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He Kai Kei Aku Ringā

(There Is Food at the End of My Hands)

Developmental Transdisciplinary Research to Inform Co-Management of Tuangi in Ōhiwa Harbour

A thesis
submitted in fulfilment
of the requirements for the degree
of
Doctor of Philosophy in Environmental Sciences,
Te Aka Mātuatua, School of Science
at
Te Whare Wananga o Waikato
The University of Waikato
By
Kiri Ripeka Reihana

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

2026

Perhaps the greatest injustice in the colonisation of Indigenous Peoples
is that a wrong is so often excused as a reason and any response to
Indigenous grievance is trumpeted as a step
along the way to resolution ….
Yet a wrong can never be reasonable and
a response can never be a resolution,
or even a step towards resolution,
if it perpetuates the core injustice ….

John Mohawk, Haudenosaunee
jurist at Conference 'Settling the Unsettled', 1996

Ko te manu e kai i te miro nōna te ngahere, Ko te manu e kai i te mātauranga, nōna te ao.

The bird that eats the miro berry owns the forest. The bird that feasts on knowledge owns the world.

Traditional Māori whakatauki

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Waitara—Abstract

Indigenous Knowledges, traditions, practices and ways of being are increasingly present within the global marine conservation discourse. As long-standing intergenerational custodians of a large percentage of the earth's natural areas, many Indigenous communities seek to play a central role in co-defining the issues, co-participating in the process and co-designing the solutions for their lands and water resources. The value and benefits of Indigenous-led conservation, knowledge creation and participation are exponentially expanding within scholarship.

This research is located within Ōhiwa Harbour, an estuarine inlet in the Bay of Plenty, in the North Island of Aotearoa New Zealand. The thesis explores historical and contemporary information of the identified taonga (sacred, treasured) species tuangi, or cockles, within Ōhiwa Harbour. The research was designed to identify relevant tools and technology to address the declines of the tuangi populations, and to assist iwi (tribes) and authorities in providing information for decision making over the shellfish beds. Finally, findings of the thesis produced species distribution models which assisted in understanding tuangi-preferential habitats within the estuary, and the development of rapid site-assessment techniques based on mātauranga Māori (Cultural knowledge system).

This thesis uses a transdisciplinary mixed method approach inclusive of mātauranga Māori, marine sciences, and technology. This research is led by kaupapa Māori (a Māori way of being, seeing, and doing) informing and developing a Tīwaiwaka framework informed by multiple evidence-based approaches as a means of weaving multiple knowledge systems. To achieve this, the guiding framework and methodology emerged from the te ao Māori conservation movement Tīwaiwaka, which prioritises kaitiakitanga (active stewardship), unification and reciprocating co-existence with our natural environment.

Results from the legislative review on marine governance highlighted historical colonial exclusionary policies, accelerated extractive practices and tools displacing Māori people and culture on the settlement of Aotearoa. The polarity of views from the two cultures set the backdrop of the ensuing misunderstandings over management and governance of the marine space, and all natural resources, within Aotearoa. Therefore, future aspirations herald a call for a paradigm shift from the existing extractive model to an inclusive

sustainable marine model which maintains a "respectful" relationship with our oceans, inclusive of Māori values such as tikanga (customs and traditional values in a Māori context), rangatiratanga (self-determination, autonomy), kaitiakitanga, mana (authority, status, influence) and mauri, (divine spark, force or energy) to name a few.

Results from the field studies showed that legal-sized tuangi have not been harvestable within Ōhiwa since the mid-1980s. There is an urgent need for integrated culturally responsive marine management actions. My study highlights the importance of the local traditional knowledge in identifying tohu (here I define tohu as a "observable cue," an expression of mana, or mauri, communicated through the environment) for rapid broad-scale mapping techniques for habitat monitoring and assessment locations. These techniques can be scaled up and prioritise areas of interest within harbours, depending on species and/or objectives. The use of technology to interpret and analyse population dynamics confirmed Elders' knowledge of the species and spaces within Ōhiwa Harbour.

The Tīwaiwaka framework developed to address the declines of tuangi has provided an exemplar for the weaving together of multiple knowledges for shellfish management within Ōhiwa Harbour. This model of transdisciplinary estuarine and coastal regeneration, inclusive of Indigenous Knowledges such as mātauranga Māori, fulfils global conservation initiatives such as Article 8(j), of the Convention of Biodiversity, and the United Nations Decade of Oceans Science for sustainability, creating "the science we need for the ocean we want" as robust scientific-based solutions.

Creating new knowledge through the weaving of mātauranga Māori, marine science and technology provides a pathway for transformative environmental change. The weaving of Indigenous Knowledge, ecological assessment and species distribution modelling generated new insights into tuangi populations and identified priority monitoring and restoration sites. The observational tohu identified are long standing environmental indicators that enabled rapid site assessment and the recognition of areas of significance. While tohu have long informed Māori environmental kaitiakitanga, this research formalised their application within contemporary conservation practice. More broadly, the Tīwaiwaka framework demonstrates a transferable Indigenous-led model for marine conservation, co-management and knowledge co-development that maintains the integrity of multiple knowledge systems while delivering culturally grounded, scientifically robust solutions for environmental governance and biodiversity conservation.

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Titiro ki te nui o te aroha o te Atua ki a tātou—kua karangatia tātou hei tamariki māna, ā, koia tonu tātou.

See how great God's love is—He calls us His children, and that's truly who we are.

1 John 3:1

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To my nieces and nephews, thank you for your support, encouragement and fanning me on, I love you, and if I can do it, so can you xox

To my sister, Sonia, the one I wished more than anything I could share this with, I know you'd be so proud of this, I dedicate this to you. I miss you every day.....

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Arohanui Kiri

Pepeha—Personal Introduction

Iti taku iti,
Ka haere aku rongo,
Ki te ao turoa,
Ki te ao marama,
Tihei mauri ora

Ko Pūhanga tōhora, ko Ninihi ngā maunga
Ko Maungatawa rao ko Ōtaua ngā awa,
Ko Hokianga te moana,
Ko Pukerata, Ko Motukaraka ngā marae,
Ko Te Rau Tawa i Nui, Ko Ngahuia te whare roimata
Ko Te Rangiheketini te wharekai,
Ko Te Whakaruruhau te wharewaka,
Ko Ngāokimatawhaorua te waka,
Ko Ngāi Tūteauru rao ko Ngāi Tūpoto ngā hapū
Ko Ōtaua ngā kāinga,
Ko Ngā Puhi, ko Te Rarawa ngā iwi
I te taha toku papa,
ko Jeff Reihana tōna ingoa

Ko Matiti, ko Hiwarau, ko Taiarahi ngā maunga
Ko Waioeka, ko Nukuhou, Ko Ohinemataora ngā awa,
Ko Ōhiwa te moana,
Ko Mataatua te waka,
Ko Opeke, ko Te Rewarewa, ngā marae,
Ko Irapuaia, ko Kuramihirangi, ko Rangimōaha ngā tupuna whare,
Ko Ngāti Ira, ko Upokorehe, ko Te Mahurehure ngā hapu,
Ko Waioeka, Ko Ruatoki ngā kainga
Ko Whakatōhea ki ngāi tuhonhono Ngāi Tuhoe ngā iwi
I te taha toku mama,
Ko Jeanne Ora no Kora, no Parkinson, no Kawana tona whānau ingoa,
Ko Kiri Reihana toku ingoa.

It is only right that my introduction places me within the awhi (embrace) of my parents and their connections to place. It is my mother's whakapapa, her connection and whenua which locates me as uri (a descendant) of Ōhiwa, of Whakatōhea and Ngāi Tūhoe who still occupy these shores with our physical being, blood, sweat and tears for our sacred place, Ōhiwa. As referred to in my later chapters and beautifully articulated by poet Ati Teepa, "He āhuru (it's sanctuary), He maru (it's security), Taku moana e hora nei (it's what anchors us), … He tauranga (she is safe harbour), he kainga (she is home)" (Teepa, 2023). A place I spent time as a child and over my adulthood, she is my moana, my home, my people's place.

Ko wai au? Who am I?

This dissertation has been a profound journey of self-discovery. After enrolling in the PhD programme, I was diagnosed with severe dyslexia as a mature student. What began as a subtle suggestion opened a pathway to understanding the challenges associated with dyslexia, how prevalent it is within our communities, and how many individuals navigate these difficulties without fully understanding or accessing the support available to them. Reflecting on this experience has highlighted the importance of recognising and managing dyslexia in ways that enable individuals to realise their full potential. Having not received learning support earlier in life, this journey has also underscored the realities of privilege, access, and equity within educational systems and society more broadly.

Throughout this dissertation, visual graphics have functioned as both a technological and creative medium, reflecting a mode of communication that aligns with my dyslexic cognitive strengths. These graphics are not merely illustrative; they function as dynamic signals of the process and procedures I engaged in at various milestones in my research journey. By channelling my creative lens, I transformed complex ideas into visual representations that supported and enhanced the written articulation of my methods, theories and explanations. This approach allowed me to bridge the gap between visual thinking and academic expression, making the dissertation both a personal and scholarly narrative.

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Papakupu—Glossary

Aotearoa	Indigenous Māori name for New Zealand
ahi kā	those who keep the home fires burning
awa	river, stream, waterway
hapū	subtribe
hākari	a feast, banquet, sumptuous meal, or celebration
huamata	traditional time for planting and harvesting
hunga tiaki	Māori caretakers or guardians
iwi	largest societal group, people, nation or tribe
kaimahi	worker
kaimoana	shellfish
kaitiakitanga	guardianship
karakia	incantation, prayers
karoro	sea gulls
kaumātua	tribal Elder
kaupapa Māori	practices, ideas and concepts embedded in a Māori world
kawa	protocol or etiquette
kura kaupapa	Māori total immersion schools
kuku	green-lipped mussels *Perna canaliculus*
maara	gardens
mahi	work
mahinga kai	uncultivated food harvesting grounds
mana	authority, status, influence, spiritual or supernatural power
manaakitanga	generosity, kindness, hospitality, and respect for visitors/others
mana moana	Historical or territorial authority for the sea
mana whenua	Indigenous people who hold historical and territorial authority for the land
mātaitai reserves	recognise and provide for traditional fishing through local management
manu	birds
maramataka	lunar calendar
mātauranga	knowledge system

mātauranga Māori	cultural knowledge system, Māori people's ways of being, knowing and doing
mauri	divine spark, force or energy, spirit
mōteatea	chants, poetic lament
Muriwhenua	northern North Island iwi
Ngāi Tahu	South Island iwi
Ngāi Tūhoe	Māori tribe located primarily in the Bay of Plenty regions of the North Island, Aotearoa New Zealand
ngā tamāhine o te Whakatōhea	The daughters of Whakatōhea
Ngāti Awa	Māori tribe located primarily in the Bay of Plenty regions of the North Island, Aotearoa New Zealand
Ngāti Porou	east coast iwi
Ngāti Ruanui	west coast of mid North Island tribe
Ngāti Whakahemo	western Bay of Plenty iwi
noa	common or not sacred
Pākehā	European colonial settler
pātaka kai	food storehouse or pantry
pātere	chant
pipi	bivalve mollusc, *Paphies australis*
pāua	abalone, *Haliotis iris*
pou	pillar, pole or post
pūrākau	sacred narratives
rāhui	customary closures, temporary prohibitions related to resource harvesting and access
rangatiratanga	the right of Māori people to rule themselves, self-determination, chiefly authority, autonomy
rohe	region
taiāpure	local fisheries of special significance, which may have additional fishing rules, comprising estuarine or coastal areas that are of significant food, spiritual or cultural reasons
takutai moana	marine and coastal area
Tangaroa	deity of the sea
tangata whenua	people from the land

tangi	cry, mourn, weep or funeral
tapu	sacredness
te reo	Māori language
te taiao	the environment
Tino Rangatiratanga	absolute sovereignty or self-determination
tītī	mutton-bird
taonga	sacred, treasure
te ao Māori	the Māori world
te kete kai a Tairongo	the food basket of Tairongo
Te kopu o te Ururoa	the womb of the great shark
Te Moananui-a-Tairongo	the large or plentiful ocean of Tairongo
Te Tiriti	abbreviation for "Te Tiriti of Waitangi"
Te umu tao noa a Tairongo	the food oven of Tairongo
tikanga	customs and traditional values in a Māori context
tīwaiwaka	New Zealand fantail, te ao Māori conservation movement
tohu	environmental signals
tōrea	oyster catcher
tuangi	cockles, *Austrovenus stutchburyi*
tūrangawaewae	standing ground, where one has the right to stand and occupy
waiata	songs
whakapapa	genealogical links, ancestry
Whakatōhea	Māori tribe located primarily in the Bay of Plenty regions of the North Island, New Zealand
whenua	land
whānau	family
utu	reciprocal obligations of care and balance

Whakapoto—Acronyms

AUC	Area under curve
BOPRC	Bay of Plenty Regional Council
BRT	Boosted regression tree
CS	Council site
DNA	Deoxyribonucleic acid.
EBOP	Environment Bay of Plenty
GIS	Geographic information system
GPS	Global positioning system
HECS	Human Resource Ethics Committee
IK	Indigenous Knowledges
IPBES	International Science Policy Platform on Biodiversity and Ecosystems Services
MACA	Marine and Coastal Area Act
MEB	Multiple evidence based
MPA	Marine protected areas
MRMT	Motiti Rohe Moana Trust
NGO	Nongovernmental organisation
NZHC	New Zealand High Court
NMR	Natural resource management
NZLR	New Zealand Law Reports
ŌHIF	Ōhiwa Harbour Implementation Forum
OGSCG	Ōhiwa Harbour Strategic Coordination Group
PD	Partial dependence plots
QMS	Quota management system
RMA	Resource Management Act
ROC	Receiver operating characteristic
SD	Standard deviation
SDM	Species distribution model
SS	Sampled sites
TB	Traditional beds
TEK	Traditional ecological knowledge
TRoNA	Te Runanga o Ngāti Awa
TTR	Trans-Tasman Resources

UN	United Nations
UNESCO	United Nations Education, Scientific and Cultural Organisation
WAI	Waitangi Tribunal Claims prefix
WWF	Worldwide Fund for Nature

Wāhanga Tuatahi—Chapter 1

There is a world of difference between viewing the Pacific as "islands in a far sea" and as "a sea of islands." The first emphasises dry surfaces in a vast ocean far from the centres of power. Focussing in this way stresses the smallness and remoteness of the islands. The second is a more holistic perspective in which things are seen in the totality of their relationships. (Hau'ofa, 1993, p. 31)

Wāhanga Tuatahi—Chapter 1

He Te Tīmatanga Kōrero—Introduction

Figure 1

Visual Illustration of Chapter Outlines and Key Concepts

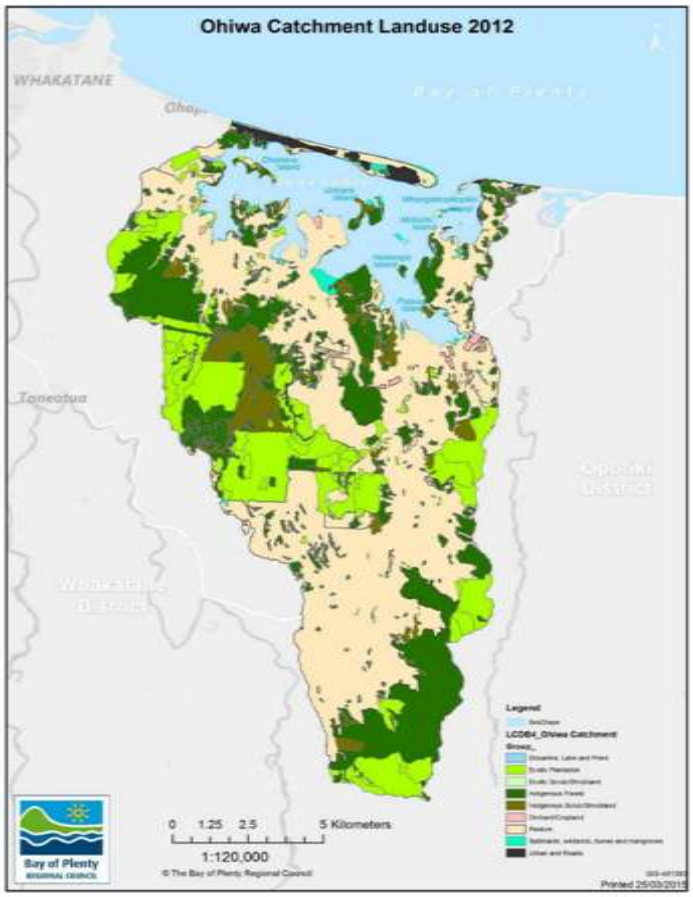
1.1 Ōhiwa Harbour

Ōhiwa Harbour is a significant estuary, culturally and ecologically, located in the Eastern Bay of Plenty between the townships of Whakatāne and Ōpōtiki along the east coast of Aotearoa New Zealand (see **Error! Reference source not found.**). For decades, the local i wi (tribes) and community have been vocal about declines in the biodiversity (Bay of Plenty Regional Council [BOPRC], 2017; Environment Bay of Plenty [EBOP], 2008; MacKenzie, 2014). The harbour is surrounded by a diverse range of land uses, heavily dominated by forestry, pastoral farming, horticulture and residential lots (MacKenzie, 2014), which are considered the key aspects contributing to the biodiversity decline.

Ōhiwa Harbour comprises a shallow intertidal lagoon enclosed by two sand spits and covers approximately 26.4 km². It has an estimated 171 km² catchment area, which culminates and deposits within the harbour. Some 12 small streams and a significant river, the Nukuhou, feed into the estuary. There are 10 small islands in the harbour, only one of which has permanent residents (EBOP, 2008; Johnston, 2003), each contributing to the harbour's rich biodiversity. Despite pressures from sedimentation (Bryan et al., 2023) and invasive species such as the 11-armed starfish (Ranapia, 2025), Ōhiwa continues to support vital shellfish beds, seagrass habitats and diverse ecosystems that maintain wildlife and local communities.

Figure 2

Landcover of Land Use Within Ōhiwa Harbour Catchment



Source: Bevan (2018).

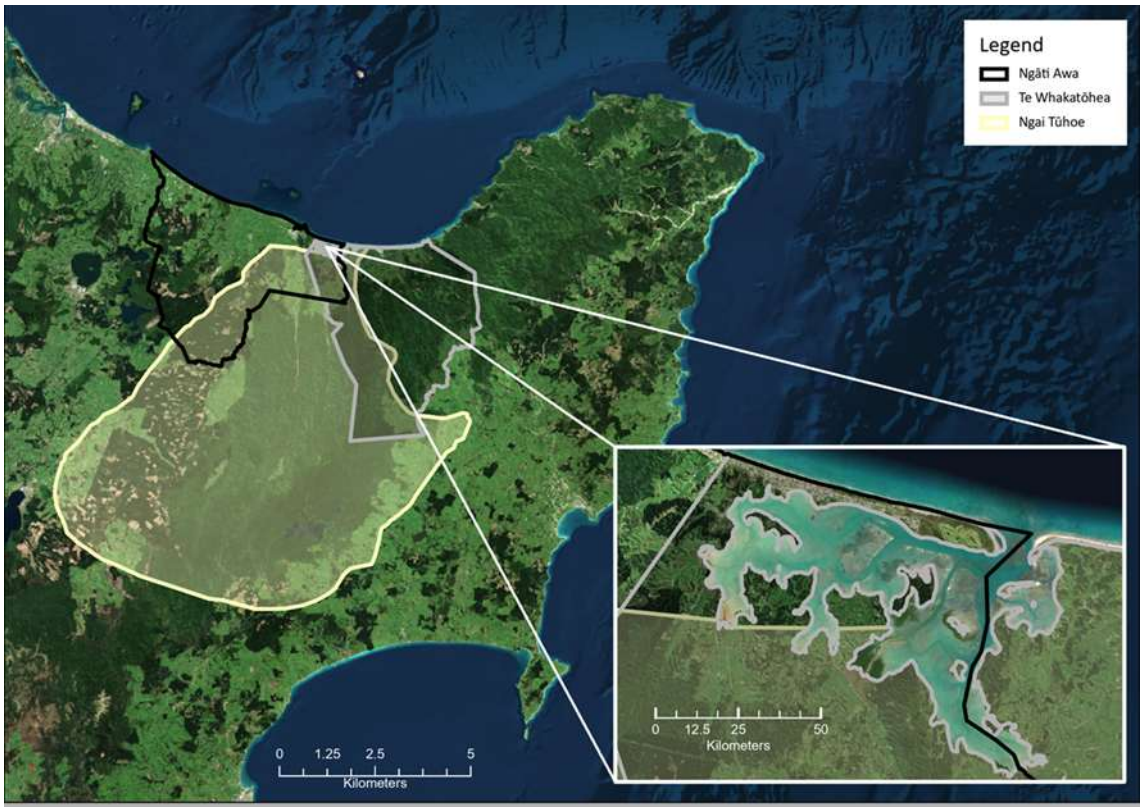
The shallow lagoon consists of mudflats and sandy sediment, and within its vicinity hosts significant pa (tribal community fortified village or settlement) sites from the local Māori hapū (subtribes) and iwi who affiliate to this harbour: namely, Ūpokorehe (hapu of Whakatōhea), Ngāti Awa, Te Whakatōhea and Ngāi Tūhoe (Johnston, 2003; Ōhiwa Harbour Strategy Coordination Group, 2014). Ōhiwa's prominence as a cultural taonga (treasure) is evidenced by the multiple waiata (songs), moteatea (chants, poetic laments), names and references within local tribal accounts (Black, 2014; Teepa, 2023). The significance of this harbour is upheld in its role as a food basket, a place of recreation and a site of cultural, historical and spiritual importance (Black, 2014; EBOP, 2008; Johnson, 2012; Te Rūnanga o Ngāti Awa, 2019; Whakatōhea, 1993).

The main iwi and hapū who exercise mana moana (ocean authority) over Ōhiwa are Ngāti Awa, over the western side of the harbour, and Ūpokorehe, over the eastern side (Ranapia, 2025). Whakātane District Council and BOPRC have jurisdiction over the Ngāti Awa side, while Opotiki District Council and BOPRC govern the eastern side (see **Error! R**

eference source not found.). Te Whakatōhea and Ngāi Tūhoe (Waimana Kaaku) iwi also have historical, traditional and customary interest in Ōhiwa (Johnston, 2003).

Figure 3

Tribal Boundaries of Ōhiwa Harbour and Surrounding District Areas



Successive colonial legislation (see legislative review, Chapter 3), policies and practices sought the enclosure, then successful exclusion, of Māori from their land and oceans, including iwi within Ōhiwa (Johnston, 2003). The subsequent effect was the loss of cultural knowledge, language, traditions, practices and te reo (language) of the tribes. Significant cultural practices such as kaitiakitanga (guardianship) and natural resource management (NRM) practices such as rāhui (temporary closures and/or bans) became illegal and some have been lost (Maxwell & Penetito, 2007).

However, for Māori who continue to reside within their tribal territories around Ōhiwa, intergenerational observations have documented the degradation of the harbour and the decline of taonga species (Paul-Burke et al., 2010). After over 100 years of frustration with the current local authority management regime, in 2005 the iwi of Ōhiwa came together to form a working group committed to the rejuvenation and care of Ōhiwa Harbour (Ranapia, 2025). BOPRC recognised the working group, leading to the development of an integrated management strategy including the local tribes within the collective (EBOP, 2008). The initial Ōhiwa Harbour strategy was released in 2008,

followed by the Ōhiwa Harbour Strategy: Te Rautaki mō Ōhiwa: Refreshed 2014. From these actions, the Ōhiwa Harbour Implementation Forum (ŌHIF) was established as a non-statutory co-governance collective, with members elected from the three tribes and hapū—Ūpokorehe, as well as the three local authorities (BOPRC, 2017; EBOP, 2008).

In 2013, BOPRC released the *State of Ōhiwa Harbour and Catchment*, aimed at an environmental assessment of the ecological health of Ōhiwa Harbour (MacKenzie, 2014). While some keystone species were identified among the list such as kuku (mussels, *Perna canaliculus*), overall, the Ōhiwa Harbour strategy signalled the clear concern of iwi and local communities at the visible degradation of the harbour. The document identified that further investigations of all shellfish populations were required to provide information for sustainable future management options (Bevan, 2018; MacKenzie, 2014). Bevan's (2018) "State of Environment for Ōhiwa Harbour" report considered the intertidal benthic habitat to be in a moderate to poor condition owing to the increased sedimentation loading within the harbour, although contaminant levels remained low. While tuangi (cockle, *Austrovenus stutchburyi*) populations within the harbour showed an increase in numbers, the health-risk indicators associated with shellfish consumption remained at levels below health consumption guidelines (Bevan, 2018).

Pollution (Bevan, 2018), overharvesting (Paul-Burke et al., 2018), disease, infestations (Paul-Burke et al., 2018; Ranapia, 2025), sedimentation (Bevan, 2018; EBOP, 2008) and climate change (Bevan, 2018) are thought to be the major contributors to the declining health of Ōhiwa Harbour. In any harbour, there is a natural level of sedimentation (Thrush et al., 2004) that occurs from soil erosion, increased sedimentation from land-use changes, vegetation clearing and forestry harvesting. However, Ōhiwa's elevated sediment input (approximately 60% increase since June 2008; MacKenzie, 2013) has increased the sedimentation burden above the natural loading into the waterways and ultimately in filling the estuary. These types of land use modifications are consistent with the systemic sedimentation processes occurring within the Ōhiwa Harbour catchment.

Elevated sediment loads have smothered shellfish beds and habitats, while increasingly muddy sediments may further limit tuangi abundance.(Ellis et al., 2002; Thrush et al., 2004). The two main effects are 1) direct mortality owing to smothering and 2) sublethal effects due to suspended sediment affecting condition and filter feeder ability (Ellis et al., 2002). The above are two important key mechanisms affecting the current state of tuangi in Ōhiwa Harbour.

1.2 Tuangi

1.2.1 Tuangi as a Taonga Species

The humble tuangi is so highly valued by the tangata whenua (people of the land) and wider communities of Ōhiwa, where it has served as both a staple food source and an economic resource, that there is a substantial body of historical, cultural and oral evidence attesting to its importance. In the earliest records, the abundance of not just these shellfish but the shellfish that could be harvested in Ōhiwa is recalled in the following accounts.

