Mātauranga Māori to inform understanding of population dynamics and health of pipi in Waihī Estuary, Bay of Plenty

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Abstract

"Mā tatou anō e kōrero"

"We talk for ourselves"

Estuaries are among the most productive ecosystems on earth. They hold significant value to Māori as they connect the whenua (land), awa (river) and moana (ocean), and are an important source of kaimoana (seafood) including shellfish. However, due to increased anthropogenic pressures, many estuaries are degraded, affecting taonga (Māori treasure) species such as pipi (*Paphies australis)*. My thesis uses kaupapa Māori methodology and is co-developed with Ngāti Whakahemo, tangata whenua (people of the land) of Waihī Estuary. This project fundamentally draws upon mātauranga Māori (traditional Māori knowledge), combined with western science to map the historic and current distribution, abundance and health of pipi in Waihī Estuary; as well as explore the perceptions of threats to pipi and estuary ecology from tangata whenua and the regional authority.

Participatory mapping was used via kōrero/interviews with kaumātua to identify sites of significance for pipi, which were then sampled in November 2020. Mātauranga ā iwi from Ngāti Whakahemo informed the sampling locations. Previous pipi sampling methodology and protocols undertaken by the Ministry for Primary Industries (MPI) were used to facilitate temporal comparisons of pipi distribution and abundance. Environmental factors including sediment grain size, organic content, total nitrogen (TN) and total phosphorus (TP) were also measured to help understand what drives the population dynamics of pipi. Perceptions of tangata whenua and staff members of the Bay of Plenty Regional Council (BOPRC) were also explored following methods similar to Klain et al. (2018) and implementing a dread risk tool via participatory mapping.

Results show that culturally significant sites identified by kaumātua support high pipi abundances of large size (40mm+), with low abundances of pipi in the upper reaches of the estuary. The inclusion of sites identified by MPI allowed for more comprehensive survey on pipi population dynamics by utilising a stratified survey design. Pipi size and abundance was significantly correlated with environmental factors with high pipi densities associated with medium grain size fractions and low levels of TN, TP and organic content. Over harvesting was perceived by kaumātua and BOPRC staff members as the dominant threat to pipi abundance and Waihī Estuary. Nutrients related to sewage inputs and runoff were rated as the second highest perceived threat and diseased shellfish ranked third by kaumātua and BOPRC staff members.

This study demonstrates that the sharing of mātauranga ā iwi can fundamentally inform western science methods and can be used as an approach to research in the marine science realm. The research space was shared by researchers and kaumātua, was honourable of the mātauranga, iwi voices were heard and a co-developed field survey plan/research plan was produced. Iwi concerns were made a priority throughout, and incorporated into the monitoring, mapping and management frameworks. Thus, I had a Māori-centred agenda which is important as Ngāti Whakahemo are looking to utilise the results from my research to inform their iwi environmental management plan. This approach will help to strengthen current marine management practices and in turn Aotearoa New Zealand's ecosystems due to iwi environmental management plans being informed by such results.

Acknowledgements

"Ahakoa he iti, he iti pounamu"

"Although small, it is precious"

A child who is given proper values at home and cherished within their family, will not only behave well amongst the family but also within society and throughout their life. With that in mind I would like to thank my immediate family and extended whānau for the encouragement, guidance, morals and support that they have expressed through not only my life, but throughout my educational journey. One tends to only seem grateful in hindsight and this thesis has allowed me not only to reflect on my own personal journey of knowledge but to also appreciate the sacrifices and support that my mum and dad have made.

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Kuputaka (Glossary of Māori terms)

Māori term	Meaning
Aotearoa	New Zealand
Atua	Distant ancestor/Guardian/Deity
Awa	River
Hapū	Subtribe
Harakeke	Flax – *Phormium tenax*
Hikoi	Walk
Hinemoana	Female deity of the sea
Hui	Meeting
Iwi	Tribe
Kai	Food
Kaimoana	Seafood
Kaitiaki	Guardian
Kaitiakitanga	Guardianship
Kanohi	Face
Kaumātua	Elder
Kaupapa Māori	Māori way of doing things
Kete	Basket
Koha	Gift
Kōrero	Talk
Kōura	Freshwater crayfish
Mahinga kai	Culturally significant food gathering location/bed
Mana	Strength/power
Mana wāhine	Women of strength
Manaakitanga	Hospitable
Māori	Indigenous people of New Zealand
Marae	Meeting house
Maramataka	Māori lunar calendar
Maruahaira	Eponymous ancestor of Ngāti Whakahemo
Mātauranga Māori	Māori knowledge
Mātauranga ā iwi	Knowledge specific to iwi, hapū, places and people
Mauri	A binding force between the physical and spiritual worlds
Moana	Ocean
Mokopuna	Grandchild
Moteatea	Traditional chants
Ngāti Kahungunu	Tribe of Hawke's Bay and Wairārapa
Ngāti Makino	Māori tribe from Te Arawa canoe
Ngāti Pikiao	Māori tribe from Te Arawa canoe
Ngāti Ranginui	Māori tribe in the Bay of Plenty
Ngāti Tunohopu	Tribe from Te Arawa canoe

Ngāti Whakahemo	Tribe of Pukehina
Otāiti	Astrolabe reef
Pākeha	New Zealanders primarily of European descent
Pipi	Shellfish - *Paphies australis*
Poutama Tukutuku	Stepped patterns
Pūkenga	Expert
Pūrākau	Traditional Māori narratives
Rakiura	Stewart Island
Rangatiratanga	Self determination
Rēkohu	Chatham Island
Rongoā	Holistic system of healing based on Māori traditions
Takitimu	Ancestral canoe of tribes Ngāti Kahungunu through to south Gisborn
Tangaroa	Great atua of sea, lakes, rivers and creatures that live in them
Tangata whenua	People of the land
Taonga	Treasure
Tapu	Scared/spiritual restriction
Tau kōura	Traditional Māori fishing method for freshwater crayfish
Te Ao Māori	Māori world
Te Arawa	Canoe of tribes from the Rotorua lakes district and Lake Taupō
Te Awa o Ngātoroirangi	Maketū estuary
Te Ika a Māui	North Island
Te Reo Māori	Māori language
Te Tirito o Waitangi	The Treaty of Waitangi
Te Waipounamu	South Island
Tiaki	Caretaker
Tikanga	Māori way of doing things/values/protocols
Tikanga ā iwi	Tikanga values specific to iwi/hapū/places/people
Tino rangatiratanga	Māori self-determination and sovereignty
Toheroa	Shellfish - *Paphies ventricose*
Toi toi	*Gobiomorphus spp*
Tuangi	Cockle
Tuatua	Shellfish - *Paphies subtriangulata*
Tupuna	Ancestor
Utu	Repaying
Wainui	Guardian of all waters
Wairua	Spirit
Waitaha	Māori tribe in the Bay of Plenty
Wānanga	To meet, discuss, deliberate, consider.
Whaikōrero	Speech
Whaingaroa	Raglan
Whakapapa	Genealogy
Whakarongo	Listen
Whakatauki	Proverbs

Whakaweku	Bracken fern - *Pteridium esculentum*
Whakawhanaungatanga	Process of establishing relationships
Whānau	Family
Whanaungatanga	Kinship, sense of family connection
Wharenui	Meeting house
Whenua	Land

Chapter 1
Introduction

“Whaowhia te kete mātauranga”

“Fill the basket of knowledge”

Mātauranga Māori (Māori knowledge) has become more notable in today’s research circles, where kaupapa Māori (Māori ways of doing things) is highlighted as a key concept that needs to be implemented in research that utilises mātauranga Māori (Royal, 2012). However, there are misconceptions around these terms and how they should be applied to science and research correctly (Smith, 2000). In the last few years mātauranga Māori and kaupapa Māori based research has started to become more prominent in research that revolves around the ocean and its resources, due to the cultural significance and value these ecosystems have to Māori (Paul-Burke et al., 2018). Furthermore, incorporating mātauranga in science has become more prominent due to the government’s ‘Vision Mātauranga’ framework which looks to provide strategic direction for research of relevance to Māori (Stevens et al., 2021). Legislative acts and policies increasingly require that Māori be involved in research management plans related to the use of oceanic areas.

My research has mātauranga Māori fundamentally informing its conception, methods and overall outcomes, with the hope that it will contribute to the holistic management of pipi in Waihī Estuary. This chapter introduces the main topics of this thesis, including the co-developed approach of implementing both mātauranga Māori and western science. Furthermore, this chapter defines the study area and acknowledges the tangata whenua (people of the land) — Ngāti Whakahemo. Finally, I outline the structure of this thesis.

1.1 Traditional knowledge

In Aotearoa New Zealand, indigenous knowledge is known as mātauranga Māori (Māori knowledge). This knowledge system has long been known to hold continuous and consistent detail around historical and contemporary resource-use practices and provides a broad range of knowledge around interactions within an ecosystem and the associated ecological processes (Mercier, 2018a). Mātauranga Māori is becoming more widely recognised as a sustainable and holistic approach to environmental management (Brodnig and Mayer-Schönberger, 2000). In Aotearoa New Zealand there is also legislative requirements to include Māori cultural, historical, spiritual and physical values in environmental/land-use planning (Harmsworth, 1997). For example, Te Tiriti o Waitangi (The Treaty of Waitangi) is an agreement that was signed by representatives of the British Crown and Māori in 1840, with the purpose of enabling British settlers and Māori people to live together in Aotearoa New Zealand under a common set of laws or agreements (Palmer, 2008). It recognises that there were people living in Aotearoa New Zealand prior to colonisation whom had developed a diverse and complex cultural, spiritual, social and economic value system and ways of living before European contact. However, there are misconceptions around Te Tiriti o Waitangi where Māori have made repeated claims to the government and the Waitangi Tribunal that their rights, as guaranteed under the Treaty, have been breached. These claims include a range of issues including misappropriated land and resources, to the preservation of language and intellectual property rights (Hudson and Russell, 2009). Overall, Te Tiriti o Waitangi is considered the founding document for relationships between Māori and the Crown. According to Broughton et al. (2015), for mātauranga Māori to flourish in Aotearoa New Zealand, the relationship between whānau, hapū, iwi and the environment needs to be restored; which is affirmed in Te Tiriti o Waitangi by instilling tino rangatiratanga (Māori self-determination and sovereignty). Mātauranga Māori will be further discussed in Chapter 2, including a definition and explanation of other associated concepts that help break down what this knowledge system is and how it will fundamentally inform this research.

Globally, indigenous knowledge is an ancient practice that has been around since hunter-gatherer times (Berkes, 1993). It can be defined as a cumulative body of knowledge and beliefs that is passed on through generations by cultural transmission, about the relationship of living beings with one another and with their environment (Ghosh and Sahoo, 2011). The use of traditional knowledge for conservation and marine resource management was described by Govan et al. (2006), where traditional knowledge was recognized as essential information inherited through generations by the local communities as part of fisheries management in the South Pacific. Due to the close relationship Pacifika Peoples have developed with the ocean over millennia, knowledge and understanding around the processes and ocean life is a key part of their culture. Traditional knowledge from the coastal communities in the Pacific has been and is invaluable to fishery management initiatives. It provides vital information to nongovernmental organizations (NGO's) and governments who are trying to help manage and restore the fisheries. For example, Govan et al. (2006) explains the implementation of community-based coastal resource conservation and management in the South Pacific has proven to be a successful project. It was able to bring together traditional knowledge and western science practices as a tool for successful management action plans in Fiji, Samoa and Vanuatu. These initiatives were not based solely on traditional methods however, communities were able to work together with NGO's and government organizations to merge traditional practices with western science practices. Results from this study concluded that Fijian communities had shown impressive progress in fisheries management by joining a national network of NGO's and government organizations to support locally managed marine areas (LMMA). Samoa had strong government investment which resulted in dozens of LMMA's spread throughout the nation; and communities in Vanuatu persevered traditional management in the form of 'tabu' areas, where government organizations and NGO's helped revive this form of fisheries management in other areas throughout the nation.

Another form of traditional knowledge that is used globally is traditional environmental knowledge (TEK), not to be confused with mātauranga Māori. TEK has only recently become recognised by the western scientific community as a valuable source of ecological information (Kimmerer, 2002). Over time a growing body of literature based on what TEK is and where it has come from has emerged as researchers become more interested in the concept and what it is capable of providing (Sherry and Myers, 2002). Common labels for this knowledge system include folk ecology, ethno-ecology, traditional environmental or ecological knowledge (Sherry and Myers, 2002). TEK refers to the knowledge base acquired by Indigenous and local peoples over multiple generations through direct contact with their environment. For example, for thousands of years the Indigenous Australian Peoples have used TEK of their environment to help sustain themselves and to maintain their cultural identity (Johnson, 1992). Berkes (1993) explains that Indigenous knowledge is held by Indigenous Peoples only, and that TEK is a subset of that claim, therefore, TEK is a broad term for all indigenous knowledge.

TEK fundamentally differs to mātauranga Māori, as TEK was derived by western scientists to build their understanding around the environment, plants and animals. Mātauranga Māori refers to knowledge that is embedded in Māori culture and all that underpins it, as well as Māori ways of knowing (Broughton et al., 2015). According to

Hepi and Foote (2013), TEK is commonly used in international research and includes concepts related to how things work and a guide to action. It also includes Indigenous peoples thinking but it not restricted to Indigenous communities. Whereas mātauranga Māori is Māori knowledge only, making it a unique and valuable source of information (McAllister et al., 2019a).

1.2 Transdisciplinary approach to science

The idea that knowledge is not strictly bound to the knowledge of an individual discipline, rather it is the sum of several related philosophical ideas regarding one common phenomena has been an approach to science since the ancient Greek times and was described by Aristoteles as reductionism (Flogie and Aberšek, 2015). Reductionism refers to breaking down a specific discipline into individual parts to help explain the overall idea (Brigandt and Love, 2008). In more recent times, this idea of reductionism has morphed into an approach referred to as a transdisciplinary approach, where many disciplines come together to solve a common issue by utilising the tools and strengths of each independent discipline before coming together and creating new outcomes/solutions (Jörg, 2011). A transdisciplinary approach is implemented in my research, where two independent knowledge systems; mātauranga Māori and western science, come together to address solve the overarching objectives.

A transdisciplinary approach to science is when research in different disciplines can work together to address a common problem by crossing disciplinary boundaries to create innovations in concepts, theories and methods (Brodnig and Mayer-Schönberger, 2000). However, this concept generally lacks information on how to go about joining disciplines, especially when joining traditional knowledge and western science (Nadasdy, 1999). An example of implementing a transdisciplinary approach of mātauranga Māori and western science was by Paul-Burke et al. (2018), whom focused on the development of a mussel management action plan to establish a harbour-wide approach to assist understanding and decision-making for mussel populations in Ōhiwa harbour. In this project, mātauranga Māori led and fundamentally informed the direction and approach, which consisted of using mātauranga Māori from tangata whenua as a tool. This approach allowed for the research practices to be respectful, ethical, truthful and transparent. Furthermore, by aligning the methods with a kaupapa Māori research-based paradigm, which is where research is done by Māori, with Māori and for Māori (Mane, 2009), key guiding principles were able to be established during this research which includes:

1. Be respectful of yourself and others.
2. Present yourself in person.
3. Look, listen then speak.
4. Share the research space and host other ideas.
5. Be generous and cautious.
6. Do not trample over the personal prestige of others.
7. Be humble.
8. Be open to other knowledge perspectives.
9. The sharing of knowledge leads to shared understanding.

These key guiding principles from Paul-Burke et al. (2018) were implemented throughout the duration of this thesis, where mātauranga Māori was sought out from Ngāti Whakahemo, tangata whenua of Waihī Estuary.

1.3 Waihī Estuary

Waihī Estuary is a shallow embayment located 37^{o} 46' S, 176^{o} 28 E (Figure 1.1) and is comprised of saltmarsh vegetation, intertidal mudflats and diverse surrounding sub tidal habitats (Squires, 2019). Waihī Estuary is one of the smaller coastal estuaries in the North Island of Aotearoa New Zealand, Bay of Plenty, covering approximately 2.4 km^2, with the majority of the estuary being completely exposed during low tide (Scholes, 2015). According to the New Zealand Estuary Trophic Index (NZETI) screening tool, Waihī Estuary fits into the category of a Shallow, Intertidal Dominated Estuary (SIDE). This is due to its shallow depth (<3m), short residence time (approximately <3 days), high flushing potential, and greater than 40% of its area being intertidal flats. This means the estuary is moderately susceptible to eutrophication and can easily host nuisance opportunistic algae such as *Ulva sp.* and *Gracilaria sp.* (Bermeo et al., 2020).

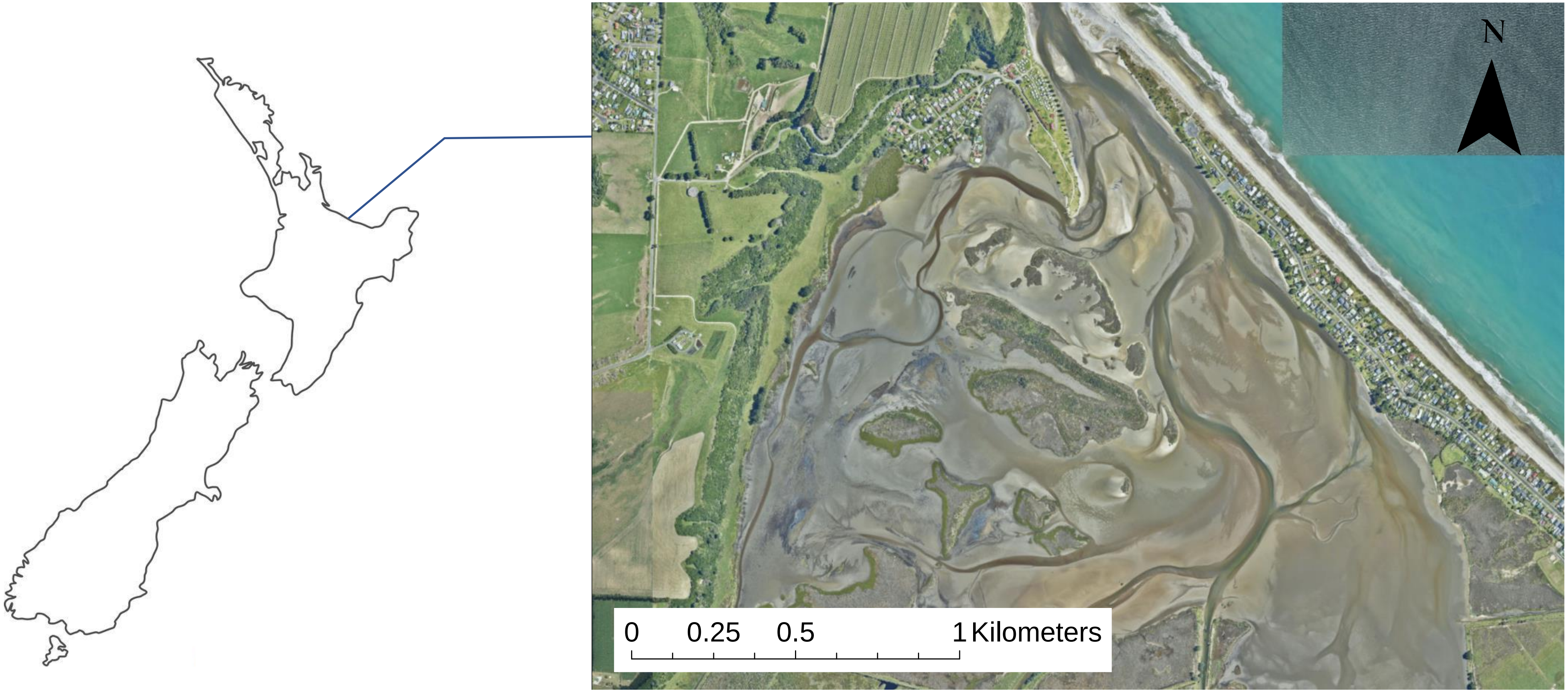

Figure 1.1 - Map of Waihī Estuary, Bay of Plenty, Aotearoa New Zealand. Map data @ Google imagery, ArcGIS pro.

1.3.1 Significance of estuaries to Māori

Estuaries are among the most productive ecosystems on Earth, and hold significant value to Māori, as they provide a connection to the whenua (land), awa (river) and moana (ocean) (Ulluwishewa et al., 2008). Their semi-enclosed nature means they also offer sheltered waters, with a freshwater source and an abundance of kaimoana (sea food) and other resources such as rongoā (holistic system of healing based on Māori traditions) (Ahuriri-Driscoll, 2014). According to Williams (2006), estuaries play an important and complex role in the life of those who inhabit the coast, where Māori favoured estuaries as a place for settlement and as an area for passing on the traditional knowledge associated with these important ecosystems.

Estuaries are also an extremely diverse and vulnerable ecosystem, sensitive to environmental fluctuations such as changes in estuarine water level such as due to tidal cycles, riverine floods, and sea level rise. Thus they are constantly changing due to being at the interface of two contrasting environments, freshwater and marine (McLay, 1976). Due to increasing anthropogenic pressures such as extensive development of urban, agricultural and industrial areas, estuaries are rapidly shifting to a degraded state (Teichert et al., 2016), and the ecosystem services which Māori rely on are declining significantly (Nyström et al., 2012). Therefore, the need for resource and environmental management to control the impacts humans are inflicting on these ecosystems is vital and urgent.

1.3.2 Health of Waihī Estuary

Bay of Plenty Regional Council's State of the Environment Monitoring Programme provides a range of estuarine ecological health indicators which provide a better understanding around the state of the estuary. First, seagrass was looked at as it is a very productive and ecologically important habitat, and changes in seagrass extent can indicate changes in water quality or other changes that affect the functioning and integrity of estuarine ecosystem (Jackson et al., 2001). Seagrass abundance in Waihī Estuary has significantly declined since the late 1940's, with the largest loss occurring between 1950 and 1960 (Figure 1.2). This loss was attributed to hydrological modification such as decreased wetlands and increased agricultural areas surrounding the estuary. According to the NZETI, the seagrass indicator classes Waihī Estuary to be in a very poor state (Park et al., 2018).

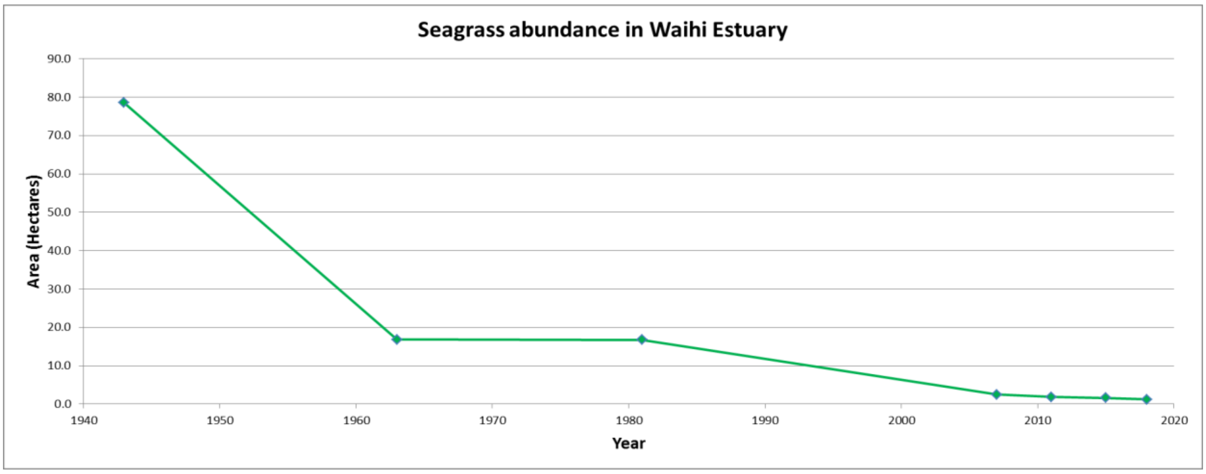

Figure 1.2 - Seagrass extent in Waihī Estuary from 1943 to 2018 (Park, 2018).

Park (2018) also assessed intertidal sediment mud content as this is widely used to indicate quality or condition of intertidal habitats with respect to ecological health (Thrush et al., 2003). Furthermore, the mud content (small silt and clay particles) in estuarine sediments has a strong influence on what species are present, the number of species present and the productivity of intertidal estuarine habitats (Flemming and Delafontaine, 2000). Mud content was assessed by analysing 47 intertidal sediment samples and classifying the mud content into bands/classes as per NZETI (Table 1.1). According to the NZETI framework, Waihī Estuary (not including saltmarsh) is covered by soft mud (defined as >25% mud content) (Figure 1.3), which means the overall ranking is poor in terms of ecology and there is likely to be significant persistent of stress on a range of species, and likely a loss of keystone species (Harris et al., 2016).

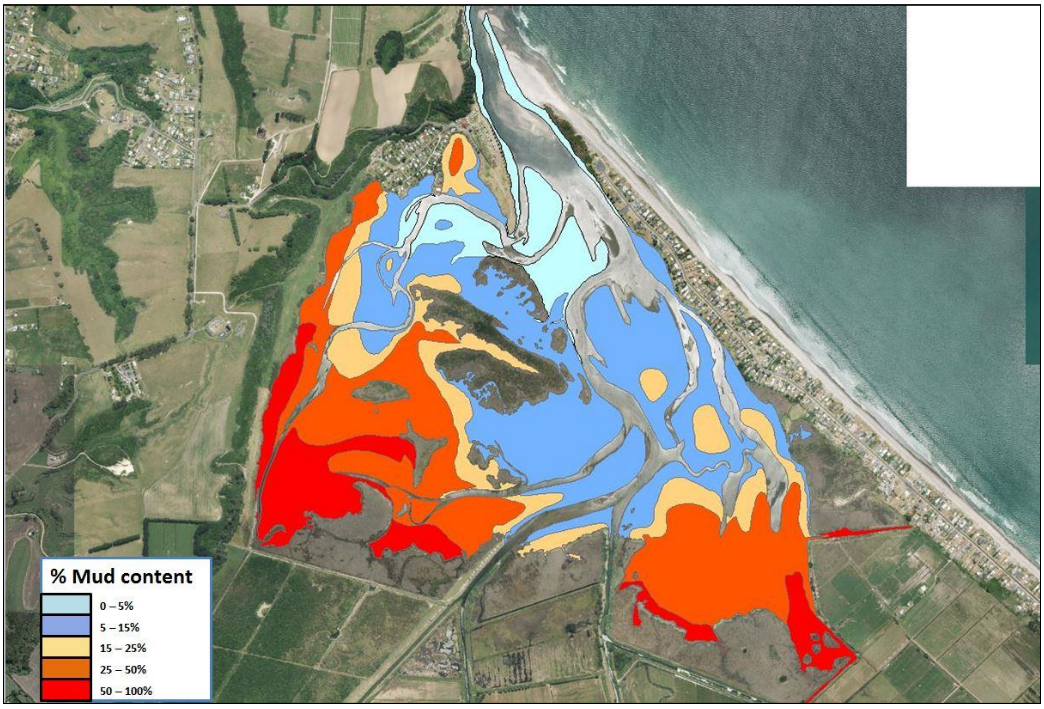

Figure 1.3 - Map of percent mud content for intertidal sediments in Waihī Estuary in 2018 (Park, 2018).

Table 1.1 - Sediment mud content class extents in Waihī Estuary in 2018 (Park, 2018).

Sediment mud class	**Area (ha)**	**% of AIA**	**Quality score – individual sites**
0 – 5%	20.6	9.3	Very good
5 – 15%	75.7	34.2	Good
15 – 25%	32.6	14.7	Fair
25 – 50%	63.0	28.5	Poor
50 – 100%	29.4	13.3	Very poor

Overall, it is clear to see that the health of Waihī Estuary has declined significantly, this is thought to be largely due to the channelisation of the four main canals located at the south end of the estuary. This is due to increased flow efficiency and in turn more freshwater input into has occurred compared to what used to be only via wetlands (Squires, 2019). Impacts from this channelisation include an increase in contaminants (e.g. nutrients and sediments) being directed directly into the estuary. There has also been an increase in dairy farming, elevated levels of faecal coliforms and other contaminates from fertilisers has significantly affected the ecology of the estuary, including the distribution and abundance of pipi, of which are a traditional food resource for the tangata whenua of this area (Grossman et al., 2020).

