptachaea_verculata				
Araneae_Araneidae_Acroaspis_decorosa				
Araneae_Linyphiidae_b				
Araneae_Desidae_harpona				
Araneae_Thomisidae_Sidymella_longipes				

APPENDIX 3A (i). Questions for semi-structured interviews

Theme 1: Presence of mangroves in New Zealand

- Do you think mangroves are part of the natural landscape in New Zealand?
- What are your opinions on mangrove presence in New Zealand (in general) and why?
- What are your opinions on mangrove presence in Pahurehure inlet 2/Mangere/Puhinui/Waimahia inlets and are these different to those above? (If so, why?)

Theme 2: Importance of mangroves in New Zealand

- Do you believe mangroves in New Zealand (in general) have an important role in coastal ecosystems?
- Do you think that mangroves have an important role in the coastal ecology of Pahurehure inlet 2/Mangere/Puhinui/Waimahia inlets? If so, why? If not, why?
- What coastal habitats do you value the most and why?

Theme 3: Expansion of mangroves

- Do you think mangroves have expanded, remained the same in area or retracted (at Pahurehure inlet 2/Mangere/ Puhinui /Waimahia inlets)?
- Why do you think mangroves have expanded/remained the same/retracted in these areas?
- What effects do you think this has had on the ecology of these areas?

Theme 4: Current and future consultation process

- What was the level of consultation you had for the resource consent(s)?
- What was your role (if any) in the resource consent hearing for Pahurehure Inlet 2?
- Were your opinions accurately portrayed in the hearing/written report you submitted (if applicable)?
- What needs to be improved in the future in terms of the consent process?

Theme 5: Mangrove management

- What are your opinions on current mangrove management? At Pahurehure inlet 2/Mangere/Puhinui/Waimahia inlets? In New Zealand as a whole?
- Do you think anything needs to be done regarding the presence of mangroves at Pahurehure inlet 2/Mangere/Puhinui/Waimahia inlets? In New Zealand as a whole?
- What (if any) management recommendations do you have?
- What do you think the future holds for coastal environments in Pahurehure Inlet 2/Mangere/Puhinui/Waimahia inlets in terms of balancing human interest and the health of our estuaries and open water?

APPENDIX 3A(ii). Coding framework and definitions

CODE	DEFINITION
FRAGMENTATION	Reference to fragmentation of coastal landscape and mangroves
MITIGATION	Efforts to reduce the negative efforts of mangrove removal
PRESERVATION	Reference to preservation of mangrove ecosystems
REMOVAL	Reference to the removal of mangrove ecosystems
ATTITUDE	
Negative	A pro-mangrove removal or anti-preservation sentiment expressed
Neutral	Neither pro- nor- anti- preservation sentiment expressed
Positive	A pro-preservation and anti-removal sentiment expressed
MANAGEMENT	
Best Practice	Mention of good management and best practices of the coastal area, including mangroves
Catchment mismanagement	Mention of bad management of the coastal area, including mangroves
Monitoring	Reference to physical or ecological monitoring of mangrove either pre- or post- removal
Recommendations	Suggestions for improvement of mangrove management
PERCEPTION	Either a point of view that mangroves do not possess positive ecological and socio-cultural qualities or that they do.
LONG-TERM	Reference to the long-term issues with mangrove removal or thinking long-term

	for sustainability
SHORT-TERM FIX	Reference to immediate alteration of the coastal landscape including mangroves
OCCUPATION	Any reference to the job of the participant and how it relates to their opinions towards mangroves
ANTHROPOGENIC FACTORS	
Contamination	Reference to mangroves holding or containing nutrients or heavy metals from the land
Development	Mention of development of the coastal landscape which has altered mangroves
Sedimentation	Reference to how sedimentation and sediment affect mangroves
Urbanisation	Mention of urban growth and development affecting mangroves
EXPANSION	Reference to the expansion of mangroves at the sites
ECOLOGICAL VALUE	
Adaptation	How mangroves have adapted or adaptations of mangroves to the euhaline conditions
Biodiversity	Mention of whether mangroves contain high biodiversity or low biodiversity
Displacement	Mention of mangroves displacing other habitats for example rush marsh or mudflat
Habitats	Relationship of other habitats to mangroves of relationship of habitats to participant
Indigenous	Mangroves as a native species
Species	Reference to particular species living within mangroves at the sites or in general
ECOSYSTEM SERVICES	