> Mr M. Rangihika—Ngāti Pukeko (1987) recalled snapper (*Pagarus auratus*) and flounder (*Rhombosolea pleabia*) located off Bluett's Creek at Ohope and Ōhiwa Harbour. Shell fish such as mussels, pipi, cockles and oysters were harvested from Ōhiwa Harbour, prior to the oyster farm being built or seeding of mussels in the Harbour. (Paul-Burke et al., 2010, p. 6)
>
> The Ōhiwa Harbour has provided Ngāti Awa hapū with an abundance of fish and shellfish such as flounder, kahawai, mussels, pipi, cockles, scallops, and oysters. The harbour was also rich in bird life and building material. (Te Rūnanga o Ngāti Awa, 2019, p. 5)
>
> Low tide at Ōhiwa is when the bountiful shellfish can be seen; known as the daughters of Te Whakatōhea. (Te Tari Whakatau, 2023, p. 12).
>
> Of food that enabled hapū to access this on a seasonal basis, Ōhiwa Harbour, named "the daughters of Whakatōhea," held plentiful supplies of shellfish, including cockles, mussels and sea snails. (BOPRC, Ōpōtiki District Council, Whakatāne District Council, Te Ūpokorehe, Whakatōhea, Ngāti Awa, & Tūhoe, 2014, p. 10).
>
> Extensive beds of the New Zealand cockle, (*Chione stutchburyi*), and the pipi*, (Paphies australis*), occur in the harbour. Smaller numbers of rock oysters (*Saccostrea glomerata*), green-lipped mussels (*Perna canaliculus*), horse mussels (*Atrina zelandica*), and scallops (*Pecten novaezelandiae*) also occur; these molluscs, with the possible exception of scallops, were reportedly very much more abundant earlier this century (Du Pontet, 1963; Marine Department data on. file M. 2/12/318, Ōhiwa Harbour) (Paul, 1966, p. 4).
>
> From the end of the 19th century, … a further lease was issued to Bruce Sargisson Baker of Whakatane to take cockles, pipi and tuatua (*Paphies donacina*) from the harbour. At this time, it was estimated that there were some 750,000 oysters

> divided between the three lease sites, and that approximately 120,000 oysters were harvested annually. The quantity of cockles and pipi in the harbour were unknown, and 120–180 kg cockles and 150–300 kg pipi were harvested each week. (Johnston, 2003, p. 216)
>
> Du Pontet likewise recalled fishing for snapper, mullet and flounder, and "digging for cockles in the apparently inexhaustible beds ... on both sides of the channel—gathering them by the bucketful for hungry visitors." Du Pontet listed the "amazing" "variety of fish to be caught at Ōhiwa years ago" as follows: "snapper, gurnard (*Eutrigla gurnardus*), kahawai (*Eutrigla gurnardus*), mullet (*Mugil cephalus*), piper (*Hyporhamphus ihi*), trevalli (*Pseudocaranx dentex*), yellow tail (*Seriola lalandi*)—even kingfish were sometimes to be had—and terakihi (*Nemadactylus macropterus*), with an occasional barracouta (*Thyrsites atun*)." Stingrays (*Bathytoshia brevicaudata*) and dogfish (*Mustelus lenticulatus*) were also caught, and used for bait, as were cockles and mussels "of which there [were] huge beds, apparently inexhaustible, on both sides of the main channel. These shellfish," Du Pontet noted, "were sent in large quantities to Gisborne and Rotorua for sale when road transport was available" (Johnston, 2003, p. 219)

As a taonga species, it occupies a prominent place within the cultural narratives of local iwi, hapū and whānau (family) featuring extensively within cultural knowledge systems and oral traditions. Its presence in pūrākau (sacred narratives), pakiwaitara (legends), mōteatea (poetry), waiata and korero tuku iho (oral traditions of the past) demonstrates its significance not only as a species within the natural world, but also as a bearer of whakapapa (genealogical links, ancestry), identity, and mātauranga Māori (cultural knowledge system). The prominence of this species within these narratives reflects the profound relationship between local hapū and place, revealing the interconnected dimensions of whakapapa, memory, identity and belonging that weave people and whenua (land) across generations and through time.

The cultural significance of this tuangi is perhaps best illustrated through the recollections of Ngāi Tūhoe kaumātua (Elder) Sir Harre Williams, who recalled his childhood in Ōhiwa Harbour, and the close relationship between local communities and the harbour's natural lavishness.

> There used to be a wharf there and then I used to play on that wharf a lot, and I'd go right down from karaka, our home, follow the tide down and fill the sledge up with tuangi, it was quite deep, quite big, there was a lot of cockles in there, and to

make the towing easier I would walk back with the tide, as the tide came in and occasionally there, a flounder would get stuck under my foot, so I'd pick that up and take it home too.

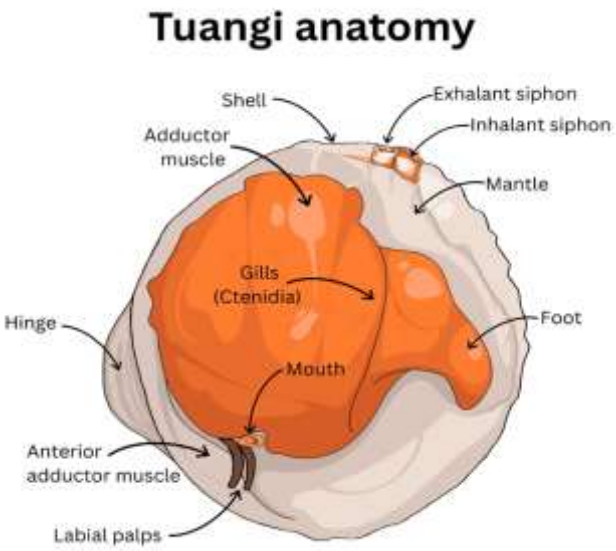
So, we had plenty of kai and the harbour provided for everything we needed from the ocean, the bush provided for everything we needed in terms of medicines and materials for buildings, for timber and the land of course provided all things we could grow and harvest so we had no need of money, so we lived in an economy without money (Sir Harre Williams, personal communication, November 25, 2024).

1.2.2 The Ecology of Tuangi

Tuangi are ecological engineers—infaunal, siphonate, filter-feeding bivalves that dwell in the intertidal and subtidal sandy bays, estuaries and mudflats of coastal areas. They occupy critical roles for coastal ecosystems, contributing, for example, to bioturbation (Van Der Schatte Olivier et al., 2020), carbon storage (E. Morgan et al., 2013) and water clarity, enhancing microphytobenthos productivity (Rakotomalala et al., 2015). In addition, they serve as bioindicators of the health of a estuary (Cheggour et al., 2001).

Figure 4

Tuangi Anatomy, With Anatomical Parts Labelled



Being a bivalve mollusc, tuangi have a hinged shell, in this case, equivalve, meaning that both sides are symmetrical in size and shape (see Figure 4). Belonging to the *Veneridae* family, known as the Venus clam, little neck clam or cockles, they are classified as an invertebrate, with a soft-flesh body protected by a hard shell. Traditionally they were known as *Chione stutchburyi* (Belton, 1986), until recent revision of taxonomic names.

Though considered the functional equivalent of *Cardium edule,* the English cockle, they are more closely related taxonomically to calm species found in North America, *Mercenaria mercenaria* (Stewart, 2005).

Endemic to Aotearoa, tuangi occupy the top 5–10 cm of intertidal sand flats (Stewart, 2005) and are widely dispersed across Aotearoa shorelines and globally. Adult tuangi prefer deeper, high-energy habitats on the edge of the channel, while juveniles and the young prefer the lower energy environments of the sheltered intertidal zone. Their natural predators include humans, birds such as gulls, tōrea (oyster catchers), whelks and starfish (Grace, 1972).

1.2.3 Healthy Habitats, Supporting Ecosystem Functionality

Tuangi inhabit the upper 10 cm of the seabed, occupying the sediment surface where it interfaces with the ocean water column. Therefore, the health of these environments is critical for the health of tuangi and how they interact and function in this niche habitat (see Figure 5). The functional roles of tuangi within the estuarine ecosystem are essential for maintaining ecological balance across trophic levels (Lam-Gordillo et al., 2025; NIWA, 2021).

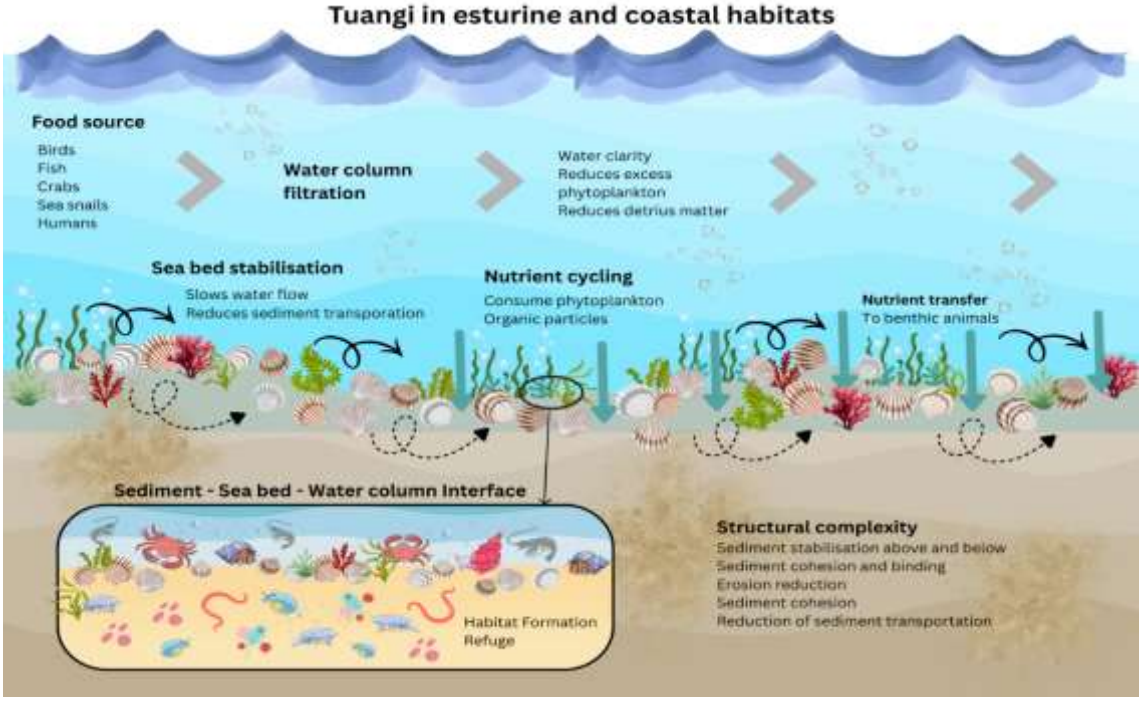
The catalogue of their essential roles begins here, within the sediment; tuangi burrowing aerates, disturbs and mixes the sediment granules, which consist of gradients of fine sands and mud, in a burrowing process known as bioturbation (Van Der Schatte Olivier et al., 2020). These movements support sediment stabilisation through the reorganising of sediment grains, altering texture and porosity. This process increases sediment roughness and creates structural complexity, boosting the integrity of stability and cohesion (De Smit et al., 2021; NIWA, 2021). These modifications build resilience of sediment structure, strengthening resistance to shear forces and impacts from currents and waves.

The aeration generated by these movements facilitates the infusion of oxygen and nutrients into the sediments, creating vital energy pathways that sustain the macrofauna and meiofauna within (Anderson et al., 2019; De Smit et al., 2021; NIWA, 2021). Thus, the term *ecosystem engineer* is employed to encompass these functional traits that underpin a wide range of ecological processes. As a benefit to the ecological communities that occupy these habitats, the sediment reformation provides habitats for juvenile tuangi and supports a wide range of benthic communities, such as gastropods (marine snails), crabs, amphipods and isopods (small shrimp-like creatures), shrimps, annelids (worms), diatoms, microbes and bacteria (Fenton et al., 2024; García De Lomas et al., 2005; NIWA,

2021). Another contribution of tuangi is sediment stabilisation through bio deposits or faeces and pseudo faeces—excretions that aid in binding sediment particles, increasing cohesion and resistance to forces and reducing sediment transportation along the seabed (Newell et al., 2002; A. Norkko et al., 2001).

Figure 5

Tuangi Functionality in Estuarine and Coastal Habitats, Showing the Key Roles of Tuangi Within the Sediment and Water Column Interface



The interface between tuangi and the water column serves multiple ecological functions, (Figure 5) operating primarily as the path for nutrient absorption. Tuangi, known as suspension or filter feeders, draw nutrients from plankton and organic particles in the surrounding water column, their siphons acting as sensory flags to the outside of their shells (see Figure 4; B. Morton, 1998; NIWA, 2021). A set of labial palps, located within the vicinity of the mouth, provides for the sorting and transporting of food particles to the mouth, as well as sorting through excess sediment and debris from food (B. Morton, 1998).

Owing to filtration feeding, accumulation of bacteria and contaminants such as metals within the flesh of tuangi is a grave concern (NIWA, 2021; Rakotomalala et al., 2015). Tuangi are thought to be able to filter up to 3 L of water per hour. Historical studies estimate that 1.6 million m^3 could be filtered with sufficient tuangi densities (Stewart,

2005), the equivalent to half the volume of Pauatahanui inlet in Wellington, demonstrating the critical role they play in the estuarine ecosystem.

Tuangi move vertically and horizontally within the sediment (NIWA, 2021), for reasons such as optimal feeding positionality at low and high tides (Anderson et al., 2019), predator avoidance (Fenton et al., 2024) and habitat preference such as current energy preference (e.g., higher currents for the more mature tuangi, to access better resource availability; Anderson et al., 2019; NIWA, 2021). This mobility provides the ability for resurfacing after shallow (a max 25 cm) burial events such as tidal currents or storm events. During the covered tide times, tuangi position themselves closer to the sediment surface, increasing friction against the seabed. This added resistance slows water flow and currents, helping to stabilise the sediment and reduce bed movement (Coco et al., 2006; Jones et al., 2011).

For many hapū, iwi and local community members who relate to a specific natural site such as Ōhiwa Harbour, the presence of tuangi in an estuarine or coastal area signals health. Tohu or bioindicators are observed for varying reasons, as they help to identify impacts on the environment such as contamination, pollution or sudden changes. In Purchase and Fergusson (1986), tuangi were successfully used as bioindicators to test levels of lead pollution within the Avon-Heathcote Estuary in Christchurch the South Island. These were used as in situ monitoring indicators over a time series to gauge the impact of lead contamination within the estuary. As with all indicators, these are but one environmental measure, and the study highlighted that the results should consider other biotic measures and analysis. However, overall, tuangi performed well due to their bioaccumulation capabilities; they are known to be sensitive to chronic environmental stressors from heavy metals, pollution and sediment changes, making them reliable sentinels indicating the health of an estuary or coastal area (Cheggour et al., 2001; NIWA, 2021).

As bioindicators, tuangi also serve as a barometer of the food web health—when their beds are abundant and contain mature adults (30 mm and over), they become a key resource for a variety of consumers such as humans, birds, crabs, snails and small fish, as well as contributing to the biodiversity in estuarine ecosystems (NIWA, 2021). They have a sweet edible flesh that may be enjoyed raw, steamed or cooked, and are a rich source of protein, iron and omega-3 fatty acids. Cockles are a nutritious and sustainable shellfish, and a valuable seafood in many cultures, especially in Europe, Asia and Oceania, as well

as a historical food source harvested both commercially and recreationally—especially here in Aotearoa (Braga et al., 2022; Pawley & Smith, 2014; Van Der Schatte Olivier et al., 2020).

1.3 Research Context

1.3.1 Tuangi in Ōhiwa

Anecdotal evidence suggests that tuangi populations in Ōhiwa Harbour have steadily declined in size and abundance over the last century. Potential reasons for this include land-use changes resulting in increased delivery of sediments and nutrients to the harbour, pollution, predation and harvesting pressures (Bevan, 2018; EBOP, 2008). With the current paucity of knowledge on tuangi in the subtidal and intertidal zones of Ōhiwa Harbour, iwi are struggling to participate and make meaningful contributions to co-management decision making regarding the long-term sustainability of these populations.

This research supports international treaties, such as the enactment of Article 8(j) of the Convention of Biological Diversity, wherein traditional knowledge, innovation and practices are integral and elevated to combat the decline in biodiversity globally. The subsequent report, Local Biodiversity Outlooks 2 (Forest Peoples Programme et al., 2020), highlighted the critical roles Indigenous Peoples and local communities play in maintaining and enhancing biological and cultural diversity in transformative change to realise the vision of a world living in harmony with nature. This is only one of many global initiatives that address Indigenous inequity within conservation. Chapter 2 of this thesis provides a historical timeline of the Māori experience.

1.3.2 Science the Colonial Project

From the outset of colonisation, science was frequently used to legitimise the appropriation of Māori lands, and all natural resources, while reinforcing policies and practices that contributed to the dispossession, displacement, marginalisation, and cultural assimilation of Māori in Aotearoa (Rata, 2022; P. Reid et al., 2019). Embedded in settler colonialism, early scientific exploration facilitated dominance and advancement of Eurocentric ideals that positioned cultural homogeneity as the preferred and most appropriate way of life, regardless of the existing cultural heritage and governance structures (Held, 2023; Rata, 2022).

Furthermore, disciplines such as evolutionary biology, eugenics, and early anthropology systematically deprecated Indigenous worldviews, treating traditional knowledge as

primitive superstition rather than systematic observation (Hikuroa, 2017; Moko-Painting et al., 2023; Rewi, McLellan & Heke, 2022). Although colonial naturalists relied heavily on Māori knowledge of the environmental, flora and fauna, this intellectual labour was exploited while the communities themselves were politically and legally oppressed (Beattie & Morgan, 2021; Fox et al., 2025). This structural weaponisation of knowledge reduced Māori ways of living into objects of assimilation, where paternalistic interventions were framed as necessary for protection and progress, yet ultimately functioned to legitimise the control, regulation, and marginalisation of Māori and their knowledge systems (Broughton et al., 2015; Macfarlane & Macfarlane, 2019).

The enduring legacy of science's entanglement with colonialism has fostered deep institutional scepticism among many Māori and other marginalised communities, where health, environmental and research interventions can be perceived not as forms of support, but as extensions of historical systems of control (Dajani et al., 2024; Viniegra-Velázquez, 2020). This scepticism reflects a broader critique of the assumed universality and authority of Western science, acknowledging that scientific institutions have often been implicated in processes that undermine Indigenous knowledge systems, erode Indigenous autonomy, and perpetuate the physical and epistemic marginalisation of Indigenous peoples. As a result, contemporary engagement with science cannot be separated from these historical experiences, which continue to shape relationships of trust, legitimacy, and authority today (Bacchi & Bacchi, 2025; Boisselle, 2016).

1.3.3 Transformational Intent and Contribution

This research was not undertaken solely to generate new knowledge about tuangi populations within Ōhiwa Harbour. Rather, it was conceived as a transformational project that seeks to contribute to the ecological restoration of tuangi, the revitalisation of Māori participation in marine governance, and the advancement of equitable conservation practices through the weaving together of multiple knowledge systems. Throughout this thesis, transformation is understood as the creation of new pathways that enable ecological, cultural, social and governance outcomes that were previously constrained by disciplinary, institutional and historical barriers.

At the local scale, this research is transformational for the whānau, hapū and iwi of Ōhiwa Harbour. Through the collection, substantiation and application of mātauranga Māori, the research contributes to the retention and revitalisation of integrational knowledge associated with tuangi, mahinga kai (uncultivated food harvesting grounds) and the

harbour itself. The work supports aspirations of Ngāti Awa, Te Whakatōhea, Ngai Tūhoe and associated communities to actively exercise kaitiakitanga through evidence-informed decision making and participation in co-management processes. By documenting traditional harvesting areas, environmental tohu and historical observations of ecological change, this thesis creates a permanent record of knowledge that can inform future generations and restoration initiatives.

At the ecological scale, this research contributes transformational knowledge for the management and restoration of tuangi populations. These findings provide the first comprehensive assessment of historical and contemporary tuangi distributions, integration of long-term observations from kaumātua, and the development of a species distribution model (SDM), the research creates practical tools that can inform monitoring, restoration planning and adaptive management. These outcomes extend beyond describing ecological decline and instead provide pathways for action and recovery.

At the methodological scale, this thesis demonstrates how tīwaiwaka a Te Ao Māori conservation movement as a framework informed by multiple evidence-based (MEB) approaches that is premised on Indigenous knowledge, can be operationalised within marine conservation research. Rather than treating Indigenous knowledge as supplementary to scientific knowledge, this research positions mātauranga Māori, marine sciences and technology as complementary knowledge system that each retain their own integrity, authority and validation processes. In doing so, this work contributes to growing international scholarship advocating for equitable knowledge co-development and offers a practical example of transdisciplinary conservation research that is grounded in Indigenous leadership.

At the technical scale, this research contributes to an innovative application of Indigenous knowledge within predictive ecological modelling. The use of mātauranga to guide field surveys, identify traditional harvesting locations and validate model outputs demonstrates how technological tools can be strengthened through Indigenous ecological knowledge. This approach challenges assumptions that advanced technologies and Indigenous knowledge systems operate separately and instead illustrates how they can be woven together to produce more culturally relevant and ecological meaningful outcomes.

At the governance scale, this research contributes to ongoing national and international discussions concerning co-management, Indigenous rights and biodiversity conservation. The work aligns with global movements that recognise Indigenous Peoples as essential

partners addressing biodiversity declines and environmental restoration. Through the case study of Ōhiwa Harbour, the research provides an example of how Indigenous-led conservation, collaborative governance and respect-based marine management can be implemented in practice.

Finally, this thesis contributes to a broader transformation within conservation science itself. It demonstrates that mātauranga Māori is not merely a source of cultural insight but a rigorous knowledge system capable of informing scientific enquiry, technological innovation and environmental management. By weaving mātauranga Māori, marine sciences and technology through the kaupapa Māori tīwaiwaka framework informed by a MEB approach, provides a model for future conservation initiatives that upholds ecological integrity, cultural continuity and Indigenous self-determination simultaneously.

This thesis makes six primary contributions:

1. Documents the historical and contemporary status of tuangi in Ōhiwa Harbour.
2. Develops a kaupapa Māori–tīwaiwaka framework and methodology informed by a MEB approach for marine conservation.
3. Demonstrates the use of mātauranga Māori tohu as rapid ecological assessment tools.
4. Integrates Indigenous knowledge into SDM.
5. Produces practical recommendations for co-management and restoration of tuangi.
6. Provides a transferable model for Indigenous-led, transdisciplinary conservation research nationally and internationally.

1.4 Conceptual Pou of Research

This research is founded upon a series of interconnected conceptual pou that collectively shape the theoretical, methodological and practical dimensions of the study. These pou provide the intellectual and cultural scaffolding through which the research questions were framed, methods were selected, data interpreted and findings translated into management recommendations. Situated within kaupapa Māori research paradigms, this thesis draws upon mātauranga Māori, marine sciences and technology through the transdisciplinary tīwaiwaka framework, while also recognising the role of creative and visual knowledge dissemination as a bridge between art and science. Together, these pou provide the foundation for understanding how diverse knowledge systems can be respectfully woven together to address complex ecological, cultural and governance

challenges associated with the management and restoration of tuangi within Ōhiwa Harbour.

Each pou serves a distinct function within the research. Mātauranga Māori provides the guiding epistemological foundation and informs the cultural values, ethics and relationships underpinning the research process. Marine science contributes ecological theory, field-based methodologies and analytical approaches for understanding tuangi populations and their habitats. Technology provides the tools required for spatial analysis, modelling and visualisation, enabling the exploration of ecological patterns and future restoration opportunities.

Being transdisciplinary creates the space through which these disciplines and knowledge systems can interact around a shared environmental challenge, while the tīwaiwaka framework provides the methodological framework for maintaining the integrity and authority of each knowledge system throughout the process. Finally, the relationship between art and science informs the communication and dissemination of knowledge, enabling complex concepts to be explored and conveyed through both visual and scientific forms. Collectively, these pou guide how knowledge is generated, interpreted and applied in pursuit of culturally grounded and ecological meaningful outcomes for tuangi and Ōhiwa Harbour.

Table 1

Overview of Pou, Their Contributions and Examples Within the Thesis

Pou	Contribution	Role in thesis
Mātauranga Māori	Historical knowledge, and Indigenous knowledge system	Kaumatua interviews, mātauranga mapping
Marine science	Ecological assessment and evidence	Population surveys and profiles
Technology	SDM and spatial prediction tools	SDM
Tīwaiwaka framework informed by MEB	Kaupapa Māori framework—knowledge weaving approach	Evaluation lens and research framework
Art and science	Knowledge communication mode	Graphics and visualisations

The following sections outline the overarching role of each pou within this research, demonstrating how their respective contributions collectively underpin the conceptual, methodological, and applied dimensions of this study.

1.4.1 Pou 1—Mātauranga Māori

Mātauranga Māori provides the foundational epistemological framework for this research, grounding the study in Indigenous knowledge systems, cultural values, intergenerational knowledge, and the relationships that connect people, place, and taonga species. It informs how research questions are framed, knowledge is interpreted, and culturally meaningful management and restoration pathways for tuangi within Ōhiwa Harbour are identified.

1.4.2 Pou 2—Marine Science

Marine science contributes to the ecological evidence base for this research, providing the theories, field-based methodologies, and analytical approaches required to understand tuangi population dynamics, habitat condition, and ecosystem processes within Ōhiwa Harbour. Through population surveys and ecological assessments, it generates empirical data that supports the identification of restoration opportunities and informs evidence-based management recommendations.

1.4.3 Pou 3—Technology

Technology provides the tools and analytical capabilities required to collect, integrate, visualise, and interpret diverse ecological and cultural datasets within this research. Through spatial analysis (GIS mapping), visualisation techniques, and species distribution modelling the identification of ecological patterns, restoration opportunities, and future management scenarios are explored for tuangi within Ōhiwa Harbour.

1.4.4 Pou 4– Tīwaiwaka Framework Informed by MEB Approach

Tīwaiwaka (informed by MEB approach) provides the transdisciplinary methodological framework that enables mātauranga Māori, marine science, and technology to work together while maintaining the integrity, authority, and validity of each knowledge system. Guided by MEB principles, it creates a collaborative space for weaving diverse forms of knowledge, supporting the co-production of culturally grounded and ecologically meaningful insights for the management and restoration of tuangi within Ōhiwa Harbour.

1.4.5 Pou 5—Art and Science

Art and science provide a complementary knowledge-sharing and communication approach that bridges scientific inquiry with creative expression, enabling complex ecological, cultural, and restoration concepts to be explored, interpreted, and communicated in accessible and engaging ways. By integrating visual, artistic, and

scientific forms of knowledge dissemination, this pou supports broader understanding, strengthens connections between people and place, and enhances the translation of research findings into meaningful action for tuangi and Ōhiwa Harbour.

1.5 Research Question and Rationale

The purpose of this thesis is to gather information on tuangi from Ōhiwa Harbour, to understand the state of their health and to inform future decision making for Ōhiwa Harbour management. This transdisciplinary inquiry incorporates mātauranga Māori, marine sciences and technology, combining each discipline's strengths to create new knowledge for managing tuangi in Ōhiwa Harbour. It thus comprises of a MEB approach that integrates distinct knowledge systems in a model to inform future conservation initiatives.

In relation to this examination, key research questions were developed to guide the research:

- What is the current state of tuangi in Ōhiwa Harbour?
- Has this changed over time and if so, why?
- Can an SDM predict locations not currently being surveyed for future surveying and monitoring?
- Can mātauranga Māori be used to inform rapid assessments of potential beds and areas for ongoing surveying and monitoring?

1.5.1 Ethics

All Ngāti Awa interviews and survey information was collected under the HREC(HECS)2021#57, #57b and with approval from Te Rūnanga o Ngāti Awa. Information from Te Whakatōhea hui was approved and supplied by the Te Whakatōhea Trust Board, under the ethics application ("He Papa Moana—Creating a Cross-Cultural Ocean Knowledge Platform to Support Iwi Interests"). Ethics for the Whakatōhea hui information was obtained for the tribal authority and was conducted under their ethics approval Te Manu Taiko; Ethics approval 8/10/19.

1.6 Thesis Structure, Aims and Objectives

This thesis is organised into six chapters. As a thesis by publication, it contains three peer-reviewed publications submitted to journals as part of its body of work (see Appendices 1–3 for author consent forms). These are bookended by introductory, methods and conclusion chapters, to synthesise the results and offer recommendations. The specific aims and objectives for each research chapter are described as follows.

1.6.1 Wāhanga Tuatahi—Chapter 1—He Te Tīmatanga Kōrero—Introduction

This chapter provides an introduction to Ōhiwa Harbour and its tribes and how this research came to fruition; the importance of tuangi and their place within the estuarine ecosystem as well as their importance to the local iwi; the context of local iwi and their ability to contribute to enact their kaitiakitanga over the tuangi and harbour; and finally, an outline of the thesis structure aims and objectives.

1.6.2 Wāhanga Tuarua—Chapter 2—Aronga Rangahau—Research Methods

This chapter provides an outline of the theoretical doctrine of this thesis. It is premised on a kaupapa Māori framework—a te ao Māori way of being, seeing and doing. Through the kaupapa Māori lens, I utilise a MEB approach to understand the science and collect information to inform the shellfish management of tuangi. I then examine the te ao Māori framework, Tīwaiwaka, which articulates a set of Māori principles employed as conservation metrics for evaluating how environmental actions and practices align with the ethic of "touching the earth lightly." As the guiding framework of this research, it threads the chapters together and constitutes the mauri of the dissertation.