1.4 Who is Ngāti Whakahemo?

The Western Bay of Plenty district has long been known to hold historical continuity of Māori living in this area, with tangata whenua being intrinsically associated to the Takitimu waka (canoe) and Te Arawa waka that arrived as a part of the Great Migration, 1340AD[1]. Ngāti Whakahemo, the iwi associated with Waihī Estuary, are descendants of Maruahaira, a chief who led the migration of his people to this region. They took up their abode alongside the Ngāti-ha tribe for some time before they were again driven forth, which led to them in turn becoming a conquering iwi who won both Tauranga and Te Puke from the Ngāti Ranginui and Waitaha iwi (Gudgeon, 1893).

This research was co-developed with and draws from the mātauranga ā iwi shared by Ngāti Whakahemo in support of this research. Mātauranga ā iwi can be described as knowledge specific to iwi, hapū, places and people (Mercier, 2018b). This form of mātauranga Māori is unique as it holds perspectives and understandings from tribal ways of thinking and refers to the mātauranga generated by our tupuna (ancestors). Mātauranga ā iwi varies from tribe-to-tribe due to the knowledge being drawn from specific tribal landscapes and values (Wilkinson et al., 2020b).

One iwi member said "Waihī Estuary was the sustenance for our whānau as we grew up"; collecting pipi and other shellfish species, estuaries remain one of the most biologically productive ecosystems on the planet, critical to the lifecycle of fish, other aquatic animals and those that feed on them (Day Jr et al., 2012). Thus, Waihī Estuary was and remains a valuable resource to Ngāti Whakahemo along with the kaimoana species that occupy this ecosystem.

1.5 Thesis aims and objectives

The overall aim of this thesis is to have mātauranga Māori lead and inform understanding of historical pipi distribution, abundance and health in Waihī Estuary, as the basis to determine and apply appropriate western science methods to compare the current state of pipi in the estuary. This aim is answered in three objectives, to:

[1] History of Ngātiwhakahemo retrieved from https://pukehinabeach.co.nz/home/history/

1. Use mātauranga Māori to map the historic distribution, abundance and health of pipi in Waihī Estuary;

2. Use western science techniques to map the size, distribution and health of pipi within Waihī Estuary, centered around sites identified using mātauranga Māori; and

3. Explore and categorize perceptions of threats to pipi in Waihī Estuary from tangata whenua and regional authority.

1.6 Thesis structure

This thesis is divided into seven chapters. Below the 6 subsequent chapters are summarised.

Chapter 2 – Literature review explains indigenous knowledge and how it links to history and the environment. The evolution of mātauranga Māori and the key concepts related to mātauranga Māori and western science are described, paying particular attention to the need for this study, the gaps in the current research and the disconnect between both knowledge systems.

Chapter 3 – Taxonomy, ecology and biology of pipi *(Paphies australis)* introduces and explains where pipi come from, focusing on the importance of this shellfish species to Māori, and the origin of pipi. Their biology, ecology and habitats are also introduced.

Chapter 4 – Methods introduces and defines the Māori research-based methodology of kaupapa Māori-based research. I also discuss how western science methods are also incorporated throughout this research, such as for sampling of pipi size and distribution using transects. I also detail the participatory mapping of historical pipi distribution and health.

Chapter 5 – Results presents the main findings of this research. This chapter highlights the state of pipi distribution and abundance in Waihī Estuary; as well as compares, contrasts and explains the answers given by all stakeholders during the interviews looking at population dynamics and health of pipi in Waihī Estuary.

Chapter 6 – Discussion takes trends and findings from the results chapter and relates these to previous works. This chapter also presents interpretations of the results, their implications, and outlines the limitations and/or recommendations for future work.

Chapter 7 – Conclusion summarises the key findings and implications from this research.

Chapter 2
Literature review

"He kākano ahau i ruia mai i Rangiātea"

"I am a seed which was sewn in the heavens of Rangiātia"

Extensive work by Māori researchers has been done to explain the protocols to follow when using mātauranga Māori and western science together as an approach to science. Frameworks which describe mātauranga Māori values and tikanga (Māori way of doing things) provide context when connecting matauranga Māori and western science (Wilkinson et al., 2020b). Recognising the legitimacy of mātauranga Māori has been accomplished through these frameworks, however, for a long time the relationship between western science and mātauranga Māori has been misguided due to the lack of understanding around the associated concepts.

2.1 Mātauranga Māori

The conception of this thesis topic and the approach/methods were fundamentally informed by mātauranga Māori, more specifically mātauranga ā iwi from Ngāti Whakahemo. This section will breakdown what mātauranga Māori is, the associated concepts and why this knowledge system is being used to lead this research.

The use of mātauranga Māori is becoming more accepted as an appropriate approach to managing and restoring degraded ecosystems due to the unique perspective this knowledge system provides through knowledge being passed down from generation to generation (Berkes et al., 2000). However, traditional knowledge has often been ignored by many scientists and authorities with some commentators in Aotearoa New Zealand saying traditional knowledge is an inadequate knowledge system to guide sustainable harvesting (Berkes, 2009). Smith (2013) further describes how the word 'research' stirs up silence, bad memories and raises a smile that is knowing and distrustful when mentioned to Indigenous peoples, due to the way scientific research was implicated during colonisation. However, there has been increased recognition that traditional knowledge holds valuable historical knowledge around resource-use practices, and a broad range of knowledge around the interactions within the environment and associated ecological processes (Gadgil et al., 1993).

Mātauranga Māori describes traditional Māori knowledge, where the knowledge originates from Māori ancestors and incorporates Māori world views and perspectives (Hikuroa, 2017). Other common definitions and linking words that are apparent across a range of literature about mātauranga Māori include sourced from the environment (Ataria et al., 2018), interwoven (relating to historical and present day knowledge) (Hikuroa, 2017), intergenerational (Paul-Burke et al., 2018) and representative of the whole body of Māori knowledge (Mercier, 2018a). Therefore, mātauranga Māori incorporates multiple aspects from past, present and future into the overall Māori world view (Te Ao Māori) and Māori cultural practices.

The word "mātauranga" comes from the root word "mātau" which means to know, be acquainted with, to understand, and feel certain of. Thus, mātauranga Māori refers to a way of knowing (Mercier, 2018a). Mātauranga Māori is derived from whakapapa, the building blocks for this knowledge system, where whakapapa refers to genealogy or taxonomy and the knowledge is gained by learning from the ways in which our ancestors did (Mercier et al., 2011). Figure 2.1 illustrates this by highlighting the order in which knowledge through mātauranga Māori is derived. Whakapapa is at the forefront which informs Māori narratives which are passed down through generations reiterating Māori-centred views and understandings (Wilkinson et al., 2020b). According to Hikuroa (2017), mātauranga Māori is also made up of pūrākau (traditional Māori narratives) and maramataka (traditional Māori lunar calendar) that have been passed down through generations. This further supports Wilkinson et al. (2020b) and Figure 2.1 where pūrākau and maramataka are both accurate and precise as they incorporate critically verified knowledge and is continually tested and updated through time. As mātauranga Māori continues to grow and evolve in response to the expanding want/need to learn more about this knowledge system, the need for understanding the terms of being used in conjunction with western science becomes just as important.

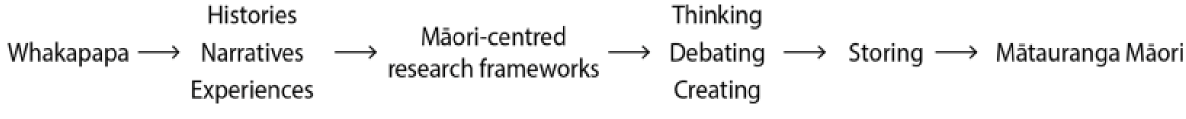

Figure 2.1 - Generation of Māori knowledge (Wilkinson et al., 2020b).

It is important to note that mātauranga Māori is its own knowledge system, therefore it is inappropriate to divide this system into compartments when being used in conjunction with western science via a transdisciplinary approach. Mātauranga Māori must be prioritised and respected when being incorporated with science (Broughton et al., 2015). According to Wilkinson et al. (2020b) mātauranga Māori has often been opposed to incorporating western science due to its inertia to recognise nature as something more than a controllable, testable and exploitable medium; while western scientists typically follow a specific criteria and are detached "observers" of natural systems. Thus, for many years each knowledge system stood on its own. Therefore the historic discord between western science and mātauranga Māori prevented the synergies that now exist between the two knowledge systems (Sunder, 2007).

2.2 Tikanga

Tikanga is an essential part of mātauranga Māori as it puts the knowledge into practice and adds the aspect of correctness. People are also able to see the knowledge being put to use through tikanga practices (Mead, 2016). The word tikanga originates from the two words "tika", meaning right, just, correct or fair and "ngā" which is the plural word in English for "the". Therefore, tikanga can be translated to "way(s) of doing and thinking held by Māori to be just and correct" (Mead, 2016). There are a number of core values that underpin the concept of tikanga, including **whanaungatanga** (kinship, sense of family connection), **mana** (strength/power), **tapu** (scared/spiritual restriction), **manaakitanga** (hospitable), and **utu** (repaying) (Smith, 2015). Each iwi has its own core values and tikanga ā iwi, however, the above are recognised as general values that underpin the associated values that other iwi highlight (Gallagher, 2008).

According to Hudson and Ahuriri-Driscoll (2005), developing tikanga that enables a robust and ethical approach to research is achieved by following key guidelines that emphasize the importance of whakapapa to Māori as a part of the process. This is done by ensuring there is ongoing engagement, cultural significance is adhered too and recognised, research integrity is kept consistent and mana which focuses on equity, including ownership of data, tribal consent and reciprocity.

2.3 Mauri

When incorporating mātauranga Māori into environmental research, mauri is a core concept. Mauri may be seen as a physical life principle or spark of life and has also been described as a measure of sustainability (Roberts et al., 1995). Mauri is the binding force between the physical and spiritual worlds, and incorporates the capacity for air, water and/or soil to support life overall. (Hikuroa et al., 2011). Mauri is a fundamental concept in Te Ao Māori (Māori world).

As described by Kennedy and Jefferies (2009), everything has mauri, this includes people, fish, animals, birds, forest, land, etc. Mauri is the source of power which allows for existence. When something has a negative impact on mauri, a bond is weakened which results in the system being damaged, with a disconnect between the physical and spiritual elements. Depending on the severity of the impact, this can result in a temporary change or death of a living thing entirely, which affects the wider networks or ecosystems that are coexisting due to the loss of life support (Hikuroa et al., 2011).

Mauri co-exists with kaupapa Māori due to both concepts drawing similarities from mātauranga Māori and western science (Ataria et al., 2018). Kaupapa Māori can be defined as Māori principles and ideas that can act as a foundation for action (kaupapa Māori is discussed in detail in Chapter 4). The connection between mauri and kaupapa Māori is critical and starts with the acceptance that there is a common centre from which all mauri flows from. Furthermore, there is an understanding that mauri relates to kaupapa (Māori principle or policy), which then informs and dictates how and what actions should be undertaken when implementing a restoration plan following mauri (Hopkins, 2018). Thus, mauri acts as an ecological indicator, showing the progression of efforts being done over time and whether the restoration goals are being met (Morgan, 2006). The beginning source is the ideal state of mauri; it is the life force, the intrinsic essence and holds the original idea of where life should be. This definition marks where the state of mauri should be when looking at "returning the mauri" to an ecosystem in restoration efforts (Pohatu and Pohatu, 2011). There have been several attempts to develop quantitative models of mauri, which have not been without controversy. Two key models are the Mauri Model developed by Morgan (2006) and the Mauri Compass developed by Ruru (2014).

2.3.1 The Mauri Model

The "Mauri Model" outlined by Morgan (2006), is a decision-making framework with a culturally-based template that incorporates Māori values and western knowledge. This framework aims to help find the best suited plan to reach restoration goals rather than dictating what is “correct”. This is done by using analytical hierarchy, a structured technique for organizing and analysing complex decisions following mathematics and psychology (Rainforth and Harmsworth, 2019). The Mauri Model was originally created to improve the water management processes by integrating critical pieces of information, including mātauranga and using them as part of the decision-making process (Hikuroa et al., 2011). The Mauri Model assesses the mauri of the community, whānau, ecosystem and hapū/iwi. According to Rainforth and Harmsworth (2019) this correlates with Aotearoa New Zealand’s legislation which indicates that sustainable development should be holistic and promote social, economic, environmental and cultural wellbeing. The relative importance of these four aspects of mauri can be assessed individually by allocating a weighting bias before measuring the overall impact upon the mauri. Furthermore, sustainability can be measured using the Mauri Model, where mauri is an indicator of life force, and how the mauri is affected dictates the sustainability level. Each dimension in relation to mauri is either being enhanced, maintained, neutral, diminished or destroyed. Once a rating has been established for each dimension it is then multiplied by predetermined weighting to give a final score which is the overall sustainability rating. This can range between -2 to +2, as illustrated in Figure 2.2.

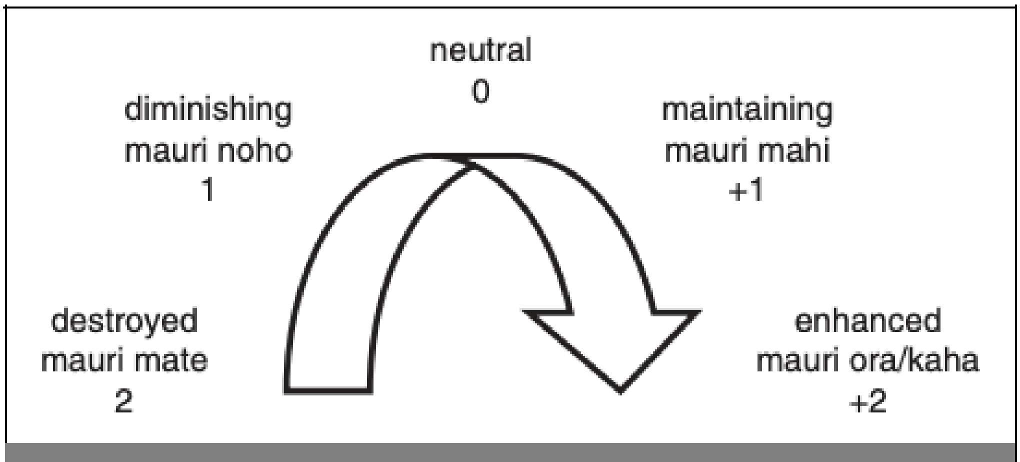

Fig. 4. Sustainability barometer for mauri

Figure 2.2 - Mauri Model restoration rating (Morgan, 2006).

2.3.2 The Mauri Compass

The Mauri Compass developed by Ruru (2014) is a digital tool that looks at twelve aspects within three overarching concepts; Tangata Whenua (people of the land), Tāne (god of the forest and birds) and Tangaroa (great atua of sea, lakes, rivers and creatures that live in them). A combination of mātauranga Māori and western science is used to answer the questions provided based on a scale of: (1) Never, (2) Rarely, (3) Sometimes, (4) Very often, and (5) Always. Results are then displayed via a visual compass (Figure 2.3). The first four attributes that are assessed belong to the Tangata Whenua concept, these include Tangata Whenua, Tikanga (Māori way of doing things), Wairua (spirit) and Mahinga Kai (traditional food harvesting areas). These four attributes are the "gateway" and must be assessed before moving forward. The next four attributes within Tāne focus on the environment and include habitat, biodiversity, biohazards and chemical hazards. The last four attributes from Tangaroa assess the quality and quantity of fish species, abundance, fish health and growth rates. This tool was designed for use by iwi/hapū, regional councils and schools (Rainforth and Harmsworth, 2019).

Figure 2.3 - Illustration of the Mauri Compass (Ruru, 2014).

Even though models of mauri such as those by Morgan and Ruru are quantitative, the unique aspect is their culturally-based template based on indigenous values. Rainforth and Harmsworth (2019) highlight that the Mauri Compass is accommodating to most people in regard to economic wellbeing and intellect, thus a strong sense of place is provided. They also note that this tool has helped to include iwi value and perspective into decision-making by assessing freshwater environments and incorporating both mātauranga Māori and western science measures, which then provides an immediate picture of the state of mauri (Michel et al., 2019). In the past and even now, hapū/iwi views are often overlooked when it comes to specific solutions to an issue; the Mauri Model provides a way to avoid this by creating a way to quantify mauri in a way that is accessible to the westernised-decision making process (Hopkins, 2018).

Further examples of commonly used frameworks for valuing culturally inclusive research, developed to help explain the connection between mātauranga Māori and western science is described in Figure 2.4, known as the “He Poutama Whakamana framework”. The mirrored image signifies the Poutama Tukutuku (stepped patterns) typically found in a wharenui (meeting house). The diagram represents observing the journey of growth and learning as you metaphorically climb up to where knowledge and understanding is achieved (MacFarlane and MacFarlane, 2018). According to Wilkinson et al. (2020a), this framework offers both spiritual and educational meanings, where Māori draw on this metaphor of climbing to symbolise levels of attainment, learning, advancement and insightfulness. This framework is applied as an aspirational tool, and highlights the principles of knowing, being and doing. Furthermore, it identifies four imperatives that are deemed significant to research based on mātauranga Māori:

- **Kaitiakitanga** (Guardianship): Ensuring the Treaty principles are upheld.
- **Mātauranga** (Knowledge): Envisioning the innovative potential of Māori people.
- **Tikanga** (Protocol): Employing culturally responsive research methodologies.
- **Rangatiratanga** (Leadership): Embodying an equitable leadership approach.

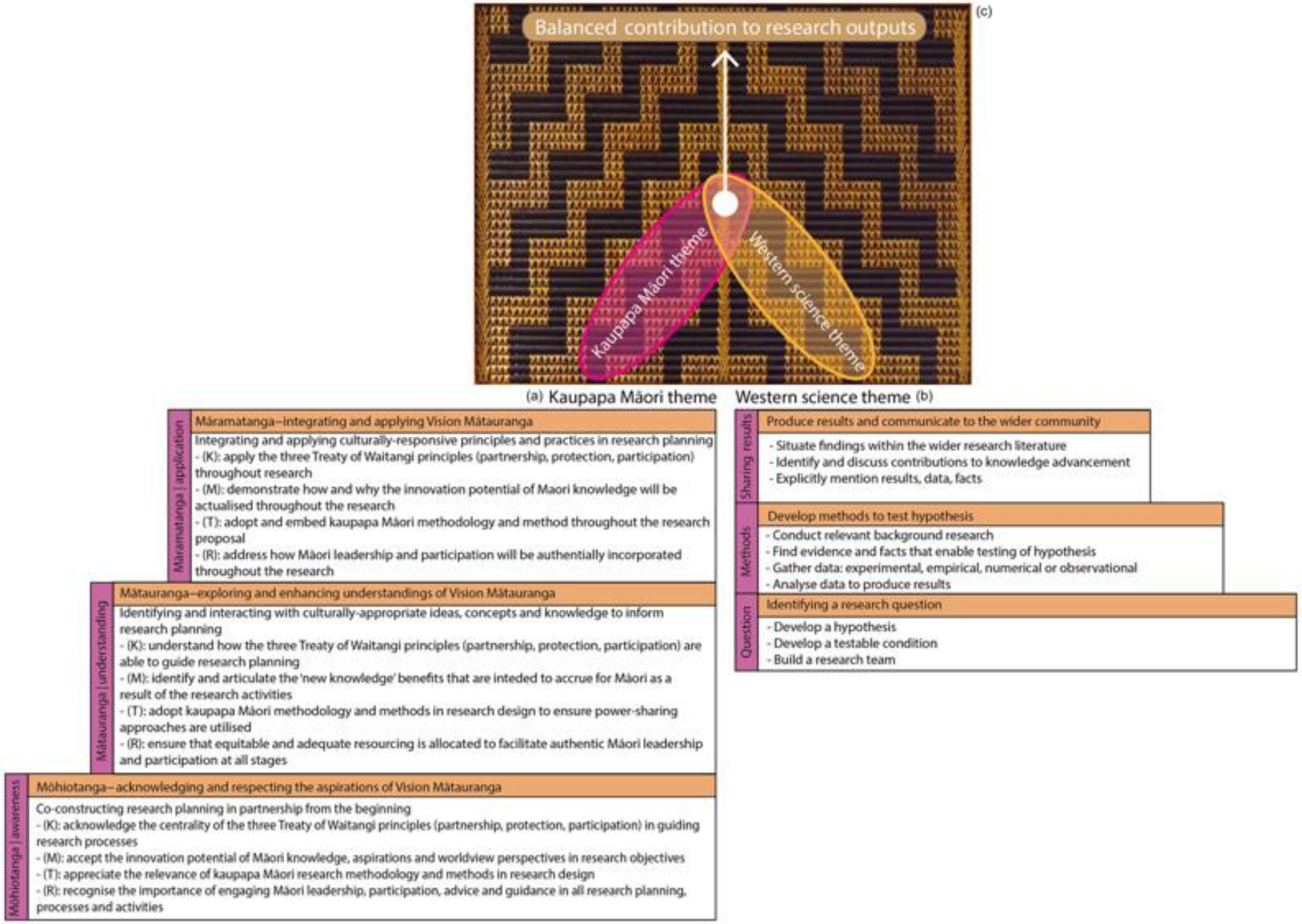

Figure 2.4 - The He Poutama Whakamana framework mirrored by (b) the scientific method theory on the opposite side of the Poutama Tukutuku. Panel (c) represents upwards growth towards co-creation of knowledge (MacFarlane and MacFarlane, 2018).

Another framework that has been developed to help describe the relationship between mātauranga Māori and western science is the He Awa Whiria framework (Figure 2.5). This framework was derived from a braided river system, frequently found throughout Aotearoa New Zealand, that has two streams (shown by the blue lines). One stream represents western science and the other represents mātauranga Māori. Like a braided river, both streams diverge, converge and meander but ultimately, they both flow in the same direction, towards the same goal. The kete (baskets) represent the initiative that the frameworks draw upon, that being mātauranga Māori. Overall, the symbols of the meandering rivers and kete represent the weaving of western science and mātauranga Māori through a Māori world view, in which the integrity and sovereignty of each are respected (MacFarlane and MacFarlane, 2018).

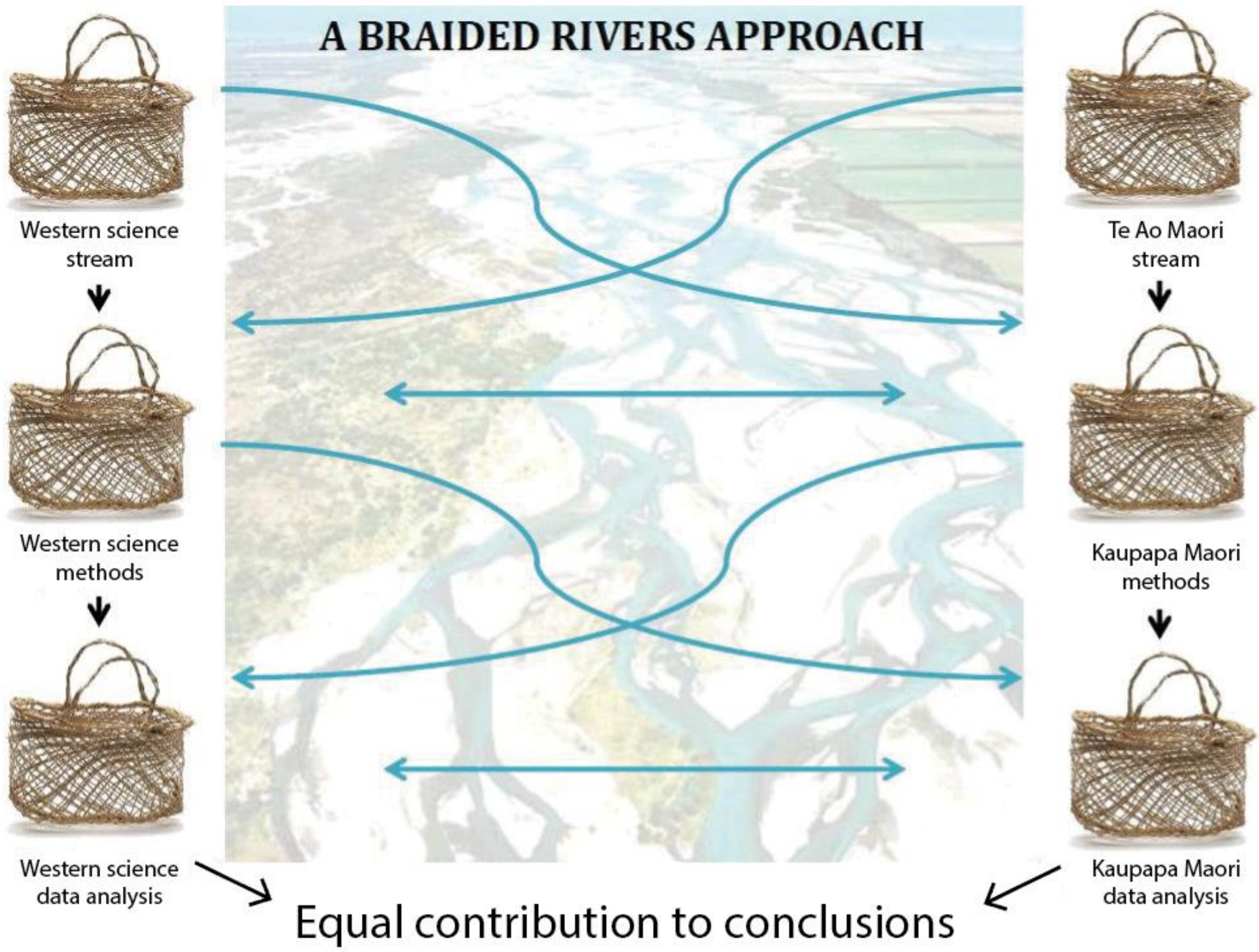

Figure 2.5 - The He Awa Whiria framework. The blue lines represent knowledge exchange and development as the two streams converge and re converge throughout the research programme. Modified from MacFarlane et al. (2015).

2.3.3 MV *Rena* example

Key examples are provided below where mauri was incorporated into the MV Rena recovery plan and Te Awa o Ngātoroirangi (Maketū estuary) restoration efforts. Mauri was used as a guide for restoration in Tauranga Moana as a part of the MV R*ena* recovery. On the 5th of October 2011, the 38,788 tonne container ship MV R*ena* struck Otāiti (Astrolabe Reef), located approximately 12 nautical miles off the coast of the Bay of Plenty, Aotearoa New Zealand. Damage to the hull and keel as a result of the collision, combined with 5–7m swells, resulted in diesel, hydraulic oil and heavy fuel oil (HFO 380) being released into the ocean. Onshore winds quickly blew most of the oil onto the sandy beaches and rocky promontories of western Bay of Plenty. Western science was used to investigate the ecological impacts of this maritime disaster, whilst an interdisciplinary approach investigated quantitative ecological data by incorporating a more holistic approach from the use mātauranga Māori with the inclusion of mauri (Schiel et al., 2016).

In December 2011, the ministry for the Environment outlined the 'Rena Long-Term Environmental Recovery Plan', with the main objective of this plan being to restore the mauri of the affected environment to its pre-*Rena* state (Fa'aui and Morgan, 2015). To achieve this a partnership between research providers and iwi was set up, and specific research projects were designed to address two key concerns: what was the impact of the oil? and how long would it take for the marine environment to recover? To address these questions an assessment of the organic and inorganic chemistry related to the spilled oil and debris was carried out. The ecological and physiological impacts on habitats and key organisms was assessed, the impact of the oil spill on the mauri was highlighted as a key concern, and the efficacy of methods used to clean oil from the coast was observed and critiqued. Finally, the identification of potential legacy effects of the grounding and oil spill was assessed. Figure 2.6 illustrates the work and partnership programme of the Rena Long-Term Recovery Plan, with mātauranga Māori leading and informing the overall process, and returning the mauri to the effected ecosystem being the key objective (Schiel et al., 2016).