Recreation	Recreation use of the coast including or without mangroves
Sediment-fixing	Properties of mangroves as fixing sediment
Water quality	Properties of mangroves as filtering water or general issues of water quality in the coastal environment
ECONOMIC VALUE	
Expense	Reference to the cost of mangrove removal
Community investment	Communities paying for the removal of mangroves
Funding	Reference to any funding given for mangrove removal
Property Value	Reference to mangrove removal increasing house values
SOCIAL VALUE	
Community aspirations	The wants and wishes of the local communities for the coast
Environmental advocacy	Fighting for the right for mangroves to remain
Equality	Equal rights for all community members
Justice	Doing the right thing for the coast
Participation	Volunteering or participating in the removal of mangroves
Personal experience	Relationship to mangroves based on experience
Political aspirations	Reference to politics and mangrove removal
Consultation and engagement	Mention of the consultation process and engagement with the removal activities

APPENDIX 3B): Ecosystem and issues data

Table 1. PERMANOVA output of pairwise comparisons between occupations and ranking of mangrove ecosystem services.

PAIR-WISE TESTS

Term 'OC'

Groups	t	P(perm	Unique perms
K, IE	1.2171	0.298	36
K, CG	2.3898	0.105	10
K, AC	1.0682	0.386	28
K, CO	0.8862	0.371	21
K, PR	1.118	0.632	3
K, LB	1.2682	0.332	3
IE, CG	**2.9361**	**0.011**	**120**
IE, AC	1.1864	0.197	780
IE, CO	**1.5132**	**0.023**	**547**
IE, PR	1.2247	0.208	36
IE, LB	**2.1407**	**0.03**	**36**
IE, IP	0.97551	0.531	36
CG, AC	**3.1779**	**0.014**	**84**
CG, CO	**2.305**	**0.016**	**56**
CG, PR	2.1164	0.104	10
CG, LB	1.7255	0.1	10
CG, IP	1.7203	0.088	10
AC, CO	**1.5761**	**0.011**	**408**
AC, PR	1.2385	0.241	28
AC, LB	**2.2448**	**0.035**	**28**
AC, IP	1.0184	0.533	28
CO, PR	1.2113	0.288	21
CO, LB	1.5638	0.151	21
CO, IP	0.68861	0.804	21
PR, LB	1.1151	0.682	3
PR, IP	0.65615	1	3
LB, IP	0.86178	0.659	3

Table 2. SIMPER output for significant pair comparisons of dissimilarity in rating of mangrove ecosystem services

Groups IE & LB

Average dissimilarity = 26.90

	Group IE	Group LB				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Carbon storage capacity	1.64	0.00	4.04	6.30	15.03	15.03
Medicinal properties	0.29	1.50	2.88	1.87	10.72	25.75
Food sources	1.64	1.00	2.64	1.35	9.81	35.56
Water quality maintenance	1.62	0.71	2.56	1.27	9.50	45.07
Fish habitat	1.28	1.00	2.52	1.40	9.37	54.44
Supporting offshore and nearshore fisheries	1.37	0.50	2.34	1.71	8.70	63.14
Nutrient retention	1.37	1.50	1.62	1.23	6.02	69.15
Source of wood/fuel/building materials	0.71	1.37	1.53	1.07	5.68	74.83

Groups IE & CG

Average dissimilarity = 25.65

	Group IE	Group CG				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Medicinal properties	0.29	1.05	2.43	1.38	9.47	9.47
Cultural value	1.38	0.80	2.25	1.32	8.75	18.23
Sediment retention	1.85	1.00	2.23	5.18	8.68	26.90
Nutrient retention	1.37	0.91	2.22	1.16	8.65	35.56
Storm buffering	1.81	1.00	2.13	5.12	8.29	43.85
Wildlife habitat	1.72	1.00	1.89	4.80	7.35	51.20
Supporting offshore and nearshore fisheries	1.37	1.00	1.69	1.69	6.61	57.81
Food sources	1.64	1.00	1.68	4.24	6.53	64.34
Fish habitat	1.28	1.00	1.48	1.55	5.78	70.12

Groups CG & AC

Average dissimilarity = 27.19

	Group CG	Group AC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nutrient retention	0.91	1.49	2.29	1.15	8.41	8.41
Cultural value	0.80	1.58	2.23	1.29	8.21	16.61
Wildlife habitat	1.00	1.82	2.07	5.52	7.61	24.22
Storm buffering	1.00	1.82	2.06	6.26	7.58	31.80
Medicinal properties	1.05	0.80	1.97	1.24	7.24	39.04
Sediment retention	1.00	1.78	1.95	8.33	7.16	46.21
Fish habitat	1.00	1.72	1.78	3.00	6.56	52.76
Carbon storage capacity	1.14	1.82	1.73	2.68	6.38	59.14
Recreational value (local)	1.00	1.63	1.59	3.49	5.85	64.99
Source of wood/fuel/building materials	0.67	0.40	1.55	1.22	5.70	70.69