1.6.3 Wāhanga Tuatoru—Chapter 3—From Protecting to Respecting Marine Relations in Aotearoa New Zealand

This chapter presents the first published manuscript, submitted to *AlterNative: An International Journal of Indigenous Peoples*. It looks at what factors set the trajectory of the tuangi towards their current state in Ōhiwa, what has had the greatest influence in disconnecting the local iwi from these taonga and what the key influences are today.

1.6.4 Wāhanga Tuawha—Chapter 4—Ko Ōhiwa e (Our Ōhiwa), How Weaving Knowledges Is Shaping Marine Research in Ōhiwa Harbour

The second publication is published in the *Journal of Ocean Technology,* Winter 2025 Special Edition: Indigenous Ocean Technology, Priorities and Practices. This manuscript explores the MEB approach I developed, which collected data from local kaumātua interviews, mapping out the traditional harvesting beds, then weaving this information with biological data from field surveying over a 3-year period, aiming to form a more comprehensive picture of the state of tuangi in Ōhiwa Harbour. Mātauranga Māori tohu (observable cues) were used to inform rapid monitoring and assessment techniques for data compilation.

1.6.5 Wāhanga Tuarima—Chapter 5—Multiple Evidence-Based Approaches for Ecological Conservation Practices in Aotearoa New Zealand

The final publication is published in the journal *Pacific Conservation Biology*. This chapter brings together the information discussed in Chapters 3 and 4 and adds in a third knowledge system—technology. The interwoven knowledge within this chapter is used to understand the distribution of tuangi within Ōhiwa and their habitat preference and characteristics. This is the second iteration of a model designed for assessing the kuku (mussels) in Ōhiwa Harbour; the data training in this research tested the robustness of the SDM and its reliability. Adding a cultural dimension to a machine-learning model provides an opportunity to reveal a greater depth of ecological knowledge embedded within a MEB framework. The pairing of mātauranga Māori with marine sciences enhanced the technological model's accuracy and cultural relevance of the SDM outputs.

1.6.6 Wāhanga Tuaono—Chapter 6—Whakamutumnga—Conclusion

The final chapter offers a synthesis of the research findings, including a final summary discussion of each chapter and its contribution to the new knowledge creation on the existing state and future management decisions for tuangi in Ōhiwa Harbour. I summarise how I used the tīwaiwaka framework as a culturally sensitive and appropriate model of an Indigenous-led and co-developed framework that respects all knowledge systems and accommodates space for multiple world views. I discuss the Tīwaiwaka framework as an exemplar of Indigenous integrity indicators, providing a culturally grounded approach for assessing conservation practices and environmental stewardship, and evaluating how these principles are enacted in practice. The chapter concludes with a synthesis of the findings and a set of recommendations.

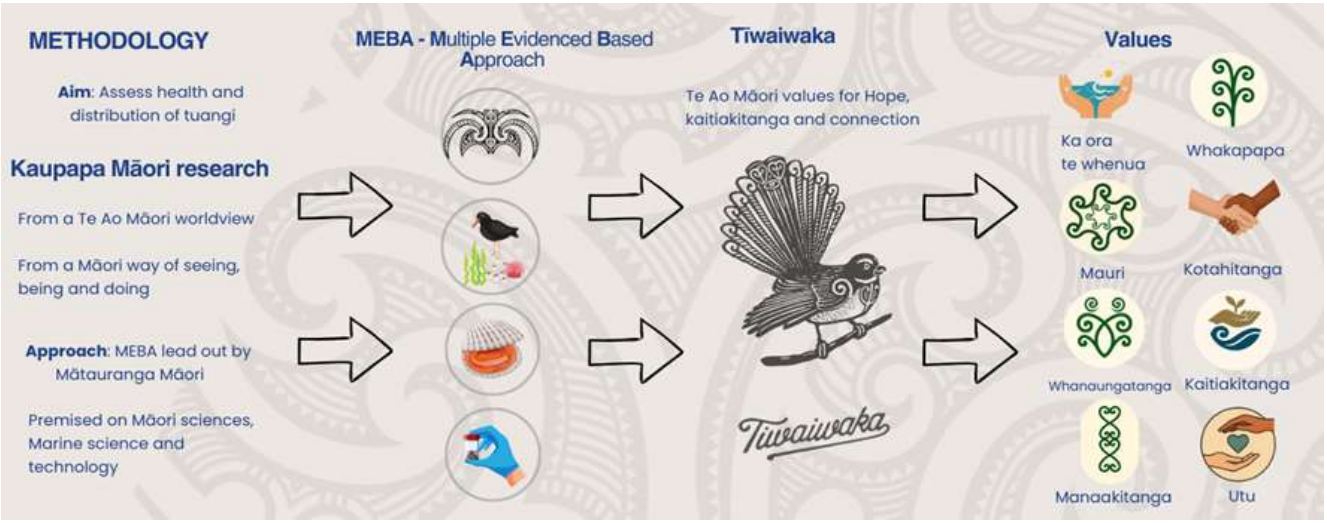
Wāhanga Tuarua—Chapter 2

Wāhanga Tuarua—Chapter 2

Aronga Rangahau—Research Methods

Figure 6

Visual Illustration of Chapter 2 Outline and Key Concepts



2.1 Aronga Rangahau—Research Methods

2.1.1 Kaupapa Māori Research

The research in this study is based in te ao Māori, culture, traditions and ways of being—and, therefore, the expression of this research is based on the theory and understanding of the world from a Māori world view (L. T. Smith, 1991, 2012). The use of kaupapa Māori for this study is as a change mechanism that aims to restructure power relationships so that those involved are autonomous and able to act from that position (L. T. Smith, 2012). Kaupapa Māori is the reframing and structuring of how we think about our practices, ideas and concepts; an actualisation or the formation of Māori mātauranga (Nepe, 1991; L. T. Smith 2012, 2015). Bishop (1996) explained this further as the "deconstruction of those hegemonies which have disempowered Māori from controlling and defining their own knowledge within the context of unequal power relations in New Zealand" (p. 13).

This research is informed by Māori principles, understanding and methods grounded in distinct cultural, physical and spiritual knowledge that finds expression through codified systems. These are expressed in many ways, one being known as whakapapa—the delineation of connections from the atua (gods) through to humans (Nepe, 1991; Rawlings & Wilson, 2013; L. T. Smith, 2012). Māori knowledge systems, or mātauranga,

and Māori ways of knowing, being and doing underpin the research. This includes all dates for field work, interviews and workshops, which are based on the maramataka, the Māori lunar calendar (Hoterene, 2021), tidal charts and rātaka (sun calendar) as elemental influencers.

Intrinsic principles of kaupapa Māori epistemology or Māori ways of knowing, being and doing have at their essence the metaphysical state of existence between the realms of physical and spiritual planes (Nepe, 1991). These planes of physical existence in a te ao Māori world span from Te Ira Atua (realms of the Gods) to Te Ira tangata (realms of the humans; Ministry of Education, 2009; Tamati, 2007). These are the whakapapa connections to which humans return to, to calibrate our wairua (spirit) and guide us on our life—or, in this context, research journey. Governing of the physical world is the inherent interaction, connection and co-existence with all living beings, in a harmonious, synergistic cohabitation.

Linda Smith (2012) proposed two categories for Indigenous researchers that exist within kaupapa Māori research: "insiders" and "outsiders." As an insider researcher, though still grounded in feminist or other critical methodological ideologies (Pulido, 1996; Twine et al., 2000), I embody the relational family ties that span multiple generations—ties that are now considered more acceptable in qualitative research (Royal, 2011; L. T. Smith, 2015). L. T. Smith (2012) postulated that, for an insider researcher to be successful, how they approach the research is the fundamental key. In the neoclassical approach, participants are viewed in an objectified manner. The research is trialled on them to resolve a hypothesis from an outside observation and approach. Importantly, this agenda may never benefit the communities that are subjected to the research (Bishop, 1996; L. T. Smith, 2012; Te Awekotuku, 1991). In contrast, an insider approach develops the research with Māori and for Māori, highlighting culturally appropriate research methodologies that consider critical thinking processes, the nature of the relationships, the richness and quality of the data and its analysis and how it can enrich the community it is created from and with (Bishop, 1996; L. T. Smith, 2012; Te Awekotuku, 1991).

Principles for culturally appropriate research methods have been identified by Te Awekotuku (1991) and summarised in L. T. Smith (2012), to ensure research follows "basic guidelines of protection and rights, interests and sensitivities" p.124, of Māori being studied. These kaupapa Māori research values determine the integrity of those who work within this research space and how others may perceive their conduct, as follows:

1. Aroha ki te tangata—Respect for people
2. Kanohi kītea—The seen face; that is, present yourself to people face to face
3. Tītiro, whakarongo … kōrero—Look, listen … speak
4. Manaaki ki te tangata—Share and host people; be generous
5. Kia tūpato—Be cautious
6. Kaua e takahia te mana o te tangata—Do not trample over the mana (authority, status, influence) of people
7. Kia māhaki—Don't flaunt your knowledge.

These research principles determine the conduct by which this research is undertaken and govern all interactions with iwi, hapū, whānau, authorities and the wider community for this research project.

The process of doing kaupapa Māori research by Māori with Māori is key in defining and establishing a kaupapa Māori methodological process in this research. Bishop (1996) extended this further by postulating that kaupapa Māori methodological research is strengthened by who initiates and benefits from the research (e.g., iwi-driven projects; Paul-Burke et al., 2018; Reihana et al., 2021) and who (iwi, hapū, whānau) legitimises its benefits in the community. Most pertinent to this process is that communities authenticate and legitimise its value through being engaged in the process (Napier Port Te Herenga Waka o Ahuriri, 2021; Paul-Burke et al., 2018; Reihana et al., 2021).

Insider/outsider research (L. T. Smith, 2012) is consistent with the banking concept of education (Freire, 1970/2017), whereby a Western research system assumes Indigenous peoples are void of our own knowledge systems and are waiting to be filled or humanised by the coloniser or oppressor. This notion of insider and outsider researchers references the marginalised in society, in which Māori uncomfortably sit. For autonomy of Māori within the environmental science arena and to participate in a meaningful way, we must be able to determine our own knowledge creation within this construct. To do so could have significant impact on the systemic racist institutionalisation that we research within:

> But to transform the structure so that they can become beings "themselves" such transformation, of course would undermine the oppressors' purpose; hence their utilization of the banking concept of education to avoid the threat of students conscientização (awareness). (Freire, 1970, p. 47)

Central to kaupapa Māori research is its transformational intent. Kaupapa Māori is not primarily concerned with the production of knowledge, but with the creation of positive

change for Māori communities, environments and futures (Bishop, 1996; L. T. Smith, 2012). Knowledge generation is therefore inseparable from action, responsibility and aspirations. As L. T. Smith (2012) argued, kaupapa Māori research seeks to challenge historical power imbalances and create pathways that enable Māori communities to exercise authority over their own knowledge, resources and development trajectories. Within this thesis, transformation is expressed through the revitalisation of mātauranga Māori associated with tuangi, the strengthening of iwi participation within marine governance, the development of practical tools to support restoration and management actions, and the creation of new knowledge through the weaving together of Māori knowledge and marine science and technology. In this sense, the research extends beyond understanding ecological decline and instead contributes towards the regeneration of both the ecological and cultural relationships that sustains the Ōhiwa Harbour.

2.1.2 Mātauranga Māori

Mātauranga Māori or traditional Māori knowledge is the potential source of creativity from within the Māori culture (Royal, 2009). Knowledge and its creation is a response to a particular culture's experience and view of the world, in this case, Māori (Royal, 2011). It represents the culmination of lessons and understandings that have been passed down by successive generations since Māori colonised Aotearoa and became the Māori people. Mātauranga Māori is an ordering of these traditions, experiences and values that make sense of the world that they exist within (Clapcott et al., 2018; Royal, 2011). Mātauranga Māori evokes tikanga (distinctive Māori processes and behaviours) and kaupapa as an expression of Māori aspirations, principles and values. Royal (2005) articulated the natural occupation of cross-disciplinarity as cross thoughts and boundaries of weaving knowledge, which Indigenous people intrinsically occupy in the "holistic" knowledge-creation space.

Mātauranga Māori has been defined and discussed in the context of the externalisation of knowing. Writing such knowledge down was a manifestation of the development of literacy itself in the new world of Māori in the early years of settlement by European in Aotearoa (Royal, 2025). Where, previously, knowledge retention was through waiata, pakiwaitara (legends), pūrākau (sacred narratives) and carvings, for example, this action, being a new form of knowledge recording, enabled the creation of a body of knowledge now recognised as mātauranga Māori. Mātauranga the word was coined, as Royal (2025) found through his search of archival documents, from the first Christian mission schools based on the original biblical verse Genisis 2:17: "Adam you must not eat from the tree

of the knowledge of good and evil." Here, the translation of the tree of "knowledge" became the first known instance of the Māori word mātauranga, and it is now translated as knowledge.

However, the continued hierarchical oppression of mātauranga Māori knowledge in the science realm is well acknowledged (Clements et al., 2021). Cultural repression of Māori knowledge has a long legacy in New Zealand, since European colonisation, the Native Schools Act 1858, the Tohunga Suppression Act 1907 to name a couple, (R. Walker, 2016) and although that process started over 200 years ago, its remnants remain instilled in the thinkers, such as these academics; Kendall Clements, Garth Cooper, Micheal Corballis, Doug Elliffe, Roberta Nola, Elizabeth Rata (not a Māori) and John Werry, and a dominant subset of the main culture within New Zealand today. Clements et al. (2021), for example, argued that "Indigenous knowledge may indeed help advance scientific knowledge in some ways, but it is not science" (p. 4). Such perspectives continue to shape debates concerning the legitimacy and status of mātauranga Māori within scientific research and practice. Clements et al. (2021) reflected the existing subculture opinion (Foon, 2020; Tapaleao & Dillane, 2021) of European extremists who are positioned in places of influence and remain in their neoclassical mindset of privilege. The current government of Aotearoa also holds an anti-Māori position, as reflected in the barrage of anti-Māori campaigns rolled out since entering government and in its policies, legislation and funding withdrawals (Woods, 2024).

Writing from an academic realm of neoclassical sciences, Clements et al. (2021) argued that Māori world views, ways of being and knowledge creation are not equal to the minority dominant elite, based on our skin colour and cultural beliefs. Engaging in the collaborative creation and dissemination of knowledge that challenges the dominant neoclassical paradigm evokes a profound sense of apprehension and uncertainty and can compromise my sense of safety within academic and professional spaces.

2.1.3 Neoclassical Science

The term *neoclassical* refers to a specific time-period in the world, associated with "new classicism" or the "revival of classical values. "It was most widely applied in the literature, music, arts and architecture of the 18th and early-19th centuries, as a conscious revival and appropriation of classical models of art and architecture (The National Gallery, 2021). It has been appropriated here as an alternative reference to "Eurocentric" as a universally accepted internationally understood term. Neoclassical theory is most commonly applied

in behavioural sciences, particularly in operations management, where the organisation is the social system and its performance is affected by human actions. Key characteristics of neoclassicism are methodological individualism, rationality, equilibrium and the importance of the price mechanism (Merriam-Webster, 2021; The National Gallery, 2021). Although originating outside the natural sciences, many of the philosophical assumptions associated with Western scientific traditions, particularly claims of objectivity, universality and epistemological authority, continue to shape scientific institutions and practices (L. T. Smith 2012; Whyte, Brewer, & Johnson, 2016). Consequently, Indigenous scientists are frequently required to navigate research systems that continue to privilege Western norms of knowledge while simultaneously advocating for Indigenous knowledge systems to be recognised as equally valid contributors to scientific understanding and environmental governance (Foulds et al. , 2025; L. T. Smith 2012; Whyte, Brewer, & Johnson, 2016).

The key point of difference between Māori and neoclassical sciences is the enduring amalgamation with the spiritual realm in the former, which stands in contrast to the disconnected, siloed perspective of the latter (Cheung, 2008; Moewaka Barnes, 2008). In neoclassical-based research, only singular species or world views are presented as a complete observation or exploration of a region, catchment, biome, habitat, macro- or microspecies (Harris, 2004). From the macro- to the microscale of work carried out, the monologue narrative is limited in its perspective to the small snapshot of the biological interactions that occur within these spheres (Moewaka Barnes, 2008).

In the Māori world view, spirituality, karakia (prayers) and rituals of processes are an ingrained way of life that maintains our connection to the earth, whenua and taiao and our interactions with it (P. Moon, 2005). In the book *A Tohunga Natural World*, Māori knowledge expert Hohepa Kereopa explained how his great grandfather used karakia while doing tasks such as gardening and how this plea to the Almighty (One true God) was his humble request for the Almighty to boost the quality of his duties (e.g., grow a great harvest of potatoes). This was seen by Hohepa as a means of connection, intimacy of a very personal kind with the spiritual and physical realms that we live in (Moon, 2005).

> Traditional schools of nature were religious in nature and in all pursuits of learning there were rituals to observe. Learning and the act of teaching were not ordinary or common. The importance of the act of acquiring knowledge was emphasized by surrounding the event with rituals. Religion was not separated from education.

> Learning was elevated high above the ordinary pursuits of a community. (Mead, 2003, p. 339)

The art or privilege of learning was not taken lightly, as illustrated above by Mead (2003). To be selected as a student meant you possessed certain characteristics, and an undeniable responsibility accompanied the knowledge you were about to attain and hold. Karakia, rituals and strict protocols were taught to retain the essence and mana of the knowledge, which you were then tasked to pass on to the next generation (Mead, 2003; Royal, 2011). L. T. Smith (2012) detailed in considerable depth the basis of kaupapa Māori knowledge methodologies, their complexities and the ways in which our ancestors have observed, collected and successfully transferred our science through consecutive generations.

2.1.4 Tīwaiwaka Framework

For the purposes of this doctoral research study, I have developed the Tīwaiwaka framework, a novel Indigenous transdisciplinary research methodology grounded in kaupapa Māori principles and informed by multiple evidenced-based approaches. While kaupapa Māori provides the philosophical and ethical foundations of the research, tīwaiwaka operationalises the principles through a relational methodology that brings together mātauranga Māori, science, technology, artistic praxis, law policy and community aspirations to address complex socioecological challenges. The tīwaiwaka framework is based on a te ao Māori conservation movement, which prioritises kaitiakitanga (active guardianship), unification and living harmoniously within the natural world (McGowan, 2021b). Tīwaiwaka, piwaiwaka, piwakawaka and tīrairaka are some of the Māori names for the New Zealand fantail (*Rhipidura fuliginosa*), which in te ao Māori symbolises a powerful kaitiaki (caretaker/guardian), a sentinel or a challenger, who is a messenger for the atua (gods), some say of death while others say of hope (Oliver, 2005).

Tīwaiwaka is most well-known for bringing death into the world through his antics with Māui (the mischievous demigod who fished up New Zealand, slowed the sun and many other acts that help explain the cycles of our everyday living), including Hine-nui-te-po (the goddess of the underworld). Tīwaiwaka was pivotal in awakening the sleeping goddess to warn her that Māui was trying to sneak into the underworld through her legs. She subsequently crushed the life out of him, and that is how death entered our human world. Through these actions comes an appreciation for the value of life and living things—and therefore hope (Department of Conservation, 2022). For this doctoral research, the tīwaiwaka is used as a messenger of hope for healing the taiao.

Discussing the principles of tīwaiwaka, founder and nationally recognised award-winning conservationist Pa McGowan (2018 Loader Cup recipient, NZQSM, 2020) explained:

> The highest priority for Māori is the well-being of Papatūānuku. Hence the saying: Ka ora te whenua, ka ora te tangata: when the Earth is well, people are well.
>
> Tīwaiwaka is an action plan. We know what we must do, and this is what we are going to do!
>
> The principles give us a foundation that we work from. Those principles find expression in everything we do.
>
> Always, taking care of Mother Earth is the highest priority;
>
> We never act as the masters, but always as members of the family of life, junior members, not as tuakana (elder);
>
> And we always work to feed the mauri, the connections that sustain life and well-being. That re-orders our whole way of living. (McGowan, 2021a) (p.2)

I interpreted these principles into six Māori values, that I then used to examine how my research reflects and expresses a te ao Māori world view in the marine research context (see Figure 7 & **Error! Reference source not found.**). The Māori values were examined against the literature and the co-design workshop held by the Māori designers association Ngā Aho, as described in Whaanga-Schollum et al. (2016) to identify fit-for-purpose use of the terms selected for my framework.

Figure 7

Tīwaiwaka Framework Infographic, Depicting the First Six Te Ao Māori Virtues Used to Evaluate the Research

2.1.4.1 Ka ora te Whenua (Taiao, Awa (river), Moana). Whenua is applied in the traditional sense, inclusive of the total environment, with the priority of the wellness of Papatūānuku (Mother Earth) as critical and foremost. When utilising environmental resources, Māori are guided by both kawa (protocol or etiquette) and tikanga to maintain their inherent expression of tapu (sacredness) and reverence (Apiti et al., 2023; Jefferies & Kennedy, 2009; Ka'ai, 2004; Kennedy, 2017; Roberts, 2013) One's actions and behaviours imbue one with mana, which has many meanings, most commonly authority, prestige or power (Ka'ai, 2004; Paul-Burke et al., Ngarimu-Cameron, Burke et al., 2022). In the wider context, mana also describes aspects of Māori sovereignty (Durie, 1998; Ka'ai, 2004; Marsden, 2003). Behaving in accordance with both tapu and its complementary opposite, noa (common or not sacred), Māori seek to maintain utu or te whē (northern dialect) (balance or reciprocity; Ballara, 2003; Kennedy, 2017; Marsden, 2003) with the natural world, enabling the sustainable use of resources. Marsden and Henare (1992) further explained this duty of care:

> So, all forms of life are nurtured in the womb of Papatūānuku [Mother Earth] and upon her breast. Man is thus an integral part of the natural order and recipient of her bounty. He is her son and therefore as every son has social obligations to fulfil towards parents, siblings and other members of the whānau (family), so has man

> an obligation to mother earth and her whānau, to promote their welfare and good. (p. 14)

The depth, importance and quality of the human–environment relationship and its sacredness, as an alternate perspective, is a fundamental underpinning of the Māori world view (Bargh, 2016; Lyver et al., 2016, 2019). An integral belief and well-known whakataukī (proverb) that encapsulates the tīwaiwaka ethos is "ka ora te whenua, ka ora te tangata": "When the earth is well, then its people are well" (Parker, 2023).

2.1.4.2 Whakapapa. Māori society was traditionally, and still is, centred on kin-based relationships or whakapapa, which encompasses immediate family (whānau), wider family subgroups (hapū) and larger descent groups or clans (iwi) (Ka'ai, 2004; Roberts, 2013; Roberts et al., 1995; R. Walker, 2004). Whakapapa is the central fabric of Māori society, the codified knowledge of our ancestors, tracing our DNA lineages across time and space, in the physical and spiritual realms (Hikuroa, 2017; Reihana et al., 2021; Royal, 2009). Whakapapa is the interpretation of creation from the Māori world view, which includes all tangible and intangible relationships (Roberts, 2013; Royal, 2005). Whakapapa is dynamic, evolutionary and fluid, but retains its kawa, integrity and origins through the intergenerational transfer of knowledge (Paul-Burke & Rameka, 2015; Roberts, 2013). Whakapapa is the relational structure by which all connections to the animate and inanimate world are processed in the human psyche. This principle informs this research through several layers of whakapapa-based ethics:

a) The concept of tuakana and teina (elder and younger) reciprocating learning relationship; for example, mātauranga Māori and neoclassical research methods
    1. Nature and human-centric relationships
    2. Place-based research; insider connectivity and transdisciplinarity
    3. Iwi, hapū and whānau of Ōhiwa-centric relationships
b) Actual whakapapa lineages
    1. Mine to the area and iwi (Te Whakatōhea and Ngāi Tūhoe)
    2. Various whānau I worked with, and our whakapapa linkages to them.

2.1.4.3 Mauri. Mauri is most commonly known as the living essence of connection through wairua (spirituality) of all living things on the earth, (Figure 7 & **Error! Reference source not found.**). Everything in the Māori world possesses mauri, i ts living being (Barlow, 1991; R. McGowan, personal communication, 2024; Reihana et al., 2023; Royal, 2009). It was further defined by Marsden (2003) as

> Immanent within all creation is *mauri*—the life force which generates, re-generates and upholds creation. It is the bonding element that knits all the diverse elements within the universe "Procession" giving all of its unity in diversity. It is the bonding element that holds the fabric of the universe together. (p. 44)

Others further defined mauri as the connections between all things, the threads by which life itself is maintained. This can be through water, air, food—all things that maintain our life essence in a state of thriving mauri (R. McGowan, personal communication, 2024; Parker, 2023). Pā (R. McGowan, personal communication, 2024) further defined mauri as follows:

> We are part of the connections that enable the whenua to thrive. We need to walk the land to ensure that it is well. That means keeping alive a physical connection to it. That is part of the meaning of our term mana whenua and tangata whenua or people of the land who hold mana from the land. A key part of the responsibility of tangata whenua is to ensure that the mauri of the whenua is sustained. When it is not, for example, when the integrity of the landscape is compromised by weed invasion, noxious animals, or inappropriate development, the mana whenua must speak and act to address the issues involved. If they don't and the mauri continues to decline, their own mauri also declines, and with it their own personal wellness, because our own personal mauri is intimately connected to the whenua to which we belong.

In the tīwaiwaka framework, this principle highlights the ethic of care (McGowan, 2021b) for the natural world and focuses the research study on the connections between all the elements required to help tuangi thrive. I have used this optic, for example, on the field data from the population surveys (distribution, abundance and population profiles), which informed the SDM. The SDM provided predictive data on the best restoration sites as well as future potential surveys sites.

2.1.4.4 Kotahitanga. Kotahitanga, as defined by Nepe (1991), is the unification of a people in solidarity, as a race, a collective. Kotahitanga is the strong affinity that can connect people over a cause, place, environment or action towards something or someone. It can prompt co-operation and reciprocation of kin relationships between all living things and is an essential ingredient in the thriving of mauri (Nepe, 1991).

In the context of this research, kotahitanga signifies the co-development of the research outcomes and deliverables for iwi, hapū, regional council and all associated parties. It

focuses on the methods and ways in which all parties can come together to provide the best outcomes for tuangi in Ōhiwa Harbour for the future.

2.1.4.5 Whanaungatanga. "Ko au, ko tāua, ko tātou" Rangiwai (2018) translated the general meaning of this whakatauki as "I am, that is, all of us"—we are a part of the whole community. The notion of being a part of the whole imbues one with a sense of co-operation and reciprocity, of obligations and commitments that each individual member, who is a contributor to the collective entity, carries out the maintenance of those relationships that uphold these communities (Nepe, 1991). For Paul-Burke et al. (2018), principles of whanaungatanga contain kinship ties, relationships shared through experiences, working together, collective belonging and mana-enhancing conduct, which is specific to a task; for example, the study of shellfish, surveying and management (Paul-Burke et al., 2018). In the context of this research, this principle was used as a portal for hapū, whānau, kaitiaki, authority and any vested party to make recommendations for the Ōhiwa Harbour shellfish management action plan.

2.1.4.6 Kaitiakitanga. A key cultural value used in the environment, meaning guardianship, stewardship, caretaking or conservatorship, kaitiakitanga in the legal context represents a Māori socioenvironmental management philosophy (Kawharu, 2000; Paul-Burke, 2011; Roberts et al., 1995). As a resource management approach, kaitiakitanga is a localised or species-specific approach that views humans as an integral part of the ecosystem, including being consumers of the resources and caretakers of the habitats to ensure the longevity of a resource (reciprocation) (Kennedy, 2017; Paul-Burke & Rameka, 2015; E. Walker et al., 2019).