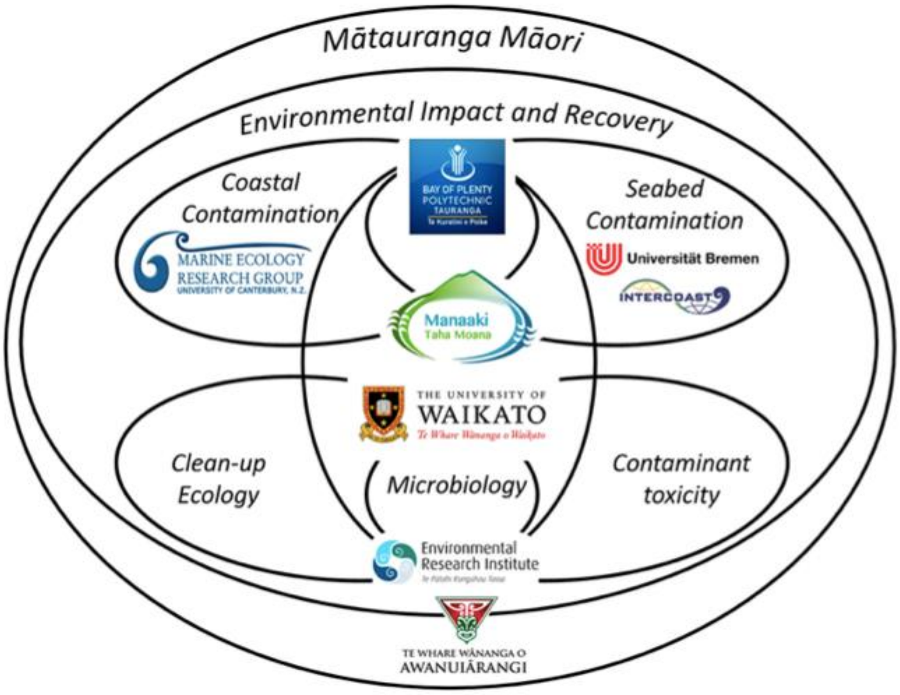

Figure 2.6 - Summary of the work and partnership programme of the 2011 Rena Long-Term Recovery Plan. (Schiel et al., 2016).

2.3.4 Te Awa o Ngātoroirangi (Maketū Estuary) example

Another example of mauri being used as ecological indicator for restoration efforts was for the Kaituna River re-diversion into Te Awa o Ngātoroirangi. Te Awa o Ngātoroirangi is a place that holds great historical and cultural significance, as a landing site for Te Arawa waka (canoe), and has been consistently occupied since the mid 1300's due to the significant resources provided by the estuary (Trilford et al., 2016). The estuary also connects more widely with Te Arawa iwi and hapū via its main freshwater source, the Kaituna River, that flows down from Rotorua.

In 1956 a river diversion was led by the Catchment Board which largely stopped the freshwater flow into the estuary, and as a result the estuary and its kaimoana degraded significantly. In 2016 a collaboration between Ngāti Pikiao and Ngāti Makino with the Bay of Plenty Regional Council (BOPRC) sanctioned the partial Kaituna River re-diversion into Te Awa o Ngātoroirangi for the benefit of ecological restoration, through the environment court. Aspects of the decision introduced tangata whenua concerns and involvement with the inclusion of mauri and how this would be addressed. One of the main drivers of this project was to restore the mauri of the river and estuary (Everitt, 2012). The goal was to significantly increase the volume of freshwater flowing from the Kaituna River into Te Awa o Ngātoroirangi in a way that maximises the ecological and cultural benefits (particularly wetlands and kaimoana) while limiting the economic cost and adverse environmental effects to acceptable levels (Domijan, 2000). To help achieve this, a mauri framework was established between both parties (iwi and the environment court) with a monitoring plan put in place and the objective being: to identify whether a decline in the mauri is occurring over time as a result of the project. Furthermore, they planned to identify the methodology for monitoring the impact of the project on the mauri and to address, as a minimum, a number of relevant matters (indicators, baseline conditions, action thresholds, monitoring frequency, consultation and reporting processes). On 12th February 2020 and 12th February 2021 there were public celebrations to mark the opening of the re-diversion control gates in two stages. Project progress updates between the BOPRC and tangata whenua/kaitiaki are ongoing with the end goal being the mauri restored to Te Awa o Ngātoroirangi (Park, 2020).

2.4 Kaitiakitanga

For Māori, as with other indigenous cultures, there are clear links between healthy ecosystems and peoples cultural and spiritual well-being, and an understanding that ecosystems require a diversity to exist, function properly and sustain ecosystem services (Harmsworth and Awatere, 2013). Therefore, in Te Ao Māori view of the environment, kaitiakitanga is a core concept. When defining kaitiakitanga, common core words included in the definitions include "to take care of", "guardianship", "to protect" and "to watch over". One interpretation is that "Kai" is a generic term for food and when added to "tiaki", it has a literal translation to caretaker, guardian, conservator or trustee (Kawharu, 2000). Traditionally, kaitiaki are seen as assistants of the gods and ancestors; some say that every hapū, iwi and whānau have their own kaitiaki, and each will have their own special story about them and how they can be recognised (Kennedy and Jefferies, 2009). However, there are different types of kaitiaki, both human and non-human, tangible and intangible. Two different types of kaitiaki include:

1. **Human kaitiaki** who embrace customary values and possess the ability to process and implement political and legal rights throughout their work. However, Matiu and Mutu (2003) describe, where kaitiaki fail to fulfil their role and obligations, mana will be removed along with harm coming to members of the whānau and hapū.

2. **Iwi kaitiaki** which is described as having obligation of whānau, hapū and iwi to protect and provide active guardianship over culturally significant land.

At this study site for this thesis of Waihī Estuary, Ngāti Whakahemo are the iwi kaitiaki. They are the guardians and those who protect the spiritual wellbeing of the natural resources within their mana.

2.5 The disconnect between mātauranga Māori and western science

This thesis is transdisciplinary, drawing on knowledge systems and methodologies from Te Ao Māori and western science to determine the distribution, abundance, size and health of pipi in Waihī Estuary. This section focuses on how diverse the definitions and beliefs are around what science is, from both a western science perspective and mātauranga Māori perspective; highlighting the disconnect between these two knowledge systems.

Understanding the connection between mātauranga Māori and western science can be a confusing and lengthy process, because both are underpinned by their own complex concepts, and associated terminology. According to Iaccarino (2003), the etymology of the word 'science' takes us back to the origin of this language and knowledge system, Latin scientia which is known as the next generation of European languages and knowledge. It is said by some that during this time nearly half a millennium ago, the first "true scientists" had come about including Galileo Galilei, Leonardo da Vinci and Sir Isaac Newton. The explosion of knowledge at this time was sparked by a reawakened interest in the writing of Greek, Roman and Arab philosophers and scholars (Nájera, 2012). During this time a large influence on the origin of this knowledge system was to understand natural phenomena following an appropriate set of rules to make generalizations and predictions about nature (Colorado, 1988).

According to Mercier (2018a), there are multiple views and perceptions around western science. Some believe that the science begins with Greek philosophical traditions and ends with enlightenment and scientific revolution, others believe western science ignores cultural contributions and focuses purely on one's own beliefs. However, the general understanding of the world is said to be derived from science which is based on beliefs, objects or universal values. These thoughts and beliefs were sourced from God for those who are religious, and believe universal values were derived from human resources, and indigenous/cultural beliefs which were sourced from ancestors and observed in nature (Anderson, 2018). Overall, science is deeply rooted and derived from many sources, the methods and ways in which science is carried out depends entirely on the culture in which it is practised (Iaccarino, 2003).

According to Basalla (1967), western science originated in Italy, France, England, the Netherlands, Germany, Austria and the Scandinavian countries during the 16th and 17th centuries. These countries, and this relatively small geographical area was known as the scene of the Scientific Revolution which is where the philosophical view point was established; along with experimental activity and social institutions, which is now referred to as western science. In relation to how this knowledge system and approach to science diffused throughout the rest of the world, a common answer to this was via direct contact such as through military conquest, colonization, imperial influence, commercial and political relations and missionary activity (Robb, 2005). Dispersion of western science into the Pacific was via the European scientists when Captain James Cook undertook three exploratory voyages between 1768 and 1780. Later in the century Sir Joseph Dalton Hooker and Alfred Russell Wallace made significant contributions to the spread of western science due to their ventures in Antarctica and Malay Archipelago (Basalla, 1967).

There have been many studies that use mātauranga Māori and western science together as an approach to research, however, the interaction and engagement between the two has been inconsistent and sometimes lost throughout the duration of the work (Mercier, 2018a). Therefore, further understanding is required on how to go about using both mātauranga Māori and western science together, and it is thought by Berkes (2009) that this starts with acknowledging how each knowledge system differs from one another. Furthermore, a basic understanding around the concepts that are fundamental to mātauranga Māori should be defined and described so that those who are using this transdisciplinary approach to research can follow correct protocols.

Further steps that need to be taken to bring together mātauranga Māori and western science include strengthening mātauranga Māori as a whole by ensuring mātauranga Māori has its own rangatiratanga (Māori driven). Furthermore, awareness around the historical pitfalls that have led to the disconnect between the two frameworks within science needs to be understood (Tauwhare, 2008). Pākeha (New Zealanders primarily of European descent) involvement with kaupapa Māori has many risks, this is due to the poor relationship and mistrust from the past where Pākeha have had a lack of respect throughout colonisation (Smith et al., 2012).

Overall, mātauranga Māori is a knowledge system that is generally poorly understood in the western science world, until recently where the relationship and bringing together of the two frameworks is becoming more widely looked upon (Ghosh and Sahoo, 2011). Mātauranga Māori is developed and practised by whānau, hapū and iwi through relationships with local environments, therefore for mātauranga Māori to thrive, those who practice it must thrive, which is why this research has mātauranga Māori at the forefront. As the demand for mātauranga Māori to be implemented in more scientific research increases, including that involving Pākeha; mātauranga Māori must be practised by the people to whom it is connected to through tikanga, and within the environment from which it has grown. In order for mātauranga Māori to flourish, the relationships between whānau, hapū, iwi and their environments must be restored (Broughton et al., 2015). This thesis is working to address this by having iwi (Ngāti Whakahemo) concerns at the forefront of the research, ensuring we maintain ongoing communication throughout, and working towards the overall objectives of using mātauranga Māori to map the historic distribution, abundance and health of pipi in Waihī Estuary and explore and categorize the threats to pipi in Waihī Estuary from tangata whenua and regional authority perspectives.

Chapter 3

Pipi *(Paphies australis)*

"Me mahi tahi tātou mo te orange o te katoa"

"We must work together for the wellbeing of all"

Pipi *(Paphies australis)* are a culturally significant species to Māori and are considered taonga, meaning they are a treasure. This chapter explains the origin and biology of pipi including from pūrākau (traditional Māori narratives), why they are considered a taonga species, their taxonomy, feeding mode, biological processes, and a description of the habitat they occupy.

3.1 Pipi as taonga to Māori

According to King (2003), bivalves are familiar edible shellfish, such as cockles, mussels, oysters, scallops and pipi; with these species being taonga to Māori. Midden pits containing such shellfish remains date back to early human habitation of Aotearoa New Zealand, commonly accepted as being ~1000 years ago (Jacomb et al., 2010). According to Craig et al. (2012), the concept of taonga includes a scared regard for the whole of nature and a belief that resources are gifts from the gods and ancestors for which current generations of Māori are responsible stewards. There is an emphasis on the guardianship of taonga species by Māori and the need to manage these resources sustainability.

Pipi are one important taonga species and are still consumed widely by Māori today. Jacomb et al. (2010) showed through the use of excavation of midden L27/4 from Karamea on the northern West Coast of the South Island (Figure 3.1) that pipi have long been a food source for Māori and hence a taonga. One such midden which was used between the 15th and 17th century (and as early as the 14th century), showed primarily pipi shells over other bivalve species. It also indicated that over this 200 year deposit, the average shell size of pipi declined; and harvesting of shellfish changed from a broad-spectrum multi-species approach to a highly specialised mono-species harvest. There are many pūrākau explaining the origin and significance of pipi to Māori (Wehi et al., 2013).

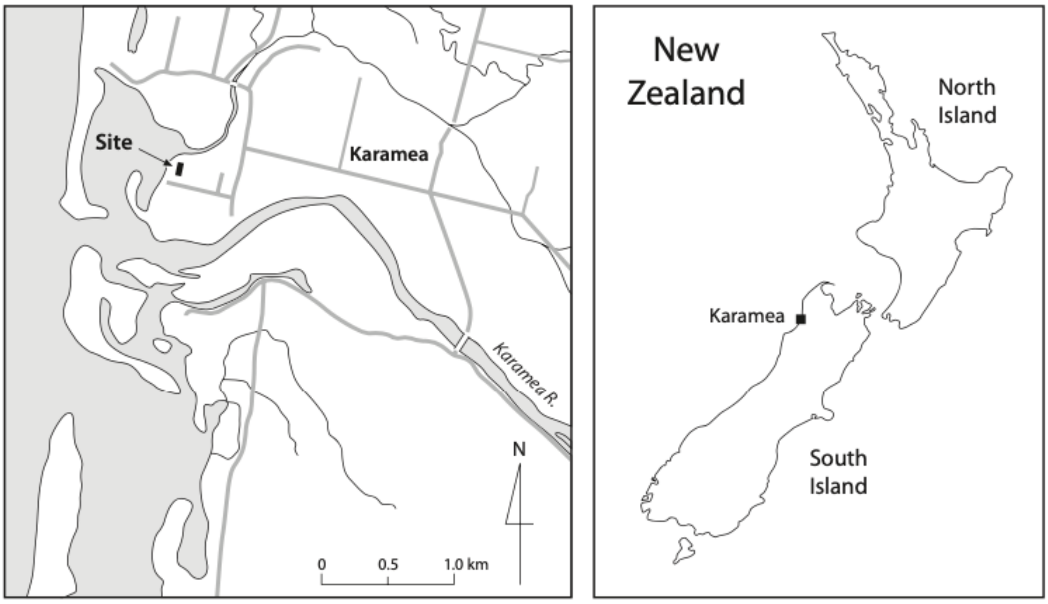

Figure 3.1 - Location of Karamea midden site L27/4 (Jacomb et al., 2010).

3.2 Origin of pipi

Pūrākau are traditional Māori narratives about the nature of the world, often highlighting creation (Pouwhare, 2016). They contain philosophical thought, epistemological constructs, cultural codes and world views (Hikuroa, 2017). According to Hall (2015), pūrākau are used as quintessential indigenous research methods with emphasis on oratory, narrative and conversational dialogue making use of traditional knowledge that is passed down from generation to generation. Forms of pūrākau include moteatea (traditional chants), reciting whakapapa (genealogy), whaikōrero (speech) and whakatauki (proverbs). Lee (2009) believes pūrākau offers all Māori to convey their personal experiences and unique stories to science; and allows narratives to deepen which builds understanding and learning, particularly when this engagement is tōna kanohi (face to face).

Hakopa (2019) explains how pūrākau contain key values and messages that connect Māori to who they are and to where they derive their sense of belonging. The key messages that are passed on through pūrākau highlight the indigenous and Māori resilience grounded in the connectedness to scared and significant sites. Furthermore, this sense of belonging and connection is firmly rooted and couched in the ethos of tangata whenua. Pūrākau remain an important concept of Māori culture, allowing whānau, hapū and iwi to communicate daily concerns and provide a unique aspect about historical reference points to modern day traditional science (mātauranga Māori) (Walker, 2020).

An example of pūrākau relating to the origin of pipi that comes from mātauranga ā iwi of Ngāti Makino, Ngāti Pikiao and Ngāti Tunohopu; explains how from Ranginui (sky father/heavens) and Papatūānuku (mother earth) came Wainui. Wainui is the spiritual guardian of all waters, signifying the link between the lands, wetlands and estuaries. Tangaroa, god of the sea and all resources within, and Hinemoana, atua of the sea and in some beliefs the wife of Tangaroa, gave birth to shellfish and is the main kaitiaki of sea-shore resources. Descendent of Hinemoana, Hunga-terewai produced an array of other univalve species including the whelk, limpet and oyster. However, pipi were progenitors from Te Arawaru (shellfish) and Kaumaihi (Associates, 2014).

These traditional Māori narratives which come from different perspectives show how beliefs can vary from one another depending on where the narratives originate from, the district in which the narrative is being told, and how the stories are interpreted and therefore repeated (Hakopa, 2019). Pūrākau can help with the management of resources due to the knowledge of the past being compared to current beliefs and practices (Lee, 2009).

According to Wehi et al. (2013), pūrākau are used to help manage marine resources as they provide historical information about the environment and the associated resources. It is understood that Māori culture has a strongly developed tradition of oral literature, including whakatauki; of which hold critical information about all aspects of life and society. Pipi were one of the few species that were specifically mentioned in whakatauki, where it was observed that they were mentioned less in subsequent pūrākau, potentially indicating species loss. Overall, it was concluded that pūrākau provide invaluable information on patterns of human thought and behaviour and the formation of cultural practices, specifically for the harvesting of a resource such as pipi (Wehi et al., 2013).

3.3 Taxonomy of bivalves

Pipi belong to the taxonomic order Bivalvia, from the family Mesodesmatidae branching from the phylum Mollusca. This Phylum is one of the largest, most diverse and important groups in the animal kingdom; with over 50,000 described species, with approximately 30,000 of these found in the ocean (Gosling, 2008). Within Mollusca there are six major classes stemming from one hypothetical ancestor (not defined), these include Gastropoda, Scaphopoda, Monoplacophora, Cephalopoda, Polyplacophora and Bivalvia (Figure 3.2) (Crame, 2000).

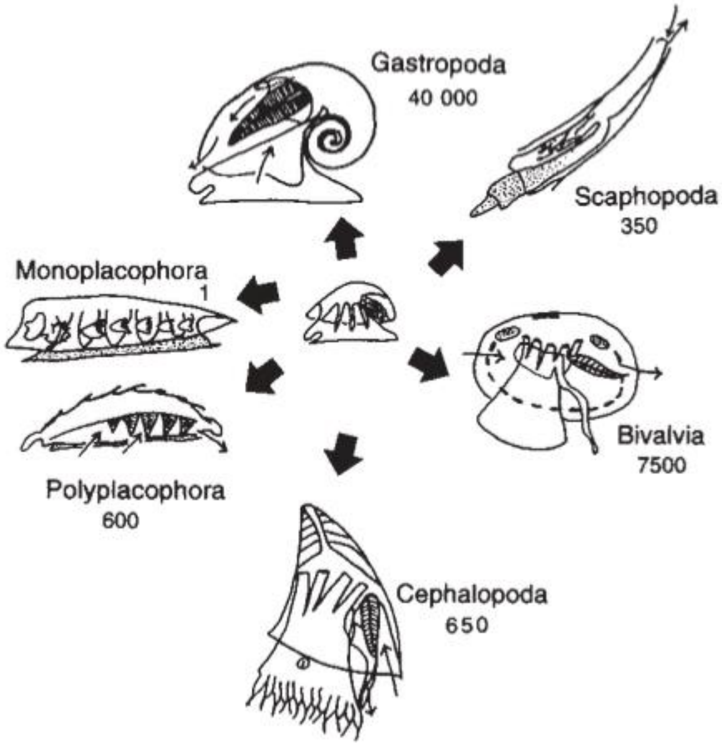

Figure 3.2 - The radiation of the six classes of molluscs from a hypothetical ancestor. Approximate numbers of species in each class are included (Crame, 2000).

Bivalves are animals that have laterally compressed bodies enclosed by two half hinged shells (Roy et al., 2002). According to Gosling (2008), bivalves are the most highly modified of all molluscs, due to becoming flatted and elongated over evolutionary time, and having a complex anatomy. Their anatomy includes, mantle lobes which secrete the two hinged shells that cover the organs, anterior and posterior adductor muscles which control the opening and closing of the shell, a raised mouth position due to becoming laterally compressed over time, and modified gills which allow for the capturing of particles for feeding (Figure 3.3).

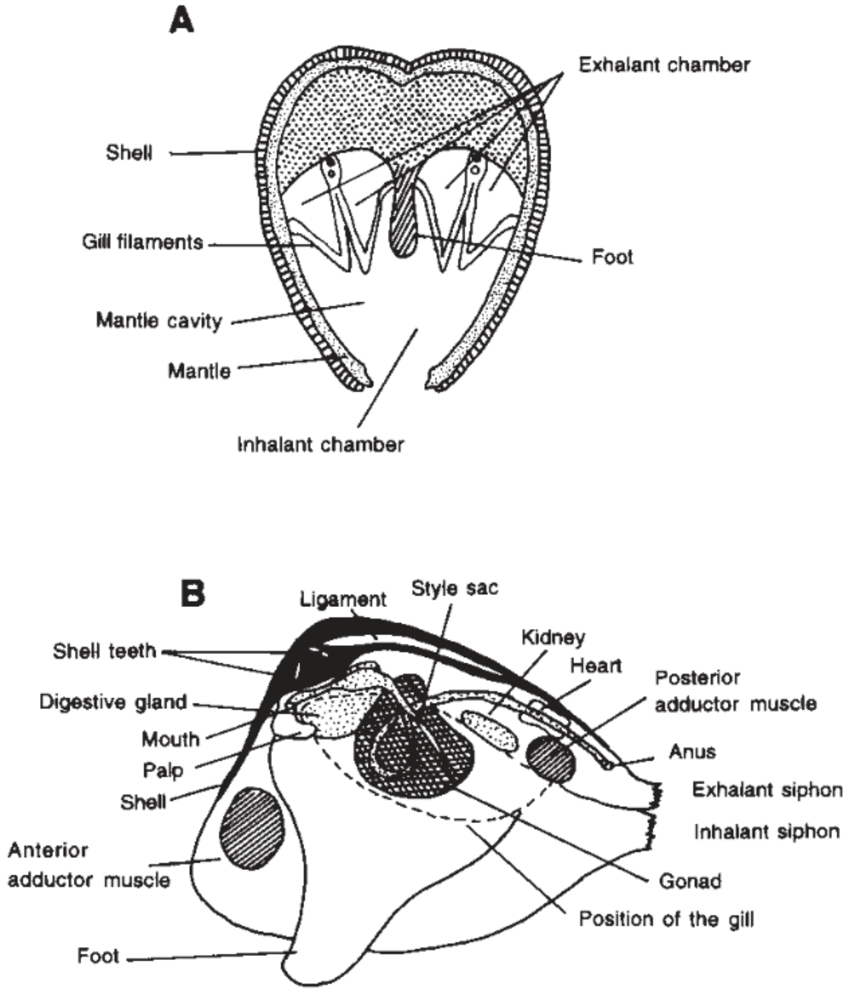

Figure 3.3 - (A) Transverse section through a bivalve illustrating lateral compression and the position of the mantle, foot and gills. (B) Longitudinal section showing the major organs; gill omitted for clarity (Gosling, 2008).

Bivalves range in shape and size depending on the species, however, they have no head and lack common molluscan organs such as the radula and odontophore, however, all obtain siphons (Taylor et al., 2007). They typically occupy estuarine environments, however there are some families such as Corbiculidae (Clams), Sphaeriidae (Pea clams) and Dreissenidae (Mussels) that live in freshwater (Bogan, 2007). In general, most bivalves, including pipi, bury themselves into the sediment where they are relatively safe from predators, however, there are other species that lie on the seafloor or attach themselves to rocks or other hard surfaces, such as oysters (Fraiser and Bottjer, 2007). Overall, there are a range of biological processes that bivalves carryout all of which have important implications on their surrounding environment (Grace, 1983), which are discussed below.

3.3.1 Biology of bivalves

Suspension feeding

Bivalves are classified as suspension feeding organisms which actively filter particles from within the water column (Smaal and Prins, 1993). Most species retain particles $\gtrsim 4\mu$m in diameter with an efficiency of 100% and retain particles of 1 μm in diameter with a reduced efficiency of up to 50% (Shumway et al., 1985). The mechanics of suspension feeding for most bivalves including pipi includes an inhalant mechanism which creates a current within the shell siphoning particles (bacteria and/or phytoplankton) in. Particles then track over the gill structure (Ctenidium) before being transferred to the labial palp (mouth); where particles that are accepted are digested and particles that are rejected become pseudofeces (Figure 3.4) (Kiorboe and Mohlenberg, 1981).

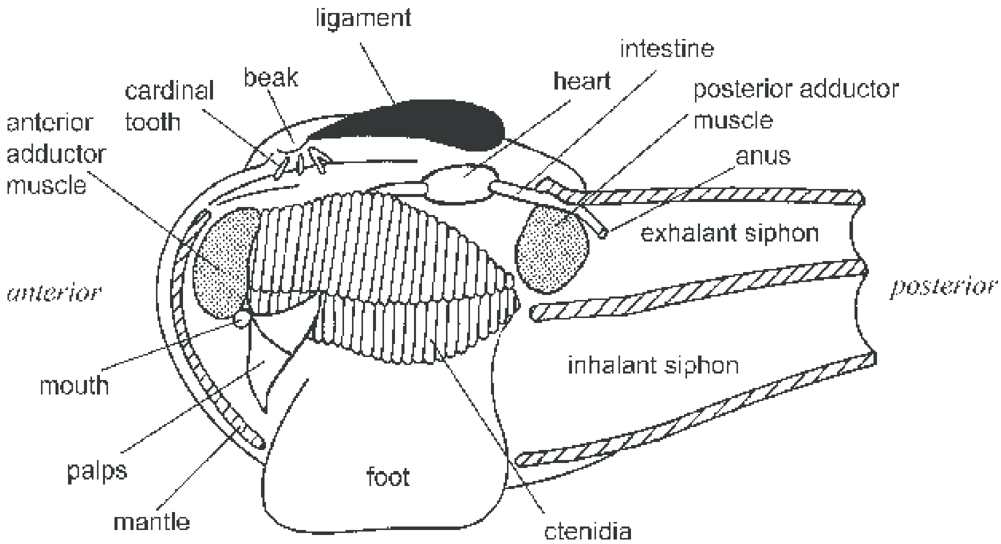

Figure 3.4 – Internal anatomy of a typical heterdont bivalve. The left valve and mantle lobe are removed. The siphons in this specimen are long and fused (Coan and Valentich-Scott, 2006).

As summarised by Meseck et al. (2020), there are 3 forms of cilia that drive the movement of particles within the bivalve during this feeding process. First, there are lateral cilia which drives the water flow into the organism. Second, there are lateral-frontal cilia which track the particles once they enter the organism and bounce them forward to be sorted. Finally, the frontal cilia binds the particles in a mucus and transports them to the labial palp to be rejected or accepted (Figure 3.5).

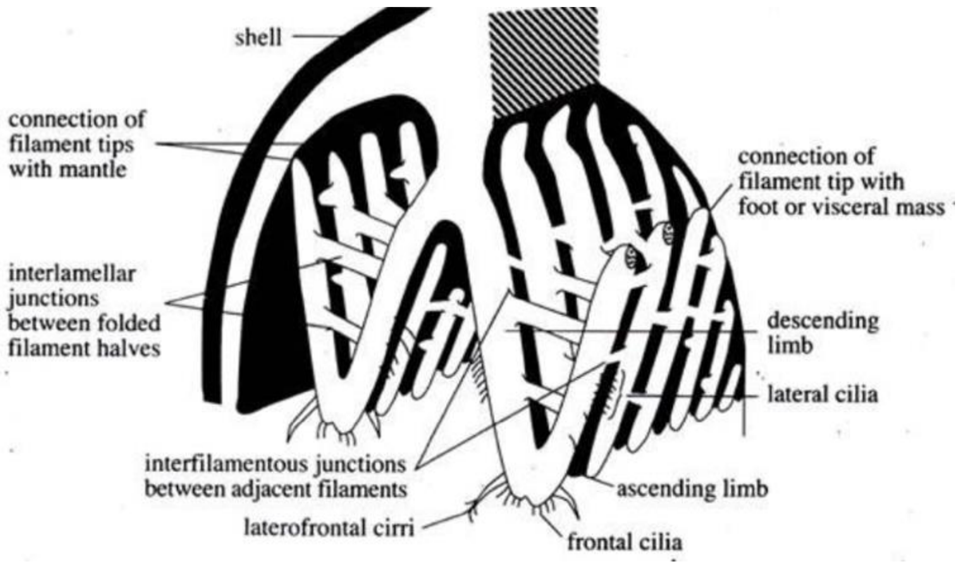

Figure 3.5 - Diagram of lateral cilia, lateral-frontal cilia and frontal cilia in filter feeding bivalve (Parkhaev, 2017).