Groups IE & CO

Average dissimilarity = 20.03

Species	Group IE Av.Abund	Group CO Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Water quality maintenance	1.62	1.20	2.21	1.16	11.05	11.05
Nutrient retention	1.37	1.15	2.17	1.10	10.83	21.88
Carbon storage capacity	1.64	1.03	2.04	1.01	10.20	32.07
Supporting offshore and nearshore fisheries	1.37	1.55	1.83	1.01	9.13	41.20
Fish habitat	1.28	1.95	1.65	1.02	8.24	49.44
Cultural value	1.38	1.32	1.50	0.80	7.50	56.94
Source of wood/fuel/building materials	0.71	1.05	1.46	1.21	7.30	64.25
Flood and water flow control	1.63	1.49	1.40	0.79	6.98	71.23

Groups CG & CO

Average dissimilarity = 34.86

Species	Group CG Av.Abund	Group CO Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sediment retention	1.00	1.60	2.73	5.08	7.83	7.83
Medicinal properties	1.05	0.00	2.72	1.30	7.81	15.64
Water quality maintenance	1.14	1.20	2.71	2.71	7.77	23.41
Supporting offshore and nearshore fisheries	1.00	1.55	2.60	3.94	7.45	30.85
Nutrient retention	0.91	1.15	2.60	1.25	7.45	38.30
Fish habitat	1.00	1.95	2.57	4.58	7.37	45.67
Food sources	1.00	1.89	2.44	3.78	6.99	52.66
Wildlife habitat	1.00	1.89	2.44	3.78	6.99	59.65
Storm buffering	1.00	1.44	2.31	3.27	6.63	66.28
Carbon storage capacity	1.14	1.03	2.29	1.69	6.57	72.85

Groups AC & CO

Average dissimilarity = 21.28

	Group AC	Group CO				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Carbon storage capacity	1.82	1.03	2.15	1.00	10.08	10.08
Water quality maintenance	1.65	1.20	2.12	1.11	9.95	20.03
Nutrient retention	1.49	1.15	2.07	0.98	9.74	29.77
Source of wood/fuel/building materials	0.40	1.05	1.82	1.33	8.55	38.32
Supporting offshore and nearshore fisheries	1.27	1.55	1.79	1.11	8.40	46.72
Medicinal properties	0.80	0.00	1.76	1.30	8.29	55.02
Cultural value	1.58	1.32	1.48	0.91	6.95	61.97
Flood and water flow control	1.65	1.49	1.43	0.82	6.71	68.68
Sediment retention	1.78	1.60	1.36	0.75	6.39	75.06

Groups AC & LB

Average dissimilarity = 27.59

Species	Group AC Av.Abund	Group LB Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Carbon storage capacity	1.82	0.00	4.31	7.62	15.61	15.61
Water quality maintenance	1.65	0.71	2.56	1.33	9.28	24.89
Fish habitat	1.72	1.00	2.54	1.22	9.22	34.11
Food sources	1.52	1.00	2.49	1.34	9.04	43.15
Source of wood/fuel/building materials	0.40	1.37	2.41	1.82	8.74	51.89
Supporting offshore and nearshore fisheries	1.27	0.50	2.11	1.67	7.64	59.53
Medicinal properties	0.80	1.50	1.90	1.32	6.89	66.43
Nutrient retention	1.49	1.50	1.62	1.32	5.88	72.31

Table 3. PERMANOVA output of pairwise comparisons between occupations and rating of mangrove issues

PAIR-WISE TESTS

Term 'OC'

Groups	t	P(perm)	Unique perms
IE, CG	**1.8986**	**0.019**	**120**
IE, AC	**1.7606**	**0.005**	**762**
IE, CO	1.4945	0.051	579
IE, PR	1.1245	0.281	36
IE, LB	1.5069	0.105	36
IE, IP	1.2368	0.199	36
IE, K	0.65231	0.743	8
CG, AC	**2.5778**	**0.011**	**84**
CG, CO	**2.1502**	**0.019**	**56**
CG, PR	1.5443	0.108	10
CG, LB	1.6705	0.22	10
CG, IP	1.9428	0.109	10
CG, K	1.0458	0.505	4
AC, CO	**1.4445**	**0.044**	**411**
AC, PR	1.0864	0.348	28
AC, LB	**1.7892**	**0.036**	**28**
AC, IP	1.0484	0.278	28
AC, K	0.76864	0.862	7
CO, PR	0.99906	0.531	21
CO, LB	1.2546	0.24	21
CO, IP	0.49825	1	21
CO, K	0.69387	0.661	6
PR, LB	0.8541	0.635	3
PR, IP	0.6255	1	3
PR, K	0.30543	1	3
LB, IP	1.308	0.324	3
LB, K	0.57557	1	3
IP, K	0.54253	1	3