Figure 8

Tīwaiwaka Values, With Example Descriptors Relevant for Tuangi Restoration Within Ōhiwa Harbour

For detailed descriptions of these values, see above.

2.1.5 Additional Te Ao Māori Values

Two other key values intrinsic to te ao Māori, which are synonymous with their interactions with the taiao, are included here. These are not by any means the only other values that are intertwined in their connection to taiao but are considered key in this context.

2.1.5.1 Manaakitanga. Additional to the tīwaiwaka values are key cultural ethics embedded within all of them. First is manaakitanga; in this instance, it understood as respect. Akama et al. (2019) expressed this as a "heightened sensitivity to interrelatedness, which requires a respect of thresholds of places, situations, knowledge's, relationships and things in realms of the beyond" (p. 69). Manaakitanga is also expressed as generosity and care, in both the human and natural world. In this instance, it is the ability to provide taonga species at a tangi (cry, mourn, weep or funeral) hākari (a feast, banquet, sumptuous meal, or celebration) or other cultural gathering to express the mana of the local tribal people. Tuangi comprise one of these taonga species and delicacies that were known and shared by the tribes from Ōhiwa.

For the tribes of Ōhiwa, it has the concept of whakamā (shame, ashamed) associated with it now, meaning that, owing to the tribes not being able to be active kaitiaki of their harbour, they do not have the ability to provide such taonga at their cultural gatherings. Manaakitanga in the reciprocating relationship with the natural world is the ability to take

care of the resources that you are tasked with, within your tribal area—a task or duty the tribes of Ōhiwa have be unable to enact without governmental interference since colonisation.

2.1.5.2 Utu. Second is utu, tau utuutu (Black, 2014) or te whē (Rakena, 2020), translated as reciprocity, exercising generosity and hospitality; the act of returning back to the earth in this case marine environments that we interact with, as a gesture of gratefulness for provision and maintaining a cyclic balance (Mark & Hargen, 2020; Paul, 2024). Akama et al. (2019) elaborated that "premised upon interrelatedness also means a commitment to sovereign relationships, which strengthen our co-flourishing and honouring of dwelling places inhabited by many beings and non-beings" (p. 69).

For Black (2014), the notion of utu (most commonly used) is similar in essence to manaakitanga; it is the sharing of bountiful resources. In his commentary on the pātere (chant) called Te Koko ki Ōhiwa (the surge at Ōhiwa) from which this description is originated, he discussed the "internal and external exchange of food resources by Tairongo being connected to the knowledge gained through interaction and collaboration" (p. 19), this being an immutable exchange between the people and the harbour. In the pātere, the need to meet social obligations by sharing food resources, for the wellbeing of the connected communities, is highlighted.

These two values, while they sit outside the framework, are integral parts of the conduct of Indigenous peoples within these stewardship spaces and are core facets of the integrity of the tīwaiwaka values.

2.1.6 The Tīwaiwaka Framework Informed by Multiple Evidence-Based Approaches

While kaupapa Māori research provides robust Indigenous philosophical and ethical foundation, and MEB approaches offer useful mechanisms for bringing knowledge systems into dialogue, neither explicitly provides a relational methodology for guiding the ongoing interactions among diverse knowledge holders, disciplinary traditions, technologies and governance systems. The tīwaiwaka framework was developed to address this gap. This thesis developed a tīwaiwaka framework informed by a transdisciplinary MEB approach—in this case, research led by a kaupapa Māori way of being, doing and seeing, utilising mātauranga Māori, paired with marine science, and technology. Unlike methodologies developed primarily to improve research outcomes, the tīwaiwaka framework was also designed to examine and transform the conditions under which knowledge is produced. The framework therefore operates simultaneously

as a research methodology, an ethical framework and a mechanism for addressing power asymmetries historically embedded within scientific institutions. In this sense, its contribution extends beyond marine conservation to the practice of science itself.

This framework utilised the MEB approach to harvest, capitalise and leverage multiple knowledge systems as a deep approach to collaborative knowledge sharing and creation. The MEB approach itself evolved from recognition by the Intergovernmental Science Policy Platform on Biodiversity and Ecosystems Services (IPBES) to "recognise and respect Indigenous and local community contributions to conservation and sustainable use of biodiversity and ecosystems" (Díaz et al., 2015, p. 1). To model equity, reciprocity and mutual benefit in conservation efforts (Tengö et al., 2014), a dialogue was initiated that brought together knowledge holders from Indigenous communities, science disciplines and policy-making sectors. This dialogue, convened by SwedBio at the Stockholm Resilience Centre, established essential principles for cross-systems knowledge exchange—trust, respect, reciprocity, equity, transparency and free, prior and informed consent (Tengö et al., 2017).

Fundamental to the MEB approach is acknowledgement that challenges arise from using multiple disciplines and knowledges from differing world views, approaches and applications within nature–human relationships. Here, I prioritise the mobilisation and equally valid Māori knowledge from within the knowledge provenance where it originates (Malmer et al., 2020).

The principles of a MEB approach, as outlined in SwedBio (2025) and discussed further in Malmer et al. (2020), are based on three phases, with five core tasks to activate the approach. The first phase is co-defining a common concern and facilitating equitable engagement for mobilising knowledge; the knowledge sourced and used is from within the knowledge base of its creation (e.g., kaupapa Māori using mātauranga Māori), that it is authenticated by the knowledge holders that it comes from, its articulation for sharing is correct as per the knowledge holders, and its sharing is permissible. This requires collective assessment of the knowledges through collaborative analysis and interpretation to determine authenticity and application as a foundational knowledge creation platform for the contributors involved.

The second phase is the actors, institutes and peoples that are central to the evidence compilation for successful co-defined and co-designed solution-orientated conservation practices; and the third phase is the processes by which dissemination of the evidence is

shared equitably and empowers those who have participated. This involves allowing for meaningful participation through all stages of the process, addressing power asymmetries and providing space for reshaping the power paradigm within the decision-making process. This mode of collaboration and inclusive participation aligns with the utilisation of mātauranga Māori in this research.

Using a MEB approach as an operational component of the tīwaiwaka methodology underscores the importance of working across knowledge systems, disciplines and technologies to generate more equitable and effective conservation outcomes. Beyond its application in this research the tīwaiwaka methodology offers a transferrable Indigenous-led model for conducting science on Indigenous lands and waters, one that seeks to restore balance between knowledge systems, strengthen Indigenous sovereignty and advance a more just and relational scientific future.

2.1.6.1 Tīwaiwaka framework a contemporary solution. As discussed earlier, Western science was often embedded within colonial structures, serving as an apparatus of empire that enabled territorial expansion, the extraction of resources and capital, and the displacement of Indigenous authority, governance, and sovereignty (Beattie & Morgan, 2021; Held, 2023; Rata, 2022). Rather than operating as a neutral pursuit of objective truth, scientific institutions provided the ideological justifications and practical mechanisms necessary to enforce colonial rule globally (Held, 2023; Mirzekhanov, 2025; Sammler & Lynch, 2021). This legacy has generated profound cultural distrust toward scientific institutions, complicating research relationships between researchers, Māori and other Indigenous communities today (Pene, 2024; Rewi, McLellan & Heke, 2022; Sammler & Lynch, 2021).

Tīwaiwaka provides a contemporary Indigenous framework for addressing the historical tensions between Western science and Indigenous communities by centring mātauranga Māori as an equal and authoritative knowledge system within research and environmental governance. Grounded in kaupapa Māori principles, the framework shifts scientific practice away from extractive, expert driven approaches toward relational, reciprocal, and collectively accountable forms of knowledge production. In contrast to colonial research traditions that privileged external observation and the acquisition of knowledge for institutional benefit, tīwaiwaka emphasises enduring relationships among communities, researchers, and the natural world, recognising knowledge as a living process embedded within responsibilities to people, place, and future generations (Pene,

2024; Rewi, McLellan & Heke, 2022). As a transdisplinary framework, it creates a space where mātauranga Māori, Western science, technology, art, and community knowledge can engage productively without requiring the assimilation of one system into another. By supporting co-design, shared decision-making, and Indigenous research sovereignty, the tīwaiwaka framework offers a practical model for rebuilding trust, enhancing collaborative innovation, and fostering more equitable and culturally responsive scientific partnerships in Aotearoa and internationally (Pene, 2024; Rewi, McLellan & Heke, 2022).

More significantly, the Tīwaiwaka framework contributes not only to Indigenous research methodologies but to the ongoing redesign of science itself, offering a relational methodology through which scientific practice can better uphold Indigenous sovereignty, knowledge equity, and environmental justice (L. T. Smith, 2012). It therefore seeks to rebalance relationships between Indigenous peoples and scientific institutions by ensuring that Indigenous communities retain authority over their knowledge systems, priorities, decision-making processes and environmental futures (Foulds et al., 2025; Tengö et al., 2017). Through values such as whakapapa, whanaungatanga, kotahitanga, mauri and kaitiakitanga, the framework repositions relationships, responsibilities and reciprocity as central methodological considerations rather than peripheral ethical concerns (Whyte et al., 2016). In doing so, it challenges the long-standing privileging of Western scientific norms and contributes to growing international efforts to develop more equitable, pluralistic and relational approaches to knowledge production and environmental stewardship (Malmer et al., 2020; Tengö et al., 2017).

The methodological contribution of Tīwaiwaka lies in its articulation of an Indigenous led transdisplinary approach that does not seek the integration or assimilation of knowledge systems, but instead creates conditions for their co-existence, mutual respect and collective application. Unlike many collaborative frameworks, which ultimately remain anchored in western scientific validation structures, Tīwaiwaka centres Indigenous epistemological authority while creating space for science, technology, art, law, and policy to contribute as equal partners in knowledge creation. The Tīwaiwaka framework contributes to international efforts to decolonise research institutions and advance knowledge equity, representing a shift from the inclusion of Indigenous knowledge within science towards the transformation of scientific practice itself.

Wāhanga Tuatoru—Chapter 3

Mirimiria te one I ahu ai koe
Korikoria ōu matiwae I te taikoraha hei tātai ki ō tipunā,
Titiro atu ai I te Ōhiwa ō Awanuiarangi,
e tū, e tū, e tū tonu ana.

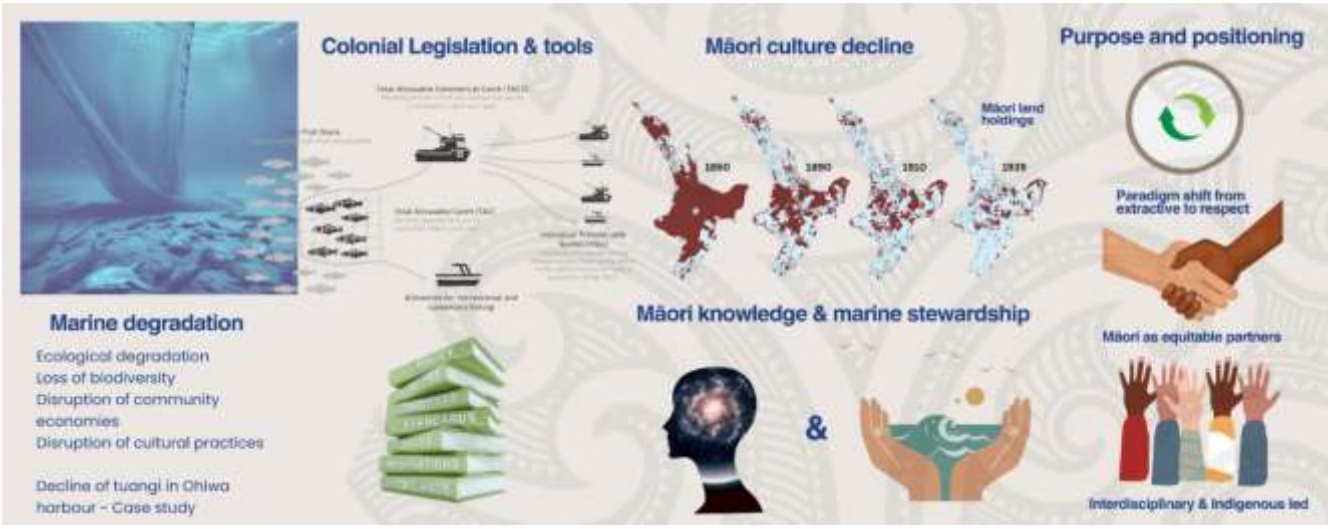
Rub the dirt from which you came,
Wriggle your toes in the mudflats as a connector to your ancestors,
Simultaneously look out and within at Ōhiwa the standing place of Awanuiārangi,
Stand, stand, we are still standing.
Ngāti Awa whakatauki

Wāhanga Tuatoru—Chapter 3

From Protecting to Respecting Marine Relations in Aotearoa New Zealand

Figure 9

Visual Illustration of Chapter 3 Outline and Key Concepts



Introduction

Overfishing has caused adverse effects on local ecology, ecological stability, community economies and the sociocultural and spiritual aspects that sustain them (Kainamu-Murchie et al., 2018; McCarthy et al., 2014). Understanding the implications and the consequences of marine biodiversity loss on Māori communities requires an examination of how legislation, policies and colonial practices have enclosed access to marine resources for Māori (D. M. T. Gibbs, 2008; Jackson, 2013; Kainamu & Rolleston-Gabel, 2023) and subsequently shaped the current landscape of estuarine management in Aotearoa.

Māori connection to place and natural resources is deeply rooted in whakapapa, a relational kin-based epistemology that connects all things, animate and inanimate to each other from a te ao Māori world view (Roberts, 2013). Whakapapa was traditionally transferred orally through the notions of layering of one upon another, these being generations or genealogy layers, ancestor upon ancestor (Ngata & Ngata, 2019), that follow a string, line or cord of descent. The intimate knowledge of the environment, particularly in relation to food harvesting, was essential not only for survival but for

managing population growth over the 800-plus years prior to European settlement (Banner, 1999; Pool, 2015). This relational world view observes land and water not as commodities but as living persons, with responsibilities of reciprocation to retain ecological balance with care intrinsically demonstrated in the concept of kaitiakitanga (Moewaka Barnes et al., 2018).

Fisheries, in particular, hold cultural sustenance and spiritual value integral to Māori wellbeing and identity. Seafoods are one of the original key sources of nutrients, in the past and today, supplying vitamins, omega-3 fatty acids and polyunsaturated fats (Jayasekara et al., 2020; Reames, 2012), and were readily available on settlement in Aotearoa (Colenso, 1869; Hamilton, 1908). Such is the affiliation with the ocean that there are numerous Māori legends of how Māori came to exist and be in Aotearoa, associated with it from the beginning of their time.

Jackson (2013) outlined how Māori fishing rights—originally guaranteed under Te Tiriti o Waitangi, the founding document of Aotearoa—have been systematically eroded through colonial legislation, policies and practices, such as the quota management system (QMS). Tools such as Taiapure (a customary place of special significance established to make provisions for recognition of rangatiratanga and Māori rights), mahinga kai (customary fisheries gathering places that are central to Māori identity and tikanga) and mataitai (customary fisheries established for the purpose of recognising and providing for customary management practices) were introduced to recognise customary rights, yet they have fallen short of restoring rangatiratanga, instead reinforcing state control. Control, or who holds the power within conservation, is consistently identified as the limiting factor for positive progress and equitable practices (K. Moon, 2025). Despite these challenges, Māori continue to assert their rights and responsibilities to protect and manage fisheries in alignment with their cultural values, emphasising the inseparability of people, place and resources.

Figure 7

Tīwaiwaka Framework Infographic, Depicting the *First Six Te Ao Māori Virtues Used to Evaluate the Research*

Modified Tīwaiwaka Framework Image Showing the Principles Discussed in This Chapter

This introductory section contextualises the subsequent peer-reviewed journal article, which constitutes the core content of this chapter, which asks, "How does legislation reflect the connections or mauri that is implicit in the principles of tīwaiwaka, the research framework developed for this thesis?" Here I discuss Principle 1—Ka ora te whenua (in this context, moana) ka ora te tangata. This chapter also considers our duty of care and how has it been upheld within the context of this research when looking at the effects and implications of legislation policies and practices within the marine environment across Aotearoa. In this chapter, a national overview of the context is explored to set the scene for the contemporary practices that have shaped our current environmental rationale, philosophies and practices. Evident from the outset are the opposing world views on how to steward or take care of the land for future generations (Banner, 1999) between Māori and the early settlers. According to Hellmann (2024), early European settlers viewed the natural environment in Aotearoa as monetised resources under the logic of economic progress, which had no reciprocating means for stewardship within their legislation,

policies or practices. This chapter seeks to explore how putting Papatūānuku, whenua, oceans and the overall environment first as opposed to considering resources just in terms of their monetary value.

Key in these polar opposite points of view is the placement of humans themselves within the context of survival and the sustainability of resources. This leads into the Tīwaiwaka Principle 2, We are not the centre of the universe but are part of it. Within te ao Māori, whakapapa situates humans as the youngest descendants in the genealogy of the universe. This understanding acknowledges that the whenua, awa, moana, flora, fauna, tipua (supernatural being, considered part human part deity) and atua precede us, shaping our responsibility as kaitiaki and reinforcing the interconnected nature of all life. In the legislation that resulted once European settlers moved into a position of dominance, environmental stewardship and Māori culture became subordinate to British settler colonial society (Cunneen & Tauri, 2016), shifting the rationale from resources as an integral part of Māori whakapapa and psyche driven by sustainable, preservation and rotational harvesting in rhythm with nature's cycles, to resource exploitation, land confiscation and cultural assimilation (Kelly, 2020; McAllister et al., 2023; N. Walker et al., 2022). A cultural shift from a nature-centric for survival to a human-centric rationale has been installed in our current contemporary culture, and the Tīwaiwaka Principle 2 looks to recentre the focus of our world view.

How did Māori culture maintain kaitiakitanga (stewardship) over whenua or the lands they have been ostracised and removed from, displacing them from their rights to culture, identity and belonging? They didn't—considerable national and international scholarship provides evidence of how Māori lost their ability to retain this connection and uphold their traditional environmental practices after colonisation (Cunneen & Tauri, 2016; Hellmann, 2024; Kelly, 2020; Waratini-Karena, 2017). As a response to decades of displacement, biodiversity declines and the environmental crisis we are now experiencing, we are entering a time of considerable resistance across all facets of society from Māori and tangata Tiriti (Māori supporters), here in the environmental sphere (Hursthouse, 2024; Kingdon-Bebb & Jones, 2025; Ruka Te Karako, 2025).

Here I highlight and seek to understand the political landscape premising the current state of tuangi in Ōhiwa Harbour, exploring the legislation that had the greatest influence in changing the seascape of the habitats for tuangi and addressing the question of how the local tribes shifted from a sustenance economy, deeply connected to place, the

environment and natural resources, such as the tuangi (EBOP, 2008; Te Rūnanga o Ngāti Awa, 2019; Whakatōhea, 1993), to the current state of health in Ōhiwa Harbour (Bevan, 2018).

The article unfolds in several key sections. I begin by examining the underpinning tenets of coastal and marine law and policy in Aotearoa, contrasting the Western legal tradition with te ao Māori perspectives. This comparison highlights the ontological and epistemological differences that shape how marine environments are understood, valued and governed (Joseph et al., 2020; Le Heron et al., 2024; Sammler, 2020).

Next, I trace the historical trajectory of Māori rights, interests and relationships with coastal and marine areas, focusing on the impacts of colonisation, legal exclusion and environmental regulation (Bargh, 2016; Harris, 2004; Ward, 1973). This section outlines how successive waves of legislation have systematically undermined Māori authority and access to marine resources, while privileging settler interests and extractive industries (Jackson, 2013; Tangaroa Ararau, 2024).

Building on this foundation, I argue that a te ao Māori world view offers critical insights and tools for reimagining marine governance, and explore how principles such as kaitiakitanga, whakapapa and mana moana can inform more holistic, inclusive and sustainable approaches to marine management (Tangaroa Ararau, 2024). These Indigenous frameworks are not only culturally grounded but also ecologically attuned, offering pathways for addressing the marine biodiversity crisis in ways that are just, effective, impactful and meaningful (Okanata, 2025; Strand et al., 2024; WWF, 2024).

The article concludes by identifying opportunities for transformative change, including co-governance models (Joseph, 2022; Sustainable Seas, 2024b), mātauranga Māori-based restoration projects (Sustainable Seas, 2024a) and proposed legal reforms that respect Māori rights and responsibilities (Joseph, 2022; Joseph et al., 2020). Through this analysis, I aim to contribute to a growing body of scholarship and practice that seeks to decolonise marine governance and restore balance between people and our ocean (Strand et al., 2024; United Nations Education, Scientific and Cultural Organisation [UNESCO], 2002; WWF, 2024).

This manuscript is published in *AlterNative*, *an international Journal of Indigenous Peoples* (Reihana et al., 2026), and explores these pressure points, advocating for a paradigm shift in determining movement towards a respectful, inclusive of humans,

participatory regime that includes mātauranga Māori, tikanga and rangatiratanga equitably in providing more sustainable laws, policy and practices for the future while simultaneously challenging the current power dynamic model within Aotearoa.

From Protecting to Respecting Marine Relations in Aotearoa, New Zealand From Protecting to Respecting Marine Relations in Aotearoa, New Zealand

> Toi te kupu, toi te mana, toi te whenua
> When work is established for the people,
> status is established too, and thus is the land secured.
>
> ——Rev. Māori Marsden, Muriwhenua Fishing Claim, 1988

Reihana, K., Macpherson, E., Ellis, J., Bulmer, R., & Paul-Burke, K. (2026). From Protecting to Respecting Marine Relations in Aotearoa, New Zealand. *AlterNative: An International Journal of Indigenous Peoples*, *22*(3), 715-726. DOI: https://doi.org/10.1177/11771801261460920

3.1 Introduction

Aotearoa New Zealand (hereafter Aotearoa) is among the many countries globally facing a marine biodiversity crisis (Herbert-Read et al., 2022). This crisis reflects the legacy of poor environmental management decisions made across the land and sea (Ministry for the Environment & Stats NZ, 2022; Ministry of Fisheries, 2009; Waitangi Tribunal, 1989, 1992a). The complex and multidimensional threats to our coastal marine areas include overextraction—for example, fishing, mining and petroleum—intensified anthropogenic activities, cumulative impacts on the coastal environment—for example, habitat loss, contaminants and pollution—and impacts from climate change—for example, ocean warming, darkening and acidification (Herbert-Read et al., 2022). In Aotearoa, as in many places, the marine biodiversity crisis incorporates a complex physical and social context, affected and enabled by Crown marine and coastal laws and policies (Macpherson et al., 2023), which have promoted extractive and destructive uses of the taiao (environment) and resources (D. M. T. Gibbs, 2008). Māori (Indigenous Peoples of Aotearoa) managed Aotearoa's marine and coastal environment pre-European settlement, by using their mātauranga Māori (cultural body of knowledge), embedded in values of utu (reciprocal obligations of care and balance).

This article is positioned as a reset of the relationship between people and the coast in the settler-colonial context; to do so, we must shift from our current mode of extraction and exploitation towards a system of intergenerational marine respect and regeneration. We argue that Māori, who hold place-based knowledge and experience, must be equitable

partners in generating new coastal marine laws, policies, practices and management approaches (Ens et al., 2021; Reyes-García & Benyei, 2019; Reyes-García et al., 2019).

Here we introduce a new conceptual framing of marine governance by shifting from "marine protected areas" (MPAs) to "marine respected areas," a notion brought into awareness by Elder Ken Paul (of the Wolastoqey First Nation at Neqotkuk, the community of Tobique First Nation, New Brunswick, Canada; Paul, 2024). Our arguments are grounded in Māori relational philosophies, which have received insufficient emphasis in dominant marine conservation literature. They draw on our historical analysis of how successive Crown laws systematically displaced Māori authority, while also highlighting contemporary innovations that actively reshape governance systems. To advance beyond the limited and polarising existing approaches to marine conservation in Aotearoa, we argue for an Aotearoa-specific biocultural "third space" that operationalises mātauranga Māori as a governance framework capable of informing transformative, pluralistic marine policy. Our arguments have broad relevance for international debates about marine conservation, and chart a way beyond limiting, "all or nothing" approaches to marine conservation.

We begin with an overview of the worldviews underpinning coastal marine law, policy and management actions in a settler-colonial context, contrasting approaches from te ao Māori. We then explore the historical evolution of Māori rights, interests and relationships related to coastal and marine areas in Aotearoa. We conclude by arguing that a te ao Māori worldview provides critical knowledge, principles and tools for improved ocean and coastal management that can work alongside Western knowledge to improve the long-term health and well-being of marine and coastal ecosystems for the benefit of future generations in Aotearoa and beyond.

We, the authors, are an interdisciplinary, Indigenous-led group of marine researchers of Māori and Pākehā (settler) heritage. The perspectives on law, language and knowledge are premised on our hapū perspectives from the Bay of Plenty and Northland, acknowledging that other iwi and hapū may draw different interpretations. Our experience spans biological, physical and social sciences and humanities, including ecology, biology, Indigenous (Māori) language, culture, environmental ethics and law. Our shared commitment is to improve the health of the marine and coastal areas, uphold place-based Indigenous knowledge and rangatiratanga and cultivate the decentralisation of Western knowledge (Stein et al., 2024). Our arguments are informed by a detailed

review of the relevant marine legal documents—legislation, case law, policy, legislative submissions—as well as Indigenous-led marine practices and marine sciences and policy literature.

3.2 Marine and Coastal Relationships in Aotearoa

In Western societies, the main response to biophysical threats, including in marine and coastal contexts, has been to devise legal frameworks that seek to preserve and protect nature from human exploitation (Weddell, 2023, p. 140). The United Nations Convention on Biological Diversity (1992) requires states to "develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity" (art. 6). The Global Biodiversity Framework sets a series of targets for the preservation of biodiversity, including that by 2030, 30% of the world's marine territories will be under "effective conservation" through "protected" marine areas (Kunming-Montreal Global Biodiversity Framework, 2022).

However, "conservation," "protection" and "preservation" ideals are rooted in a dualist Western ontology (Fisher et al., 2022), in which nature preservation is separated from human use (Brockington, 2002; Tănăsescu, 2022). This approach has been described as "environmental colonialism" (O'Donnell et al., 2020), producing negative impacts on Indigenous Peoples and their culture, livelihoods and traditions throughout the world (McCormack, 2021). Conservation and environmental law frameworks have primarily focused on the protection of largely unmodified environments, while de-emphasising the need for restoration of degraded areas. Tănăsescu (2022, p. 89) reminds us that there are ways of relating to the natural environment that are mutually beneficial and restorative.

Māori are characterised by kin-based relationships or whakapapa, which encompasses immediate whānau (family), wider family hapū and iwi (Ka'ai, 2004; Roberts, 2013; R. Walker, 2004). Whakapapa is the core fabric of Māori society, the sacredness that flows from the divine by way of genealogical networks (Roberts, 2013; Royal, 2005). Whakapapa depicts the creation of humankind and its place within the context of our natural world. Whakapapa is dynamic, evolutionary and fluid, but retains kawa (protocol or etiquette), integrity and origins through the intergenerational transfer of knowledge via one's relational connection to place (Paul-Burke & Rameka, 2015; Roberts, 2013).

When using natural resources, Māori are guided by both kawa and tikanga, such as those relating to gathering shellfish, whereby shellfish is never eaten or processed at the gathering site, and only one species is taken at a time (M. Whaanga, 2012) to maintain

the inherent expressions of tapu (sacredness) and reverence (Apiti et al., 2023; Kennedy & Jefferies, 2009; Roberts, 2013). Each person's actions and behaviours are imbued with mana, which has many meanings, but is most commonly understood as authority, prestige or supernatural power (Ka'ai, 2004; Paul-Burke, Ngarimu-Cameron, Paul et al., 2022). In the wider context, mana also invokes Māori sovereignty (Durie, 1998; Ka'ai, 2004; Marsden, 2003). Behaving in accordance with both tapu and its complementary opposite, noa (common or not sacred), Māori seek to maintain utu or te whē (reciprocal obligations of care and balance; Ballara, 2003; Kennedy, 2017; Marsden, 2003) of the natural world, enabling the sustainable use of resources.