According to Jørgensen (1996), higher concentrations of suspended particles that get retained by bivalves cause higher secretions of mucus, thus more particles are likely to become entangled in the mucus and get transferred along rejection tracts to the label palp and excreted as pseudofeces. Furthermore, when high levels of mucus are produced, the chance of particles being caught and ejected depends on size, shape and other physical characteristics of the particles. The water pumping and filtration processes associated with suspension feeding is autonomous and is not subject to physiological regulation at the organism level such as nutritional needs. Overall, suspension feeding is a complex process and there are conflicting views on what initiates the mechanisms associated with feeding and the sorting of particles that are accepted and rejected (Shumway et al., 1985).

Reproduction

Another important process that is associated with bivalves is reproduction. The age at which most bivalves become sexually mature varies between species, with the mussel *(Mytilus edulis)* maturing in one year and scallop *(Patinopecten yessoensis)* in 2–3 years (Hooker, 1995b). The reproductive cycle of bivalves once they reach sexual maturity was described by Gosling (2008). Before fertilisation is externally carried out, both male and female undergo an annual reproductive cycle which entails a period of gametogenesis, several spawning phases and gonad reconstruction. For males, spermatogenesis occurs where primary spermatogonia undergo multiple mitotic divisions to produce secondary spermatogonia. Secondary spermatogonia then undergo meiosis to become spermatocytes, which then develop into flagellated spermtazoa. Oogenesis follows a similar process in females where primary oogonia undergo repeated mitosis divisions to produce secondary oogonia. Secondary oogonia undergo meiosis however, arrest at the prophase stage (first phase) of meiosis and the remaining stages are completed at fertilisation. The oocytes undergo a period of vitellogenesis where an accumulation of lipid globules and small amounts of glycogen act as reserves for oocytes as they increase in size. The cell wall of the oocyte eventually ruptures throughout the gonadal cycle; which is particularly associated with the start of spawning and end of breeding (Gosling, 2008).

Overall, the reproductive system in bivalves is considered extremely simple, where paired gonads are made up of branching tubules, and gametes are budded off the lining of the tubules. The tubules unite to form ducts that lead into larger ducts which eventually end in a short gonoduct (Mathieu and Lubet, 1993). Fertilisation is then externally carried out and the gametes are shed through the exhalant opening of the shell (Bayne, 1976).

3.3.2 Ecology of bivalves

Bioturbation and bioirrigation

Bivalves are key species in soft sediment ecosystems due to a number of their biological processes having positive impacts on their surrounding environment, including bioturbation and bioirrigation, benthic-pelagic coupling and nutrient cycling (Norkko et al., 2001). Bioturbation and bioirrigation is the mixing and flushing (respectively) of sediments that stems from bivalves feeding and burrowing behaviours (Norkko and Shumway, 2011). Soft sediment ecosystems rely on bioturbation and bioirrigation as these processes have desirable influences on the sand and mud in which organisms live in (Mermillod-Blondin and Rosenberg, 2006).

Bioturbation was first described by Charles Darwin as he looked into the effects animals had on the structure of the substratum in which they live (Kristensen et al., 2012). Today a common definition for bioturbation in marine ecosystems is the reworking of aquatic sediments as a result of organisms movements, feeding, ventilation, burrowing, tube construction and bio deposits (Figure 3.6) (Norkko and Shumway, 2011). Bioturbation from bivalves and other macrofauna that inhabit the marine soft sediments can significantly alter both the physical and chemical composition of the sediments; resulting in these species being “ecosystem engineers”

(Mermillod-Blondin and Rosenberg, 2006). The infaunal burrows that are created are semi-permanent and act as unique environments which can support different physiochemical properties; furthermore they ventilate the soft sediments by introducing fresh oxygenated water allowing greater solute exchange and an extension of the oxic/anoxic layer (Laverock et al., 2011). Overall, bioturbation can transform a homogenous sandy or muddy bottom into a heterogeneous landscape with physical structures such as burrow, pits and mounds.

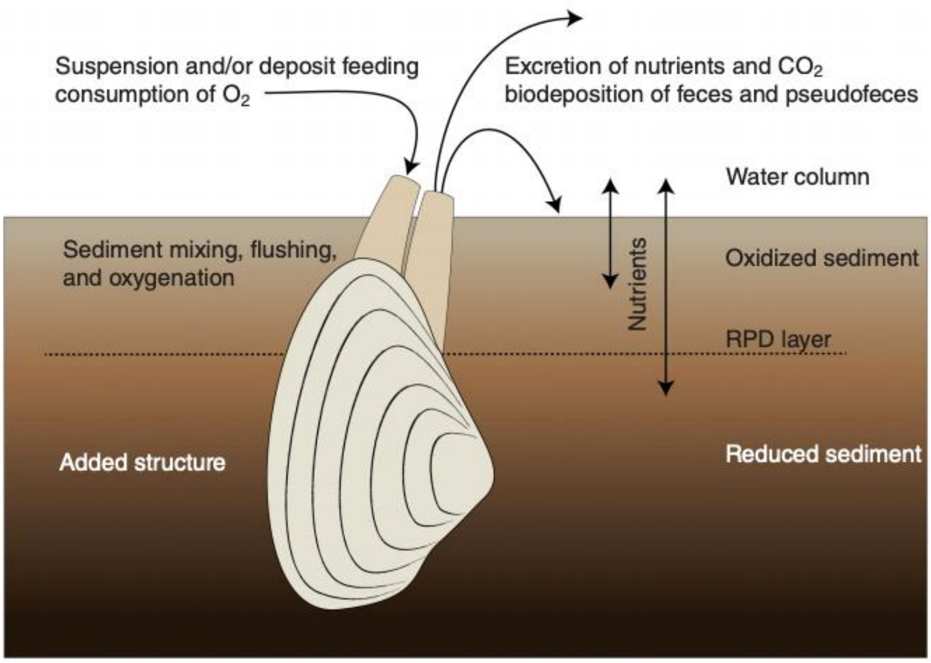

Figure 3.6 - Diagram of the processes around a bivalve buried in the sediment (Norkko and Shumway, 2011).

Bioirrigation results from bioturbation, and refers to the transport of solutes between the sediment and overlying water (Mermillod-Blondin and Rosenberg, 2006). This is directly associated with bivalves due to the flushing of burrows that stems from the suspension feeding of these animals and the ventilation activities that initiates the transport of oxygen and organic matter (Norkko and Shumway, 2011). Ventilation associated with bioirrigation has ecological importance both below and above sediments due to the blind ended burrows. Water is pumped down into the sediment by the animal and gradually forces its way into the surrounding porous sediment (advective porewater transport) (Delefosse et al., 2015). This process of advective porewater transport is an important bioirrigation process associated with organisms such as arenicolid polychaetes (Figure 3.7); thalassinid crustaceans and tellinids which are nearshore bivalves that use their inhalant siphon to take up surface particles and overlying water; and transport this 2–10cm down into the sediment via a separate siphon (Volkenborn et al., 2012).

Advective porewater transport is driven by species specific processes and behaviour, of which pressure gradients and alterations to the sediment can be detected tens of centimetres away from the animal (Woodin et al., 2010). A consequence of this is significant volumes of sediment surrounding the infaunal organisms and their burrows experience irregular oxygen supply and frequent fluctuations between oxic and anoxic conditions (Wethey and Woodin, 2005). This process, along with nutrient cycling, both have significant implications on the environment in which the animal lives and the surrounding species (Huettel and Rusch, 2000).

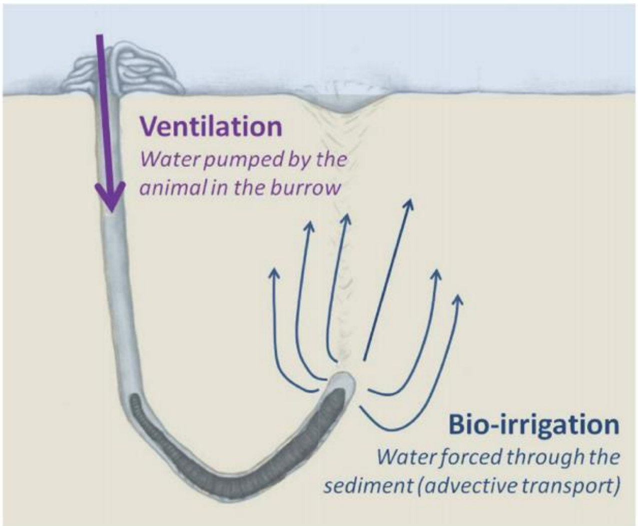

Figure 3.7 - Ventilation and bio-irrigation in the blind-ended burrow of the lugworm, Arenicola marina (Delefosse et al., 2015).

Nitrogen cycling

The nitrogen cycle is considered one of the most complex and fascinating processes among all biogeochemical cycles in the ocean (Rodil et al., 2011). Nitrogen (N) is at the centre of all ocean biochemistry and has a significant influence on the presence of other elements (e.g., carbon and phosphorus) and cycles (Gruber, 2008) (Figure 3.8). Benthic-pelagic coupling and nutrient cycling are both important processes for the nitrogen cycle due to the low levels of available N for primary production in marine coastal and shelf regions (Pelegri and Blackburn, 1995). Benthic pelagic coupling and nitrogen recycling which takes place in the sediments tends to be increased by macrofaunal activity, including that of bivalves; therefore, the rate at which N is being mineralized and becoming readily available is increased (Pelegri and Blackburn, 1995).

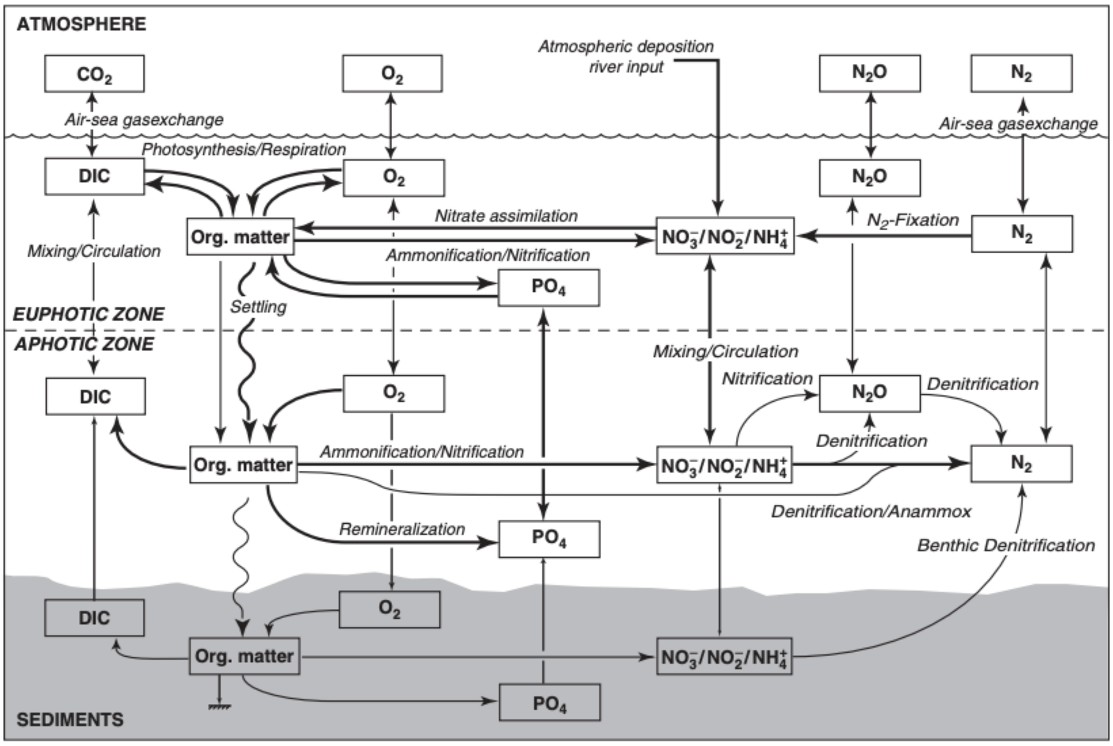

Figure 3.8 - Diagram of the marine nitrogen cycle and its coupling to the marine cycles of oxygen, phosphorous, and carbon (Gruber, 2008).

According to Hagemann et al. (2016), nitrogen mineralization is the conversion of organic nitrogen to inorganic forms. During this process ammonium is released (ammonification) which bacteria and other microorganisms utilise (Schaechter, 2009). Furthermore, nitrification which is the process of ammonium (NH_4^+) being oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-), links the most oxidized and most reduced components of nitrogen together (Gruber, 2008). Nearly all of these transformations related to nitrogen are undertaken or altered by marine organisms as a part of their metabolism, either to obtain N to synthesize, or to gain energy for growth (Rush and Sinninghe Damsté, 2017).

The infaunal activity of benthic communities highly influences nutrient recycling and the overall productivity of shallow water ecosystems (Zapperi et al., 2016). Most processes such as bioturbation, bioirrigation, nitrogen mineralization and nitrification influence the dynamics of the sediments and coastal ecosystem in the benthic boundary layer, which is the layer in which the exchange of materials between the sediments and the water column takes place (Norkko et al., 2001). Due to bivalves often being dominant in terms of biomass and/or abundance in soft sediments, their influence on habitat engineering is vital due to the processes they carry out having a significant effect on their surrounding environment. Conversely, where changes in condition, abundance or distribution of bivalve species occurs, cascading effects on both the benthic and pelagic ecosystems is possible. Within the order of Bivalvia there consist 1,100 genera of which pipi belong to the genus Paphies, these being one of the most common and abundant bivalve species in Aotearoa.

3.4 Genus Paphies

Paphies are a genus of large edible surf clams, classified by shell shape, shell colour and adductor muscle colour (Smith et al., 1989). Within this genus there are three main species endemic to Aotearoa New Zealand, Toheroa *(Paphies ventricose),* Tuatua (*Paphies subtriangulata)* and Pipi *(Paphies australis)* (Figure 3.9).

Toheroa are the largest species of this genus, measuring up to 150mm in shell length as an adult and juveniles measuring <40mm (Kondo and Stace, 1995). Toheroa have broad lateral distribution and are commonly found on exposed west-facing beaches with high-energy and fine sand (grain size ~0.25mm) (Gadomski and Lamare, 2015).

Figure 3.9 - Images of pipi (left), toheroa (middle) and tuatua (right) (Spurgeon, 2020).

Toheroa population abundances have drastically declined throughout Aotearoa New Zealand over the last few centuries, with the northern population decreasing from 10 million individuals in 1964 to just 1 million in 1971 (Rapson, 1954). Southern populations followed a similar trend, decreasing from 2.2 million in the mid 1970's to 78,000 by 1990 (Millar and Olsen, 1995). Reasons for this decline include habitat degradation, increased foot/beach traffic and significant overharvesting during the early 20th century (Beentjes et al., 2006). The popularity of this species as a recreational harvest significantly increased around the 20th century and soon after commercial operations were established to export canned toheroa. As a result of the commercial fishery and unregulated recreational harvesting the species was quickly depleted as a resource and by the mid 1900's they were no longer viable for harvest (Rapson, 1954).

According to Ross et al. (2018), the ecology and biology of toheroa differs slightly to that of pipi, where the shell is solid and oval in shape with valves that do not completely close unlike pipi. The mantle which partially covers the gap between the valves can appear pink in some individuals and the siphons are noticeably longer and highly contractile compared to other Aotearoa Paphies species. The inhalant siphon is comprised of complex tentacle structures which prevent large particles entering the mantle cavity. Furthermore, the foot of toheroa is large and triangular which allows the animals to burrow rapidly into the sand and down to depths greater than 20cm (Figure 3.10).

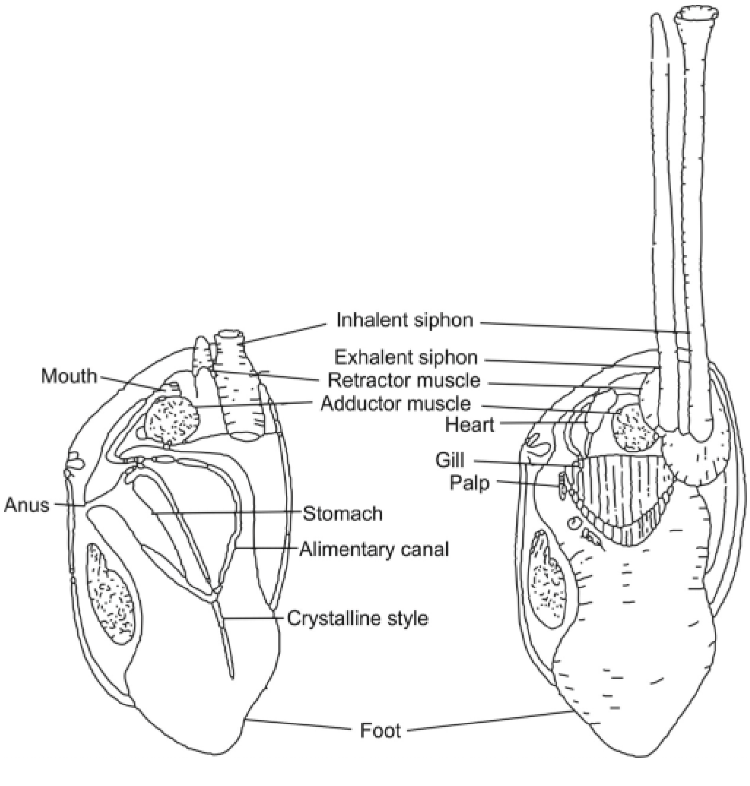

Figure 3.10 - Internal anatomy of toheroa (Ross et al., 2018).

Tuatua *(Paphies subtriangulata)* are edible surf clams found on fine-sand beaches along the open coast of Aotearoa New Zealand (Hannan, 2014). Another species, *Paphies donacina* are also referred to as tuatua but are a deep water species and are differentiated by the shell outline (however, are really hard to differentiate) (Richardson et al., 1982). Tuatua inhabit beaches all over Aotearoa ranging from the North Island to along the North coast of the South Island. The deep water species *(P. donacina)* inhabits areas around the South Island and the north coast of Stewart Island. Some have also been found around the mid-lower regions of the North Island; however, both tuatua species are sympatric and their distributions overlap in areas (Redfearn, 1987).

The biology of tuatua is similar to that of pipi and toheroa, where their growth is relatively rapid with most individuals reaching 40–70mm in approximately three years. The maximum shell length varies with location however most reach 50 to 80mm after five years (Aljadani, 2013). Tuatua are usually found wedged a few centimetres into the sand with short siphons often exposed due to being suspension feeders. They are considered ecological markers of fine, clean, fluid sands on open coast beaches with moderate wave exposure and are easily redistributed by being dragged out of the sediment by swash/wave action by which they burrow back into the sediment once they settle (Leach et al.).

Overall, toheroa and tuatua are two of the Paphies species which are distributed along the open coast and rely on moderate to significant wave action. Pipi, the third endemic Paphies species are found in estuaries and rely on low wave action and considerable water flow *(Paphies australis).*

3.5 Pipi *(Paphies australis)*

Pipi are moderately sized compared to toheroa and tuatua, measuring up to 90mm in shell length. They are recognised by their umbo (lateral prominence about the hinge of the shell) being located on the posterior side of the centre of the dorsal margin, whereas the other Paphies species have it located near the posterior end (Hooker and Creese, 1996). All three Paphies species are suspension feeders, however, pipi have shorter siphons and have a thick, solid, white shell covered with a periostracum (skin) (McNabb et al., 2014). Most taxonomists separate pipi as a separate sub genus due to it being more inequilateral compared to most other species (Beu and De Rooij-Schuiling, 1982).

For pipi, burrowing is a particularly important behaviour, especially in soft sediment ecosystems due to the potential for sediment accretion and erosion to occur (da Silva Cândido and Brazil Romero, 2007). If pipi are too exposed above the soft bottom they become vulnerable to predators, whilst burial may result in suffocation or starvation due to loss of contact with the overlying water and food; however in general more deeply buried organisms are less likely to be washed out (Hull et al., 1998). Burrowing is the process of repeated probing and anchoring sequences in which the muscles of the foot alternately contract. Other movements such as rocking and ejecting water from the mantle cavity are thought to assist the effectiveness of burrowing. Shell shape as well as sediment porosity and contaminants is correlated with burrowing behaviour as it has been found that courser sands are easier to penetrate and burial by some bivalves is inhibited by sensitivity to sediment contaminates (Trueman et al., 1966).

Due to pipi having short siphons, their burrowing activity is limited to being slightly exposed or shallow-living therefore, if they are inundated by sediment and fail to burrow back to the surface, death from lack of oxygen and/or starvation will occur (Damodaran, 2020). Furthermore, pipi have been observed being squeezed out of the sediment as a result of high densities, thus it is suggested that interactions between pipi that occupy the same bed necessitate reburial (Hull et al., 1998). Overall, pipi burrow best when in their natural orientation (inverted) and can survive inundations of at least 10cm per day for several days, making them sufficiently robust bivalves that could withstand potential anthropogenic alterations to their habitat (Cummings and Thrush, 2004).

3.5.1 Pipi habitat (marine soft sediment ecosystems)

Marine soft sediment ecosystems are the most common habitat on earth and is host to hundreds of different organisms, including pipi (Thrush et al., 2006). These muddy and sandy sediments cover 70% of the worlds seafloor and are found in New Zealand, Aotearoa’s harbours, estuaries and open coastal environments. The resident flora and fauna play important roles that influence ecosystem functioning and ecosystem services such as nutrient and sediment transport (Wilson, 1990). Animals that are subsurface deposit feeders alter the vertical distribution of the sediment grain size and change the spectrum of grain sizes by ingesting small sediment particles and excrete them as larger faecal pellets (Wilson, 1990). Pipi are burrowing infauna therefore, the porosity and erodibility of the sediment is effected by their daily activities (Bianchi, 1988).

Compared to most other marine ecosystems, where animals are confined to hard, impermeable surfaces (e.g. rocky shore), soft sediments are unique as they are made up of settled particles which create a three dimensional environment for organisms to inhabit (Zajac, 2008). Due to sediments being the accumulation of settled particles, they are generally rich in organic matter therefore animals that occupy this environment use this organic matter as a food source, but may also feed on algae and suspended particles in the water column (e.g. pipi) (Hull et al., 1998).

Algae growth depends largely on the pore water interface between the sediment and seawater which is permeable therefore, water fills the small spaces between the sediments (Raven and Geider, 1988). Once the pore water enters the sediments the concentration of oxygen in the pore water decreases rapidly with depth, therefore the organisms must maintain access to an oxygen-rich supply. Also the concentration of nutrients is generally greater in areas where there is pore-water exchange thus, acting as a fertiliser for algal growth and having a significant effect on the plants and animals that can occupy the area (Hewitt et al., 1997). Interpreting these fluxes of oxygen and nutrients flowing in and out of the sediment remains a complicated process due to marine soft sediments being inherently complex, with the interactions between many different organisms altering the oxygen and nutrient concentrations, as described in Section 3.3.2, as well as trying to understand the geochemical and ecological factors the affect these flux rates and in turn ecosystem functioning (Zajac, 2008).

3.5.2 Pipi distribution

Pipi are endemic to Aotearoa New Zealand and one of the most widespread infaunal bivalves, distributed throughout the country with populations found along the coast of Te Ika a Māui (North Island), Te Waipounamu (South Island), Rakiura (Stewart Island) and Rēkohu (Chatham Islands). They commonly occupy protected areas where there is little wave action and high water flow such as harbours and estuaries (Hannan, 2014). They occur in dense aggregations (up to per 1000m^2) over a broad tidal range, from intertidal to subtidal in areas to a depth of approximately 7m; and are mostly considered sedentary once they have settled (Pawley et al., 2013).

There is growing evidence that indicates that during the period immediately following settlement of bivalves, including pipi, they are able to disperse as juveniles. Adult pipi are considered sedentary once they have settled, however, Jones and Bloomberg (1983) suggest juvenile pipi slowly migrate down shore as they grow, and smaller movements of larger individuals can occur sporadically. Observations of larger pipi have been noted by Hooker

(1995a) where 12 pipi, roughly 45mm in shell length were observed drifting in mid-water on the ebb tide at the entrance of Whangateau Harbour. It was further explained in this study that mucus is used by the animals to help support them in the water column. Grace (1972) confirmed pipi utilise water currents to disperse actively within the harbour, which could also have a major influence on the population dynamics of pipi.

Berkenbusch et al. (2015) conducted an intertidal shellfish monitoring programme in the northern North Island region during 2015–2016 targeting tuangi (cockles) and pipi. Surveys were carried out in non-commercial fishery areas where populations were assessed; sites included Bowentown Beach, Cheltenham Beach, Cockle Bay, Little Waihī Estuary, Marokopa Estuary, Ohiwa Harbour, Okoromai Bay, Pataua Estuary, Tairua Harbour, Umupuia Beach, Whangateau Harbour, and Whitianga Harbour (Figure 3.11). Nine of the survey sites contained pipi populations with few or no pipi at Cheltenham Beach, Cockle Bay, Okoromai Bay, and Umupuia Beach. Five of the six sites contained large pipi, and time series data highlighted significant differences across all sites over time; but all current density estimates of large pipi were low (Table 3.1).

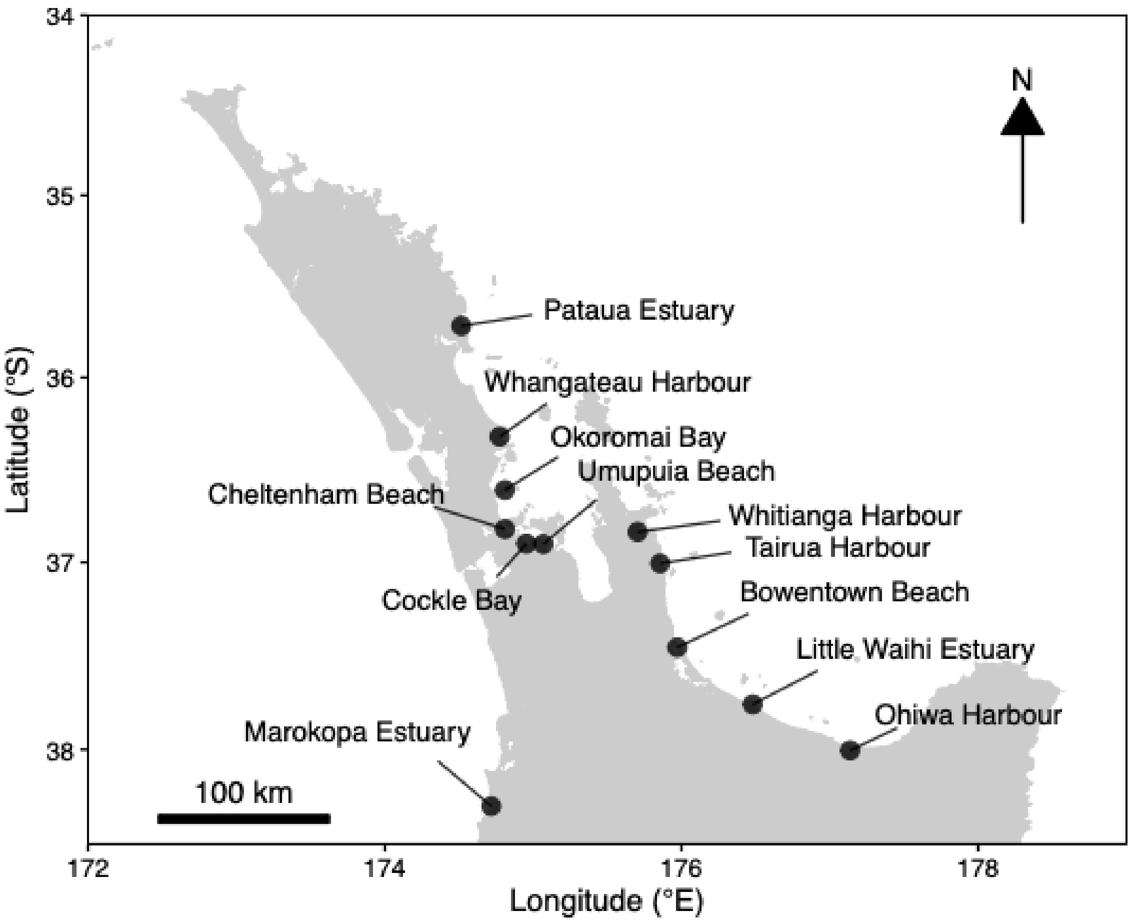

Figure 3.11 - Sites included in the northern North Island intertidal bivalve surveys in 2015–16 (Berkenbusch et al., 2015).