Table 4. SIMPER output of significant pairwise dissimilarities in rating of issues facing mangrove by occupation

Groups IE & CG

Average dissimilarity = 13.77

	Group IE	Group CG				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nutrient pollution	1.43	0.67	1.83	1.27	13.32	13.32
Sea-level rise	1.57	1.15	1.66	0.95	12.03	25.36
Climate change (more severe droughts, floods and storms)	1.24	1.67	1.60	1.31	11.58	36.94
Illegal cutting/clearance	1.84	1.24	1.43	1.79	10.35	47.29
Chemical contamination	1.34	0.94	1.36	0.89	9.86	57.15
Dredging of channels	1.47	1.00	1.08	1.31	7.86	65.02
Coastal erosion	1.40	1.00	0.94	1.91	6.80	71.82

Groups IE & AC

Average dissimilarity = 9.84

Species	Group IE Av.Abund	Group AC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Climate change (more severe droughts, floods and storms)	1.24	1.72	1.09	0.89	11.10	11.10
Nutrient pollution	1.43	1.62	1.00	1.48	10.20	21.30
Dumping rubbish	1.56	1.79	0.91	1.14	9.21	30.51
Coastal erosion	1.40	1.82	0.88	1.78	8.95	39.45
Chemical contamination	1.34	1.72	0.85	1.33	8.61	48.06
Sea-level rise	1.57	1.96	0.83	1.30	8.39	56.45
Dredging of channels	1.47	1.60	0.81	1.24	8.26	64.71
Aesthetics (views of estuaries, the harbour, open water)	1.52	1.87	0.73	0.94	7.40	72.11

Groups CG & AC

Average dissimilarity = 13.68

	Group CG	Group AC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nutrient pollution	0.67	1.62	2.09	1.38	15.28	15.28
Sea-level rise	1.15	1.96	1.81	0.92	13.21	28.49
Coastal erosion	1.00	1.82	1.78	7.11	13.00	41.49
Chemical contamination	0.94	1.72	1.73	1.03	12.67	54.15
Illegal cutting/clearance	1.24	1.96	1.51	2.00	11.03	65.19
Dredging of channels	1.00	1.60	1.30	1.85	9.53	74.72

Groups CG & CO

Average dissimilarity = 18.55

	Group CG	Group CO				
Species	Av.Abund		Av.Diss	Diss/SD	Contrib%	Cum.%
Nutrient pollution	0.67	1.63	2.27	1.45	12.24	12.24
Chemical contamination	0.94	1.43	2.03	1.15	10.95	23.18
Expansion of mangroves impacting negatively on estuaries	2.00	1.15	1.98	2.74	10.66	33.85
Sea-level rise	1.15	1.58	1.69	0.97	9.09	42.94
Coastal erosion	1.00	1.69	1.61	1.81	8.66	51.60
Illegal cutting/clearance	1.24	1.95	1.59	1.93	8.57	60.17
Climate change (more severe droughts, floods and storms)	1.67	1.48	1.54	0.92	8.28	68.45
Dredging of channels	1.00	1.63	1.46	1.58	7.87	76.31

Groups AC & CO

Average dissimilarity = 11.42

Species	Group AC Av.Abund	Group CO Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Expansion of mangroves impacting negatively on estuaries	1.87	1.15	1.50	2.19	13.18	13.18
Climate change (more severe droughts, floods and storms)	1.72	1.48	1.24	0.90	10.83	24.00
Aesthetics (views of estuaries, the harbour, open water)	1.87	1.35	1.22	1.47	10.65	34.65
Chemical contamination	1.72	1.43	1.20	0.85	10.52	45.17
Nutrient pollution	1.62	1.63	0.94	1.14	8.26	53.43
Increased need for access by boats	1.77	1.45	0.85	1.57	7.43	60.86
Sea-level rise	1.96	1.58	0.84	1.15	7.35	68.20
Dredging of channels	1.60	1.63	0.81	1.24	7.09	75.30

Groups AC & LB

Average dissimilarity = 9.51

	Group AC	Group LB				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sea-level rise	1.96	0.87	2.31	1.17	24.33	24.33
Climate change (more severe droughts, floods and storms)	1.72	1.00	2.12	1.26	22.31	46.64
Nutrient pollution	1.62	1.73	0.79	1.30	8.29	54.92
Dumping rubbish	1.79	1.73	0.63	1.27	6.61	61.53
Increased need for access by boats	1.77	1.57	0.52	1.15	5.43	66.97
Chemical contamination	1.72	1.87	0.49	1.17	5.14	72.10