Māori developed extensive knowledge, skills and understanding of their lands and waters in the 800 years prior to the arrival of British settlers (McCormack, 2017; Skipper, 2020). Early settlers' descriptions of the volume, accessibility and stability of Aotearoa's coastal fisheries (Colenso, 1869; Dieffenbach, 1843) are testament to the sustainable fishing practices that had been developed to support increasing human populations (M. Campbell et al., 2025; Paulin, 2007). Hersoug (2003) described the extent of mātauranga held regarding fish species and fishing techniques, as outlined in the following quote: "pre-European Māori fishing provided the main source of sustenance, with methods of procuring fish based on careful observations of generations of fisherman. Fish were taken with nets—some over a mile in length—traps, spears and hook-and-line" (p. 11).

The concept of mana moana (historical and territorial authority for the sea) helps explain Māori connection to sea, ocean and coast, denoting the authority or jurisdiction held by hapū or whānau over a particular resource area. While beliefs and practices vary between iwi and hapū, Māori relationships with te taiao (the environment) are generally underpinned by reciprocal obligations of care (kaitiakitanga—stewardship, caretakership) to enable the sustainable long-term use and enjoyment of natural resources (Henwood & Henwood, 2011; Waitangi Tribunal, 1989, 1992b). Kaitiakitanga is a place-based resource management approach that conceives of humans as an integral part of the ecosystem, both as carers and consumers of resources (Ngāti Porou, 2015; Paul-Burke & Rameka, 2015; E. Walker et al., 2019). In te ao Māori, the responsibilities of kaitiakitanga transcend Western legal title boundaries to encompass the totality of the environment and all who are connected to it (Mutu, 2020).

Obligation of hunga tiaki (Māori caretakers or guardians) towards oceans and coasts sit uneasily alongside scientific management approaches to environmental conservation,

protection and preservation. For example, Crown fisheries management often permits year-round fishing, whereas traditional Māori practices are guided by the maramataka (lunar calendar), which regulates fishing according to season, species and lunar cycles, ensuring ecological balance, sustainability and cultural continuity (Martin, 2025). Another example of underpinning worldviews in tension is that Crown fisheries management often emphasises maximum yield, quotas or catch limits, where Māori customary practices incorporate seasonal restrictions, such as rāhui (temporary customary closures), to allow stocks to replenish, and only taking the required quantities (M. Whaanga, 2012).

An example of this preservationist approach in Aotearoa is the establishment of MPAs (Macpherson, 2023), which typically prohibit extractive activities such as commercial fishing (B. Ballantine, 2014) and may even impede traditional customary practices (see *Attorney-General v Trustees of the Motiti Rohe Moana Trust* [2019] NZCA 532), even when these are part of longstanding Indigenous resource-management practices. One such practice is rāhui, a cultural management approach that prohibits the taking, harvesting or use of a natural resource for a certain period of time. This method serves to conserve ecosystems through seasonal or temporary closures, restore depleted resources and maintain the spiritual and cultural connection between people and the environment. Although intended to have similar conservation outcomes, MPAs, which represent a permanent ban of the extraction of any species, have often resulted in severing spiritual and cultural connections to place. This is largely owing to exclusionary consultation processes with local iwi or hapū. A notable example of this is the Motunau Island case, discussed later in this article. In the following sections, we detail how Māori relationships with coastal and marine areas have been encroached upon and enclosed because of colonisation, through inconsistent but mutually reinforcing Crown practices of resource extraction, exclusion and conservation.

3.3 Colonising Marine and Coastal Relationships in Aotearoa

Māori approaches to resource management were largely disregarded following colonisation of Aotearoa by British settlers from the 1800s. Although some northern Māori signed a declaration of their independence, known as “He Whakaputanga o Te Rangatiratanga o Nu Tirene,” in 1834 (O’Malley, 2017/2023, p. 25; R. Walker, 2004; Ward, 1973), in 1840, the Crown and various Māori chiefs signed Te Tiriti o Waitangi (The Treaty of Waitangi). After signing Te Tiriti, the Crown assumed sovereignty over Aotearoa and accelerated its colonisation project, despite significant differences between

the Māori and English versions in terms of respective rights and interests retained by each party (Bargh, 2016; Jackson, 2013; R. Walker, 2004). The rest of the 19th century is characterised by intensive European settlement and war, as Māori resisted Crown authority and land acquisition, and disputed their claim to sovereignty, claiming that the Treaty, rather than ceding sovereignty, guaranteed tino rangatiratanga (absolute sovereignty or self-determination), and that the Crown's assertion of sovereignty was contrary to the Treaty and international law (Harris, 2004; Ward, 1973).

Despite the imposition of Crown legal frameworks, Māori continued their economic activities related to lands, oceans and coasts (Petrie, 2006). In the mid-19th century, Māori were considered major players in Aotearoa's shipping industry, marking a transformation in their technology, economy and social structure (Barber, 2003; Petrie, 2006). However, despite the recognition of tino rangatiratanga over their lands and resources in Te Tiriti, Māori rights, interests and authority over marine and coastal areas since colonisation have been largely disregarded or overridden (Bambridge, 2016; Tau, 2006). This has occurred through a series of laws, policies and practices that sought to facilitate encroachment into Māori marine and coastal authority, rights, interests and benefits via (a) excluding Māori from legal regimes that authorised the productive and beneficial use of marine and coastal environments and (b) subjecting Māori to conservation regimes that overrode the exercise of their marine and coastal relationships, as well as resource management authority.

3.3.1 Legislating Displacement: Excluding Māori From the Benefit of Land and Resource Rights

During the 19th century, successive legislation facilitated Crown control of, and settler encroachment into, coastal marine environments and the accumulation of benefits from resources. During this time, much Māori land was converted from Māori customary title to readily alienable freehold title through the Native Land Court process (Erueti, 2003; Native Lands Act 1862; Native Lands Act 1865). Together with an aggressive purchasing campaign and Crown confiscation, this facilitated European settlement and displaced many Māori from their coastal territories (Boast, 2013; Jackson, 2013; Ward, 1973). The Oyster Fisheries Act 1866, enacted to incentivise and regulate the exponential growth of the oyster industry, paved the way for successive legislation that overrode Māori rights in coastal areas and excluded Māori from commercial fisheries (Jackson, 2013; Ministry of Fisheries, 2009; Paulin, 2007). Māori fishing rights were also recognised in early legislation (Jackson, 2013), for example, the Fish Protection Act 1877, which sought to regulate fisheries, included a savings provision that,

> nothing in this Act contained shall be deemed to repeal, alter, or affect any of the provisions of the Treaty of Waitangi, or to take Treaty of Waitangi away, annul, or abridge any of the rights of the aboriginal natives to any fishery secured to them thereunder. (s 8)

Similarly, the Sea Fisheries Amendment Act 1903 provided that "nothing in this Act shall affect any existing Māori fishing rights" (s 14), a provision that was carried through to the Fisheries Act 1983. However, over time, the imposition of Crown law and regulation meant that traditional, community-based resource management, including Māori fishing practices such as seasonal harvesting in commercial use were gradually eroded, and Māori were relegated to a subsistence-based economy at best—and absolute poverty at worst (Orbell, 1996; Petrie, 2006).

By the 1970s, the global Indigenous rights movement reached Aotearoa, and Māori mobilised in calls for the Crown to "Honour the Treaty" (Mutu, 2019) and respect their rights and interests. The Crown passed the Treaty of Waitangi Act 1975, which established the Waitangi Tribunal to address Māori grievances regarding Crown Treaty breaches. By the late 1980s, many claims had been made to the Tribunal, some of which sought the restoration of access and cultural rights to fisheries (Mahuika, 2006). These included the Ngāi Tahu (South Island iwi; WAI 27) and Muriwhenua (northern North Island iwi; WAI 22) claims, through which the Waitangi Tribunal (1989, 1992a, 1992b) recognised a range of Crown Treaty breaches relating to the seas and fisheries, including failures to support the Māori fishing industry. Māori took to the courts to defend their fisheries rights and interests, including the landmark case *Te Weehi v Regional Fisheries Officer* [1986] 1 NZLR 682, in which Tom Te Weehi from Ngāti Porou iwi successfully avoided prosecution for possessing pāua or abalone (*Haliotis iris*) under the Fishing (Amateur Fishing) Regulations 1983 based on the saving provision in the Fisheries Act 1983: "nothing in this Act shall affect any Māori fishing right."

Ironically, by the early 1980s, fish stocks were seriously overexploited (Hersoug, 2003; Mahuika, 2006). The government proposed a new QMS, with the intention of sustainably managing fish stocks within the waters of Aotearoa via a system of transferable property rights to catch fish for commercial use (McCormack, 2020). But, in establishing a new system of property rights for fishing, the Crown breached its obligations to Māori, who had recognised fishing rights under common law and Te Tiriti that were protected by the then Fisheries Act 1983. In response to legal and political action, the Māori Fisheries Act 1989 was enacted to resolve long-standing fisheries disputes by establishing the Māori

Fisheries Commission, creating the Aotearoa Fishing Company, transferring 10% of existing quota to Māori and introducing a legal mechanism for customary co-management through taiāpure—local fisheries of special significance, which may have additional fishing rules, comprising estuarine or coastal areas that are significant for food, spiritual or cultural reasons. These provisions were later incorporated into the Fisheries Act 1996, and the original Act was replaced by the Māori Fisheries Act 2004. This historical progression is often overlooked, including in Bodwitch (2017), an otherwise insightful analysis. Furthermore, both Stephens (2013) and Bodwitch (2017) raised concerns about the financialisation of settlements and its impacts on iwi approaches to their kaitiaki responsibilities. The settlements also provided other commercial fishing interests to Māori with the ability for individual iwi settlement rights to be collectively managed and allocated by the Māori Fisheries Commission (now known as Te Ohu Kaimoana) (Māori Fisheries Act 2004).

The Māori fisheries settlement also recognised and enabled the protection of Māori customary fishing rights and their management. This is provided for through the Fisheries (Kaimoana Customary Fishing) Regulations 1998 and South Island Customary Fishing Regulations 1999, which enable locally managed mātaitai reserves—to recognise and provide for traditional fishing through local iwi or hapū management—taiāpure, temporary customary closures or rāhui and restrictions on fishing methods under sections 186A and 186B of the Fisheries Act. However, formal legal and administrative processes to establish these customary management areas are bureaucratic, privilege Western science and Crown retention of power, and provide inadequate funding to support equitable co-management aspirations (Kainamu & Rolleston-Gabel, 2023; Marriott & Alinaghi, 2021; Urlich et al., 2022).

Iwi and hapū Māori have also been excluded from rights and interests in the foreshore and seabed since the British assumption of sovereignty. In 2003, the Court of Appeal recognised that Māori customary title to the foreshore and seabed, in the area between the low-water mark and mean high-water springs, had not been lawfully extinguished and could be recognised by the courts (*Ngāti Apa v Attorney-General* [2003] NZCA 117). After a period of political controversy and uncertainty, in 2011, the government passed the Marine and Coastal Area (Takutai Moana) Act 2011, which provided that the common marine and coastal area—from mean high-water springs seaward to 12 nautical miles—can be "owned by no one" (s 11), but set out the process by which Māori can apply to the High Court for recognition of customary marine title or protected customary rights in the

marine and coastal area—or obtain these in direct negotiations with the Crown. An applicant must prove to the Court that it "holds the specified area in accordance with tikanga" and has "exclusively used and occupied it from 1840 to the present day without substantial interruption"—s 58, the requirements of which were amended to make the test harder to meet in 2025. The process is widely considered unjust and inequitable as it requires Māori to prove, via lengthy and costly court processes, the continuance of their marine relationships that have been unfairly affected by colonisation, that is, Waitangi Tribunal (2020), The Marine and Coastal Area (Takutai Moana) Act 2011 Inquiry Stage 1. Report: prepublication version [WAI 2660].

Crown laws and policies have excluded Māori from legal procedures, obstructing their use, ownership and receipt of benefits from coastal land and resources. Even gains from recognition of Māori customary rights in the marine and coastal area under the Marine and Coastal Area Act is under threat, as the current (2026) coalition government moves to limit the scope for recognition and overturn the decisions of the courts (Cheng & Gabel, 2024). However, the High Court recently declared in *Te Ohu Kaimoana v Attorney-General* [2025] NZHC 657 that it was a breach for the Crown to appropriate settlement quota from Māori under the Fisheries Act 1996 without providing redress that preserves the value of the quota acquired as part of the 1992 settlement. The High Court reasoning emphasised that "Treaty settlements are steps towards reconciliation, the restoration of mana and the putting right of historic wrongs."

3.3.2 Further Encroachment on Māori Rights and Interests

As well as directly appropriating Māori rights to coastal lands and resources, Crown authorities have further encroached into Māori cultural and economic livelihoods through the imposition of resource management and conservation laws and policies (Bodwitch, 2017; Bodwitch et al., 2022; Sullivan, 2017). Land use change and development intensified after settler encroachment into Māori coastal territories in the 20th century, as coastal settler landholders began to transition farming land into holiday homes (Carter, 2018; Pearson, 2021; Xie et al., 2025). Originally, with no planning or regulation, these coastal developments went unabated (Carter, 2018), but in the mid-20th century, the government passed the Town and Country Planning Act 1953 and in 1968 established the National Development Council to oversee coastal developments (J. E. Morton et al., 1973; Peart, 2009). The subsequent Town and Country Planning Act 1977 was the first piece of legislation to recognise the relationship between Māori and their culture, traditions and ancestral lands. It was followed by the Resource Management Act 1991

(RMA), which delegates resource planning and consenting—including in the coastal marine area—to regional councils under the overarching objective of promoting the "sustainable management of natural and physical resources" (s 5).

The RMA includes some obligations to Māori (Jacobson et al., 2016; J. Reid & Rout, 2020), including that decision makers are to "recognise and provide for" the relationship of Māori, their culture and traditions with their ancestral lands, water, sites, wāhi tapu (sacred sites) and other taonga (treasures) (s 6), "have particular regard" to kaitiakitanga (s 7) and "take into account" the principles of the Treaty (s 8). The RMA also provides for a number of potential collaborative governance mechanisms that could be utilised to involve Māori in marine governance and planning; however, these have not typically been employed in marine environments, and decision makers are generally considered as failing to fairly collaborate with Māori in resource management (Macpherson et al., 2023).

To highlight Māori agency within marine governance and in the exercising of rangatiratanga, hapū in Northland demonstrated adaptation of statutory tools under the RMA, to uphold customary principles when legal mechanisms for rāhui proved insufficient (Stephens, 2013; Urlich et al., 2022). Similarly, Te Ohu Kaimoana's stewardship of pan-iwi quota rights reflects a strategic assertion of collective Māori interests within the commercial fisheries framework, even as tensions with place-based hapū reveal the complexity of self-determination in a plural governance landscape (Bodwitch, 2017). These examples illustrate that Māori are not passive recipients of policy but active agents navigating and reshaping regulatory systems to maintain authority over marine resources. However, we note here that the RMA is proposed to be replaced in 2026 with two new pieces of legislation: the Natural Environmental Bill 2025 and the Planning Bill 2025.

In the absence of recognised authority for resource management in marine and coastal areas, Māori have continued to practise kaitiakitanga and tino rangatiratanga (J. Reid & Rout, 2020). An example is the rāhui placed on the Mōtū River on the east coast of Aotearoa by Te Whānau-ā-Apanui iwi since 1900, following the tragic drowning deaths of 16 children and two adults. The rāhui was implemented to allow the river to wash away the associated impurities of the tragedy, as well as allow a spiritual pause for all associated with the accident. Since the establishment of the rāhui, the river has been closed to the public every Saturday and on the 12th day of each month as a memorial of the tragedy

and to allow the river time to rest from all activities. It is also closed to fishing each year from 1 June to 1 November, a period known as huamata (the traditional time for planting and harvesting). The Mōtū River is revered as a sacred place or pātaka kai (food pantry) for the iwi (Maxwell & Penetito, 2007; Trotman & Rāpihana, 2022). What makes the Mōtū River case effective, despite any formal conferral of legal authority by the Crown, is the education and regulation by locals to inform users and their voluntary compliance with the rāhui (Trotman & Rāpihana, 2022).

Marine conservation law and policy is largely led by the Department of Conservation, which must also be consulted in the preparation of regional and coastal plans by local authorities (Macpherson, 2023). Aotearoa's conservation laws have had the effect of further enclosing Māori out of their traditional marine relationships. Specifically, Māori have been excluded in various ways from accessing, fishing or collecting resources across a range of MPAs, which are typically located along small terrestrial edges of the coast and restrict certain activities (such as commercial fishing and mining) in the area, but allow other activities (such as recreational fishing) to occur (W. J. Ballantine & Langlois, 2008). These include a range of marine parks and reserves established under the Marine Reserves Act 1971, Marine Mammals Protection Act 1978, Marine Protection Rules (Maritime Transport Act 1994) or other policy (Macpherson et al., 2023).

MPAs are a key concern for Māori, as they may override the rights, access and authority of Māori around the coast (Watson et al., 2021). An example can be seen in the creation of a no-take MPA around Motiti and surrounding islands by the regional council following a series of court cases concerning the relationship between fisheries legislation and the RMA (*Motiti Rohe Moana Trust v Bay of Plenty Regional Council* [2016] NZEnvC240; *Attorney-General v Trustees of the Motiti Rohe Moana Trust* [2019] NZCA 532). The unilateral imposition of this no-take area has the impact of preventing local hapū Ngāti Whakahemo from accessing their traditional fisheries on Motunau Island (WAI 2521, Waitangi Tribunal n.d., p. 141). Their legal title to Motunau had been recognised by the Native Land Court in 1878, and despite the imposition of a wildlife sanctuary around the island under the Wildlife Act 1953, Ngāti Whakahemo were still entitled to enter onto the island to fish, harvest tītī (mutton-bird) and kaimoana (shellfish) and camp (Wildlife Sanctuary (Motunau Island) Order 1969). The no-take MPA was imposed without consultation with Ngāti Whakahemo (Ogden, 2021).

Contentions surrounding MPAs are not unique to Aotearoa. In British Columbia, Canada, similar issues arise regarding the recognition of Indigenous communities as co-management partners in both development and decision-making processes, as well as the acknowledgement of their rights and authority within government-led governance frameworks (Watson et al., 2021).

3.4 Repositioning Respect and Reciprocity

Marine biodiversity continues to decline, and it is clear from the discussion in the previous section that relevant Māori rights and interests have not been adequately respected (Rout et al., 2024). Crown legal and policy frameworks have disregarded Māori sovereignty over their ancestral marine spaces (Bargh, 2016; Joseph et al., 2020) and have concentrated coastal lands and resources in the hands of others.

Indigenous relational approaches to natural resources around the world position nature as an ancestor living and under the care of their related communities, through reciprocating benefits of food, shelter, clothing, adornments and spiritual nourishment (Arstein-Kerslake et al., 2021). Relational approaches reflect the idea that there is no delineation between using and protecting nature.

Mātauranga Māori, through kaitiakitanga practices, provides a significant opportunity to apply Indigenous knowledge of the natural world to contemporary socioenvironmental challenges (Roberts et al., 1995; Rout et al., 2024) in ways that do not polarise environmental protection and use. Kaitiakitanga is increasingly embraced, not only by Māori but also by non-Indigenous allies. One such example is evident in the Trans-Tasman Resources (TTR) case, relating to consents under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, to mine iron sands in the South Taranaki Bight (Macpherson et al., 2021) where iwi such as Ngāti Ruanui and Te Kāhui o Rauru partnered with conservation boards, nongovernmental organisations (NGOs), fisheries groups and other ocean community user groups such as surfers to challenge the consents (Widener, 2018). The coalition emphasised tikanga Māori and Treaty of Waitangi principles, framing seabed mining as incompatible with kaitiakitanga and iwi rights (Wheaton, 2024). Scientific evidence on environmental risks was combined with cultural arguments, creating a strong multidimensional case against mining (Franks Ogilvie, 2024; Macpherson et al., 2021). The outcome was that the Supreme Court unanimously dismissed TTR's appeal, quashing the consent. These alliances challenge entrenched governance structures that are positioned to gain significant economic benefits

as well as shift the conservation discourse within Aotearoa and the wider Pacific (Bambridge, 2016; McCormack, 2011, 2018). Kahui and Richards (2014) argued that kaitiakitanga and other Māori resource management approaches can be used, such as seasonal fishing practices versus all year-round contemporary commercial practices, together with other models such as ecosystem-based management (Joseph et al., 2020) to support sustainable resource use (New Zealand's Biological Heritage Science Challenge Ngā Koiora Tuku Iho, Adaptive Governance and Policy Working Group, 2023). Such an approach does not mean that human resource use is completely excluded, but that impacts on mauri (living essence) are managed, to not compromise the overall ecosystem, thus maintaining the well-being of the community as a whole.

Drawing on comparative studies of marine biodiversity conservation in Aotearoa and Canada, J. Stephenson et al. (2014) showed how the "recognition of Indigenous interests in fisheries management is creating a distinctive 'third space' of biocultural conservation that differs quite radically from the polarising all-or-nothing regime of commercial fisheries vs marine reserves" (p. 257). Degrees of marine protection may be combined with fishing activities in ways that respect Indigenous authority (Chávez et al., 2018). As noted earlier, in a speech at the 2024 UNESCO Oceans Decade Conference, Ken Paul referred to this as a need to move from "marine protected areas" to "marine respected areas" (Paul, 2024).

Enabling te ao Māori, tikanga and mātauranga in marine and coastal relations will require collaboration and sharing jurisdiction with iwi and hapū. When governance is shared, it may be interpreted (among other ways) as giving Māori their own sphere of authority or decision-making power (Joseph, 2022, p. 148). However, embedding such a partnership approach for the governance of marine areas appears elusive, especially in the current political climate where te reo (Māori language) and Te Tiriti o Waitangi are being publicly challenged by the coalition government (Shaw, 2023). Similar challenges are evident in other nations striving for equitable participation. For instance, Vaughan et al. (2017) highlighted that in Hawai'i, achieving meaningful recognition of traditional customary practices would require fundamental institutional change. Central to this process is ensuring that legal frameworks remain flexible enough to effectively accommodate traditional epistemologies and practices.

Even in the current political context, there are glimpses of what marine law and policy that respects Māori rights, interests and authority might look like (Fisher et al., 2022; Rout

et al., 2024). An example can be seen in the restoration project for kuku (green-lipped mussels) within Ōhiwa Harbour, known as Awhi Mai, Awhi Atu (meaning Embrace me, and I will embrace you; Paul-Burke, Ngarimu-Cameron, Burke et al., 2022). This iwi-led research project used biowaste materials, called taura kuku, as biodegradable spat lines, instead of traditional synthetic lines, and explored habitat connection and restoration through Māori science. The project's benefits were observed through another large research project within Aotearoa called the Moana Project, which found, through sequencing of DNA, that the mussel spat from Ōhiwa Harbour was seeding the Whakatōhea mussel aquaculture facility further along the east coast of the North Island (MetOcean, 2024). For Māori, this connectivity of relationships through the ocean emphasises why mātauranga Māori is integral to implementing a kaitiakitanga approach to marine and coastal environments.

Building on these examples, Stevens et al. (2021) further demonstrated how traditional navigation systems reliant on celestial cues, wave patterns and ocean swells offer critical insights for contemporary coastal management by foregrounding deep, relational understandings of the marine environment. Seasonal tohu (environmental signals) embedded within oral traditions and maramataka continue to guide resource use and harvesting cycles, providing a time-tested framework for sustainable and place-based marine practices. Likewise, recent work (Lyver et al., 2024) highlighted mātauranga Māori as an essential foundation for biodiversity conservation, with national workshops confirming that practices such as rangatiratanga and kaitiakitanga are central in shaping Aotearoa's long-term vision for ecological restoration and the Department of Conservation policy direction.

Importantly, for Aotearoa to move beyond exclusionary regimes, an appraisal of how areas are designated, consultation practices, agreement on levels of protection, partnership and power sharing are required to avoid overriding Māori resource rights.

3.5 Conclusion

In this article, we have examined the ways in which marine and coastal laws and policies in Aotearoa have systematically overridden Māori culture, practices, knowledges and relational ways of knowing, being and doing—and privileged other knowledge systems in doing so. This pattern has been entrenched through successive waves of legislation that first excluded Māori rights and interests over marine and coastal spaces and later constrained their ability to exercise authority within their own traditional domains

through conservation and environmental regulation. Yet, despite these structural constraints, opportunities remain to address the persistent deficits within national marine and coastal policy frameworks. Mātauranga-based restoration projects such as Awhi Mai, Awhi Atu (Paul-Burke, Ngarimu-Cameron, Burke et al., 2022) exemplify what becomes possible when Māori resource management and leadership is not only recognised but also empowered. Highlighted are Indigenous innovations, international and local, which are scalable in designing templates for global marine governance reforms that prioritise Indigenous agency and rangatiratanga. However, to preserve the integrity and avert de-contextualisation of Indigenous Knowledges, the dissemination of such innovation must remain Indigenous-led and anchored in place, ensuring that their application elsewhere is governed by the cultural protocols and epistemologies from which they derive.

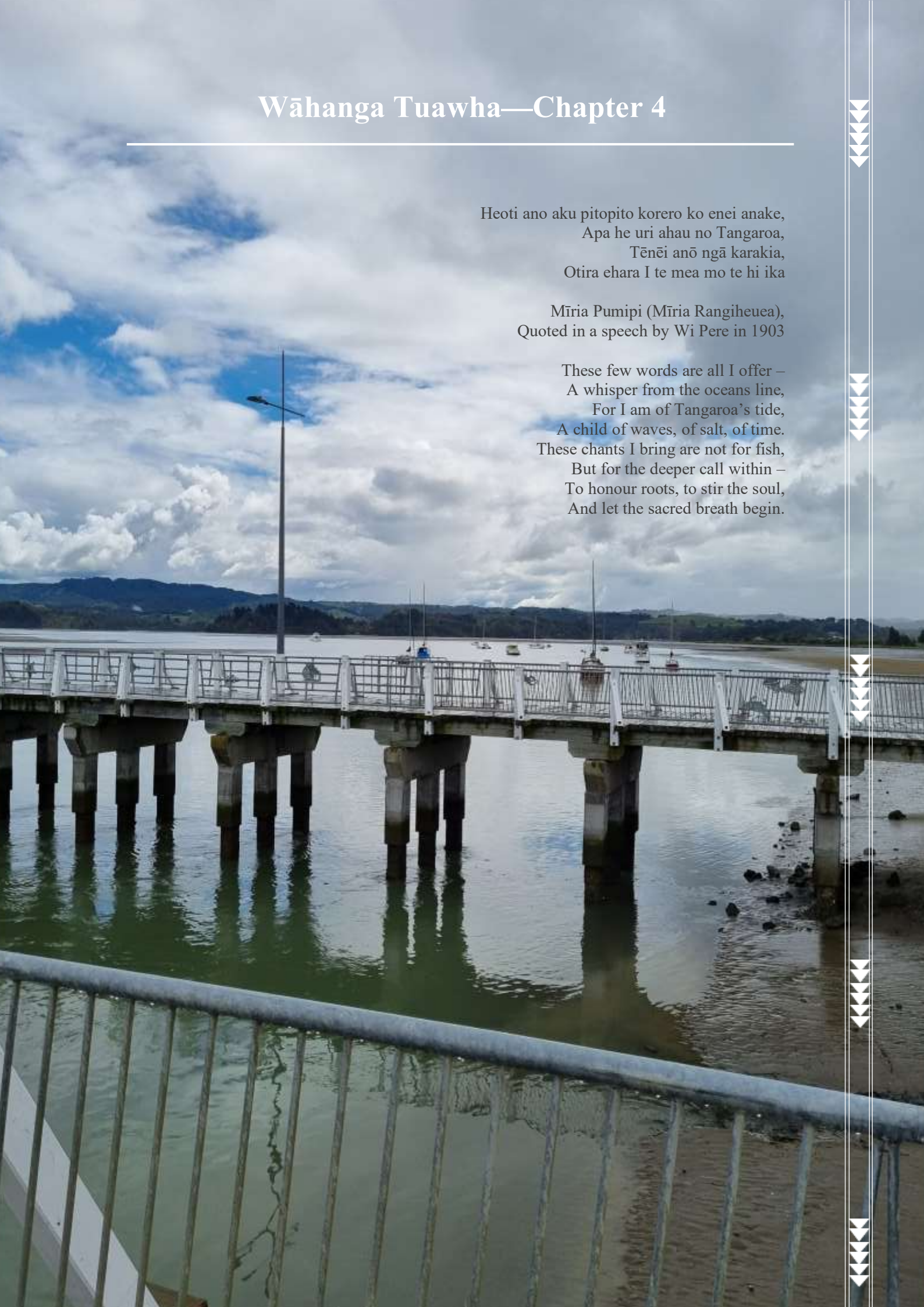
This article advances marine governance scholarship by introducing a new conceptual framing that shifts from a preservationist approach to marine conservation towards marine respected areas. This approach is grounded in Māori relational philosophies—a reframing that is largely absent from existing Aotearoa-focused literature concerning marine conservation—and reorientates marine governance towards reciprocity, responsibility and place-based authority. In doing so, we trace how successive Crown laws and policies have systematically displaced Māori authority in marine and coastal domains while highlighting contemporary Māori innovations—legal, cultural and regulatory—that actively reshape governance structures from within.