Table 3.1 - Estimates of pipi abundance for all sites with more than ten pipi found in the 2015–16 survey. For each site, the table includes the estimated mean number, the mean density, and coefficient of variation (CV) for all pipi (Total) and for large pipi (≥50mm shell length) (Berkenbusch et al., 2015).

Survey site	Population estimate			Population ≥50 mm		
	Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
Bowentown Beach	0.15	10	16.6	0.01	<1	72.82
Cockle Bay	0.11	<1	>100	0.00	0	
Little Waihi Estuary	83.84	456	16.62	2.35	13	43.62
Marokopa Estuary	8.62	333	11.26	0.00	0	
Ohiwa Harbour	41.26	1225	12.1	3.70	110	18.37
Pataua Estuary	6.45	23	14.67	0.19	<1	79.86
Tairua Harbour	26.71	327	15.64	0.38	5	39.85
Whangateau Harbour	15.00	14	23.2	0.40	<1	9.04
Whitianga Harbour	6.36	104	18.17	1.91	31	22.66

This study by Berkenbusch et al. (2015) is one of the most comprehensive intertidal shellfish monitoring programmes carried out in Aotearoa New Zealand. With eight years of data collected and seven reports comparing bivalve populations in estuaries, bays and large inlets throughout the northern North Island region; there is a significant amount of data that can be incorporated into this study, including the field sampling methods and data analysis methods which were replicated and are outlined in Chapter 4 of this thesis.

3.5.3 Threats to pipi

Marine soft sediment ecosystems are among the most intensively used and most threatened natural ecosystem on Earth (Squires, 2019). They are continuously shifting state and at present are threatened by major anthropogenic disturbances such as bottom trawling, poor land management practices, unsustainable fishing practices, climate change and pollution (Thrush et al., 2004). This section outlines the key threats pipi face.

Suspended sediments

Like most filter feeders, pipi are influenced by suspended sediment loads which are generally a function of alterations and impacts affecting the catchment of estuaries, such as urban development, forestry, farming, dredging and inadequate land management practices (Ellis et al., 2002). With generally increased sedimentation rates and suspended sediment levels, the health, abundance and distribution of many benthic organisms including pipi are altered due to the surrounding environment being physically changed e.g. reduced light attenuation (visibility), reduced photic zone and altered vertical stratification of heat in the water column (Gibbs and Hewitt, 2004). Common issues associated with increased suspended sediments includes high concentrations of seston, which are biological components such as plankton, bacteria, larvae, and fish eggs which have densities similar to water with low settling velocities, meaning they remain in permanent suspension (Hutchens Jr et al., 2017). This has negative impacts on suspension feeding bivalves as well as increased silts and clays which supplements pseudofaeces production and decreases the amount of algal food actually ingested by the bivalve and damages the bivalve gills (Foe and Knight, 1985).

Dredging

Many human activities disturb and alter aquatic habitats, causing resuspended bottom sediments and creating turbid conditions that differ in scope, time, duration and intensity. Dredging associated with commercial fishing and of navigation channels are common sources of bottom disturbance that occur all over the world (Wilber and Clarke, 2001). The impacts on the benthic communities as a consequence of dredging have been well documented in numerous studies however, other associated impacts remain largely unquantified such as the effects of resuspended sediments on shellfish (as described above) and the direct removal of species during the dredging process (van Gils et al., 2006). As a result of directly removing all organisms larger than 19mm in the top 5 centimetres, the biodiversity of dredged sites is lost as bivalves, polychaetes and crustaceans are all taken out of the ecosystem (Mercaldo-Allen and Goldberg, 2011). According to van Gils et al. (2006), indirect effects of dredging that occur over a long period of time includes altered sediment grain size as the sediments become coarser after dredging events. As a result bivalves experience reduced settlement success and altered feeding performance; thus dredging leads to both short and long term declines in quantity and quality of a variety of macrobenthic organisms, including pipi.

Over harvesting

Pipi are popular among recreational and customary fishers, with the shellfish fishery being valued at approximately $190 billion globally and nearly one billion people participating annually (Embke et al., 2019).

Hotspots for recreational gathering include estuaries as they are thought to be highly resilient and self-regulating, thus attracting gathers. However, due to the rapid pace of environmental change their vulnerability to overharvest and collapse is increasing (Cox et al., 2002). As gathering effort becomes easier and hotspots become increasingly populated, total harvest increases and so too does the potential for excess harvesting (Post et al., 2002).

According to Ministry for Primary Industries, (2008) pipi were introduced into the Quota Management System (QMS) in 2004 due to being an important species both commercially and non-commercially. In 2005 pipi stocks listed in Table 3.2 were introduced with the Total Allowable Catch (TAC) under the QMS being 713 t. Of this 713 t, 204 t is allocated to Total Allowable Commercial Catch (TACC), 242 t to customary fishers, 249 t to recreational harvest and 25 t for other sources of mortality (Table 3.2). No changes have been made to the TAC since then. Regulations require gathering to be done by hand and there is no minimum legal size however, most favour pipi larger pipi (>60mm). There is no season specified for gathering, therefore pipi are available for harvest year-round (Ferguson and Hooper, 2017).

Table 3.2 - Recreational, Customary non-commercial allocations, TACs and TACCs (t) for pipi (Ministry for Primary Industries, 2008).

Fish stock	Recreational Allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
PPI 1A	25	25	0	200	250
PPI 1B	76	76	8	0	160
PPI1C	115	115	10	3	243
PPI 2	3	3	1	0	7
PPI 3	9	9	1	0	19
PPI 4	1	1	1	0	3
PPI 5	1	1	1	0	3
PPI 7	1	1	1	1	4
PPI 8	1	1	1	0	3
PPI 9	10	10	1	0	21
Total	249	242	25	204	713

Climate change

Anthropogenic climate change began and is sustained by human industrial activities that produce significant amounts of greenhouse gas (CO_2 and methane) (He and Silliman, 2019). Climate change impacts that affect estuaries and pipi include rising air temperature, with the average global surface air temperature increasing by 0.85°C between 1880 and 2012. Also, rising sea surface temperatures, where the global mean sea level rose by 0.11m between 1910 and 2010. Climate change also has impacts on precipitation and hence river/stream flows, rising sea level, and changes in ocean salinity due to the dissolution of CO_2 into the ocean causing chemical changes (lowered pH); with the pH of the global ocean decreasing by 0.1pH units since the preindustrial period (Poulin and Mouritsen, 2006). Ocean acidification which is a result of altered pH levels from climate change causes an increase in protons (H+ ions) and decrease in carbonate ions (Feely et al., 2009). Many marine organisms such as corals and bivalves rely on carbonate ions to produce their limestone skeleton structure or shell (Doney et al., 2009). As ocean acidification increases animals such as pipi are having an increasingly difficult time producing their outer shell and marine plants are impacted due to altered community structure and functioning (Gattuso and Hansson, 2011).

Most marine ecosystems are already threatened by oxygen deficiency however, the warming climate will further exacerbate the deoxygenation of the sediments with the potential for serious consequences to be had for ecosystem functioning and services (Norkko et al., 2019). Increased hypoxia will cause macrofaunal processes such as bioturbation and bioirrigation to

be reduced due to changes in the behaviour and diversity of species furthermore, the nutrient concentrations are effected as a result of altered biogeochemical processes and oxygen concentrations in the sediment-water interface (Piersma et al., 2009).
There is no doubt that these environmental changes will significantly alter the ecological processes of our natural ecosystems such as marine soft sediments due to weather and climate dictating processes the performance of organisms distribution and dynamics of species populations (Gammal et al., 2019).

Algae blooms

According to Hallegraeff (1992), of the ~5000 marine phytoplankton species, approximately 300 can at times occur in such high numbers they discolour the surface of the sea (so-called "red tides"). Eighty of these species have the capacity to produce harmful toxins in response to environmental changes and undergo rapid proliferation with their numbers reaching several millions per litre (referred to in literature as harmful algae blooms). Harmful algal blooms occur globally and in some locations are a common and seasonal occurrence however, recent literature has correlated the occurrence and spread of algal blooms with human activities such as fishing, aquaculture and tourism (Basti et al., 2018).

Algal blooms may be toxic or noxious with potential consequences being anoxia due to decaying organic matter and toxins bioaccumulating and becoming easily ingested by planktivorous fish leading to the trophic transfer of these marine toxins throughout the food web (Reis Costa, 2016). Furthermore, harmful algal blooms can cause death in fish, marine mammals, humans and shellfish due to their associated toxins or their sheer quantity (Townhill et al., 2018). Due to the source of these blooms being microscopic plankton, which are a critical food source for many marine animals, the ability for toxins to be transferred through multiple species is highly likely however, shellfish species can be rendered toxic overnight and can obtain clogged gills when filter feeding causing death by starvation (Shumway, 1990). In August 2018 Waihī Estuary was issued with a public health warning by Toi Te Ora Public Health as a result of algae mats forming in shallow areas of the estuary. The toxic algae that was forming was known to cause asthma, hay fever, rashes and muscle paralysis. Shellfish were deemed toxic as they could accumulate the poison via filter feeding (Zealand, 2018).

Pollution

Pollution includes oil, plastic and sewage entering the ocean in large amounts as a result of both marine and land based activities (Wabnitz and Nichols (2010),). Urban cities are a main source for pollution due to the waste being carried along waterways and washed out to sea via drain pipes. Other sources of waste include recreational boating, commercial fishing, shipping and oil/gas operations (Azzarello and Van Vleet, 1987). Coastal waters, harbours, estuaries and reefs are particularly vulnerable to the effects of pollution, especially plastic pollution due to waste washing up and collecting in these areas (Islam and Tanaka, 2004). Plastics is a major concern for estuaries and the wider marine environment. Plastics are synthetic organic polymers that have existed for just over a century. The versatility of these materials has led to a significant increase in their use over the last few decades due to being lightweight, strong, durable and cheap (Laist, 1987). However, plastics are a major hazard to the environment due to being made up of chemicals that have a gradual breakdown process taking up to 450 years to decompose (Boyle, 2004). The threat of plastics to the marine environment increases tenfold since they are a buoyant and can be dispersed over long distances. These aspects coupled with the long decomposition rate mean the treat of plastics to the marine environment is detrimental and has long been overlooked as to how serious this issue is (Derraik, 2002).

Further issues associated with marine pollution is the effects of hydrocarbons which are universal components of the marine environment due to synthesis by marine organisms producing a variety of hydrocarbons that then spread through the ecosystem because of their stability in the food chain and their resistance to degradation (Blumer et al., 1970). However, more recently hydrocarbons from pollution by fossil fuels and oil products are being found in alarming amounts which is raising concerns around the toxic content associated with these oil products (Rios et al., 2007). Hydrocarbons derived from fossil fuels and pollution differ to those of the natural form produced by organisms; they are more toxic and have a distinctive aromatic component to them, furthermore, they are not as easily degraded (Rochman et al., 2013). Shellfish are highly vulnerable to hydrocarbons and their associated toxins due to being filter feeders making them easily contaminated and a hazard to those who consume them, for example the shellfish along the coast of the Bay of Plenty were significantly affected by the toxic materials that were released into Tauranga moana from the MV *Rena* that struck astrolabe reef in October 2011 (Fa'aui and Morgan, 2014).

3.6. Summary

Shellfish provide a wealth of ecological services including bioturbation, bioirrigation and nutrient cycling (Lowery et al., 2007). They are consumed by many finfish, vertebrate and invertebrate species, thus play an important role in the food-web directly as prey and indirectly through bottom-up provision of nutrients and energy (Vaughn and Hoellein, 2018). Particular materials that build up in the soft tissue of bivalves can be assessed and used as environmental monitors and where there are dense aggregations of specific bivalve species biogeochemical transformations in the sediments can be found. In relation to the importance of bivalves to humans, pipi support a portion of the commercial and recreational fisheries (Ministry for Primary Industries, 2008). However, pipi are exposed to a range of threats due to the nature of the environment in which they inhabit. Current awareness and management of pipi is carried out by iwi due to pipi being a taonga species who gather this species and other shellfish as a part of their diet.

Chapter 4
Methods

"He rau ringa e oti ai"

"Many hands make light work"

The aim of this research was to use mātauranga Māori to inform our understanding of population dynamics and health of pipi in Waihī Estuary. The methods to achieve these objectives used both qualitative and quantitative approaches. The qualitative component involved getting ethical approval followed by kōrero (talk)/interviews with kaumātua (elders), adhering to kaupapa Māori research principles, and participatory mapping. In this chapter we introduce how this project was fundamentally driven by mātauranga Māori, from conception of the topic, through to selecting sampling sites. We also show how tikanga was implemented throughout the entirety of this research and how western science methods were incorporated to help quantify the kōrero. The quantitative component involved field surveying of pipi, replicating methods of Berkenbusch et al. (2015).

4.1 Kaupapa Māori research

Qualitative data may be obtained by a researcher via firsthand observations, interviews, questionnaires, participant observations, recordings and documents (Maxwell, 1961). The qualitative components of this research included kaupapa Māori research methods and participatory mapping, which are detailed below. Kaupapa Māori research is research done by Māori, for Māori, with Māori (Mane, 2009), and it is this concept that fundamentally informed this research including the conception of the topic, methods and sharing of information. However, before describing in depth what kaupapa Māori research is, kaupapa Māori on its own needs to be understood as this concept forms the base of the research methods being implemented throughout this study.

Kaupapa Māori is the essence and desire of Māori to be Māori, and captures Māori cultural philosophies and practices (Pihama et al., 2002). The theory behind it is derived from attempts to make sense of the efforts to revitalise Māori language and culture that began in the late 1970s (Keegan, 2012). According to Walker et al. (2006), the first Māori arrived in Aotearoa approximately 1000 years ago from the Polynesian islands. During 1769 the first Europeans arrived and in 1840 the establishment of the British government in Aotearoa New Zealand was formed via Te Tiriti o Waitangi which was signed by representatives of Queen Victoria and over 500 Māori leaders. Māori expected a partnership to be formed between British/Crown and themselves, however, British expectations were that they were now in charge and would operate a new colony and bring civilization to Māori. After 130 years of colonization, exploitation and oppression of Māori, the Māori language, culture and practices had diminished. Not until after World War II, had Maori begun to revitalize their culture through increased education of Māori and kaupapa Māori, or Māori philosophies. It was during this time that kaupapa Māori re-emerged as a strong and legitimate concept, influencing education, politics and research (Pihama et al., 2015).

Kaupapa Māori research is thought to have arisen from mātauranga Māori, due to the theory and analysis of the work being carried out involving Māori (Smith, 2000). It has been said that kaupapa Māori research came out of a particular struggle for legitimacy of Māori identity and the ability to operate within a Māori sector (Curtis, 2016). Therefore, tradition is important in kaupapa Māori research as it ensures the people who hold the basis of the knowledge (such as hapū/iwi) are included throughout the research process, and it is their concerns that make up the key guiding principles for the overall research being carried out (Smith et al., 2012). Throughout the duration of this research, consultation with iwi was made priority from the beginning and upkept throughout, with their key concerns for Waihī Estuary being the conception of this research.

According to Kerr (2012) there are five elements which are necessary for the overall vision of kaupapa Māori research:

1) It is seen as a potentially useful tool for assisting positive transformation of Māori conditions;
2) Should be seen as a 'tool' that is "useful in the right hands and potentially destructive in the wrong hands." Thus, the onus is on the person selecting to use the theory (or not to use it), i.e., to assess its relevance and usefulness;
3) Is transformative because the 'status quo' for most indigenous contexts is not working well and needs to be improved;

4) Moves beyond a homogenizing position of seeing 'struggle' as a single issue and therefore needs to be adaptable to develop multiple transforming strategies (some of which might be applied simultaneously); and
5) Is accountable to the community; the ideas around praxis and 'action research methodology' are useful.

4.2 Principles of kaupapa Māori research

According to Smith (2015), there are set principles, values, beliefs and attitudes that kaupapa Māori research implements within its approach to science. These principles have been established through past experiences and help Māori people regain, reconnect and re-centre what it means to be Māori. Walker et al. (2006) cites *tino rangatiratanga* which translates to sovereignty, self-determination, governance and independence is the main principle or standpoint of kaupapa Māori research. When implementing kaupapa Māori research, tino rangatiratanga follows a Māori-centred agenda where the issues and needs of Māori are the focus and outcomes; and acceptance of Māori as the controlling group to the research is achieved (Kiro, 2000).

Another important principle to kaupapa Māori research is *social justice* which seeks positive outcomes for whānau, hapū, iwi and Māori, where the conception of the research has been determined by Māori and the research methods are derived from Māori concepts, views and values (Mane, 2009). Some researchers believe that if Māori are not to benefit from the research then kaupapa Māori research should not be implemented (Curtis, 2016). Social justice needs to be included so the outcomes enhance the quality of life for Māori and their wider community (Teariki et al., 1992).

Other principles of kaupapa Māori research include *Te Reo Māori* (Māori language) which refers to the revival and retention of the Māori language by increasing the use of te reo in schools, house of parliament and science/research (Mercier, 2018b). *Tikanga Māori* is an important principle due to the notions of tikanga and what it means to be Māori. However, the issue of tikanga coming across as a recipe or formula in Māori research is a common occurrence, therefore, kaumātua need to explain the protocols and matters of tikanga in this field (Smith, 2015). Finally, the principle of *mana wāhine* refers to women being absent from Māori research; therefore, hidden gender grounds need to be addressed in the Māori research space due to the perception that neither a man or woman can do the same job (Simmonds, 2011). Mana wāhine is about making the narratives and experiences that Māori women face visible, especially in research (Smith, 1993). Overall, these principles form the base of kaupapa Māori research; by implementing and following these, kaupapa Māori research is able to be maintained as science and culture grows and develops (Pihama, 2012).

The methods being implemented throughout this research follow a transdisciplinary approach, where mātauranga Māori and kaupapa Māori research methods inform the process, and western science protocols help build on the overall aim to understand the population dynamics and health of pipi in Waihī Estuary. Once the findings have been collated, as per kaupapa Māori research principles the results are taken back to the iwi (in our case, Ngāti Whakahemo).

4.3 Process of developing kaupapa Māori research

4.3.1 Ethical principles and concerns

To ensure that the afore-described principles were upheld in this thesis, kaupapa Māori research principles were stated in the application for human ethics approval. Human ethical frameworks ensure Māori values and beliefs are given equal consideration when working in a research space that incorporates mātauranga Māori. Such ethical frameworks that are informed by mātauranga Māori require parameters such are tikanga, tino rangatiratanga, te reo and mana wāhine described in the application due to these principles being at the forefront of kaupapa Māori research (Hudson and Ahuriri-Driscoll, 2005).

For a number of years Māori pushed for a Māori ethical framework due to ethical issues surrounding Māori interests and lack of control over research that includes mātauranga Māori (Hudson, 2004). The development of Māori research and mātauranga Māori are considered ethical issues within The Treaty of Waitangi, in which the Crown identified as having a responsibility to support Māori development and aspirations (Gelling, 2016). However, due to no specific Māori ethical framework being developed, Māori researchers such as Hudson and Ahuriri-Driscoll (2005), Smith (2013) and Smith (2006) developed key guiding principles that are stated within human ethics, such as:

1. Controlled by Māori;
2. Consistent with Māori beliefs and values;
3. Focused on areas of importance and concern to Māori;

4. Going to result in positive outcomes for Māori and the wider community; and
5. Cognisant of Māori culture and preferences.

Based on these principles and relative to my project, my ethical application included the below as guiding ethical principles:

1. Community-based (outcomes are for Māori iwi community);
2. Iwi recognition throughout;
3. Iwi concerns as the key focus; and
4. Iwi participants guiding the overall methods.

These key guiding principles highlight the Māori-centred agenda and the use of mātauranga Māori fundamentally informing this research. Protection of the participants and iwi was also achieved by clearly stating how they would be involved in the research and how we would go about storing and protecting the information they provide us with. Overall, it was vital that kaupapa Māori research principles were illustrated in the ethics application. This allowed researchers and the university of Waikato to demonstrate and commit to the joint approach to research being carried out (that being between the iwi and the university student).

The process of gaining ethics approval consisted of completing the 2020 University of Waikato application for ethics, ethics number HREC(HECS)202#20, approval by the Human Ethics Committee, Human research ethics sub-committee; providing information about the research design, research procedures, ethical concerns and legal issues. In addition, to the kaupapa Māori guiding principles. We also included details on access to participants, informed consent, confidentiality, potential harm to participants, participants right to decline, arrangements for participants to receive information, use of information, conflicts of interest (which was not applicable), cultural sensitivity, compensation for participants, procedures for resolution of dispute and mention of any financial contributors for this work aside from the university, which was by the BOPRC who funded $6000 NZD.

Access to participants was at the discretion of Ngāti Whakahemo, with help from Kura Paul-Burke who is the marae secretary and a supervisor for this project. In regards to the wider stakeholders from BOPRC staff, contact was via email, therefore left to the participants discretion. Informed consent was required by all participants prior to completing the interviews. Confidentiality was kept simple by ensuring no names would be used in publications or outputs. Potential harm to participants was considered minimal due to access and choice to participate being left to the discretion of the iwi. Mindfulness was kept around the age of some participants (these being elderly), therefore, the interview session was kept to maximum time of one hour, and the right for participants to decline any involvement or withdraw at any stage throughout was supported. Procedures for resolution of dispute was mitigated by researchers and supervisors providing contact details to all participants, and all contact was made through the marae secretary, therefore any concerns/disputes would be made through her.

Due to myself, the lead researcher being Māori and affiliated to Ngāti Kahungunu which has whakapapa to Ngāti Whakahemo, there are close historical ties between our two iwi; hence kaupapa Māori research methods were implemented where research was done by Māori, with Māori, for Māori. Compensation was provided to the participants in the form of a koha (gift) for the time and valuable information each participant provided. Furthermore, findings will be gifted to Ngāti Whakahemo and BOPRC in the form of the completed thesis and other reports/papers, as well as an oral presentation at the end of the project via a hui (meeting) to Ngāti Whakahemo.

4.3.2 Research topic design

The aim and objectives of this research and the overall methods were co-developed with Ngāti Whakahemo via the Pukehina Marae secretary also my co-supervisor, who consulted with the chair and marae committee what their priorities were in regards to Waihī Estuary. Pipi were selected by the iwi as the species under most pressure due to perceived over harvesting. Therefore, this informed the aim of the research to look at population dynamics and health of pipi in Waihī Estuary. Participatory mapping was decided by the iwi as the main contact between the researchers and iwi participants via face-to-face interviews. A brief description of the interviews was provided in the application along with an example of the types of questions to be asked. Finally, the significance of the research was outlined, stating estuaries provide a wealth of ecosystem services and play a fundamental part of the Māori culture.

4.3.3 Sovereignty and consultation

Ethics approval required information on how we would go about respecting intellectual property and copyright. We planned to follow kaupapa described by Henry and Pene (2001) ensuring respect and recognition of Māori culture was upkept. Allowing the iwi to have control over research principles such as conception of the objectives, methods and involvement; and ensure all mutual benefits were stated and reciprocated. By working closely with the iwi continuous feedback and changes could be made easily. Everyone's wants and needs are respected and all are treated as equals.

To ensure protection of information and individuals, the ethics application also included how we would handle information and materials produced throughout the research, including how we would protect the confidentiality of the data gathered, as national laws require this. As a result we outlined that hard data (annotated maps) would be kept in a locked drawer located in the supervisors office and electronic data would be stored on a password-protected hard drive, and cloud system for backup. All data would be stored for a minimum of five years and would be destroyed after this. All photos published throughout this thesis were with permission from Ngāti Whakahemo.

Other information that the ethics application required included ownership of materials, where the research would be conducted and any further considerations. Once ethical approval was gained a marae hui was arranged with Ngāti Whakahemo to ensure that the iwi board approved of the research objectives, and discussion could be had regarding participant involvement and dates moving forward for fieldwork. Following kaupapa Māori research methods, hui are required as this is where ideas, issues or concerns are discussed amongst the board regarding the research outline. Ngāti Whakahemo hold bi-monthly marae hui to ensure key concerns and proposals are shared throughout the iwi. On October 10th 2020 I was given the opportunity to propose my research to the iwi asking for their blessing, involvement and whether this research would be useful to the iwi as a whole. A lot of time was spent preparing a concise but clear kōrero for this occasion. Following tikanga, I and one of my supervisors Shari Gallop were welcomed on to Pukehina marae and I waited for my opportunity to speak as dictated by the meeting's agenda (Figure 4.1 & 4.2). Key points from the kōrero included:

1. Introducing who I am as the lead researcher, where I come from and my whakapapa to Ngāti Kahungunu;
2. Introducing my supervisors as they are fundamental researchers associated with this project, including that one of my supervisors was also the marae secretary
3. Explaining what my proposed research was;
4. Explaining how it may benefit the iwi and wider community;
5. Discussing what the research methods may be;

6. Ensuring all findings would be shared and made easily available to the iwi; and
7. Asking if this is what they were wanting

Early consultation with iwi follows kaupapa Māori research principles, as iwi involvement is prioritised from the beginning and key views, values and concerns from the iwi were highlighted early on resulting in the formation of the research objectives; fundamentally informed by the iwi. This approach adheres to the kaupapa Māori research principles as described by Mane (2009), where the proposal was presented in person, the research space was shared with the iwi as early as possible and others perspectives were included in the development of the study. It was at this time that I received a blessing from the iwi for my research, and I was also welcomed as whānau (family), as a mokopuna (grandchild) due to the connection my iwi Ngāti Kahungunu has with Ngāti Whakahemo.

Figure 4.1 - Tyla Kettle (lead researcher) and Dr Shari Gallop (supervisor) inside Pukehina Marae waiting to give research proposal to iwi at annual hui. Photo taken by Kura Paul-Burke.

Figure 4.2 - Ngāti Whakahemo members and researchers including A/Prof. Kura Paul-Burke (second from left) Tyla Kettle (middle) & Dr Shari Gallop (third from right). Photo taken by iwi member.

4.3.4 Research procedure design

Interviews with iwi participants were conducted as per Paul-Burke et al. (2018) where participatory mapping was used to gain an understanding around the history of pipi and Waihī Estuary following methods similar to Klain et al. (2018). Participatory mapping has long been used as a method in science to gain specific information using local knowledge (Emmel, 2008). Robinson et al. (2016) showed that incorporating participatory mapping with indigenous communities is an effective way of including indigenous rights and knowledge about the environment into science-based initiatives; where the combination of local knowledge and technologies such as geographic information system (GIS) allowed for the mapping of traditional community conversation in regards to land rights decisions and access to natural resources. Participatory mapping is generally used when local community participation is required to set boundaries and dictate what is located in the area of interest. Furthermore, it is a popular tool for spatial data collection. When paired with GIS, it allows for the ability to capture individuals or groups perceptions of local issues and development efforts (Vajjhala, 2005). For this research, interviews with members of Ngāti Whakahemo, who were selected at the discretion of the iwi, were made up of two sections which included written responses and voice recording; this was with the understanding that this information would fundamentally inform where surveying would be conducted in the estuary at a later date.

For Section 1 of the interview twelve open-ended questions focusing on pipi distribution, abundance and the history of the estuary were asked to help gain an understanding around what information tangata whenua hold in relation to Waihī Estuary and also highlight areas of significance in relation of pipi abundance (Figure 4.3). Maps and pipi shells for recollection and reference (Figure 4.4 and 4.5) were used during this phase of the interview to help describe the state of the estuary and how big pipi used to be compared to now (Paul-Burke, 2011). These were important resources as they provided an alternative option to help describe the formation of sand banks, areas of significance and exactly how big pipi used to be compared to now. Furthermore, they made it easy for kaumātua to answer the interview questions as they could talk to the map and draw over what it was what they were thinking, as opposed to only verbally describing the areas in which they believed were important to sample. These questions were only asked to Ngāti Whakahemo participants and were co-developed with the marae secretary to ensure they were written in plain language so that they were easily understood. Furthermore, Kura ensured the iwi had a say in what needed to be asked in relation to key concerns around the estuary and pipi populations, thus aligning with kaupapa Māori research principles. The 12 open-ended questions included:

1. Where did you used to go to get pipi?
2. How did you know where to find the pipi?
3. How old were you then? – Was it the 1950’s, 1960’s, 1970’s etc.
4. What size were the pipi you gathered? (refer to Figure 4.5 for the size guide used to answer this question).
5. How many pipi did you take roughly per gathering?
6. Are there any signs you looked out for to help with when to gather pipi?
7. If so – are the signs the same as they used to be?
8. What did the estuary used to look like when you were younger? (Refer to Figure 4.4 which was the map used to help answer this question).
9. What kind of changes have you noticed to pipi and the estuary over time?
10. How do you open and prepare pipi? – Do you use a knife? – Has it always been the same way?
11. Describe the taste of the pipi? – Is it the same as pipi collected elsewhere?

12. Is there anything else you think we should know before going out into the field and doing the research?

Section 2 of the interview was based on perceived threats to pipi and Waihī Estuary following methods similar to Klain et al. (2018). The recruitment of participants for the kōrero about the distribution and abundance of pipi and the history of Waihī Estuary was led by Ngāti Whakahemo, the iwi and kaumatua identified those they believed would be most knowledgeable on this topic. Recruitment of the wider stakeholders from the BOPRC were selected due to their involvement with the management of the estuary, where 6 people were approached, and 5 responded.

This section had both Ngāti Whakahemo and wider stakeholders contribute, and required participants to rank each threat based on whether they perceive it as a high impact (uncontrollable, has fatal consequences to pipi or the estuary, are hard to reduce and have high risk for future generations) or low impact (controllable, easily reduced, have low consequence to pipi, the estuary and future generations). For Waihī Estuary external threats are a key risk to the overall functioning of the estuary and have significant effects on pipi populations (Squires, 2019). The process of selecting what threats were considered most important to Waihī Estuary and pipi was completed by carrying out a literature review (see Section 3.5.3) on common threats to estuaries internationally and in Aotearoa New Zealand. Ten top priority threats that were identified and listed for the participants to rank. For the exercise iwi participants were asked to distribute 20 tokens across the 10 threats, the more tokens placed on a threat means the participant perceived that threat as a higher risk (Figure 4.6). For the wider stakeholders from the Bay of Plenty Regional Council (BOPRC) staff, they completed this exercise online via a Google forms survey where the same 10 threats were ranked on what participants perceive as high risk and low risk. The list of impacts that participants were asked to rank included:

1. Dredging
2. Climate change
3. Over harvesting
4. Algae blooms
5. Rubbish/litter/pollution/microplastics
6. Nutrients/sewage/runoff
7. Diseased shellfish
8. Muddy/turbid water (suspended sediments)

9. Freshwater inputs (from Pongakawa canal)
10. Other (please specify further)

The final stage of the qualitative aspect to this research was a hikoi (walk) around the estuary with kaumātua to physically identify the distribution and abundance of pipi, and to highlight areas of significance which would then be surveyed at a later date (Figure 4.7). Kōrero from this hikoi was recorded and annotations were made on maps. A Global Positioning System (GPS) marked out traditionally significant waypoints using the Garmin 64csx to ensure the mapping of pipi distribution and abundance was backed up and accurate when revisiting the sites to survey.

Figure 4.3 - Participatory mapping interview with kaumātua including Tyla Kettle (right) (Photo by Kura Paul-Burke).

Figure 4.4 - Map used in interviews to identify traditionally significant areas of interest within Waihī Estuary for pipi. Map data @ ArcPro basemap 2018.

Figure 4.5 - Examples of pipi size class used in interviews to assist sizing recollection (adapted from Paul-Burke (2011). (Photo by Tyla Kettle).

Figure 4.6 - Perceived risk to treats exercise replicating methods of Klain et al. (2018) (Photo by Kura Paul-Burke).

Figure 4.7 - Kaumātua identifying areas of significance in relation to pipi distribution and abundance during the hikoi showing Tyla Kettle on the left (Photo by Kura Paul-Burke).

4.4 Matauranga Māori-informed field sampling design

The quantitative field surveys used the information gained from the interviews and hikoi with kaumātua to inform where in Waihī Estuary field sampling would take place. Intertidal surveys were conducted looking at the distribution and abundance of pipi, sites were identified by iwi and a sub-sample of previously sampled Ministry for Primary Industries (MPI) sites were looked at. MPI is a public service department who oversee, manage and regulate the farming, fishing, food, animal welfare, biosecurity and forestry sectors for Aotearoa New Zealand's primary industries (Gabriel et al., 2004).

Surveying begun with a karakia before sampling commenced. The sites identified by iwi were a priority and marked out as waypoints on the Garmin 64csx GPS; with surveying methods replicating those of Berkenbusch et al. (2015) which have followed the same sampling protocols since 1996 in the North Island bivalve surveys commissioned by MPI. The surveying methods consisted of a systematic design. In previous MPI surveys, the stratification accounted for spatial variation along and down the shore, whereas at each site along the intertidal areas were sampled based on existing information and input from kaumātua/pūkenga. First a reconnaissance exploration of the sampling area was carried out to identify potential boundaries, access points and water depth in relation to tide times. Access points were set as way points on the Garmin 64csx GPS as well as areas of significance dictated by the kaumātua.

The number of sampling points for the sites identified by the kaumātua was determined by the size and shape of the bank which the kaumātua identified as the area of interest. To ensure sampling was representative of the site, transects were laid covering the sand bank edges, where pipi are generally known to be most abundant due to high water flow (Murray-Jones and Steffe, 2000). Systematic sampling was carried out by sampling every 7m along the transect until the end of the bank was reached. A transect was also laid through the center of the bank and sampled to ensure we extensively covered the area of interest. This was carried out across two sand banks in the estuary which were identified by kaumātua resulting in 54 sites being sampled. The previously sampled MPI sites were determined by the population size and variability with the sampling area informed by data from previous surveys. A total of 60 sites were selected. Furthermore, an additional 20 sites were haphazardly added from the upper reaches of the estuary near one of the major freshwater outlets, Pongakawa Canal, as a comparison of sediment characteristics and pipi density between the upper reaches and lower reaches. The field component of this study was carried out in Austral summer on 23rd November through to 27th November 2020. At each site, the intertidal sampling was conducted centered around low tide.

4.4.1 Field sampling – bivalves

Bivalve sampling at each site consisted of a pair of benthic cores of 15cm diameter each that sampled a surface area of $0.035m^2$ (to 15cm depth). The sampling depth encompassed the maximum burrowing depths of pipi, which resides in the top 10cm of the sediment. Sampling points within the MPI stratum were located using a handheld GPS, whereas sites within the iwi stratum were previously identified by kaumātua and systematically sampled using a 60m transect and sampling every 7m until a total of 20 sites were surveyed. At each sampling site, the cores were pushed 15cm into the sediment directly adjacent to each other. The cores were excavated, and all the sediment from each core was sieved in the field on 5mm mesh using water in the surrounding tidal channels (Figure 4.8). All pipi retained on the sieve were counted and measured with a measuring card (length of the maximum dimension, to the nearest millimetre) (Figure 4.9), before being returned to the benthos.

Figure 4.8 - A/Prof. Kura Paul-Burke and Tyla Kettle carrying out bivalve sampling on site identified by kaumātua (Photo by Dr Shari Gallop).

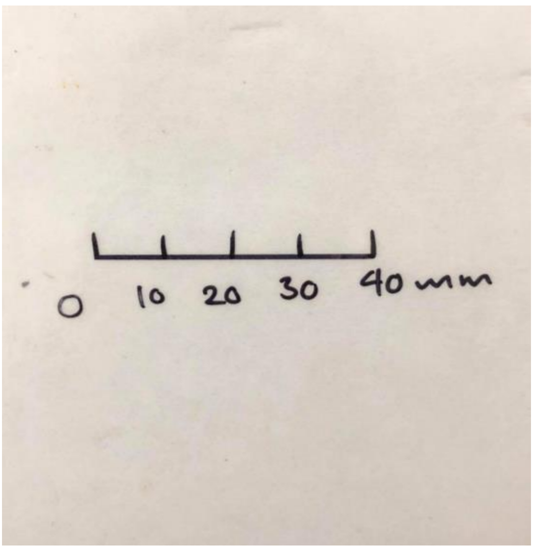

Figure 4.9 - Pipi measuring card (Photo by Tyla Kettle).

4.4.2 Field sampling – sediments

Due to the importance of sediment properties for infaunal bivalves, field surveying also included the collection of sediment samples to provide baseline information about the sediment properties at the survey sites. Pipi are sensitive to changes in sediment regimes, and show reduced abundance in response to increased turbidity (reflected by increased sediment mud content) therefore grain size and organic content were analysed.

Sediment sampling involved the analysis of a subset of sediment cores (5cm diameter, sampled to 10cm depth) for sediment grain size and organic content that were collected across the spatial extent of existing bivalve beds, and also in directly adjacent areas. The subsequent grain size analysis of the sediment samples was based on wet sieving to ascertain the proportion of different size classes, ranging from sediment fines (silt and clay 63μm grain size) to gravel (+2000μm grain size).

4.4.3 Data analysis - bivalves

Data analysis followed the protocols of Berkenbusch et al. (2015) which focused on estimating pipi distribution and population density. According to past surveys completed by MPI following the same data analysis protocols, the two cores within each grid cell were considered a single sampling unit. Bivalve abundance within the sampled strata at each site was estimated by extrapolating local density (individuals per m^2), calculated from the number of individuals per sampling unit, to the stratum size:

$$\hat{y}_k = \frac{1}{S_k}\sum_{s=1}^{S}\frac{n_{s,k}}{0.035},$$
$$\hat{N} = \sum_{k=1}^{K} A_k \hat{y}_k,$$

Where n_s,k is the number of individuals in sample S within stratum k. S_k is the total number of samples processed in stratum k, and $\hat{y}$ is the estimated density of bivalves (in individuals per m^2) within the k. The total number of bivalves at each site is then the sum of total abundance within each stratum, estimated by multiplying the density within each stratum by the stratum area A_k.

4.4.4 Lab processing – sediment

The sediment analysis focused on correlation between sediment data grain size, organic content, total nitrogen (TN), total phosphorous (TP) and pipi abundance. The sediment grain size was determined by digesting each sample in 10% hydrogen peroxide before analysing in the Malvern Mastersizer 2000 lasersizer. Organic content of each sample was determined by loss on ignition (4 hours at 550˚C) after drying the sample to a constant weight at 60˚C. TN and TP were sent to the University of Waikato ICP suite to get tested via Hill's laboratories.

4.4.5 Data analysis – statistics

Statistics was analysed via Primer where a non-metric multidimensional scaling (MDS) test was run on each set of replicate data per site (in total 268 samples) and total pipi abundance per site. MDS graphically represents the relationship between plots in multidimensional space by taking the original set of replicate data and calculating a dissimilarity (distance) measure for each pairwise comparison of samples (Carroll and Arabie, 1998). Furthermore, a distance based Redundancy Analysis was run on total pipi density per site and environmental factors measured throughout Waihī Estuary. The redundancy analysis method is used to extract and summarise the variation in a set of response variables that can be explained by a set of explanatory variables.

Chapter 5

Results

"Hapaitia te ara tika pumau ai te rangatiratanga mo nga uri whakatipu"

"Foster the pathway of knowledge to strength, independence and growth for future generations"

5.1 Pipi distribution, abundance and size

In this thesis I incorporated pipi sampling sites identified by MPI and IWI (blue and green respectively in Figure 5.1). I used a sub-sample of the locations that MPI previously implemented by a stratified survey design that covered the entire estuary. This was combined with IWI sites identified by kaumātua which focused on mahinga kai, an area used for gathering kai (food) both today and in the past due to its high abundances of pipi. This enabled me to conduct a more comprehensive survey of pipi population dynamics in Waihī Estuary. Pipi density was highly spatially variable, with the north-eastern region of the sampling area having relatively high pipi counts compared to the south-eastern region of the sampling area (Figure 5.1). The majority of the IWI sites were in the north-eastern region, opposed to the sites identified by MPI being located in the south-eastern region. Higher pipi abundances were found within the main estuary channel, with both IWI sites and some MPI sites at this location.

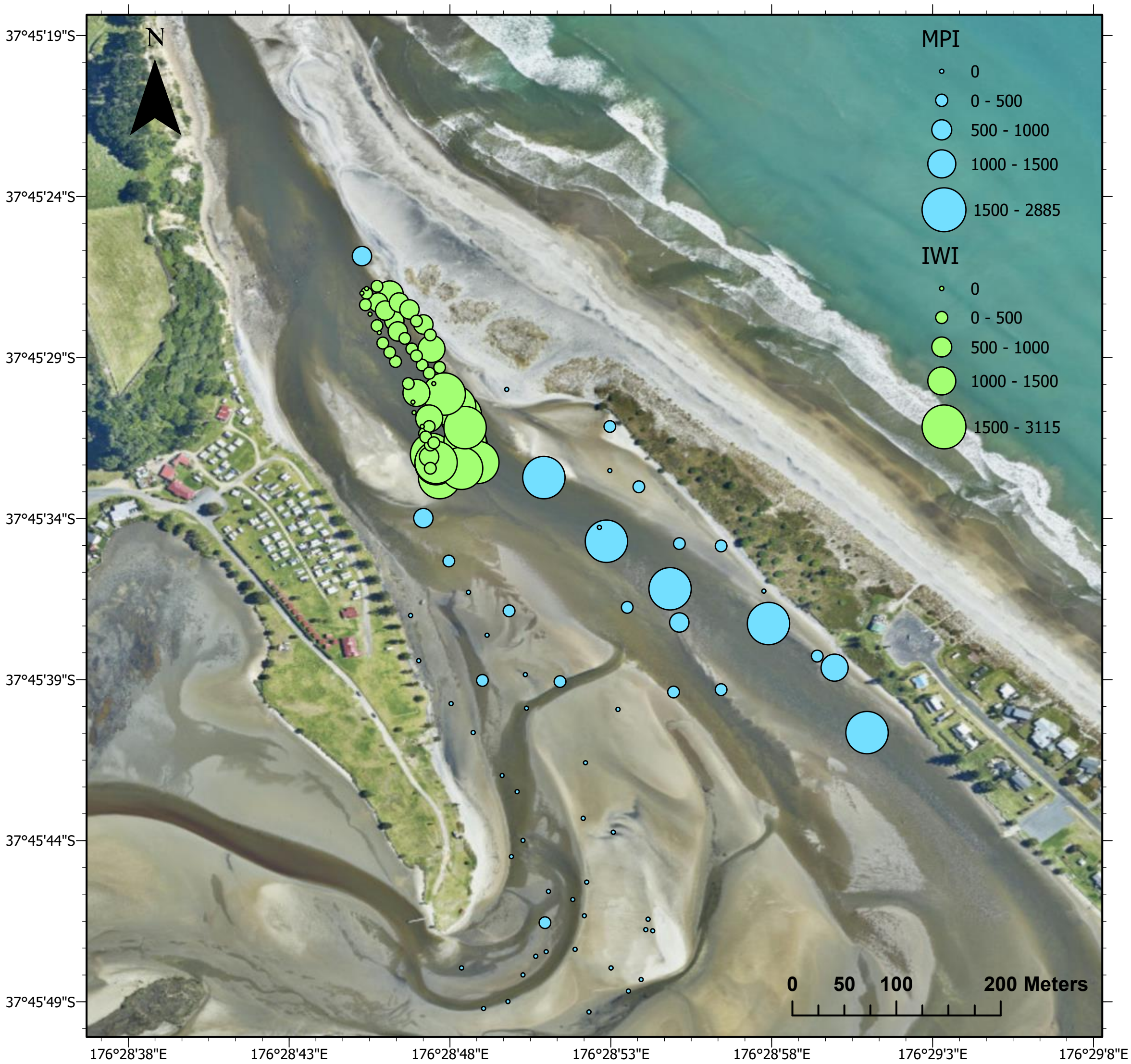

Figure 5.1 - Map of pipi survey sites in Waihī Estuary, Bay of Plenty, with the size of the circle proportional to the number of pipi found per m2 (extrapolated data). Samples with zero counts are shown as small dots. Green circles represent IWI sites, blue circles represent MPI sites. (Aerial image source: Esri. "NZ imagery" [basemap]).

Of the seven sites surveyed, Site 5 (which was a culturally significant IWI site identified by kaumātua) had the highest pipi abundance, with a total of 20,371 pipi per m^2 (extrapolated data) (Figure 5.2). Conversely, Site 3 had the lowest pipi abundance, with 29 pipi per m^2 (extrapolated data) (Figure 5.2). Overall, the four sites identified by kaumātua had the highest pipi abundances with an average of 10,514 pipi found per m^2. This is not surprising due to the stratified design of the MPI surveys focused on obtaining overall population densities and abundance information of pipi, rather than areas of highest densities (Berkenbusch et al., 2015).

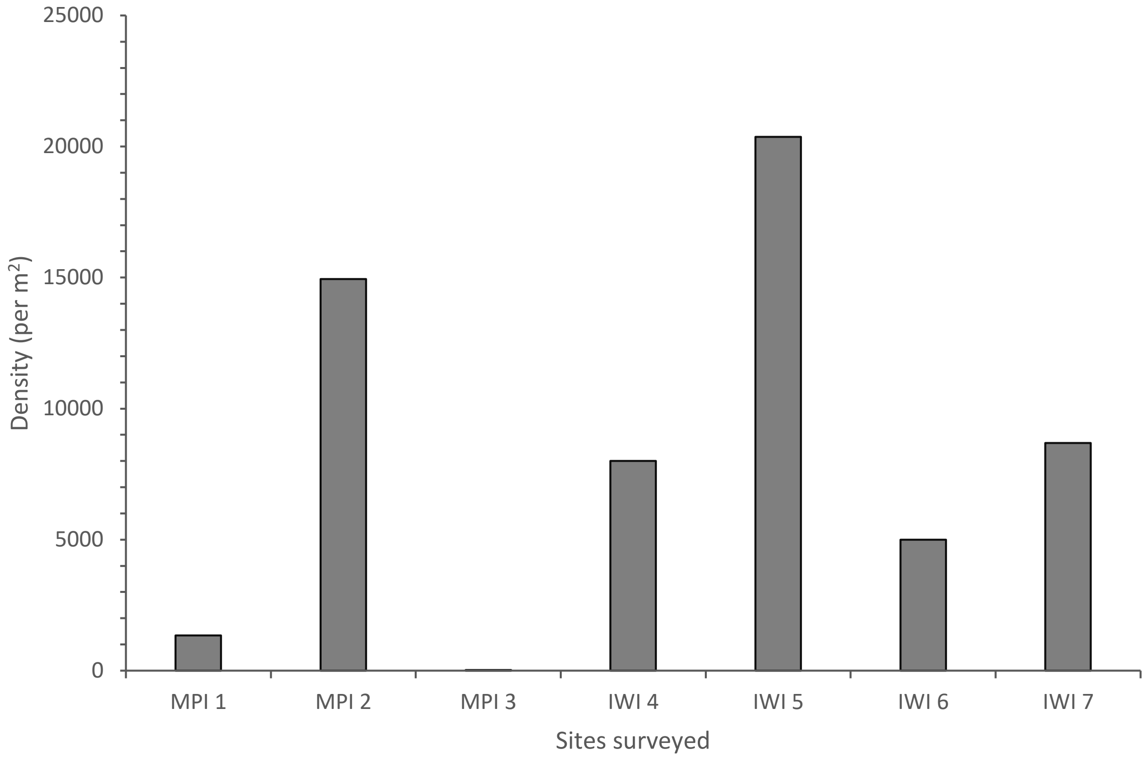

Figure 5.2 - Bar graph illustrating total number of pipi per m2 at all sites surveyed in Waihī Estuary. MPI indicates sites identified by Ministry for Primary industries and IWI indicates sites identified by kaumātua.

Across the 7 sites surveyed, 40mm+ was the most common pipi size class and 0–10mm was the least common; with 33,114 40mm+ sized pipi found per m^2 across all seven sites, compared to 1,571 0–10mm sized pipi. The 4 sites identified by kaumātua, namely IWI Sites 4, 5, 6 and 7 had the highest abundances of 40mm+ sized pipi, whereas the sites identified by MPI had high abundances of 31mm – 40mm sized pipi. Site 5 had the highest abundance of 40mm+, with 10,971 pipi found per m^2 (extrapolated data); this site also had the greatest variability in size range. The average standard error of all sites surveyed is 13, in relation to average pipi abundance per site being 15,952 per m^2. Suggesting that we have reasonable estimates of pipi abundance.

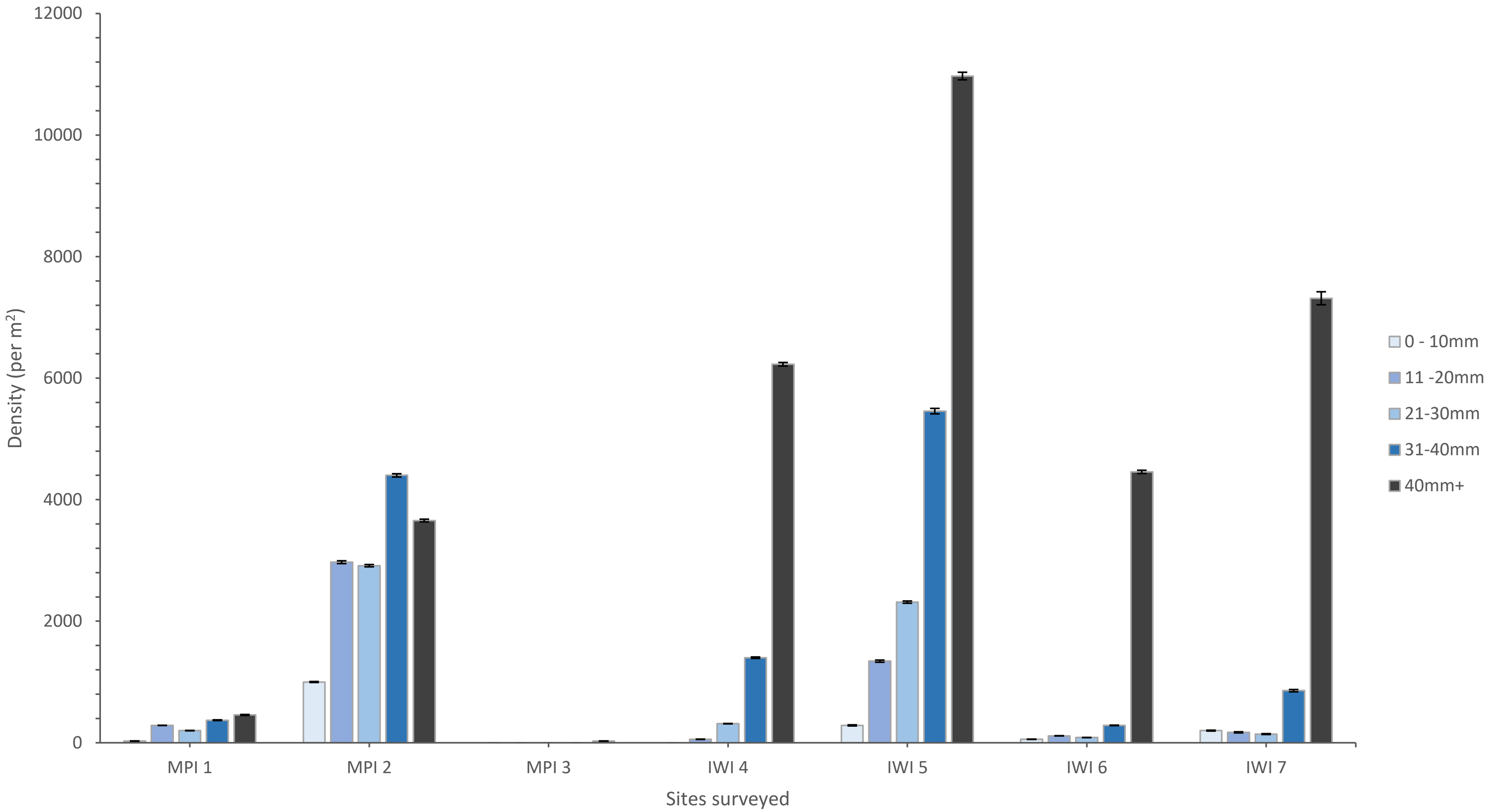

Figure 5.3 - Comparison of pipi size classes at all sites surveyed throughout Waihī Estuary, with Sites 1, 2 and 3 being identified by Ministry for Primary Industries (MPI) and Sites 4, 5, 6 and 7 being identified by kaumātua from Ngāti Whakahemo (IWI). Error bars represent the standard errors.

5.2 Environmental factors

This section illustrates the results of the sediment samples collected during field surveying. This includes both at the sites identified as a mahinga kai by kaumātua (Figure 5.4) and MPI sites (Figure 5.5).

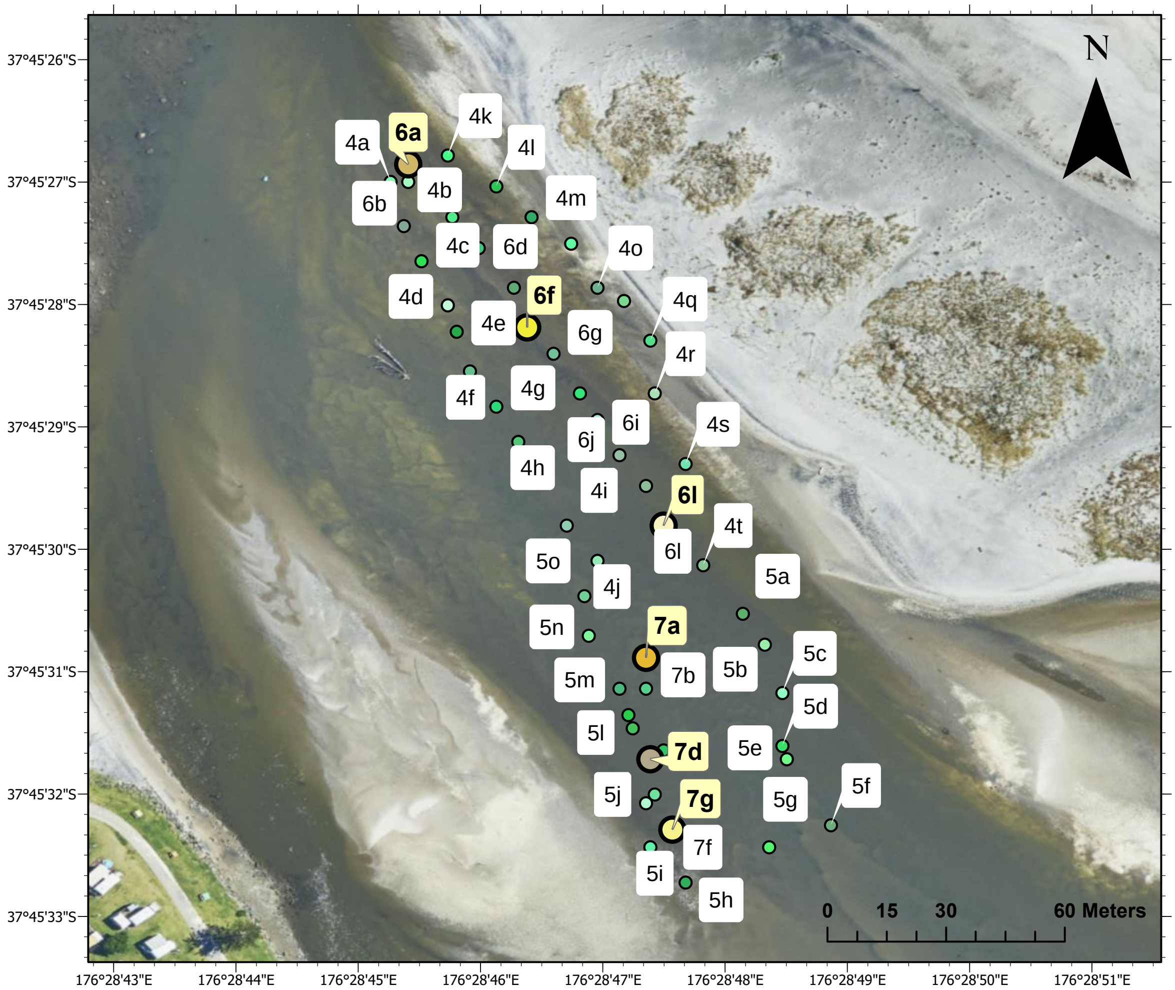

Figure 5.4 - Map of survey site locations identified by IWI that were tested for sediment characteristics (grain size, loss on ignition, TN and TP) in Waihī Estuary. Labels correspond to sample site and number. Additional measurements of TN and TP are shown as yellow markers. (Aerial image source: Esri. "NZ imagery" [basemap]).