Finally, we argue for an Aotearoa-specific biocultural third space that operationalises mātauranga Māori as a governance framework capable of informing transformative pluralistic marine policy—one that reconciles biodiversity objectives with rangatiratanga, kaitiakitanga and enduring cultural continuity. Here we have positioned Māori governance models as transformative rather than peripheral, offering pathways for legal pluralism, co-design and biocultural conservation that move beyond the dichotomy of Western conservation and extractive use.

Emerging partnerships, such as those evident in the TTR litigation case, demonstrate the potential of these approaches to weave cultural, legal and scientific strategies in ways that strengthen recognition of Māori sovereignty and reshape national debates on marine governance (Franks Ogilvie, 2024; Macpherson et al., 2021). While shifts may unsettle established power structures (Clements et al., 2021), Māori have sustained their knowledge tradition, laws and relational responsibilities to the marine environment across

generations, with or without Crown recognition. Indigenously positioned governance frameworks grounded in kaitiakitanga, rangatiratanga and mātauranga Māori offer compelling and durable pathways to marine and coastal futures that harmonise biodiversity conservation and cultural continuity. In asserting the centrality of Māori governance and mātauranga, we chart a pathway towards ocean futures in which ecological integrity and cultural authority are restored together, offering a paradigm shift with enduring national and global implications.

Wāhanga Tuawha—Chapter 4



Heoti ano aku pitopito korero ko enei anake,
Apa he uri ahau no Tangaroa,
Tēnēi anō ngā karakia,
Otira ehara I te mea mo te hi ika

Mīria Pumipi (Mīria Rangiheuea),
Quoted in a speech by Wi Pere in 1903

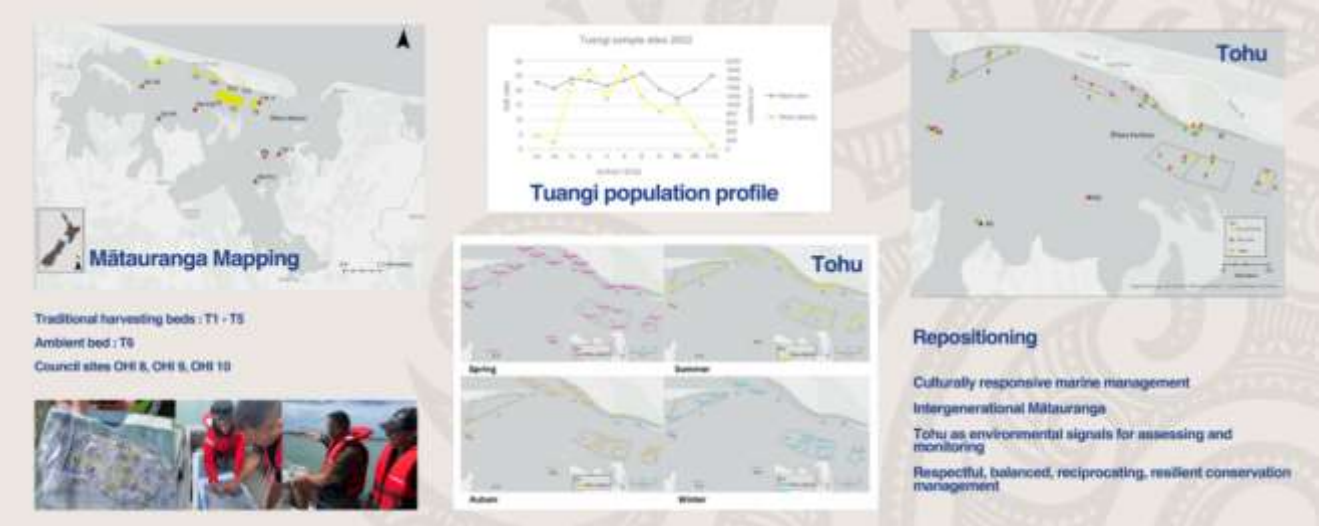
These few words are all I offer –
A whisper from the oceans line,
For I am of Tangaroa's tide,
A child of waves, of salt, of time.
These chants I bring are not for fish,
But for the deeper call within –
To honour roots, to stir the soul,
And let the sacred breath begin.

Wāhanga Tuawha—Chapter 4

Ko Ōhiwa e (Our Ōhiwa), How Weaving Knowledges Is Shaping Marine Research in Ōhiwa Harbour

Figure 10

Visual Illustration of Chapter 4 Outline and Key Concepts



Introduction

Over the last few decades, the continued decline of the world's oceans has garnered international concern. In response, in 2017 the United Nations General Assembly proclaimed a Decade of Ocean Science ('the Ocean Decade'), from 2021–2030 (UNESCO, 2017). This initiative aims to "stimulate ocean science and knowledge generation to reverse the decline of the state of the ocean system and catalyse new opportunities for sustainable development from our oceans." Its guiding vision is "the science we need for the ocean we want," reflecting an urgency to align diverse knowledge, practices, policies and governance models to address oceanic degradation. While this declaration has mobilised international efforts, this urgency is particularly felt in the Pacifica and Oceania, including Aotearoa. Here, the Sustainable Seas National Science Challenge (2014–2024) centralised experts from across disciplines and cultures within Aotearoa and internationally, to reimagine ocean stewardship (Sustainable Seas, 2023). This decade-long research initiative focused on transforming prevailing understandings,

practices and resource-use models to support regeneration of marine ecosystems and uphold the wellbeing of the oceans (Sustainable Seas, 2023).

Contemporary conservation governance, practices and processes are continually evolving in response to the rapid complex changes affecting our environments; most notably, the degradation of habitats and ecosystems that are fundamental to human wellbeing. In the face of the current ecological crisis, there is growing demand for solutions that are both responsive and inclusive solutions that genuinely reflect and integrate diverse perspectives (Alexander et al., 2019; Parsons et al., 2025). However, even with the increase in calls for a more visible presence of Indigenous voices within conservation practice, uptake remains prolonged (Turnhout et al., 2012).

Figure 11

Modified Tīwaiwaka Framework to Show Principles Discussed in This Chapter

The preface of this chapter situates my second peer-reviewed article; once again, this forms the core content of the chapter. Here I contemplated how Principle 4: Kotahitanga, defined earlier in this thesis as "connecting people over a cause, place, environment" in an effort to "prompt co-operation and reciprocation" (Nepe, 1991) p.77, can emanate as

a kaupapa Māori-based principle in implementing research. My aim here was to bring together the participants and hapū around the shared purpose of exploring the best ways to evaluate and plan for future restoration of tuangi. Gathering of the research data was done based on our kaupapa Māori research values, No 1: Aroha ki te tangata (respect for people) for the hau kainga (people of place) (EvalIndigenous, 2024; Katoa Ltd, 2024) who willingly shared their knowledge with me in mapping out the traditional harvesting beds. This in turn was reciprocated (utu, to maintain balance in our relationship and the giving back of the shared generosity) once I had results, by sharing my findings with them. This happened on 23 September 2025, prior to any public information being released. Another example of the kaupapa Māori research values used is in No. 2: Kanohi kītea (present yourself to the people) (EvalIndigenous, 2024; Katoa Ltd, 2024), which was followed at the beginning in our first initial meeting and throughout the research process, as mentioned above in September 2025. These intrinsic kaupapa Māori guidelines embody kotahitanga in practice within Māori communities. They can also be extended to our wider collaborations; for example, engaging with BOPRC staff to understand what research information would be most useful to them and what they would share with me. Kotahitanga, at its core, indicates this described unity.

The second principle I discuss here, woven throughout every aspect of this research, is mauri—described in detail in the methodology chapter as the interweaving of connections among all living things to ensure that our focal species, habitat or place can thrive (Apiti et al., 2024; Harmsworth & Awatere, 2013). Mauri encompasses all forms of connections within the physical, spiritual and mental realms. As Indigenous peoples, our responsibility to Papatūānuku or Mother Earth is centred on safeguarding mauri, the life force that sustains the interconnectedness of all living things, so that every being can thrive.

In the following published manuscript, the scene is first set with Ōhiwa as an eponymous living ancestor, deeply cherished and held in high regard by local tribes, Ngāti Awa, Te Whakatōhea and Ngāi Tuhoe. This reverence has endured since their earliest occupation of the area and is reflected in the many names they have for the harbour, as well as in their pūrākau, moteatea and waiata.

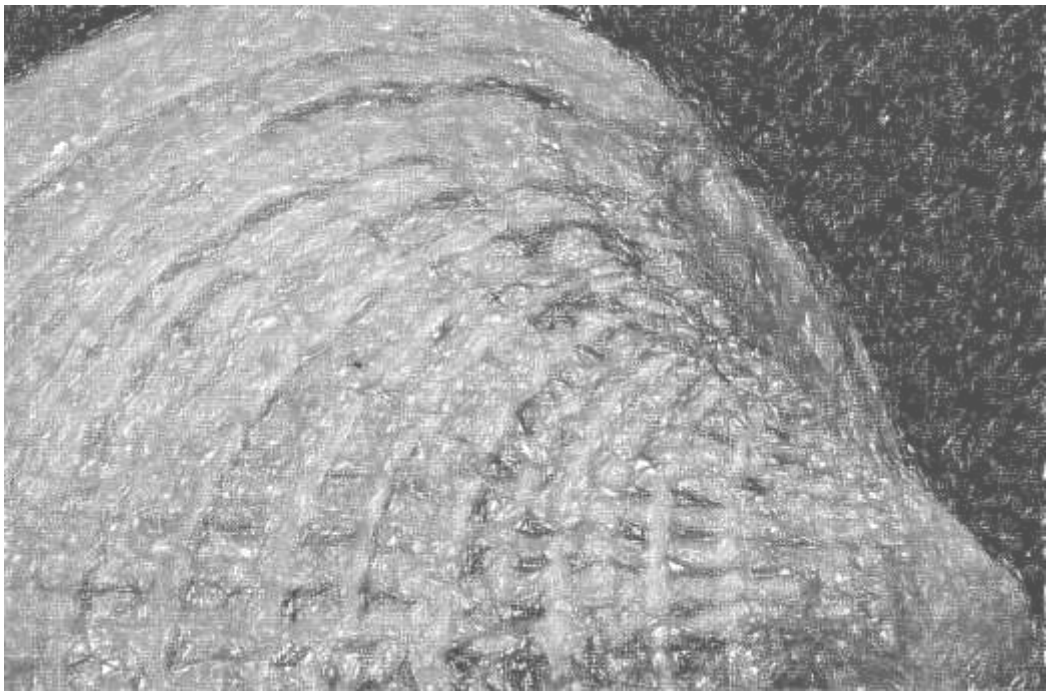
I then use the tīwaiwaka framework and the MEB methodological approach of the knowledge systems, mātauranga Māori and marine sciences to gain a deeper understating of emerging Indigenous-led NRM. To appreciate the historical and contemporary health of tuangi in Ōhiwa, I examined changes over time leading to their present state. I drew

on mātauranga Māori shared through interviews with Ngāti Awa and Whakatōhea kaumātua to construct a historical narrative of the shifts they had observed. Within the narrative, we see how the degradation of the harbour has affected local tribes through the loss of food sources, cultural practices and the erosion of mana, caused by the inability to uphold manaakitanga. These concerns ultimately led to the establishment of the ŌHIF to co-govern this taonga.

I then mapped the Ngāti Awa traditional harvesting beds and surveyed the associated tohu (environmental signals) including manu (birds), barnacles, sea anemones and red and green algae. Drawing also on marine sciences, I assessed tuangi populations, their profiles, density, abundance and biological health based on these key metrics.

Via this work, I provide a strong case for culturally responsive marine management with emphasis on the value of international knowledge. I provide a scalable example that has potential international impact. One of the reviewing editors for this article, submitted to the *UN Decades Special Edition: Indigenous Oceans Technologies Practice* and the *Journal of Oceans Technology* Winter Edition, offered the following feedback:

> REV 490: This is a truly exceptional paper in that it represents a tangible example of precisely how transdisciplinary knowledge co-development is done correctly. Although a discrete study focused on a relatively small area, the impacts of this paper could be profound.



Ko Ōhiwa e (*Our Ōhiwa*), How Weaving Knowledges Is Shaping Marine Research in Ōhiwa Harbour.

4.1 Introduction

He atua,	*She is godly,*
He tipua,	*She is ancient,*
He kaiwhakaora,	*She is the giver,*
He kaiwhakamate.	*and taker of life.*
He tauranga.	*She is safe harbour.*
He kainga.	*She is home.*
Taku Moana e hora nei,	*This harbour that lays before us,*
Ko Ōhiwa e.	*Our Ōhiwa.*

Ko Ōhiwa e, Ati Teepa, 2023. Full version in Appendix D.

Reihana, K., Paul-Burke, K., Ellis, J., Bulmer, R., Burke, J., O'Brien, T., & Bluett, C. (2025). Ko Ōhiwa e (our Ōhiwa), How weaving knowledges is shaping marine research in Ōhiwa harbour. *Journal of Ocean Technology*, *20*(4), 82.
DOI: https://doi.org/10.48336/P8KD-0T92

Complementarity of knowledge systems is a notion that has been emerging in NRM, conservation, and preservation globally over the last few decades (McGregor, 2013; Mistry & Berardi, 2016; Tengö et al., 2014; Winter et al., 2021). Indigenous Knowledges, once suppressed and oppressed, are now increasingly recognised as equitable and valuable knowledge systems (Drake et al., 2023; Paul-Burke et al., 2018; Tengö et al., 2014; Wheeler & Root-Bernstein, 2020; Yanou et al., 2023). As a result, they are being incorporated into NRM and conservation programmes and projects internationally. The value of Indigenous Knowledges is widely recognised in international scholarship (Bates, 2007; Hauser et al., 2023; Muashekele, 2018; Ntiamoa-Baidu, 2008). In Aotearoa, it is understood that the union of mātauranga Māori and marine sciences (biology and ecology) knowledge systems is creating dynamic place-based responsive solutions to culturally important marine species and spaces (Drake et al., 2023; Paul-Burke, Ngarimu-Cameron, Paul, et al., 2022; Wheeler & Root-Bernstein, 2020). The United Nations Decade of Ocean Science, which aims to reverse the decline of the current state of our ocean, details

the contribution of Indigenous sciences as a key factor in meeting sustainability targets, as seen here in Objective 3.2.6 (UNESCO, 2023):

> Indigenous science is disciplined and uses practices of observing, hypothesizing, etc. which all fit the definition of 'science.' The difference between Indigenous science and academic science may be in the way Indigenous wisdom keepers and knowledge keepers transfer their knowledge and wisdom. Indigenous communities therefore have a historic baseline and unique approaches for understanding ecosystem and environmental change.

The introductory poem *Ko Ōhiwa e* by Ati Teepa (2023) identifies Ōhiwa Harbour as a living being and ancestress to the local iwi, Ngāti Awa, Whakatōhea, and Ngai Tūhoe. Ōhiwa has a long history of ancestors who stood in this place, including Māku who observed it as the place where the sharks come to spawn so called it Te Kopu o te Ururoa (the womb of the great shark). Another ancestor to reside on these shores according to Ngāti Awa was Awanuiārangi I, and thus it became known as Te Ōhiwa o Awanuiārangi II after his son. Further generations acknowledged a prominent ancestor named Tairongo who arrived from Rapanui (Easter Island) and intermarried with the descendants of the Mataatua waka (canoe) (Waka Huia, 2010). Tairongo acknowledged the harbour as a significant food basket able to nurture the people into the future. As a result, the harbour is also known as Te Moananui-a-Tairongo (the large or plentiful ocean of Tairongo), Te kete kai a Tairongo (the food basket of Tairongo), and Te umu tao noa a Tairongo (the food oven of Tairongo) (BOPRC, 2021b; Te Rūnanga o Ngāti Awa, 2019; Whakatōhea, 1993).

The key cultural values that tie these tribes to Ōhiwa are whakapapa (Te Rito, 2007) and tūrangawaewae (standing ground, where one has the right to stand and occupy) (Kēpa, 2007). These concepts entrench the connection to places and the rich history associated with them through generations (Cheung, 2008; Marsden, 2003).

Interwoven into the above values are other specific tenets associated with genealogical ties to place, such as ahi kā (those who keep the home fires burning) through visible land occupation, tangata whenua, and mana whenua (Indigenous People who hold historical and territorial authority for the land) (Apiti et al., 2023; Kēpa, 2007; Te Rito, 2007). These concepts exemplify the importance of whenua and our inherent responsibilities as Māori to ensure the well-being of the natural world and its resources for the following generations (Apiti et al., 2023; Jefferies & Kennedy, 2009; Skipper, 2020).

Complementary to kaitiakitanga is manaakitanga onto your tūrangawaewae. As a display of a tribe's mana (authority, status, influence, spiritual, or supernatural power), locally sourced food delicacies are part of the act of manaakitanga (Rameka et al., 2022; R. Walker, 2004). Providing visitors with the same food that sustained the ancestors is a tangible acknowledgment of the tribes' abilities to have cared for the environment through to modern times. However, a lack of access to tribal food resources is a woeful example of degradation, colonisation, and a loss of mana (Kaa & Willis, 2021; R. Walker, 2004) .

In response, Ngāti Awa have been active in reclaiming kaitiakitanga over their harbour for several decades (Paul-Burke, 2011; Paul-Burke et al., 2010, 2018; Paul-Burke, Ngarimu-Cameron, Paul, et al., 2022) (Figure 12) as a traditional mahinga kai (uncultivated food harvesting grounds). Ōhiwa Harbour is unique in that it is governed by a nonstatutory board—the ŌHIF, where the three tribes are equitable partners with the three local authorities (BOPRC, 2021a) in the management and maintenance of the harbour's natural resources. This nonstatutory body is tasked with the responsibility of Ōhiwa future sustainability and value as a living entity to the surrounding community (BOPRC, 2021a; EBOP, 2008). However, for many years, the iwi partners have consistently voiced strong concern at the declining state of shellfish in the harbour, including the tuangi, which are recognised as a significant taonga (EBOP, 2008; Johnson, 2012; Te Rūnanga o Ngāti Awa, 2019; Whakatōhea, 1993).

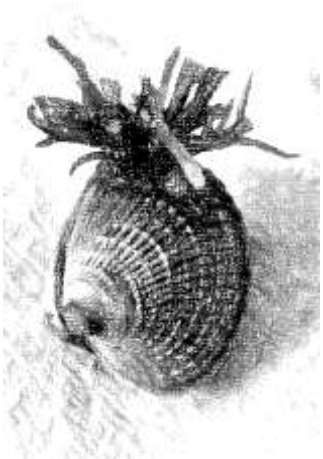


Figure 12

Location Map of Survey Sites, Tuangi Count and Size Class Trays, and Mapped Survey Sites.

Note: (top) An example of the stratified-random mapping of sampled tuangi beds within a traditional harvesting location, with live survey collections for size, counts, and sediment samples. (bottom) Study sample beds (T1a, T1b, T1c, T2, T3, T4, T5—traditional harvesting beds—and T6—ambient site) and council sampling sites (Ohi P8, P9, P10) monitoring data used in this research, as well as the site marked PA with a red dot indicating the monitoring sites referred to in Pawley (2012).

4.2 Methods

The methods used in this research are a kaupapa Māori-led mixed methodology, using mātauranga Māori and marine ecological science methods. All research was premised on Māori ways of being and interacting within the natural world; for example, maramataka (lunar calendar) was used to determine appropriate times to conduct activities within the marine environment, under the appropriate environmental domain deity of Tangaroa. These are described in more detail below. The research methods are delineated into three parts. Part 1 focuses on qualitative mātauranga Māori interviews on informed traditional harvesting bed locations and observations through time of the species. In Part 2, tohu surveys are the observations over a year to correlate with the wider ecological connections and signals within the environment of the harbour. Part 3 is the quantitative marine sciences field survey methods looking at sediment characteristics, size class, abundance, and density.

4.2.1 Part 1 Qualitative Interviews

Mātauranga Māori mapping was previously conducted by Paul-Burke (Paul-Burke et al., 2018, 2020) with Ngāti Awa kaumātua identifying intergenerational ecological information about shellfish (in particular, kuku, *Perna canaliculus*, green lipped mussels) in the harbour. However, the previous research did not identify specific information on tuangi. Therefore, this research study sought to engage with Ngāti Awa kaumātua to understand Traditional Knowledge of tuangi population dynamics over time and space in the harbour.

Ngāti Awa kaumātua and chair Tuwhakairiora (Tu) O'Brien was interviewed in 2021 on the locations of the traditional tuangi beds, then taken out into the harbour to map them (Paul-Burke, Ngarimu-Cameron, Burke, et al., 2022; Paul-Burke, Ngarimu-Cameron, Paul, et al., 2022) (Figure 12).

In a separate study with Whakatōhea Elders, a workshop was conducted to assess the enduring impact on mauri in the Whakatōhea rohe (region) in 2022. The kaumātua and tribal community examined what impacted mauri from the broader natural landscape encompassing Ōhiwa Harbour. The Whakatōhea community identified a nexus of events that impacted mauri of the iwi and rohe moana (sea territory) over time, including Ōhiwa Harbour.

Key quotes, statements, and metrics derived from these interviews were then analysed using NVivo 1.3 to understand the general themes discussed. Word clouds identified the

most common words and the frequency. These themes were then synthesised into descriptive statement groups and modelled in Sankeymatic (https://sankeymatic.com/build/) to visualise sentiment changes over time. To identify patterns in key themes and principles, automatic coding was divided into three time periods: pre-1900s, 1900s, and post-1900s. These three eras had the most poignant impact on Māori communities in multifaceted ways. The statements were then themed into adverse (or negative) and optimistic (or positive) sentiments of impact on the environment and Māori cultural practices.

4.2.2 Part 2 Tohu (Environmental Signals) Surveys

Kaumātua identified seven locations for the traditional harvesting beds. In the field, delineation of the beds was undertaken, and the extents were GPS marked for distribution mapping and surveying (Figure 12).

Field surveys were generated from randomised grids across the beds. Mapped shellfish beds were overlaid with 5 m x 5 m plots on GIS maps. These plots were numbered and then processed with a randomised selection software picker (https://miniwebtool.com/random-picker/). Plot sites were assigned numbers across the extent of the mapped beds (Figure 12). Each grid had a randomised sample location within it, which was GPS located.

The known tohu associated with tuangi is the tōrea pango (black oystercatcher (*Haematopus bachmani*) bird, so observations of these were noted at each site. Here we have chosen to use "signal" as the definition of tohu as a deliberate or automatic transmission of information, often considered in triggering a response. In this context, it is a dynamic, functional, and purposeful signal of a state within nature, a signal of sediment type, or location of sizable tuangi specifically in this study.

All sampling for tuangi and surveying collection was determined by the maramataka, which focuses on monthly moon cycles. Historically, and as a reviving practice of today, the maramataka was used to guide all aspects of life within Māoridom (Hanara & Jackson, 2019; Hoterene, 2021; H. Whaanga et al., 2022), including daily activities such as planting, harvesting, fishing, and hunting.

4.2.3 Part 3 Field Survey

Survey sites were in the traditional bed (TB) areas identified by kaumātua in the mātauranga Māori mapping part of this study. Each bed was identified as a site (T1a, T1b,

T1c, T2, T3, T4, T5, T6); see full site reference in Figure E1 (Appendix E: Supplementary Material, Chapter 4). The initial sample design consisted of a 5x5 m grid overlaid on the mapped area (Figure 12). This area was then randomly stratified and systematically labelled and sampled at the given locations. Sampling protocols for tuangi were based on the benthic ecology protocols from BOPRC surveys (Pawley, 2011, 2012).

4.2.3.1 Sediment Cores (Grain Size) and Population (Sizing and Abundance).

Sediment cores (13 cm diameter x 15 cm depth) were collected and ranged from three to 16 cores based on site area. Sediment samples were passed through a 5 mm mesh sieve to separate target animals. Tuangi were retained, size classed, and counted for abundance. Sediment samples were taken and analysed for grain size.

Tuangi were size classed and allocated as juvenile, adult, and harvestable adults as follows (Taiapa et al., 2014; Williams et al., 2006):

Shell Length Classifications.

Juvenile: 0–4.99, 5–9.99, 10–14.99, 15–19.99
Adults: 20–24.99, 25–29.99
Harvestable adults: 30–34.99, 35+

Tuangi sizes were recorded for each specimen. The shell length (maximum distance on the anterior–posterior axis), the shell height (maximum distance on the dorsal–ventral axis, across the umbo), and the shell width (maximum length on the lateral axis between both valves of the closed shell) were measured with a digital calliper to the nearest .01 mm. Population size structure was then summarised in graphs for comparison (Figure E2).

Sediment particle size was determined on samples that were predigested (10% hydrogen peroxide for 48 hours) to remove organic matter and dispersed using a Calgon solution. Subsequent samples were sized with a Malvern Mastersizer 2000 lasersizer, a laser diffraction particle size analyser. Subsequently, percentage volumes for sediment fractions (gravel; coarse, medium, and fine sand; silt; and clay) were determined on particle size > 63 μm.

Shellfish densities were calculated on the mapped bed parameters (the total bed area). Core animals were counted, and a mean core density was calculated. The estimate of the mean population size is the sum of the weighted averages from all cores. The coefficients of variation are estimated as the standard deviation of the unweighted means of all the

cores divided by the root of the number of cores in a bed area. Abundance of cockles was calculated by mean density rate/m² (Figure E3).

4.2.3.2 BOPRC Sediment and Shellfish Survey Data. Previous sediment and shellfish survey information conducted by the BOPRC (December 1990 to December 2012), which displayed vicinity spatial surveys, was included with our datasets to extrapolate trends over time.

4.3 Results

4.3.1 Mātauranga Māori Interviews and Mapping

In 2021, the traditional tuangi harvesting beds identified by Ngāti Awa kaumātua were mapped (T1a to T5; Figure 12), with a combined total area of 439,949 m². The ambient bed (T6) had a total area of 128,035 m² (see Table E1). The sampled sites (SS) are shown in Figure 12. The BOPRC long-term monitoring data that were used (1990–2021) were in the vicinity of our traditional harvesting beds, Ohi P8, Ohi P9, and Ohi P10 (P8, P9, and P10).

Changes over time and observations from the Ngāti Awa interviews (Paul-Burke et al., 2010) and Te Whakatōhea mauri workshop found that Mr. M. Rangihika, Ngāti Pūkeko (1987), recalled "Shellfish such as mussels, pipi, cockles, and oysters were harvested from Ōhiwa Harbour, prior to the oyster farm being built or seeding of mussels in the harbour" (Paul-Burke et al., 2010).

Following is a selection of interview quotes speaking of the abundance within the harbour and the changes over time:

1930 to 1940s

"Muka nets were used on the Ōhiwa Harbour floor to catch shellfish."

"Sharks were known to leave their young within Ōhiwa, pipi tuangi and oysters were harvested from here."

1960s to 1980s

"Abundance of kaimoana, koura, pāua, kina, mussels, toheroa."

"Koura—freediving or by hand they were so abundant."

"Free diving in lagoon getting huge amounts of kina, parore en masse and took hundreds home for the people."

1990s to 2000s

"Fish species now fished were kahawai, tamur, tarakihi and gurnard. Shellfish include paua, reduced size limits mussels, pipi, koura, and titi being purchased outside the rohe as stocks are low to nonexistent."

"Mussel bags—now take more than 30 minutes to fill a bag."

2000s to today

"Bringing forth kaitiaki to start being active within the marine environs again."

"Bring in more rāhui to help with species recovery as a means for fishing management."

The Whakatōhea hui included similar statements that the harbour "had a diversity of shellfish, pipi, tuangi and kuku, etc.," "there were multiple coloured kaimoana shells," and "our kaimoana was flourishing" (anonymous participants) (K. Morgan, 2022).
A selection of the quotes speaking on the changes they observed include:

1950s to 1960s

"Road infrastructure development, increase in farming and forestry practices impacts on Whakatōhea harbours and waterways, infilling from silt dramatically increases."

"Plenty of kai [food] around Awakino, Opape."

"We had a diversity of shellfish, pipi, tuangi, and kuku, etc., including coloured kaimoana shells."

1970s to 1980s

"Loss of cockle and kuku beds in Ōhiwa."

"QMS [quota management system] is introduced."

"Recreational fisherman outnumbered by commercial. Fish dumping practices start, as excess fish and crayfish washed up on shore from commercial fishermen."

Sentiment synthesis statements and clustering of changes over three time periods are shown in the Sankeymatic visuals (Figure 13). Adverse effects and optimistic views show clear correlations such as the increase in extractive and infrastructure development and the decline in species. Impacts over time and what increased while other aspects declined, such as ecosystem shifts, can be clearly seen in the Sankeymatic visualisations.

Three other commensalisms (living on the tuangi) tohu were observed. These were the red algae (*Chondracanthus chapmani*) and some small marine filamentous green algae (*Cladaphora*), barnacles (*Cirripedia*), and anemones (*Actinaria*), which are in a mutual relationship within the habitat of tuangi (Cook, 2010). (The algae family were recorded as a singular species.)

Maps shown in Figure 14 represent tohu presence at all sites sampled between December 2021 to June 2023. A lower presence of manu (birds) was noted in the winter months (June to August) at 50%, with autumn (March to May) at 66%, spring (September to November) at 70%, and summer (December to February) at 100% coverage. However, TB sites identified no manu presence in winter on the shore sites. The predominant species observed at TB sites were the tōrea (oystercatcher) and karoro (sea gulls). The bird presence was most prolific (100%) over the traditional harvesting beds in the summer months.

From the mud and sand composition, Table 2, all TB sites and site P8 had all three commensalism tohu present, with algae present in only five of the correlating sites. Of the 12 TB sites, 10 had sea anemones present, as well as P8; barnacles were present at nine sites; algae were present at only five of the commensalism survey sites.

4.3.2 Field Surveys

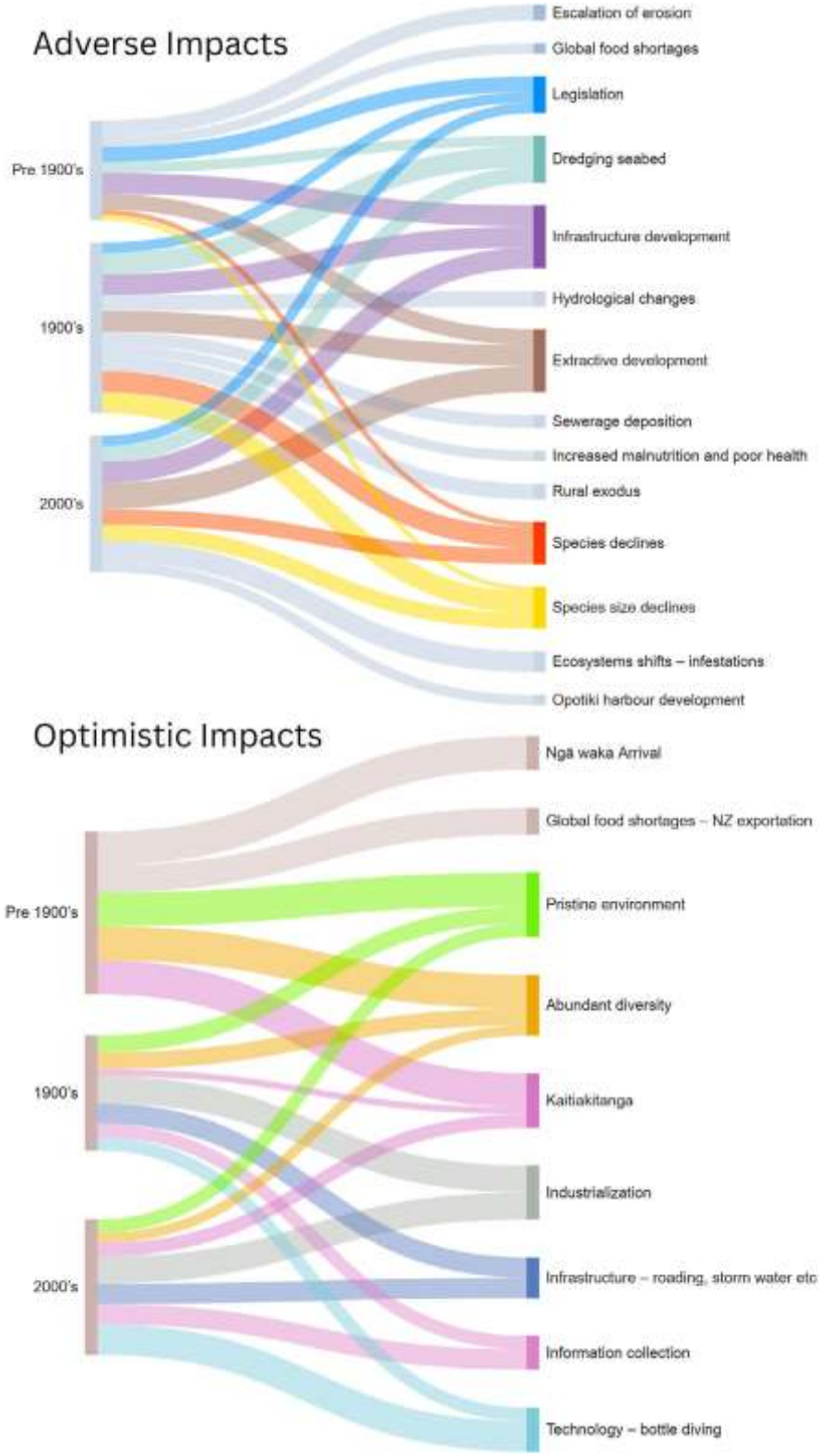
Mud content ranged from .5% to 20%, while Council Sites (CS) ranged from 12% to 16%. Sand content ranged from 80% to 99.5% while CS ranged from 83% to 87%. Sand content recorded the lowest sand ratios compared to the TB (see Table E1).

All CS are located within the edges of channels (Figure E1). These all had lower sand mud ratios, 17% mud to 83% sand, except for Site 2.9, which was also located on the edge of a channel in the TB area. Site 2.9 had a 20% mud to 80% sand ratio.

Organic content averages across TB and all SS were within the range of 2.08 to 3.13 with exception of P10 being the lowest at 1.26, see Table E2 and Table E3.

Figure 13

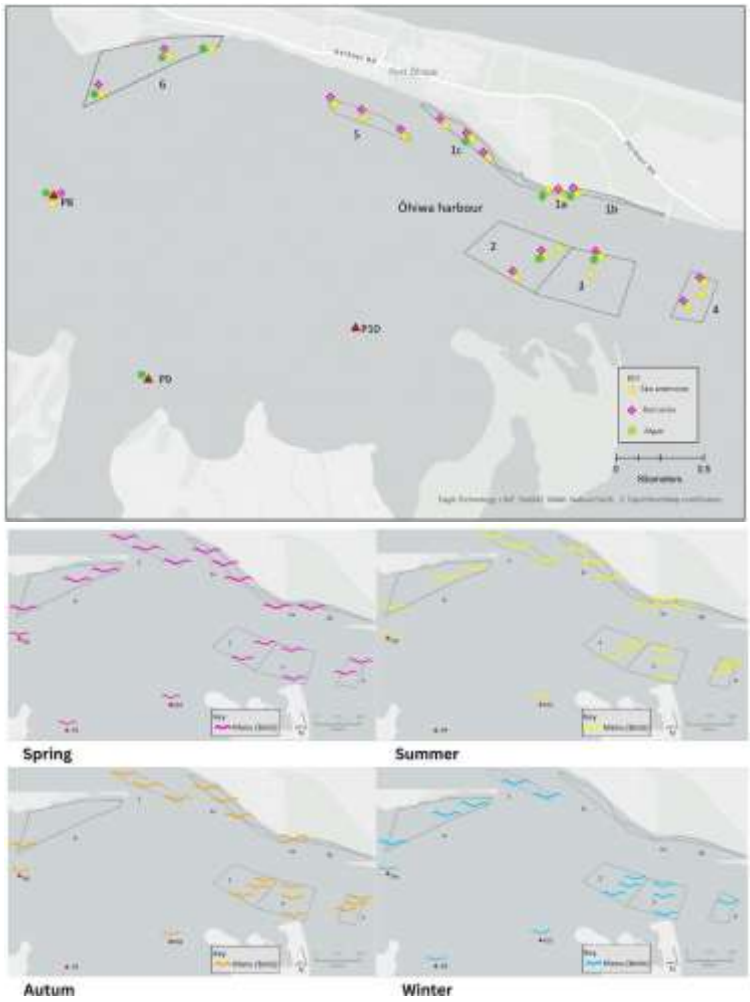
Sentiment Synthesis Statements and Clustering of Changes Over the Three Time Periods



Note: Adverse statements synthesis (top) and optimistic statement synthesis (bottom) from Ngāti Awa interviews Paul-Burke et al. (2010) and Whakatōhea, K. Morgan, (2022). Colour codes indicate synthesised impact statements; impact weight in each era is indicated by line thickness.

Figure 14

Tohu Presence at All Sites Sampled Between December 2021 to June 2023



Note: (top) All commensalism tohu observed across survey sites; namely, algae, barnacles, and sea anemones. (bottom) Maps depicting the presence of the tohu through the seasons from autumn to spring at live sampling sites as indicated by L1, L2, and L3 across each tuangi bed.

Table 2

Mud and Sand Content From Each Sampled Site

Site ID	Algae	Barnacles	Sea anemones	% Mud	% Sand
1a 1	1	0	1	4.24	95.76
1a 2	1	1	1	8.89	91.11
1a 3	0	1	1	7.36	92.25
2 9	1	1	1	20.08	79.92
4 2: L1	0	1	1	0.5	99.5
4 3	0	0	1	0.78	99.22
4 7: L3	0	1	1	5.06	94.94
5 2: L1	0	1	1	2.84	97.16
5 3	0	1	1	3.41	96.59
5 4	0	1	1	4.48	95.52
5 5: L 2	0	1	1	3.85	96.15
5 6	0	1	1	6.68	92.59
OHI 8	1	1	1	12.61	87.39
OHI 9	1	0	0	16.97	83.03
OHI 10	0	0	0	16.14	83.86

Note: Mud and sand content from each sampled site (SS), lowest and highest groupings with correlating tohu (environmental signals) presence.
Colour coding: orange represents a single individual, while yellow is >1 individuals larger than 30 mm recorded at the SS. (L1, L2, and L3 are live sample sites.)

Tuangi sizes from the TB had an average ranging from 17.7mm to 23.5mm, with the largest individuals at TB sites T1a and T5. Tuangi abundance in the TB lowest range was 151/m², with the highest being 1,902/m², and in the ambient bed (T6) 854/m², see Table E2.

Low abundance trends from density/m², shown in Table E3, in Year 1991 at site P8 with 8/m², and in 2000 with 6/m², indicate the bottom variation over time in the CS. The average abundance density/m² is 476/m². There are three low periods in each site over the time series ranging from 6 to 200/m². High peaks from all sites range from 681 at P8 to 1,761/m² at P9. There are two clear positive trends from 2009 to 2016 showing increases from 31 to 1,573/m² at P8. Then there are declines for 2017 and 2018, followed by steady increases again from 392 to 1,138/m² at P10 in 2020. P9 and P10 show declines in 2021 while P8 indicates a continuation of the positive trend at 967/m².

At SS P8, individuals larger than 30 mm were last recorded in 2016; prior to that, the period of 1999 to 2007 consistently had one or more larger individuals. For SS P9, large numbers were recorded in 1991 and 1999, again in 2003, and then nothing until 2020 with one record. At SS P10, consistent levels of singular large individuals have been recorded with the last in 2021, with gaps of 1 to 3 years between clusters of presence reports (Figure

E4, Figure E5, and Figure E6). In the size-class percentages-frequency tables (Figure E5), CS P8 has not had any harvestable tuangi since 2016, with a consistent 4% or less for the previous survey years to 1990. We find similar results for P9 with an unusual 8% falling back to 2% or less for the years going back to 2000; however, in Years 1991 and 1999 surveys, we see that these populations were at an abundant 11% to 23%, respectively. However, the decline from 1991 to 1999 is twofold in the 8-year period. A similar pattern is also observed in site P10 where, from 2021, a consistent 1% to 2% is noted in the peaks and troughs of the data, with two notable spikes in 2006 and 2016 (Figure E3).

Average abundance from CS over the time series was 6.32/m², while the average TB and council SS data was 12.66/m². For the sites T1a to T6 plus the CS P8, P9, P10, sampled for this study, results show abundances of densities/m² in the lower ranges for sites T1a, T1b, P9, P10, which were around 500/m². For sites T1c, T2, T4, the highest densities were recorded, which were 1,500/m² and above. The top sites T1a and P10 had the largest mean size as well as the lowest mean densities.

Based on these datasets (Pawley, 2012), size class averages were 17 to 22 mm, CS ranged from 12.74 to 21.25 mm, and our data size classes ranged from 17 to 23.5 mm; all studies were within range of each other. However, the proportion of these that can be harvested commercially or traditionally, that is tuangi over the legal limit of over 30 mm in size, is only 1%.

4.4 Discussion

Management of estuaries using two knowledge systems is considered beneficial because it helps build long-term resilience in social, ecological, and cultural aspects of local communities.

Dual knowledge systems natural-resource conservation programmes, which are led or co-led by Indigenous Peoples, comprise a favourable approach that fosters collaboration, respects Traditional Knowledge, and enhances the effectiveness of conservation efforts (Delevaux et al., 2018; Prober et al., 2011; Tengö et al., 2014; Winter et al., 2021).

Dawson et al. (2023) synthesised literature on conservation projects across 10 countries, revealing that top-down governance excluding Indigenous and local knowledge negatively impacts social and ecological outcomes, exacerbated by legislation and policy. Their study highlighted the positive effects of including Indigenous Knowledge and participation in governance structures, due to their intimate, localised, and

intergenerational knowledge transfer. This success of ŌHIF exemplifies the benefits of such a model. The results from this study have provided a robust baseline of information on the tuangi in Ōhiwa Harbour, of which Ngāti Awa intergenerational knowledge has been pivotal. The inclusion of tohu such as the tōrea gives insight into locations of interest, which have the potential for scalability across the entire estuarine areas where species and Indigenous Knowledge declines are in parallel. Interactions between intra-species can indicate population fluctuations and changes in habitats or ecosystems. These environmental signals highlight the need for solutions to be place based and specific to endemic species (Delevaux et al., 2018; Turner & Spalding, 2013). Further dissemination of tohu and correlation to the wider context would be beneficial to answer future research queries.

From the pre-1900s to the 2000s, the history of Aotearoa reflects significant changes in culture and NRM. The colonial era saw the establishment of government and infrastructure, leading to the assimilation of Māori into a hybrid society and the detrimental impact of laws on Māori culture and their environment. The 1900s witnessed a dilution of Māori practices, with a steady decline in cultural traditions. Post-1900s, there was a shift toward justice, equity, and autonomy, despite ongoing challenges like property changes and species declines. Throughout these periods, economic opportunities and recollections of natural abundance offered optimism, highlighting the complex interplay of adverse and beneficial impacts over time.

Other anthropogenic modifications that had significant impact, such as land clearing practices from within the catchment area (Yao & Velarde, 2014), contributed to the infilling sedimentation that modified and smothered shellfish beds in the harbour. Sediment loading within the harbour was described as follows: “three times as much sediment accumulates in the harbour relative to natural (pre-European) conditions (1.47 kt/ year versus .47 kt/year)” (Bryan et al., 2023) p.2, with the potential of significant future increases based on modelling predictions. Supporting the notion of increased sedimentation, specifically the muddier content of Ōhiwa Harbour is seen in the analysis of historical studies and current survey data in La Croix (2022). Observed in this study is the dynamic nature and changing of the lagoon area sediments through time; however, correlations were found between mud content and organic carbon in the finer grained sediments that are located around the perimeter of the harbour areas impacting various shellfish resilience (Paul-Burke, Ngarimu-Cameron, Burke, et al., 2022).

Data were collated for comparison against BOPRC time series data (Pawley, 2012) and shown in Table E2 and Table E3. TB mean density/m² in 2020–2021 was significantly higher when compared with Pawley's (2012) survey results from 2005, 2006, and 2009, with a range from 854–1,485/m². The CS P8 was the other site within the TB range with 1,046/m², while the other two CS were 515/m² and 84/m², respectively.

Comparisons across three studies (ours, BOPRC 1991–2021, and Pawley, 2012) show that tuangi are not present at densities or sizes sufficient to support harvesting for cultural or commercial practices. Council records suggest that this has been the case since 1999. Interviews with Ngāti Awa Elders identified these declines as dating back to the early 1980s and earlier. Results from this research showed that the abundance and diversity across species within this harbour have not been seen since the early 1900s and that the harvestable practices that were upheld by Māori did not impact the environment as detrimentally as the accelerated colonial settler impacts. Potential restorative practices that were traditionally used by Māori are viable practices in today's climate, such as rāhui or anthropogenic modifications to support higher yields, or extending the bed area such as in the clam gardens practices from the Kwakwaka'wakw (Indigenous tribe from the Northwest coast of North America) peoples. Traditional Knowledge holders have the advantage of proximity supported by intergenerational knowledge to respond with instant adaptation to their resource management strategies. Their intergenerational modification of clam beds is a traditional practice to enhance productivity and yield. The Kwakwaka'wakw people utilised the varieties of shellfish, including cockles, for subsistence as well as commercial economic trading with other tribes and foreigners. The acute awareness of climatic and ecological changes through proximity ideally places the tribe to respond when conditions or climatic events such as freshets—freshwater flooding from ice melts or storm disturbances—happen (Deur et al., 2015). Berkes (2018) highlighted that small island nations, due to their proximity and ability to respond quickly, can provide rapid feedback on resource exploitation. This capability allows them to review and adjust their response in real time and effectively. For Ōhiwa, this Indigenous response to degradation could hold promise for future considerations.

Although primary drivers of these declines are unclear, interviews indicated several possible scenarios. These include sedimentation from land-clearing practices during the settlement period from late 1880s, among others. These factors align with the marine sciences knowledge on ecological dynamics, as evidenced by the sedimentation characteristics (Bryan et al., 2023; La Croix, 2023; Yao & Velarde, 2014).

Although there was variation in location proximity across three studies, all class comparisons were within a similar range. For densities, we observed that shore-based populations were significantly lower overall compared to the central intertidal beds. Tuangi at the central intertidal TB sites were recorded to be in a healthier condition overall. Our results concur with Pawley and Smith (2014) who stated that less than 1% of total tuangi populations are harvestable in Ōhiwa. This statement remains true today and supports iwi concern over this taonga species.

This research utilised complementary knowledges, both qualitative and quantitative methods, to provide robust information for both iwi and council to inform future decision-making on shellfish management within Ōhiwa Harbour.

Research outcomes for rapid mapping and surveying techniques can expedite areas of interest depending on the ecological, biological, or species-based objectives. The selection of methods, or "method bundles" (Drake et al., 2023), is crucial. Seasonal records of tohu, interconnected with tuangi, can guide rapid future surveys of key areas based on tōrea presence. Survey locations to understand gradients across stratum or tuangi beds can be informed by species-specific tohu, such as barnacles, red algae, and anemones, which also provide insights into hydrological and grain size conditions.

Rapid mapping and surveying techniques are continually being sought and explored. This study identified how these tohu can support and complement other knowledge systems in marine sciences. These methods reflect the "sequencing" or the order in which methods can be conducted, especially if timelines are short and budgets are sparse (Drake et al., 2023).

Future management considerations could include implementing rāhui for tuangi in the harbour, which has not been done before. Additionally, focusing on the time-series data to analyse the impacts and its drivers on these species would also be beneficial. We have outlined clear benefits of bringing together knowledge systems. Local tribal members have raised concerns about the declining state and abundance of the taonga species. By identifying TB locations, surveys were able to rapidly target sites of cultural and ecological significance and identify priority management locations moving forward. Council or authorities can benefit from the rapid mapping techniques identified in this study, as well as the historical data held by Elders within the local community. These methods complement the existing biological data being collected by local authorities.

To better understand the drivers of the tuangi decline and potential recovery solutions, it is essential to incorporate both mātauranga Māori and marine sciences. Mātauranga Māori provides valuable insights into local ecosystems and species, which, when combined with marine sciences methods, can offer a comprehensive understanding of ecological changes (M. C. Gibbs et al., 2024). This integrated approach can help identify specific factors contributing to the decline and inform effective conservation strategies. By identifying TB locations, surveys were able to rapidly target sites of cultural and ecological significance and identify priority management locations moving forward. Explicitly, for Ōhiwa, mātauranga Māori and marine sciences provide a pathway to inform management decision making via the ŌHIF, allowing the co-designed information to be informed by all vested parties from the community.

This research provides an exemplar of the United Nations Declaration on the Rights of Indigenous Peoples (2007) principles, where Indigenous voices lead the research process, Indigenous rights and perspectives are foremost, and international human rights are upheld and reflected through this kaupapa Māori-led research.

4.5 Conclusion

Adopting a complementarity approach by weaving various knowledge systems can enhance our understanding and management of tuangi, leading to improved mahinga kai and estuarine environment outcomes in Aotearoa. Interviews and environmental tohu data have highlighted key information that contributes to understanding the biology and context of the tuangi assisting in the broad scale mapping of Ōhiwa Harbour. These holistic insights can better inform research questions relevant to local iwi.

Key benefits from this research are rapid insights into ecosystems and species, which offer a comprehensive and holistic overview of ecological change within Ōhiwa. Expediting mapping and surveying techniques, while identifying the range of techniques that would be most beneficial are also identified (Drake et al., 2023). Extending what can be used in the suite of methods is providing science excellence in our research programmes. Using mātauranga Māori and tohu or environmental signals, which indicate species changes and inform rapid surveying techniques, cannot be underestimated. Tohu used as indicators of habitat characteristics can rapidly identify stratum gradients without substantial heavy and intrusive equipment in the substrata.

These practices can rapidly address gaps in biological data that are often present in isolated research approaches. Terms like bridging, weaving, co-creating, co-development,

and co-management are becoming more common in our current marine research areas. For Māori, it is essential that these relationships are founded on long-term, respectful, and reciprocal cultural principles embedded in a te ao Māori worldview. These principles are inclusive and embrace knowledge systems that align with the fundamental ethos of kaitiakitanga. For Māori, these tenets ensure a future-proofed, sustainable use of the environment, allowing all inhabitants, both human and nonhuman, to coexist harmoniously on this Earth. Our study highlights that prioritisation of Māori knowledge in NRM can significantly help halt the biodiversity crisis.

Wāhanga Tuarima—Chapter 5

Karikari kirikiri takutai e, Kimihia kimihia he kai e,
He tuangi, he tuangi ka rawe e, Mo te puku nui o Māma e.

Digging, digging the sandy shore, Searching, searching for
food once more, Cockle, cockle what a delight!
For Mum's big belly, a tasty bite

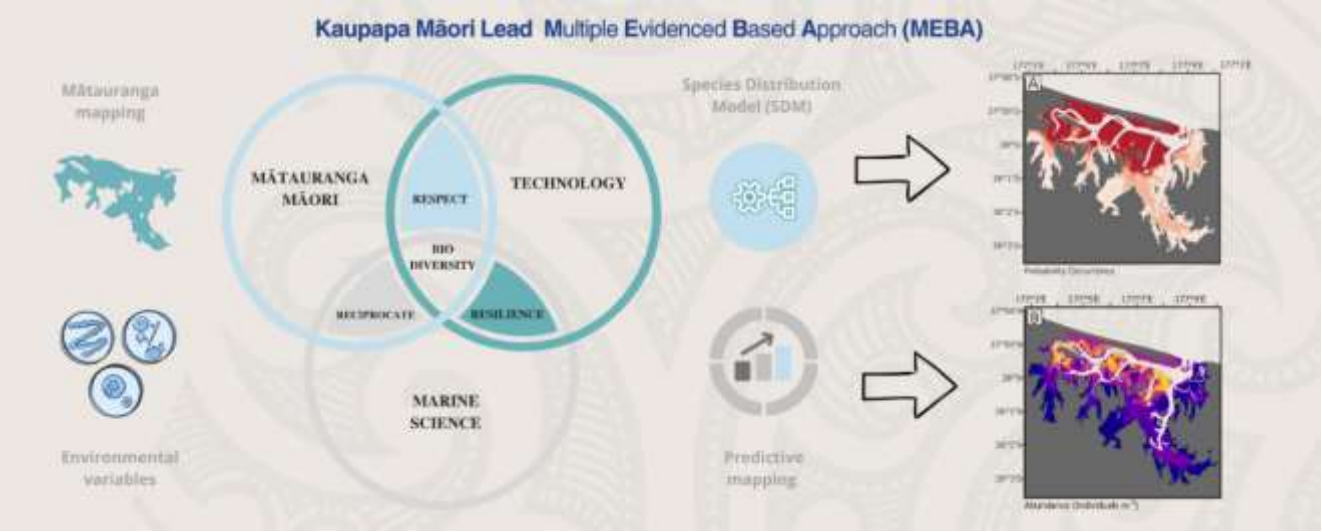
Hirini Melbourne, He waiata kōhungahunga 2, 1995

Wāhanga Tuarima—Chapter 5

Multiple Evidenced-Based Approaches for Ecological Conservation Practices in Ōhiwa Harbour, Aotearoa New Zealand

Figure 15

Visual Illustration of Chapter 5 Outline and Key Concepts



Introduction

The technology we use today has become fundamental to everyday human life, and its evolution is accelerating at an exponential rate, especially with the rapid adoption of artificial intelligence, propelling advances at an unprecedented pace (McClain et al., 2025; Tuhin, 2025). The definition of technology has also evolved through time—in its simplest form, from human origins, technology was stone implements used to curate and modify the surrounding environment to procure sustainable sources for food and shelter to survive (Stout et al., 2011). In our modern times, technology may be defined as a deliberate ensemble of objects, processes, systems and knowledge created or discovered through defined functions, which enhance human capabilities or alter the environment through efficient, purposeful application of scientific or rational understanding, across both the material and digital realms (Carroll, 2017; Solove, 2025).