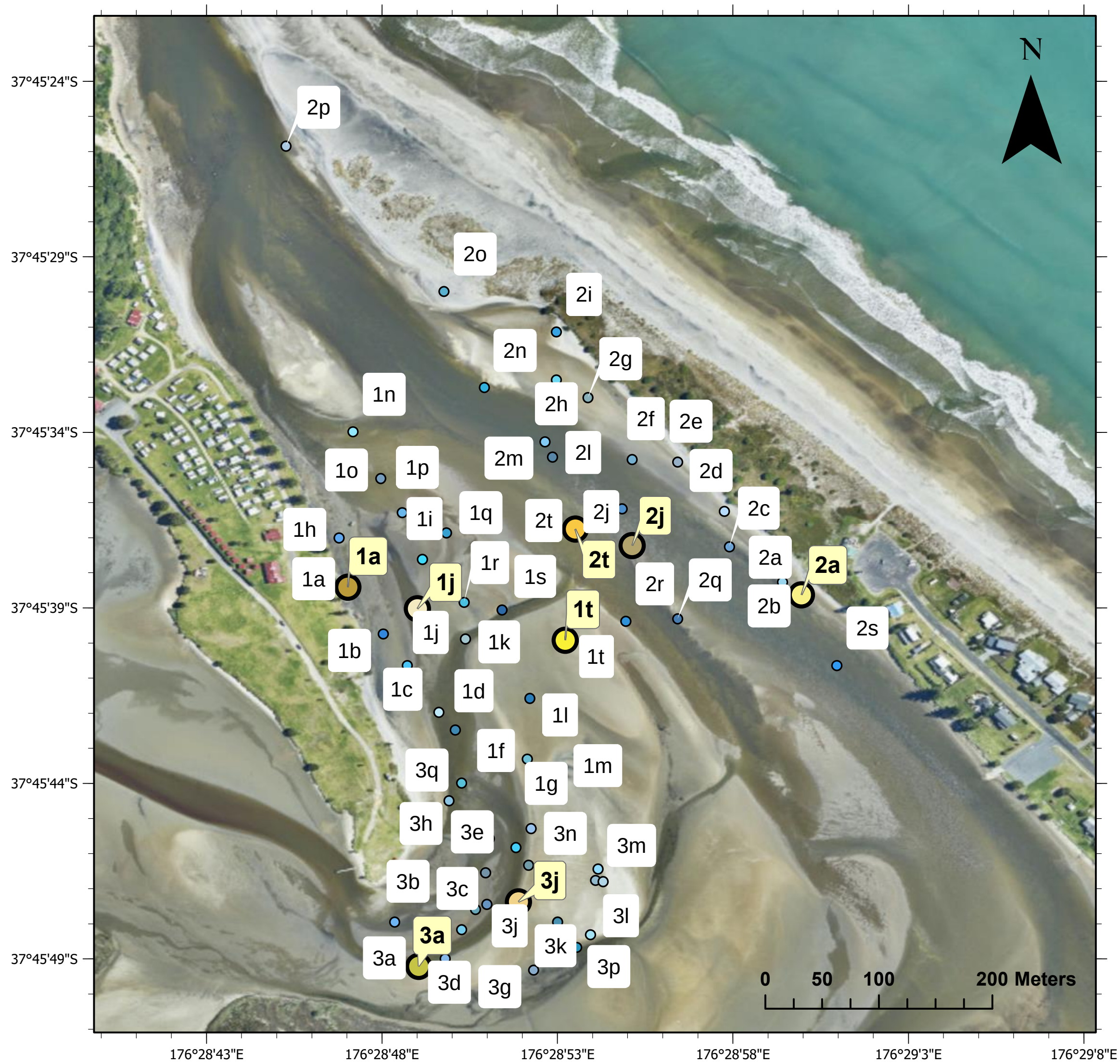

Figure 5.5 - Map of survey site locations identified by MPI that were tested for sediment characteristics (grain size, loss on ignition, TN and TP) in Waihī Estuary. Labels correspond to sample site and number. Additional measurements of TN and TP are shown as yellow markers. Esri. (Aerial image source: Esri. "NZ imagery" [basemap]).

An additional 20 survey sites were analysed for grain size, organic content, TN and TP in the upper reaches of Waihī Estuary at the outlet of the Pongakawa canal (Figure 5.6). The Pongakawa canal is a freshwater stream that travels through extensive farmland from its source lake Rotoiti (Brown, 2018).

Figure 5.6 - Map of Pongakawa canal, the location 20 extra sites were tested for sediment characteristics (grain size, loss on ignition TN and TP) as a comparison between the upper and lower reaches of Waihī Estuary. Yellow box indicates the vicinity in which the samples were collected. (Aerial image source: Esri. "NZ imagery" [basemap]).

5.2.1 Grain size

The most common grain size across all eight sites was fine sand (63µm–125µm), followed by medium sand (125µm–250µm) (Figure 5.7). Significantly higher levels of very fine sand (63-125µm) and fines (0-63µm) had occurred in the upper reaches near the Pongakawa canal compared to the lower estuary.

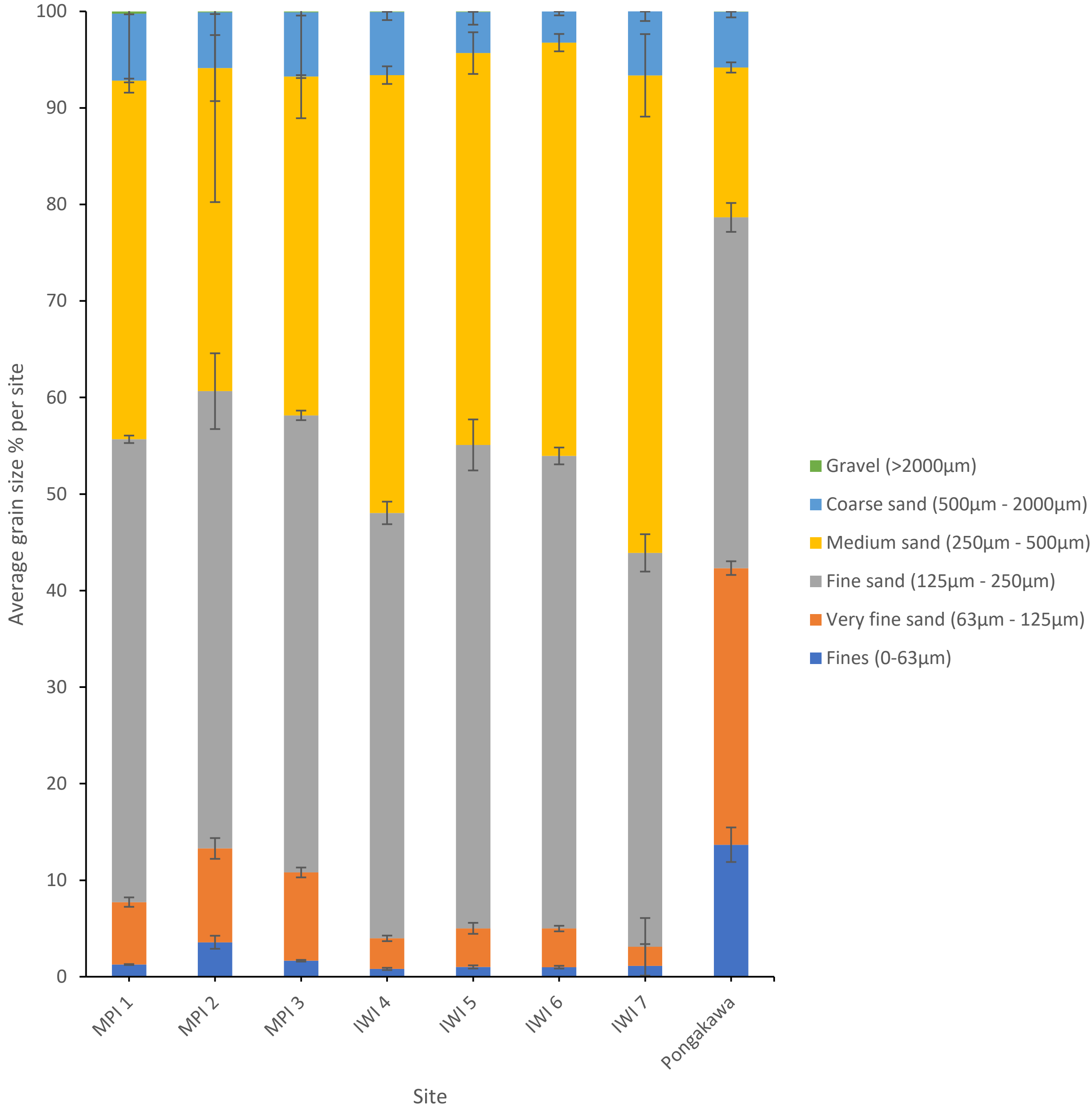

Figure 5.7 - Comparison of average grain size percentage at each site surveyed in Waihī Estuary. Sediment grain size fractions include gravel, coarse sand, medium sand, fine sand, very fine sand and fines. Error bars represent standard error of the mean.

5.2.2 Organic content

Average organic content varied across all sites, with the Pongakawa Site having a significantly higher average percentage (1.62%) compared to all other survey locations (Figure 5.8). The overall average organic content was 0.91%.

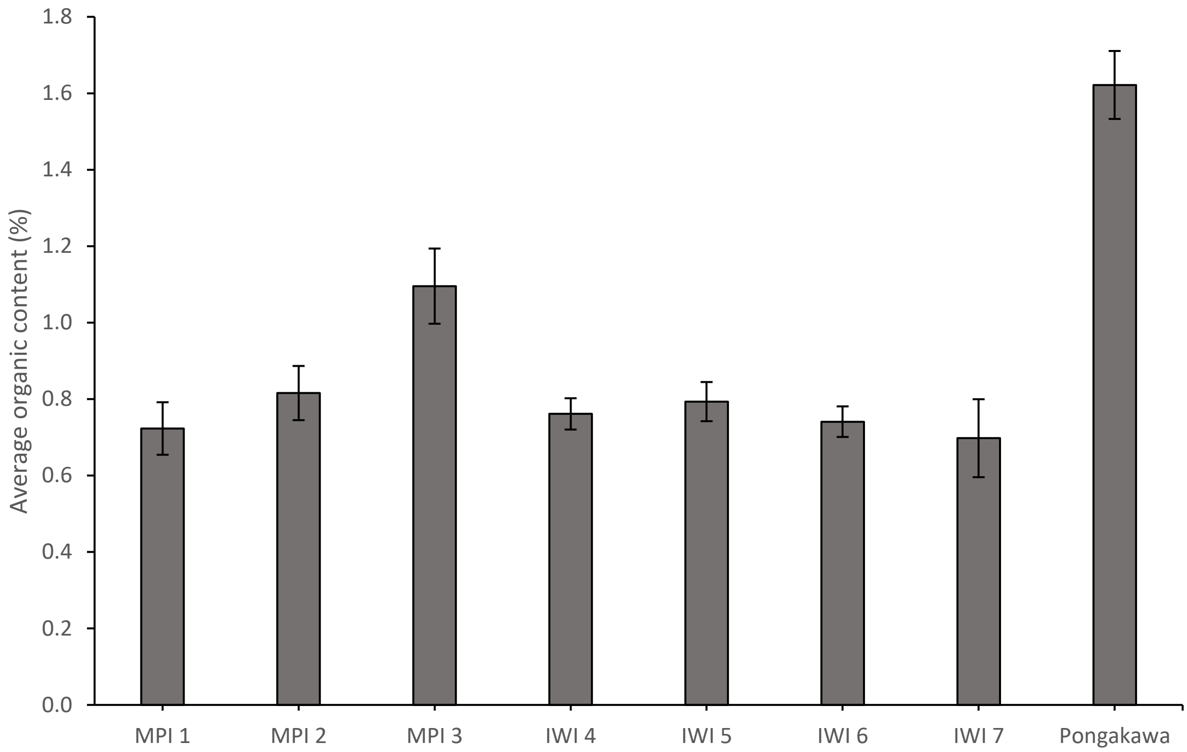

Figure 5.8 - Bar graph illustrating average organic content (%) for each site surveyed in Waihī Estuary. Error bars represent standard error of the mean.

5.2.3 Total nitrogen and total phosphorus

Total nitrogen levels in Waihī Estuary were generally low across both IWI and MPI Sites (0.4%). However, the Pongakawa Site had raised TN levels of 0.06% (Table 4). Total phosphorus levels varied throughout Waihī Estuary with the IWI Sites having relatively low levels in comparison to the MPI Sites which were significantly higher. Overall a trend of increasing TP levels was observed from the lower estuary to the upper reaches.

Table 3 - Total nitrogen (percentage) and total phosphorus ppb (µg/L) for each site surveyed in Waihī Estuary.

	Total Nitrogen	Total Phosphorus ppb (µg/L)
MPI 1	<0.04	58,0393.9
MPI 2	<0.04	31,1559.7
MPI 3	<0.04	17,6880.9
IWI 4	<0.04	14,2354.1
IWI 5	<0.04	13,5872.3
IWI 6	<0.04	13,7657.2
IWI 7	<0.04	14,0772.2
Pongakawa	0.06	17,0586.4

5.3 Perceived threats

Over harvesting had the highest level of concern as a major threat to pipi and Waihī Estuary, from both the kaumātua who placed 14 tokens on this threat, and the BOPRC staff who placed 15 tokens on this threat. Kaumātua considered diseased shellfish the second highest concern with 11 tokens being placed on this threat, whereas BOPRC staff considered nutrients/sewage/runoff the second highest concern with 19 tokens being placed on this threat (Figure 5.9). Overall, overharvesting and nutrients/sewage/runoff was perceived as the two dominant impacts to pipi population dynamics and Waihī Estuary ecology. A low number of tokens were placed on the "other" category by kaumātua, indicating that the dominant threats were likely identified in the pre-defined categories. Within this "other" category, spraying of drains located south of the estuary (on private farmland) was raised as a concern by kaumātua.

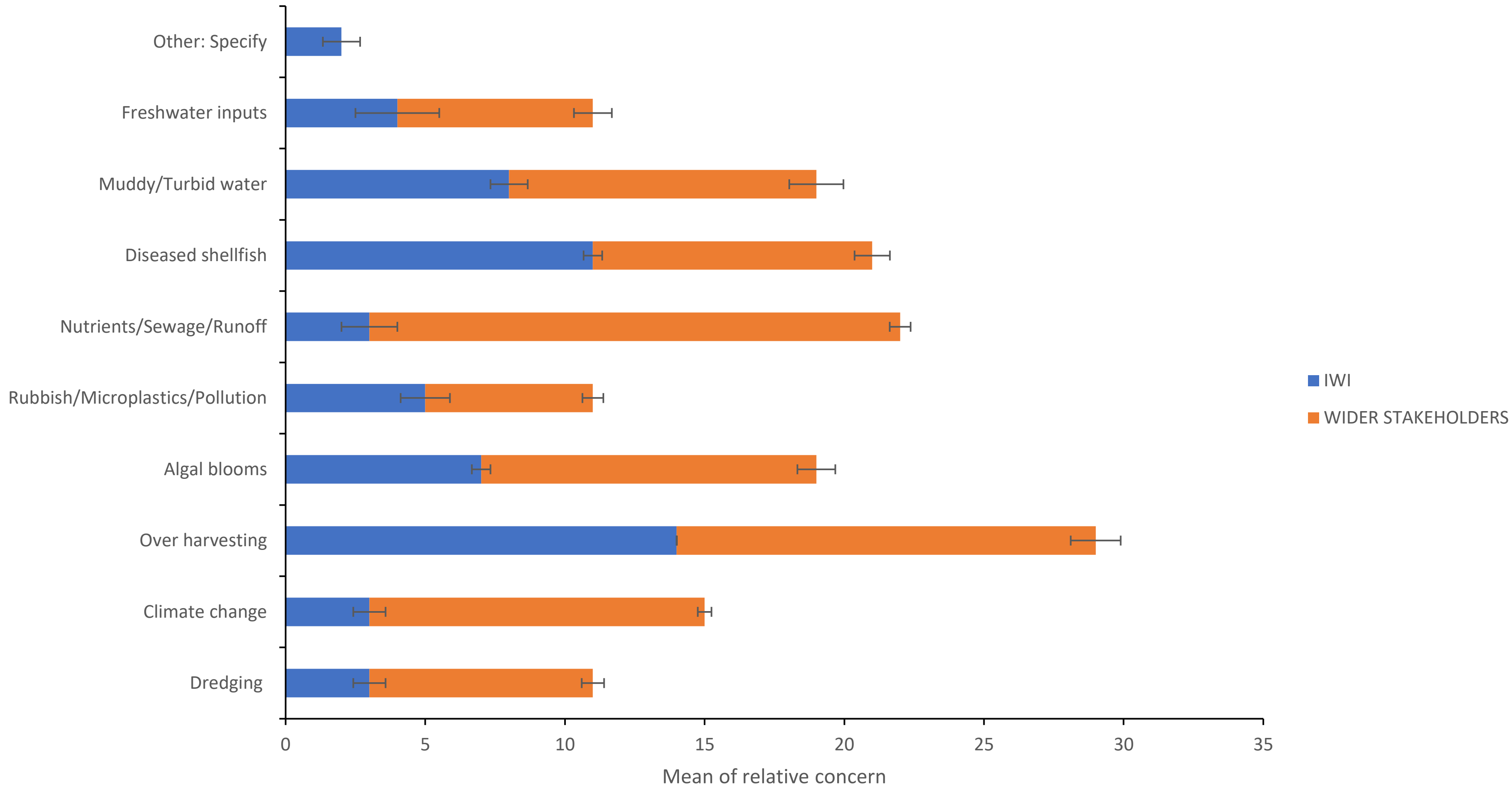

Figure 5.9 - Perception of mean relative concern around 10 common threats to pipi and Waihī Estuary from the perspective of 3 kaumātua (blue) and 5 staff members of the BOPRC (orange). The mean number of tokens assigned to each benefit is presented with the standard error.

5.4 Pipi and environmental variables

IWI Sites 4, 5, 6 and 7 had similar pipi abundances to one another while MPI Sites 1,2 and 3 had similar pipi abundances to each other (Figure 5.10). The Pongakawa Site had significantly different pipi densities compared to all the other survey sites. The overall trend demonstrated by this plot is that heading from the IWI Sites in the lower reaches through to the MPI and Pongakawa Sites in the upper reaches, pipi populations decreased.

Figure 5.10 - Non-metric multidimensional scaling (MDS) orientation plots showing the relative similarities in the grouping of replicate data for each site surveyed in Waihī Estuary. IWI Sites are identified by lighter shades, and MPI Sites by darker shades.

Figure 5.11 the dbRDA plot separated the Pongakawa Site based on the 63-125µm grain size fractions, higher TN levels and average organic content (%). Conversely, sites located in the lower estuary (IWI 4, 5, 6, 7 and MPI 2) were associated with coarser grain size fractions including medium to fine grained sediment (250µm - 500µm) and increased TP levels.

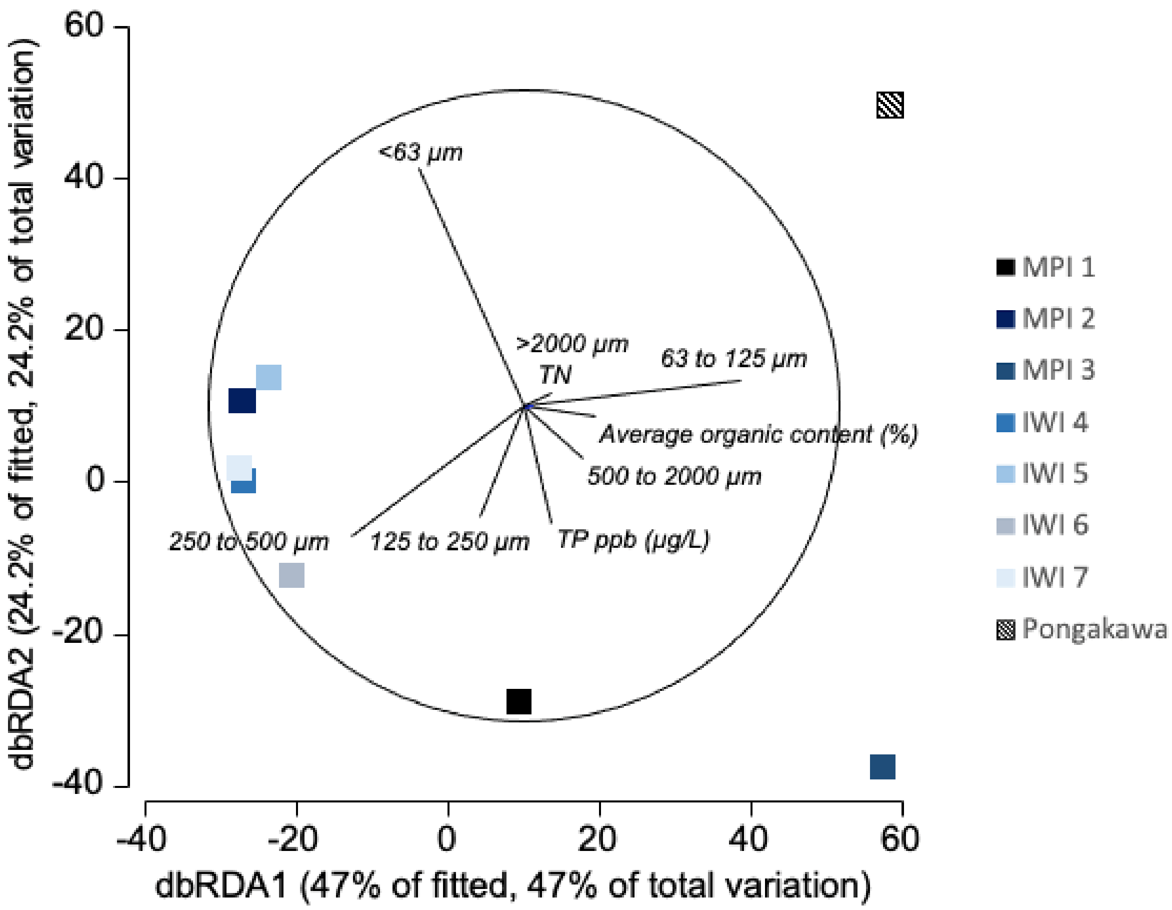

Figure 5.11 - Distance based Redundancy Analysis (dbRDA) plot correlating environmental factors (Total nitrogen – TN, average organic content %, grain size and total phosphorus - TP) with overall pipi abundance for each site surveyed in Waihī Estuary. IWI Sites are identified by lighter shades, and MPI Sites by darker shades.

Chapter 6
Discussion

"Ehara taku toa, i te toa takitahi, he toa takitini"

"My success should not be bestowed onto me alone, as it was not individual success but success of a collective"

6.1 Science informed by mātauranga Māori

6.1.1 Mātauranga ā iwi and knowledge protection

The first objective of this thesis was to use mātauranga Māori to map the historic and current distribution, abundance and health of pipi in Waihī Estuary. This was achieved using mātauranga ā iwi from Ngāti Whakahemo, tangata whenua of Waihī Estuary. Locations of culturally significant areas with high abundances of pipi (mahinga kai) were shared via interviews with kaumātua, which also included kōrero around perceived threats to pipi and the wider estuary. The pipi locations from the interviews informed the field survey sites, and in turn the outcomes of this study. The three kaumātua interviewed shared their "secret" harvesting sites, which have been passed down from generation to generation through whānau (Paul-Burke, 2011). Kaumātua agreed to the terms in my ethical approval and shared during our kōrero that they trusted and believed that sharing their knowledge would positively impact my research being carried out on pipi and Waihī Estuary. They also said that this research would benefit the following generations and help the natural ecosystem provide sustenance to the iwi and local community. As a result, I as the lead researcher was obligated to get the research "right" and ensure the research space being shared (between researchers and iwi) was fair, honourable of the mātauranga Māori and culturally sensitive (Paul-Burke, 2011). As outlined by Walker et al. (2006), the knowledge Māori share is special and must be treated with respect and be protected. Sometimes, specific knowledge will only be entrusted to a few people to ensure the knowledge is protected (Smith, 2015). Throughout the entirety of this research, draft figures were shared with Ngāti Whakahemo via Kura Paul-Burke to ensure the information in my thesis (and also presentations I did) was honourable of the mātauranga ā iwi shared with me.

6.1.2 Kaupapa Māori work

To draw upon mātauranga Māori is to draw upon and implement kaupapa Māori research methodologies (Hikuroa, 2017). According to Pihama et al. (2015), kaupapa Māori research is based upon and informed by mātauranga Māori and provides a cultural template that is culturally defined and determined. The processes I undertook throughout the entirety of my research was to follow and instil kaupapa Māori research methods and principles (described in Chapter 4). By following and prioritising key principles associated with kaupapa Māori research (outlined in Section 4.2) I adhered to culturally-correct protocols that must be followed when using mātauranga Māori. Implementing kaupapa Māori research allowed iwi concerns to inform the conception of my thesis. Thus, the focus of my research addressed an issue that was a priority for Ngāti Whakahemo, which was population dynamics and health of pipi in Waihī Estuary. By doing so I prioritised their wants and needs in relation to providing evidence-based information to assist decision-making for Waihī estuary.

It was also important to present and discuss the research proposal face-to-face with iwi. By doing so I was able to bring whanaungatanga (as described in Section 2.2) into my research space. This was fundamental to my research as the relationship between researchers and participants (in this case Ngāti Whakahemo) was established early on. The importance of the researcher/iwi relationship was described by Fitzgerald (2004), who explains how the interconnectedness between researchers and participants is about whanaungatanga and honouring what we have and what we share. Walker et al. (2006) explains how one of the more important concepts of kaupapa Māori research is that of whakawhanaungatanga which refers to the process of identifying, maintaining or forming past, present and future relationships. At times this may mean we offer the kōrero (we speak), and other times we need to whakarongo (listen). In turn, we all have a part to play and can draw on one another for what we need. Thus, I met with Ngāti Whakahemo face-to-face during the planning phase of my research and I was able to initiate this connectedness and provide a space to introduce myself, explain my research, explain the significance of my research and whanaungatanga with Ngāti Whakahemo. Once the initial introduction between myself and Ngāti Whakahemo was made, following kaupapa Māori research methods, continuous communication was key. This was made possible by liaising with my supervisor Kura Paul-Burke who would pass on draft figures and any relevant questions I had regarding the iwi wants, needs or concerns. This ensured the voices of Māori were heard throughout my research and the relationship between researchers and iwi was maintained (Paul-Burke et al., 2018). This also highlights the importance of trust between researchers and iwi. In my case it was critical to have Kura Paul-Burke who is my co-supervisor, Ngāti Whakahemo and secretary of Pukehina marae. She was able to pave my way to form this trust and build relationships with iwi by liaising regularly. By maintaining and continuing to build upon this relationship which was achieved through communication, more in-depth information was shared and entrusted to myself, the researcher.

6.1.3 Site selection based on mātauranga ā iwi combined with western science approaches

Site selection for my field surveying was dictated by mātauranga Māori. The structure of my interview questions was open-ended and based around the historic distribution and abundance of pipi in Waihī Estuary. This allowed for guided questions to be asked, and gave the opportunity for kaumātua to discuss any other relevant information they had. This approach is referred to as the conversational method and is common in research involving Indigenous Peoples (Drawson et al., 2017). According to Kovach (2010), the conversational method is a means of gathering knowledge found within Indigenous research, and is of significance to Indigenous methodologies because it is based on oral story telling. This method utilises open-ended and semi-structured interview questions to prompt the conversations had between researchers and participants. For my research I merged the conversational method with kaupapa Māori research methods by ensuring my questions were based around the key concerns of Ngāti Whakahemo which was population dynamics and health of pipi in Waihī Estuary. As a result, the kaumātua identified 4 sites of significance, which were later sampled by applying western science techniques. In conjunction with this, western science methods were also integrated into site selection by adding 3 sites made up of 60 sampling points from a study by Berkenbusch et al. (2015). This was to gain a more in-depth understanding around population dynamics of pipi in Waihī Estuary. These 60 sampling points (denoted as MPI Sites in this thesis) are a subsample from a total of 192 identified by Berkenbusch et al. (2015) using the western science approach of implementing a systematic design, two phase stratified random design and observation of any physical environmental factors such as sandbanks, channels, streams, sediment size and tidal flow. The aim of the study carried out by Berkenbusch et al. (2015) was to gain and overall understanding about shellfish density and abundance. Thus, in my thesis I merged the total number of pipi found at IWI and MPI Sites to provide an overall understanding around the distribution and abundance of pipi in Waihī Estuary.

6.1.4 The value of a transdisciplinary approach

This thesis had a transdisciplinary approach by drawing upon kaupapa Māori research methods and mātauranga Māori, as well as western science methods including the conversational approach (Drawson et al., 2017), field surveying methods of Berkenbusch et al. (2015) and social science methods of Klain et al. (2018). A transdisciplinary approach means the ability for multiple knowledge systems to work together to solve a common issue, in my case it was mātauranga Māori informing the research and western science methods producing quantifiable maps and figures. This approach allowed Māori voices to be heard, which was fundamental to my research, and will contribute to the management of the culturally significant ecosystem of Waihī Estuary. In the past, Māori knowledge and Māori voices have commonly been disregarded when it comes to environmental management (Smith, 2013). One such piece of pioneering work that my thesis was inspired by was Paul-Burke et al. (2018) who looked to this transdisciplinary approach and allowed mātauranga Māori to co-develop and co-design a mussel management action plan (MMAP) for Ōhiwa harbour in the Bay of Plenty of Aotearoa New Zealand. Paul-Burke et al. (2018) explains how mātauranga Māori was considered fundamental to the collaborative development of the MMAP but also provided a space for the voices of Māori and their roles as kaitiaki. Mātauranga ā iwi informed the research, including via hui to discuss research issues, priorities, ethics and tikanga for the MMAP. Kōrero/interviews were also carried out to gain historically invaluable mātauranga. Kaumātua were also invited out into the field and included in the surveying process where researchers were able to gain a more in depth understanding around the mussel populations in Ōhiwa harbour based on traditional intergenerational harvesting sites. As a result, the design of the MMAP for Ōhiwa harbour was based on decisions informed by mātauranga ā iwi which helped shift the focus of the MMAP from only the western side of the harbour to all areas of the harbour. Overall, Paul-Burke et al. (2018) concluded that by co-designing the MMAP with iwi, a wider, more in depth and inclusive range of knowledges and practices resulted in an empowered and collaborative strategy plan to be developed for the mussels in Ōhiwa harbour. These findings resonate with those of my study, highlighting the importance of co-developed research. My work brought together the University of Waikato and Ngāti Whakahemo to work synergistically via a transdisciplinary approach. In addition to this BOPRC staff participated in the perceived threats interview. By fundamentally drawing upon mātauranga Māori and incorporating western science techniques of MPI (through the use of Berkenbusch et al. (2015)

field sampling protocols and previous data), I was able to carry out an inclusive study (between researchers and iwi) and gain a more in-depth understanding of pipi population dynamics and health in Waihī Estuary.

6.2 Pipi distribution, abundance and size

6.2.1 Mātauranga Māori and western science to facilitate temporal comparisons

Objective one of this thesis was to use mātauranga Māori to map the historic distribution, abundance, and health of pipi in Waihī Estuary. This was achieved through the sharing of mātauranga ā iwi from Ngāti Whakahemo, where a total of eight sites of significance regarding pipi were identified and surveyed. The second objective focused on using western science techniques to map the current size, distribution and health of pipi in Waihī Estuary, with a focus on sites of high cultural importance identified using mātauranga Māori. This was achieved by incorporating western science techniques via a transdisciplinary approach and replicating the field surveying methods of Berkenbusch et al. (2015). By adopting previous pipi sampling methodology and protocols undertaken by MPI, temporal comparisons of changes in abundance and size over time are possible. This builds on western science-approached research summarised in Berkenbusch et al. (2015), who conducted regular intertidal shellfish monitoring in Waihī Estuary in 2013–14, 2015–16, 2017–18 and 2019–20. It is important to note that the aim of MPI surveys (Berkenbusch et al., 2015) are to obtain overall density and abundance information within Waihī Estuary rather than to identify areas of high abundances.

6.2.2 Field surveying to determine current pipi population densities

Adopting the same sampling methods as MPI enables temporal comparisons of density to be investigated for Waihī Estuary. By looking at the findings and trends in Berkenbusch et al. (2015) and Pawley (2011), similarities and differences in the population dynamics of pipi were found. Both studies support my findings in regards to high densities of pipi being found in the outer estuary, and lower densities in the upper reaches.

My field survey results indicate that the total number of pipi found per site varied throughout Waihī Estuary, with the highest number of pipi in the lower mouth of the estuary along the fast-flowing embankment. The lowest density of pipi occurred in the upper reaches of the estuary. Sites identified by kaumātua supported the overall highest pipi abundances, demonstrating the importance of culturally significant areas known as mahinga kai. The low pipi abundances in the upper reaches of the estuary coincide with previous studies in other estuaries in Aotearoa New Zealand (Ellis et al. 2017; Thrush et al. 2004). These studies found that as stressor levels increase such as nutrients, sedimentation and metal loading, infaunal abundances generally decrease. These increased stressor levels are typically associated with the upper reaches of estuaries due to the delivery of terrestrial sediments and contaminants via rivers and run-off which tend to accumulate in the upper estuary (Abrahim and Parker, 2002). This is also because the upper estuarine areas can be more sheltered (less wind wave disturbance) and have lower current speeds, which means terrigenous muds and nutrients will tend to accumulate in these upper reaches of the estuary (Ellis et al., 2017). In Waihī Estuary, higher levels of TN, organic content and finer grain size fractions were found in the upper reaches of the estuary (Figure 5.7, 5.8 and Table 4), near the sites consisting of low pipi abundances. In regards to the sites containing high pipi abundances, according to Berkenbusch et al. (2015) pipi are associated with high-flow areas, close to tidal currents and prefer coarse, clean sands, thus explaining the high abundance of pipi at IWI 5 in the lower estuary (Figure 5.3). This site was located on a small sandbank in the centre of the main estuary channel, with significant water flow either side of the embankment in tidal channels. Furthermore, this area was predominantly made up of medium to fine grain size fractions (Figure 5.7). Therefore, the environment becomes less favourable to pipi from the lower to upper reaches due a build-up of terrestrial sediments and contaminants entering the estuary via run-off. An increase in finer grain size fractions and nutrients levels occurs causing pipi abundances to decrease (Ellis et al., 2017). Due to the hydrodynamics of the upper reaches (less wind and wave disturbance) contaminants will tend to accumulate overtime (Hewitt and Norkko, 2007).

Comparing my overall surveying area (Figure 5.1) to Berkenbusch et al (2015), two distinct sampling regions can be identified and compared in regards to overall pipi abundance. In my research the two sampling regions were labelled as IWI (green) and MPI (blue). For Berkenbusch et al. (2015), these regions are stratum A (blue) and B (red) (Figure 6.1). Stratum A of Berkenbusch et al. (2015) equates to my MPI sampling region, and stratum B equates to my IWI region. Figure 6.1 shows that Berkenbusch et al (2015) found significantly more pipi in stratum B opposed to stratum A. My results illustrate the opposite to this, with more pipi being found in the IWI region opposed to the MPI region. These findings are not unexpected given the rapid change in geomorphology that occurs in Waihī estuary in that the position and morphology of tidal shoals and channels can change. Additionally, the seasonality of these two studies differed. My sampling was conducted in November 2020 (Spring), while Berkenbusch et al. (2015) carried out their sampling during January/February 2016 (Summer). One major implication of sampling during different seasons is the influence that juvenile recruitment can have on overall abundance estimates. According to Hooker (1995a), adult pipi (up to 58mm shell length) and juvenile pipi (<15mm shell length) were observed drifting in a small north-eastern harbour of Aotearoa, New Zealand. This suggests the mucus drifting of pipi is an active process, adopted for movement to other areas and is triggered by very high densities in conjunction with seasonality. Another study observed bivalve species richness which varied greatly in space and time, with an observation of species recruitment pulses occurring, including that of pipi (Cole et al., 2000). It was suggested that high densities of bivalves occurring at different sites and different times is a result of emigration, mortality and seasonality.

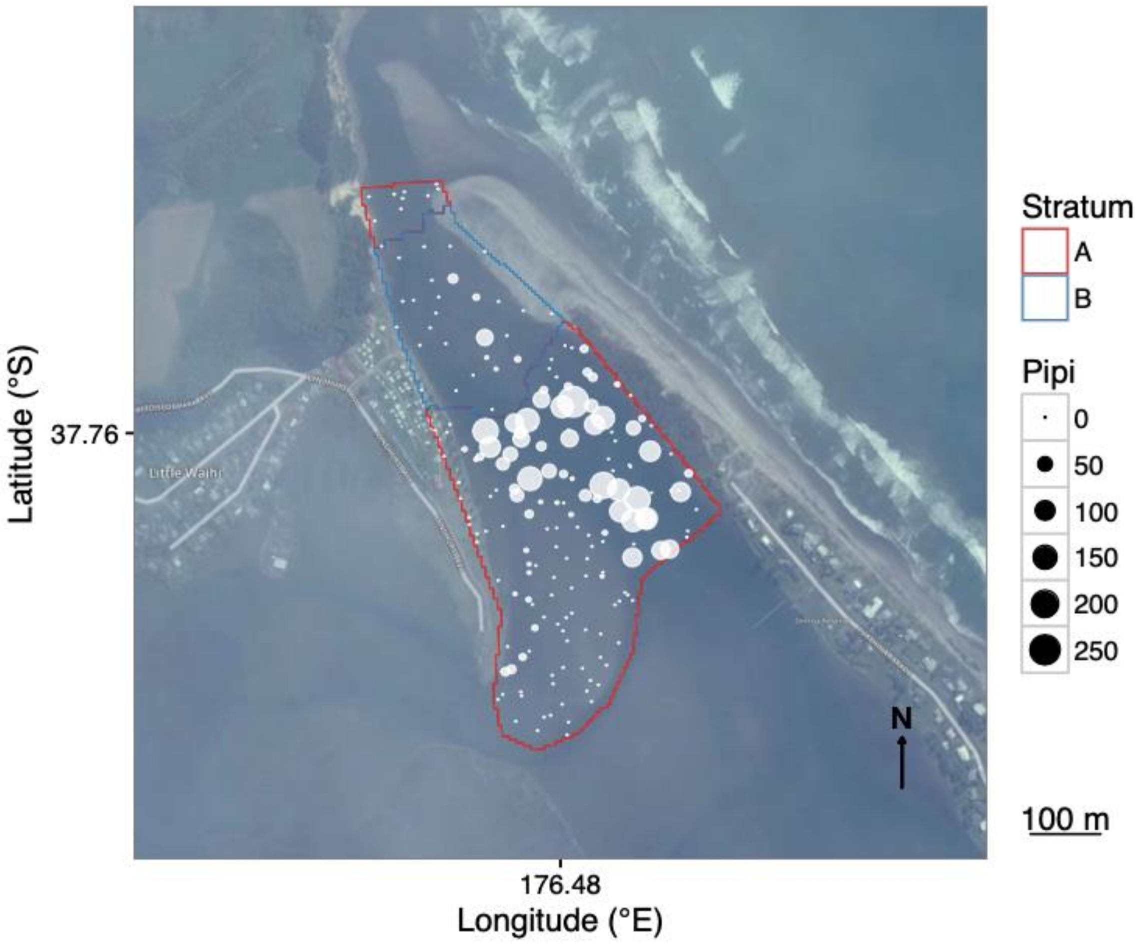

Figure 6.1 - Map from Berkenbusch et al. (2015) showing sample strata and individual sample locations for pipi at Little Waihī Estuary, with the size of the circles proportional to the number of pipi (per 0.035 m2) found at each location. Samples with zero counts are shown as small dots.

Previous work on pipi distribution and abundance in Waihī Estuary was also undertaken by Pawley (2011), part of a study to gain an understanding around harvesting rates of shellfish at a number of harbours and estuaries located throughout the northern North Island region. Figure 6.2 illustrates the sampling regions for this study, showing we sampled similar regions within the estuary. Information regarding exact locations was not provided, however, a total of 174 points were surveyed. Trends in the density of pipi in this study by Pawley (2011) included that the overall pipi population had increased significantly since their previous sampling in 2006. This was due to an influx of juvenile pipi found on the western back (labelled as C in Figure 6.2). Furthermore, Pawley (2011) found high densities of pipi within the main channel of Waihī Estuary, similar to our study. Pawley (2011) found slight shifts occurred over time in hotspots of high pipi abundances which is to be expected in energetic estuarine environments where hydrodynamic conditions vary and morphology, such as the location/ shape of tidal channels and sand banks is dynamic (Perillo, 1995).

Figure 6.2 - The sampling extent of Pawley (2011) for Little Waihī Estuary covering pipi and cockle populations found at the mouth of the estuary (yellow polygons indicate strata A – D that subdivide the sample extent).

6.3 Perceived threats to pipi populations and Waihī Estuary

6.3.1 Social science to categorize perceptions of threats

Objective three was to explore and categorize perceptions of threats to pipi in Waihī Estuary, from tangata whenua and the key regional authority — the Bay of Plenty Regional Council. This was achieved by applying social science methods similar to Klain et al. (2018) (described in Chapter 4). This approach focused on how individuals perceive risk and whether the risk invokes a feeling of dread. This general method is commonly used in research that relates to impacts on the environment. According to Klain et al. (2018), this approach can help explain why and how people evaluate a hazard according to various psychometric rating scales, such as severity of consequences. Therefore, I selected ten common threats to bivalves and estuaries based on existing literature and kaumātua engaged in a wānanga (inclusive of everyone – both iwi and researchers) to rank the threats based on whether they perceived it as a high impact (high consequences) or low impact (low consequences). BOPRC staff also participated in this exercise separately via an online Google form. Results showed that both kaumātua and BOPRC staff (Figure 5.9) perceive overharvesting as the greatest threat to pipi and Waihī Estuary health. According to Karlson et al. (2021), human activities such as overharvesting alter biodiversity by influencing bottom-up and top-down food control on food webs. This in turn affects ecosystem functioning. Karlson et al. (2021) also examined the impact of the presence and absence (simulating an overharvesting scenario) of a large suspension-feeding bivalve on an intertidal sandflat. Results imply that the loss of bivalves potentially increase the rate of eutrophication. Thus, overharvesting can also have broader consequences for the health of the estuary.

Nutrients related to sewage and runoff was the second highest perceived threat by both kaumātua and BOPRC. Coastal regions and estuaries around the world are being affected by increased rates of sediment input and as a result, marine infauna biodiversity is being lost (Ellis et al., 2004). Thrush et al. (2004) evaluated the consequences and extent of sediment input to estuaries and coastal waters occurring in Aotearoa New Zealand. Results indicate that terrestrial sediment input can influence estuarine and coastal ecology, with changes in the magnitude of the effects varying depending on the scale of disturbance. Evolving land-use and uncertain climate projections (Howarth et al., 1991) are likely to increase nutrient run-off into estuarine environments and make it difficult to manage this issue. According to Whitall et al. (2007), increased nutrients related to runoff has been identified as the greatest threat to U.S coastal water quality. This is due to the excess amounts of nutrient pollution that enter the water via land-based point and non-point sources i.e. runoff. Consequences from excess nutrients may include toxic algal blooms and diseased shellfish potentially resulting in serious health issues for humans who consume infected shellfish (Shumway, 1990). Overall, as terrigenous muds and nutrient levels within estuaries increase over time bivalve populations decrease (Ellis et al., 2017). Mud makes the environment less favourable to pipi, with increased fine grain size fractions which block suspension feeding bivalves gills, and a loss of healthy abundant shellfish beds which can alter ecosystem functioning (Norkko et al., 2013).

6.3.2 The values of implementing social science and mātauranga Māori to assess environmental impacts

Incorporating the dread risk tool enabled kaumātua to wānanga together around current threats to pipi and Waihī Estuary. This process worked well because it was inclusive of everyone (researcher and participants), suited to a range of audiences, and coincides with kaupapa Māori research by relying on kōrero and good communication (Walker et al., 2006). Furthermore, this approach of talking to iwi or community to gain a better understanding around impacts and threats to their local environment is considered an environmental management tool, referred to as the expert elicitation approach (Singh et al., 2017a). This approach is particularly useful when decision-makers face novel challenges where prior research and data are insufficient. However, there are potential limitations associated with this approach, such as experts may be prone to overconfidence in their judgements, resulting in potential errors in information (Kynn, 2008). Nevertheless, the expert elicitation approach is a powerful tool to gain empirical data. This is important because it is generally expensive and sometimes difficult to collect the data required to make informed environmental decisions (James et al., 2010). Moreover, there are always spatial and temporal limits on how much sampling can be conducted to gather such information (biophysical data) (Roy et al., 2020). The expert elicitation approach works by analysing a collection of expert judgements of various uncertainties and mixed biases regarding an issue. Multiple experts may not perceive the issue in the same way, however, well-designed elicitation processes help to alleviate challenges associated with the impact resulting in informed decision making (Singh et al., 2017b). I adapted the expert elicitation approach to include tangata whenua and in my case mātauranga ā iwi addressed this gap of overconfidence in judgements and expensive reconnaissance sampling. Furthermore, I gained culturally invaluable knowledge that had been passed down from generation to generation. The concept of ahi kā is highly relevant here, which in its literal form means the fires that burn and refers to the continuous occupation of the land by Māori (Lindsay, 2018). This strengthens the knowledge and connection Māori have to the local whenua, and in turn culturally invaluable knowledge in place over a long and continuous period of time (Teddy et al., 2008).

6.4 Limitations and future work

6.4.1 Guidance on the process of implementing mātauranga Māori

Throughout my thesis I was grateful for the guidance of my supervisor Kura Paul-Burke to navigate the space of kaupapa Māori research. However, as a new researcher to kaupapa Māori I still found it challenging understanding how to apply these principles in practice in the context of my research as there is a limited body of research published in this space. Therefore, a recommendation for future work would be to provide literature that practically guides researchers through the space of implementing mātauranga Māori and western science in a range of contexts. It is important to consider that this process can be very different depending on a variety of factors including, for example, personnel involved, existing relationships, and the tikanga of the participating hapū/iwi (Smith, 2015). Resources that are currently available and I found invaluable included that of Paul-Burke et al. (2018), Pihama et al. (2002), Smith (2013), whom all outline principles that must be followed when using kaupapa Māori research (Section 4.2). However, most literature states the importance of these principles, but no or little explanation is given on how implement them into your research. And such, as an emerging researcher I would have benefited from being able to access resources that document the practical processes followed and how to approach them. This includes guidance on areas that Kura Paul-Burke guided me through, such as attending a hui with the potential hapū/iwi research partner, and how to best communicate amongst different entities such as iwi vs. regional authority. I also found it challenging understanding my role as an emerging researcher but also my being Māori in this journey. This is outlined by Smith (2013) and Webber (2009) as an internal dilemma where struggles and contradictions are associated with being Māori and an academic. According to Webber (2009), to the uninitiated, being a Māori academic may not appear to be a dilemma, however, personal experiences made it apparent that Māori academics are constantly aware of the ways in which we are being positioned by those with whom we interact with as a researcher, as well as those we interact with as a Māori; and the differences between the two. In my case I faced the internal dilemma of being Māori thus an insider from a researcher's perspective, however, an outsider as I am not Ngāti Whakahemo (from a cultural perspective) (Smith, 2013).

If such guidance was readily available more young Māori researchers like myself would be encouraged to step forward and take on this approach of implementing mātauranga Māori and western science, resulting in the development of Māori speaking / mātauranga experienced scientists. Moreover, by building the capacity and capability of upcoming students in this field, the marine science sector may become more receptive to transdisciplinary and mātauranga-led research, thus revitalizing Māori culture through implementing kaupapa Māori research (Smith, 2015). Guidance and understanding on how to approach the above stated practical process will instil confidence in the researcher as they engage with iwi and help provide better terms of reference of what the practicalities can look like, resulting in more Māori academics and mātauranga-led research. According to McAllister et al. (2019b) in Aotearoa New Zealand the Māori academic workforce (particularly at universities) is severely under-represented, and if research is informed by western science it is more likely to be published compared to that of mātauranga-led research. This is reiterated by Smith et al. (2016) who explains academics who carry out mātauranga-led research are expected to "play the game" and refocus their practice, as indigenous rights are irrelevant when it comes to the structure of their academic tenure and role. Therefore, having more young scientists develop this approach of mātauranga-led research, the science academy may also become more receptive to publishing this research as it becomes the norm.

6.4.2 Temporal limitations in kaupapa Māori research

When drawing upon mātauranga Māori and implementing kaupapa Māori research, whanaungatanga and following due process (such as aligning with the time of hapū/iwi hui) is an important concept associated with my thesis approach. I found it challenging to do this within the time constraints of 18 months for my master's thesis. Throughout my journey of following kaupapa Māori research, it was apparent that developing and maintaining a relationship with iwi allows for more in-depth knowledge to be shared. Furthermore, by taking the time to meet and kōrero with kaumātua a space is provided for past experiences and mātauranga ā iwi to be shared in a place that both researchers and iwi are comfortable. For my research I meet with members of Ngāti Whakahemo on three separate occasions including an informal reconnaissance day of the estuary, a formal hui to present my research proposal and a day to conduct interviews/kōrero with three kaumātua. In addition to this I had hoped to spend a day in the field with members of the iwi to teach and share our field surveying methods with them which was not able to take place. Not only does time support whanaungatanga but it strengthens the relationship between mātauranga Māori and western science. However, due to the time constraint I had, having an existing relationship with Ngāti Whakahemo was critical. I was fortunate to have Kura Paul-Burke as my co-supervisor, who is Ngāti Whakahemo. She was able to initiate conversations and meetings between myself and the iwi early on as there was a strong foundation in regards to a relationship between both parties (researcher and iwi).

6.4.3 Spatially and temporally limited pipi sampling

While I was able to compare to previous pipi sampling by Berkenbusch et al. (2015) and Pawley (2011), my sampling was limited to one period in November 2020, thus was temporally and spatially constrained to fit within the time and scope of my thesis. It would have been useful to sample a larger area in Waihī Estuary. This would have resulted in a more robust data set (due to more sites surveyed throughout the estuary), making it more similar to that of Berkenbusch et al. (2015). Furthermore, I would have extended my surveying timeframe out over months (opposed to a week) to gather more replicates of data per site and look at the effects of seasonality to gain a better understanding around pipi recruitment in Waihī Estuary.

Moreover, one of the key findings from the dread risk survey was that overharvesting was identified as the highest impact to pipi population and Waihī Estuary health. I was not able to investigate the potential impacts of this on pipi further within the scope of this thesis, but it is a priority for Ngāti Whakahemo moving forward. I would recommend investigating the issues related to overharvesting which would require sampling a large area of the estuary over an extended period of time.

6.5 My journey as a transdisciplinary researcher

Before my masters my background in science and research was very much based on western science knowledge systems, protocols and methods. When beginning my literature review and learning more about mātauranga Māori and kaupapa Māori research, I was excited to learn about my own culture and implement the knowledge of our tūpuna into my research. I found switching my mindset from western science to kaupapa Māori research challenging, including due to the methods, concepts and ways of approaching situations was co-developed with Ngāti Whakahemo (as per kaupapa Māori research principles). A key experience that helped to cement my shift in mindset was after attending my first marae hui in Pukehina to present my research proposal to Ngāti Whakahemo. By having early communication with Ngāti Whakahemo and presenting myself in person, I adhered to kaupapa Māori research principles and started the journey of a transdisciplinary scientist implementing mātauranga Māori and western science. This processes of early communication and presenting yourself in person was described by Walker et al. (2006) as being one of the core concepts to mātauranga Māori.

When it came to conducting the kōrero/interviews with the kaumātua I felt honoured to gain this sacred knowledge which had been passed down from generation to generation. It was during these times where I had come face-to-face with the iwi that I was grounded and truly valued the approach I was implementing in research. It was the stories and generosity of the kaumātua giving up their time to come forward and help me conduct my research. Literature which is based on the use of mātauranga Māori and western science, highlights the importance of meeting with iwi in person. Bishop (1999) describes this as whanaungatanga where the recognition of the deeper kinship between ourselves and others is prioritised. This connectedness and engagement is valued by Māori and is one of the fundamental concepts associated with mātauranga Māori. In regards to navigating the spaces of mātauranga Māori and western science I found communication to be the most important principles to follow as this enabled everything to be on the table between the iwi and researchers. The wants and needs of the iwi drove the methods being implemented throughout my research, however, to incorporate western science methods developed a plan explaining what it is I wanted to include and why. This was shared with the iwi to make sure they were included in the entirety of my research and agreed with the process I was implementing.

Overall, I have learned the importance of following kaupapa Māori research methods, I know there is still much to learn however, I have gained a significant amount of respect and value for this approach and believe that Māori voices need to be heard and included in environmental and ecological research. They are experts in this field with knowledge that can only be gained through trust and respect.

Chapter 7
Conclusion

"Manaaki whenua, Manaaki tangata, Haere whakamua"

"Care for the land, care for the people, go forward"

I looked to mātauranga Māori to inform understanding of population dynamics and health of pipi in Waihī Estuary. I fundamentally drew upon mātauranga ā iwi from Ngāti Whakahemo, tangata whenua of Waihī Estuary. I followed kaupapa Māori research methods to engage with kaumātua who identified culturally significant pipi beds, known as mahinga kai. This informed extensive field surveying using the western science field sampling methods of Berkenbusch et al. (2015), to map the size, distribution and health of pipi in Waihī Estuary. To complement this, I also categorised perceptions of threats to pipi in Waihī Estuary from tangata whenua and the regional authority, implementing participatory mapping methods similar Klain et al. (2018).

Looking to mātauranga Māori and kaupapa Māori research methods in science is a unique approach, with very few scientists looking to this knowledge system in the marine sector. For this thesis, three kaumātua volunteered their time to share knowledge that had been passed down from generation to generation. As a result, 54 sites of significance regarding pipi were identified and sampled within Waihī Estuary. In Aotearoa New Zealand, and elsewhere, looking to the knowledge of our ancestors and incorporating the voices of Indigenous Peoples including Māori into science and environmental management plans is immensely important and would strengthen our overall knowledge on the changes and impacts made to our ecosystems.

Pipi distribution and abundance varied significantly throughout Waihī Estuary, with the most pipi found in the lower estuary, and lower densities further in the upper reaches that are more influenced by freshwater. Sites identified by kaumātua supported the overall highest pipi abundances, with 20,371 pipi/m^2 at IWI 5 (extrapolated data). This demonstrates the importance of mātauranga Māori being incorporated into ecological surveys, with culturally historic knowledge specific to Waihī Estuary being shared with us from Ngāti Whakahemo.

The inclusion of western science techniques allowed me to map the size, distribution and health of pipi in Waihī Estuary, based around sites identified using mātauranga Māori. By replicating previous field surveying methods of Berkenbusch et al. (2015) I was able to facilitate temporal comparisons and compare pipi abundances from past surveys. These comparisons illustrated that pipi abundances decreased from the lower estuary to the upper reaches. This is due to an increase in stressor levels such as TN, organic content and fine sediment grain size fractions. Both Berkenbusch et al. (2015) and Pawley (2011) found similar results in their studies at this location.

A participatory mapping approach following methods similar to Klain et al. (2018) was used to carry out kōrero/interviews with kaumātua and wider stakeholders from the BOPRC. Overall, kaumātua and BOPRC staff members ranked over harvesting as the highest perceived threat to pipi populations in Waihī Estuary. The second highest perceived threat was nutrients related to sewage inputs and runoff, followed by diseased shellfish. Overall, I provided a space for kaumātua to engage in an inclusive hui style kōrero to discuss what they perceive as high impacts to pipi and Waihī Estuary. All three kaumātua agreed upon what threats were most salient to pipi and Waihī Estuary, this being overharvesting and diseased shellfish. They also provided one extra impact under the "other" category which was runoff from the spraying of drains south of the estuary. Overall, I adapted the expert elicitation approach to include tangata whenua and in my case, mātauranga ā iwi. This allowed culturally invaluable information to be shared which may inform future management strategies and reduce the need for expensive reconnaissance sampling to dictate priorities.

It is evident that pipi populations in Waihī Estuary are of major concern to both iwi and regional authority. My thesis provides baseline data from iwi perspective regarding pipi distribution and abundance. By fundamentally drawing upon mātauranga Māori from Ngāti Whakahemo culturally significant sites were included in ecological surveys and the voices of tangata whenua were heard. Furthermore, the collaboration of mātauranga Māori and western science via a transdisciplinary approach was used to assist the development of management strategies for marine ecosystems.

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