There is growing evidence that Indigenous peoples face significant challenges in access to and use of modern technology. Barriers arise from issues of availability, usability and the capacity to navigate existing applications and systems, making digital engagement

disproportionately difficult for these communities (Galla, 2016; Hunter, 2005). Therefore, the persistent digital divide adds to the list of barriers for Indigenous peoples when advocating for participation in equitable conservation and biodiversity management of their natural resources and is amplified through inadequate infrastructure and insufficient culturally relevant technological solutions, restricting their ability to engage fully and assert their rights (in the Aotearoa case, rangatiratanga) in decision making (Bawack et al., 2025; Roy et al., 2025).

This chapter brings together the science information collated within Chapters 2 and 3 and adds in the third knowledge system—technology. Mātauranga Māori, marine sciences and technology are woven together to understand the distribution of tuangi within Ōhiwa Harbour and their habitat preference and characteristics. This is the second iteration of a predictive model designed for assessing the kuku (green lipped mussels, *Perna canaliculus*) in Ōhiwa Harbour, done by Bulmer et al. (2024); the data training in this research tested the robustness of the SDM and its reliability. Adding a cultural dimension to a machine-learning model provides an opportunity to reveal a greater depth of ecological knowledge embedded within the tīwaiwaka framework. The pairing of mātauranga Māori with marine sciences enhanced the technological model's accuracy and the cultural relevance of the SDM outputs.

This chapter positions the third and final manuscript of this thesis; again, the manuscript forms the core body of work for this chapter. Within this chapter introduction, I explore kaitiakitanga, manaakitanga and utu as tīwaiwaka values, which is the mauri interweaving this research. I have elected to cluster these three together as they intertwine through their lived expression in the following ways, as a means of enacting kaitiakitanga in Ōhiwa Harbour.

Figure 16

Modified Tīwaiwaka Framework to Show Principles Discussed in this Chapter

Kaitiakitanga, as defined earlier, is a culturally based resource management approach that evokes the ideals of guardianship, stewardship and caretakership. It is a relatively new recorded legislated concept, although the principal of it, in action in te ao Māori, is as old as Māoridom itself. Its formalisation as a resource management concept emerged in 1987 as part of the development of the Resource Management Act 1991 (Oxford English Dictionary, 2023). Numerous references to kaitiakitanga were made in multiple claims lodged in the Waitangi Tribunal, where iwi and hapū throughout Aotearoa raised their concerns at the state of their taonga, their environment.

Moko Mead (2025) added another layer of depth to our understanding of kaitiakitanga, by highlighting the spiritual, the element of wairua

> that recognises the coming together of our human wairua, with the wairua of the whenua and the environment. They connect into a special relationship that manifests into an attachment with the land. The phrase "taku tūranga waewae" means a place where my feet are grounded, and it is loaded with emotion; with

> love for the land and our long historical connection with it, and because our ancestors are buried at the place, we call home. (p. 157).

This description recognises the depth of our profound affiliation to the resources we are brought up with; in this case, for those of us on this mahi (work), it is our harbour, Ōhiwa Harbour. The concept of manaakitanga, the act of generosity of care given to a beloved person, place or thing, is imbued in this emotive idea of connection and caretakership. In this instance, manaaki, as the verb, can be viewed as the desire of the team working on this research to look out for and take care of the tuangi. As a taonga, a special piece of the whole harbour, tuangi declines have a significant impact on the whole ecosystem and place—and would represent a true catastrophe should it disappear. The duty as kaimahi (worker) is to bring awareness and practical steps of action in restoration of the tuangi populations.

Here we used technology to analyse the data and to inform our understanding of the current state of the tuangi population, its preferences in so far as optimal habitats for thriving within the harbour, and where we can look for sites of future restoration as well as further sampling locations for monitoring. These enquiries and actions bring together the te ao Māori practice and scientific enquiry to formulate tangible pro-environmental behaviours that align with kaitiakitanga and manaakitanga in action.

Enacting these values does not work in isolation—overarching these behaviours is the ultimate aim of the wellness of the environment, bringing utu or reciprocity, also known as the balance of nature, bringing nature back into its natural state of energy flow. Black (2014) described tau utuutu as the "internal and external exchange of food and resources by Tairongo is connected to knowledge gained through interaction and collaboration" (p. 19), a process of recurring manaakitanga, a two-way exchange of nutrition and wellbeing, occurring in the sustaining of the harbour or natural resources, and the human and other beings that sustain themselves from there. It is thus a continuum of exchange of care, love and mutual wellbeing, to maintain balance and harmony for all living beings.

Within the Tīwaiwaka framework, these reciprocal relationships are enacted through whanaungatanga, the process of establishing, nurturing and maintaining meaningful relationships. Whanaungatanga extends beyond kinship ties to encompass the relationships formed between people, place, knowledge systems and the wider environment. In this research, it provided the relational foundation upon which collaboration occurred, bringing together kaumātua, researchers, community members

and technology within a shared commitment to the wellbeing of Ōhiwa Harbour. Through whakawhanaungatanga, trust, respect and collective responsibility were cultivated over time, creating the conditions necessary for the respectful exchange of mātauranga Māori and scientific knowledge. From a tīwaiwaka perspective, whanaungatanga is not merely a social principle but an active process that enables the interconnected practice of kaitiakitanga, manaakitanga and tau utuutu in pursuit of environmental and community wellbeing.

These values, in particular, embody kaupapa Māori principles of manaaki ki te tangata—share and host people, be generous. In our research, we hosted and shared with our kaimahi whānau who worked on this project with us—from the kaumātua, to whom we provided many shared lunches, to listen to their concerns and knowledge regarding how they thought this work could best be done; to the volunteers who gave their time to come to do field work with us; each opportunity was taken to live these principles out in our daily programmes. This is tikanga Māori expressed through our daily lives.

These values also encompass other kaupapa Māori principles such as "tītiro, whakarongo … korero," which translates as "look, listen … speak." An additional illustration of this is based on the old Māori proverb that essentially says that "to build trust and long-standing relationships, you need to drink 1,000 cups of tea together" (Vickers, 2021, para. 1). When we interviewed our kaumātua and they shared their knowledge in mapping the traditional harvesting beds, these were essential tenets in our natural te ao Māori way of being.

The following manuscript used technology through a predictive model to assess tuangi distribution and abundance as proxy for the state of health of the tuangi. We then cross-validated the model with the traditional harvesting-bed data. This information gave us information that identifies optimal locations for future sampling and possible restoration sites. Most importantly, this information can provide an opportunity for co-management strategies that respect Indigenous rights and knowledge in contributing to restoration efforts for tuangi in Ōhiwa Harbour. The interlacing of these three knowledge systems offers a powerful, equitable and culturally respectful approach to conservation that enhances understanding of tuangi habitats, supports restoration planning and strengthens co-management frameworks in Aotearoa and globally.

Multiple Evidenced-Based Approaches for Ecological Conservation Practices in Ōhiwa Harbour, Aotearoa New Zealand.

5.1 Introduction

> E tipu e reā , mo ngā rā o tou āo, ko to ringā ki ngā rākāu ā te pākeā hei ārā mo to tinana:
>
> Ko to ngākā u ki ngā taonga ā o tipunā Māori hei tikitiki mo to māhuna: ko to wairua ki te ātua nānā nei ngā mā kātoā.
>
> Grow up, little one, in the way of your day and age, your hands grasping the tools of the Pakeha (European colonial settler) for your physical well-being. Remembering in your heart the works of your ancestors which are worthy of being worn as a diadem upon your brow; your soul ever turned toward God. Who is the creator of all things.
>
> —Sir Apirana Ngata, 1949

Reihana K, Bulmer R, Paul-Burke K, Ellis J, Burke J, Stephenson F. (2026) Multiple Evidenced-Based Approaches for ecological conservation practices in Ōhiwa Harbour, Aotearoa New Zealand. *Pacific Conservation Biology* 32, PC25090.
https://doi.org/10.1071/PC25090

Sir Apirana Ngata's famous whakataukī can be summarised as urging young Māori to grow strong in two worlds—to learn the practical skills and knowledge of non-Māori (in the context of this article, marine science and modelling), while also holding tight to the language, culture, practices, and values of our Māori ancestors (in the context of this article, intergenerational environmental data such as species distribution and abundance). The message promotes balance, cultural identity, pride, education, and two knowledge systems working together for future generations.

SDMs are correlative models that predict species occurrence or abundance of species in relation to environmental variables. They are widely used to estimate habitat suitability across broad spatial scales, including data-limited systems (Elith & Leathwick, 2009; Guisan & Zimmermann, 2000). In coastal and estuarine environments, SDMs have become an important component of resource management, supporting restoration planning and sustainable harvests by identifying areas of high ecological value (F. Stephenson et al., 2023). Recent applications in the Bay of Plenty, including Tauranga and Ōhiwa Harbour, have provided fine-scale spatial insights for culturally and

economically important kaimoana species such as tuangi (*Austrovenus stutchburyi*), pipi (*Plebidonax deltoides*), and kuku (mussels, *Perna canaliculus*)(Bulmer et al., 2024; Rullens et al., 2021, 2022).

However, coastal kaimoana populations, including tuangi, have declined prominently across many estuaries in Aotearoa New Zealand (Pawley, 2011; Rullens et al., 2022) owing to a combination of habitat degradation (MacKenzie, 2014), sedimentation (J. Norkko et al., 2006; Thrush et al., 2004), changes in freshwater inputs (Ministry for the Environment and Stats NZ, 2025; NIWA, 2021), and historical overharvesting (Fisheries NZ, 2006), resulting in reduced availability of customary food resources. These pressures are particularly acute in estuarine systems such as Ōhiwa Harbour, where cumulative impacts interact with localised ecological processes (MacKenzie, 2014), rendering restoration planning both necessary and challenging. Identifying where environmental conditions remain suitable for recovery is therefore a key management priority, particularly given that legal harvesting of tuangi (individuals ≥30 mm) has not been possible in Ōhiwa Harbour for more than 35 years (Reihana et al., 2025).

Bringing together Indigenous Knowledge and ecological sciences—often described as knowledge coexistence or "two-eyed seeing"—is increasingly recognised as an effective and culturally appropriate approach to conservation practice and decision making in the Pacific region and beyond (Hill et al., 2020; A. J. Reid et al., 2021). Evidence demonstrates that Indigenous Knowledge complements marine and ecological sciences by informing SDMs, habitat suitability and long-term monitoring, while supporting adaptive responses to environmental change (Bulmer et al., 2024; B. L. Campbell et al., 2022; Ens et al., 2021). Despite historical resistance within some scientific institutions, pluralistic and Indigenous-led approaches are now reflected in international conservation frameworks and have been associated with positive outcomes for biodiversity conservation and Indigenous community wellbeing (Conference of the Parties to the Convention on Biological Diversity, 2022; Dawson et al., 2023; Reyes-García et al., 2019).

Tuangi, once found ubiquitously throughout Ōhiwa Harbour, are ecologically important and culturally significant to the local iwi Ngāti Awa, Whakatōhea, and Ngāi Tūhoe. These iwi recognise the harbour as important, recording it in their environmental management plans as a significant pātaka kai, mahinga kai, or mātaitai (legislated customary fishing areas managed by local iwi); that is, it represents a crucial local source of food. These iwi

have actively maintained kaitiakitanga over the harbour, with notable efforts such as the successful restoration and management of the kuku population using mātauranga Māori, science research methods and management strategies (Paul-Burke et al., 2018; Paul-Burke et al., Ngarimu-Cameron, Burke et al., 2022) having had exponential success in restoring the kuku population (Haimona-Riki, 2023).

Reflecting the vision articulated by Ngata, contemporary Māori communities are harnessing emerging technologies alongside Indigenous Knowledge to guide sustainable environmental monitoring and resource management (Galla, 2016; Hunter, 2005; Reihana et al., 2021, 2023). In line with this ethos, in this paper we aimed to (1) predict spatial distribution and relative abundance of tuangi across the harbour; and (2) identify priority areas to inform co-designed assessment, monitoring and restoration activities. We demonstrate how multiple knowledge systems can strengthen management strategies for the harbour, and provide a practical, transferable framework for co-managed shellfish restoration in estuarine systems in Aotearoa and the wider Pacific.

5.2 Materials and Methods

Knowledges that are woven together can be understood as a transcendence of disciplinary divergence, giving rise to a new realm of knowledge creation where distinct bodies of knowledge interface (Cockburn, 2022). Such weaving can further be defined as a method of transdisciplinarity that encourages integrative approaches and the deconstruction of institutional, disciplinary, stakeholder and governmental knowledge silos (Moewaka Barnes et al., 2021).

Here, semistructured interviews (see Reihana et al., 2025 for detailed discussion) were conducted with the kaumātua of Ngāti Awa (Paul-Burke et al., 2018) to identify traditional tuangi beds. These kaumātua identified six locations, which were GPS-located and then validated in the field through surveys, population profiles, and sediment samples (see Reihana et al., 2025 for further detail). A mātauranga mapping exercise (Paul-Burke et al., 2018) was used to identify historically and contemporary significant tuangi harvesting beds mapped in Reihana et al. (2025). For a partial reproduction of the tuangi harvesting beds, see Figure F1. These locations were refined over generations through harvesting success, environmental observations, and integrational knowledge transfer.

The mātauranga Māori and tuangi surveying methods included measuring data on tuangi presence/absence and abundance (m^2) and sediment characteristics (percent mud and sand) in 75 sample sites across the traditional tuangi harvesting beds from 2021 to 2023 and

three regional council long-term survey sites (Figure 17). Tuangi were size-classed and characterised as juvenile, adult, or harvestable adult following the method used in Taiapa et al. (2013) and Williams et al. (2006). Individuals measuring >30 mm and above were size classed as large, and relative numbers were then compared with the overall population.

Survey sites (number of samples per traditional bed) were allocated based on a 5 m × 5 m grid overlayed across each traditional bed. Sampling locations were randomly identified within each grid cell. Traditional bed sites were assigned numbers across the extent of the mapped beds. For each grid, a randomised sample location was selected and GPS-located.

Four spatially explicit environmental variables were used as the co-variates in the SDM to estimate tuangi distributions in Ōhiwa Harbour. Spatial estimates of bathymetry (water depth) and tidal current at a 10 m^2 grid resolution were obtained from Bulmer et al. (2024) and Bryan et al. (2023). Spatial estimates of percent mud (see data source, variables and definitions in Table F1) were converted to a harbour-scale environmental layer (10 m^2 grid resolution) from the empirical field measurements using the Inverse Distance Weighting tool in ArcGIS Pro (ESRI Inc. ver. 2.9.5 with Spatial Analyst Toolbox). For the analysis, all layers were constrained to the intertidal and lower subtidal channels using the bathymetry layer (from −1.1 m to 2 m below and above the mean mid-tide height).

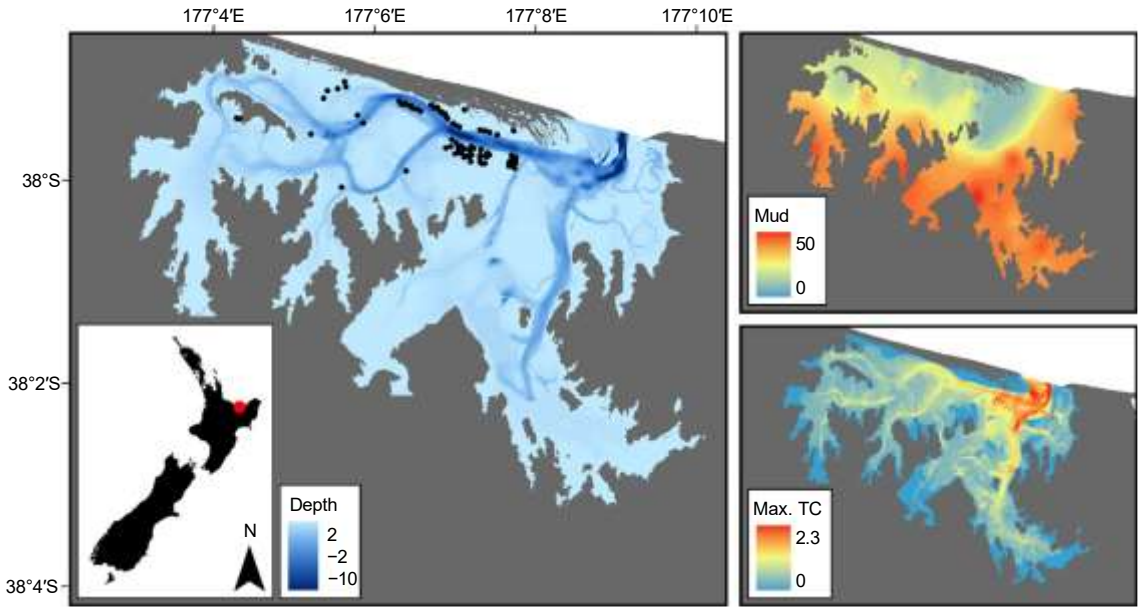
5.2.1 SDMs

To characterise spatial patterns in tuangi distribution and abundance across the study site, an SDM framework was adopted. SDMs are well-suited to benthic invertebrate datasets that exhibit strong spatial heterogeneity and a high proportion of zero observations (Elith & Leathwick, 2009), as is typical for tuangi owing to their patchy distribution and environment filtering. A two-part hurdle (Delta) modelling approach was used to explicitly separate the ecological processes governing occurrence from those determining abundance where the species was present (Barry & Welsh, 2002; Bulmer et al., 2024). This approach allowed presence and absence to be modelled independently from conditional abundance. Boosted regression trees (BRTs) were selected within this SDM framework owing to their ability to accommodate complex, nonlinear relationships, and interactions between environmental predictors without prior specification of functional forms. BRT models combine many individual regression trees (models that relate a response to their predictors by recursive binary splits) and boosting (an adaptive method for combining many simple models to give improved predictive performance) to form a

single ensemble model. Detailed descriptions of the BRT method are available in Ridgeway (2007). All statistical analyses were undertaken in R v4.0.3 using the "dismo" package (Hijmans et al., 2024). As in Bulmer et al. (2024), the spatial distribution and abundance of tuangi within the study area were predicted using a two-part hurdle model (or Delta model) approach. In this procedure, a binomial model (using a Bernoulli error distribution) was used to predict the distribution of occurrence, followed by a separate (second) model for log-transformed abundance of tuangi (using a Gaussian error distribution) to estimate abundance conditional on presence. Spatial predictions from both the occurrence model and the abundance conditional on presence model were multiplied together to produce spatial estimates of abundance (number of individuals m^{-2}).

Figure 17

Study Site Area Locations of All Tuangi Sampling (Black Circles) and Water Depth Within Ōhiwa Harbour



Note: Inset maps show sediment mud content (percent) and maximum tidal current (m s^{-1}) environmental variables.

To explore the distribution of large individuals (tuangi >30 mm), an occurrence model was developed using the same approach as when considering all size classes. However, there were too few data points to model the abundance of large individuals, so a full hurdle modelling approach was not undertaken.

The occurrence and the abundance conditional on presence BRT models were parametrised following recommendations from: with tree complexity of 2 (allowing 2-way interactions of predictor variables); a learning rate of 0.0001 (parameter selected so

as to fit between 2,000 and 4,000 trees for each model); and a bag fraction of 0.7 (the proportion of data drawn at random, without replacement, for each tree).

The BRT models were assessed using two measures of model performance, following Rullens et al. (2021). The occurrence model was evaluated using the area under the receiver operating characteristic curve (AUC), which measures the model's ability to discriminate between presence and absence observations. AUC ranges from 0 to 1, where a value of 1 indicates that the presences and absences are perfectly discriminated, while a value of ≤0.5 indicates that discrimination is no better than random chance. The abundance conditional on presence model was assessed using the Pearson correlation between predicted and observed abundance.

For both the occurrence and the abundance conditional on presence models, the relative influence of each environmental variable was calculated by summing the number of times it was selected for splitting, weighted by the squared improvement to the model as a result of each split (using in-bag data) (Friedman & Meulman, 2003). The association between the environmental variables and species presence/absence and abundance (following hurdling) was explored using partial dependence plots (i.e., predicted response curve of species occurrence and abundance respectively across the gradient of the predictor variable of interest when all other variables were held at their means).

The occurrence and the abundance conditional on presence models were each bootstrapped 100 times. That is, a random "training" sample with a sample size equal to the number of records was drawn with replacement, and a model was constructed with the same settings as the original. This process was repeated 100 times, and at each iteration, predictions were made on the "evaluation" data (the remaining data not randomly selected from the abundance database), allowing model fit to be examined both on the training and evaluation data (F. Stephenson et al., 2020).

Bootstrap models were predicted geographically using the environmental variables (10 m^2 resolution within the study area). The bootstrapped spatial predictions from the occurrence and the abundance conditional on presence models were hurdled (multiplied) together and averaged (mean) to produce a "final" spatial estimate of tuangi abundance. The R code used in this analysis was based on that produced by Rullens et al. (2021) and F. Stephenson et al. (2021).

5.2.2 Informing Future Sampling

To facilitate further sampling and improve model predictions in subsequent iterations, coverage of the environmental space was estimated using techniques described in A. B. Smith et al. (2013) and F. Stephenson et al. (2020). The environmental space is the multidimensional space produced by considering each of the environmental variables as a dimension. Some parts of this environmental space will contain many samples, implying greater confidence in the relationships and the predictions (A. B. Smith et al., 2013), while other parts will contain few samples. Predictions for the less sampled parts of the environmental space are considered less reliable and should be interpreted with greater caution (A. B. Smith et al., 2013). Future tuangi samples would be most beneficial in places where abundance estimates of tuangi are predicted to be high, but the environment coverage is low.

Coverage of the environmental space was estimated by combining sample data (assigned as "present") with an equal number of randomly sampled values from the environmental space (i.e., where no taxonomic samples exist, assigned as "absence"). A BRT model was then used to model the relationship between these present (true) samples and absent (random) samples for the four environmental variables used in the SDM to estimate tuangi distributions. The "dismo" package (Hijmans et al., 2024) was used with BRT models fitted using a Bernoulli error distribution, a learning rate that yielded 2,000 trees and an interaction depth of 2 (so that only pair-wise combinations of the environmental variables were considered). Predictions using this model yielded estimates of the probability of a sample occurring in each part of the environmental space that ranged between 0 and 1, where 0 indicated very low sampling of the environmental space and 1 indicated a very high level of sampling (F. Stephenson et al., 2021).

5.3 Results

5.3.1 Model Evaluation

Mātauranga mapping revealed several areas throughout the harbour traditionally harvested by Ngāti Awa for tuangi (see Figure 17). By parametrising survey design around Iwi (capital "I" denotes single tribe; specifically here, Ngāti Awa) identified beds, the model is grounded in ecological reality already tested through live practice. The traditional beds were generally found nearer to the mouth of the harbour and along the deeper channel area and were typically easily accessible for harvesting. Interviews suggest that the traditional beds were still present in these locations; however, owing to a

lack of tuangi reaching the required minimum harvesting size (>30 mm), harvesting was not permissible at the time of writing (Reihana et al., 2025).

Based on the model fit metrics, the tuangi presence and absence models performed well with training and evaluation AUC scores 0.8 (±0.09) (see Table 1). Abundance models had comparatively poorer model fit (Pearson's correlation <0.6, although moderate correlations are common in ecological abundance modelling, with correlations above 0.7 typically considered relatively strong for ecological prediction. When only the large individuals were modelled, presence absence models also performed well (AUC: 0.7 ± 0.12 as assessed using the withheld evaluation data); however, there was a greater difference between training and evaluation metrics(see Table 3).

Tuangi were predicted to be most abundant in depths shallower than 1 m below mean tide line (average position of the shoreline across all stages of the tide) and in areas where sediment mud content was <20%, with variables (depth and mud content) making relative contributions of 70.2% and 25.8%, respectively, while tidal currents were less important (contributing 3.95%) (**Error! Reference source not found.**). The model showed higher t han expected variability, suggesting a lower overall fit for predicting large tuangi presence. Large tuangi were predicted to be most likely to occur in deeper water (i.e. between 4 m and 0 m below mid-tide (halfway between the high and low tide mark; 46.5% contribution), areas of lower mud content (5%–10% mud; 35.9% contribution) and in areas of higher current (17.6% contribution) (see **Error! Reference source not found.**). H owever, model performance metrics suggest differences in predictive strength and reliability between models for the full population versus large individuals only.

5.3.2 Spatial Distributions

Mātauranga Māori results showed the current spatial distributions from the traditional harvesting beds were considerably reduced in size and extent relative to historical accounts from previous 20 years, the comprehensive interview results are in Reihana et al. (2025).

Size class comparisons revealed that tuangi ranged from 30 mm to 45 mm were regularly harvested before the 1980s (T. O'Brien, pers. comm.).

Table 3

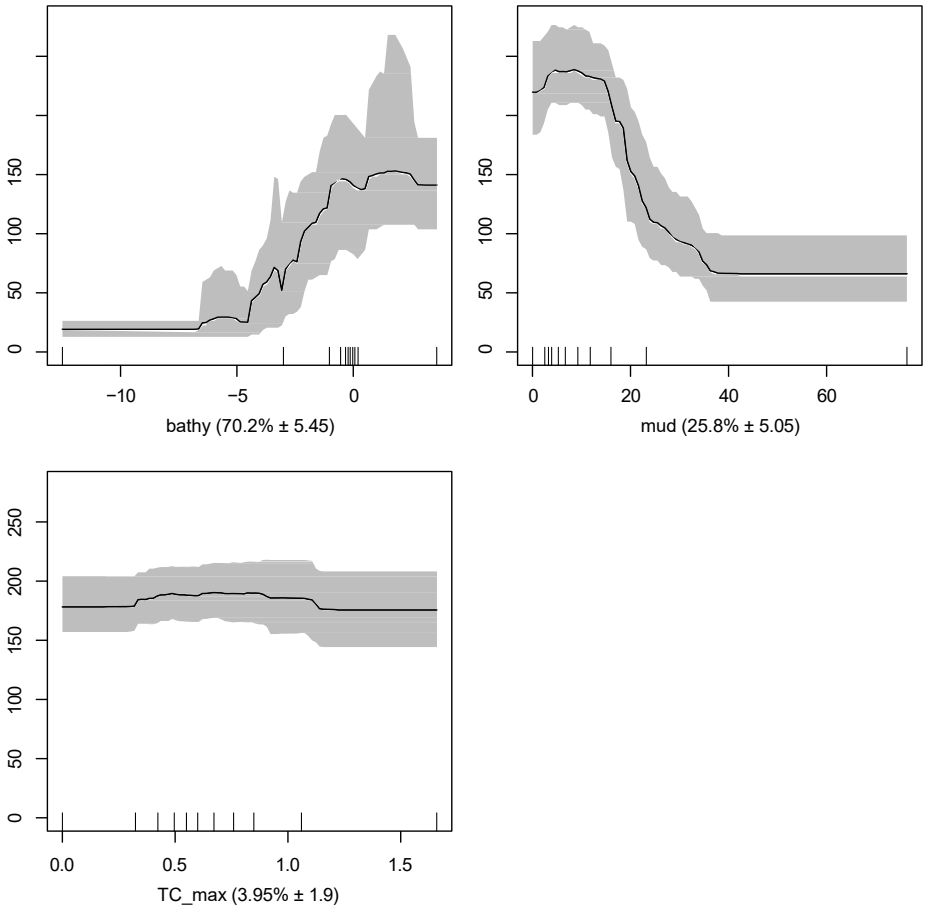
Cross-Validated Estimates of Model Performance for the Bootstrap BRT Models Fitted for Presence/Absence of Tuangi (Austrovenus stutchburyi)

	AUC		Large individuals
Presence/absence mean (±s.d.)	(train)	0.8 (±0.03)	0.86 (±0.06)
	(eval)	0.8 (±0.09)	0.70 (±0.12)
Abundance mean (±s.d.)	(train)	0.59 (±0.03)	
	(eval)	0.45 (±0.14)	

Note: Mean AUC (±s.d.) calculated on training (train) and withheld (eval) data.

Figure 18

Partial Dependence Plots Showing the Relationships Between Predictor Variables and Tuangi Abundance Modelled Using Bootstrapped BRT.



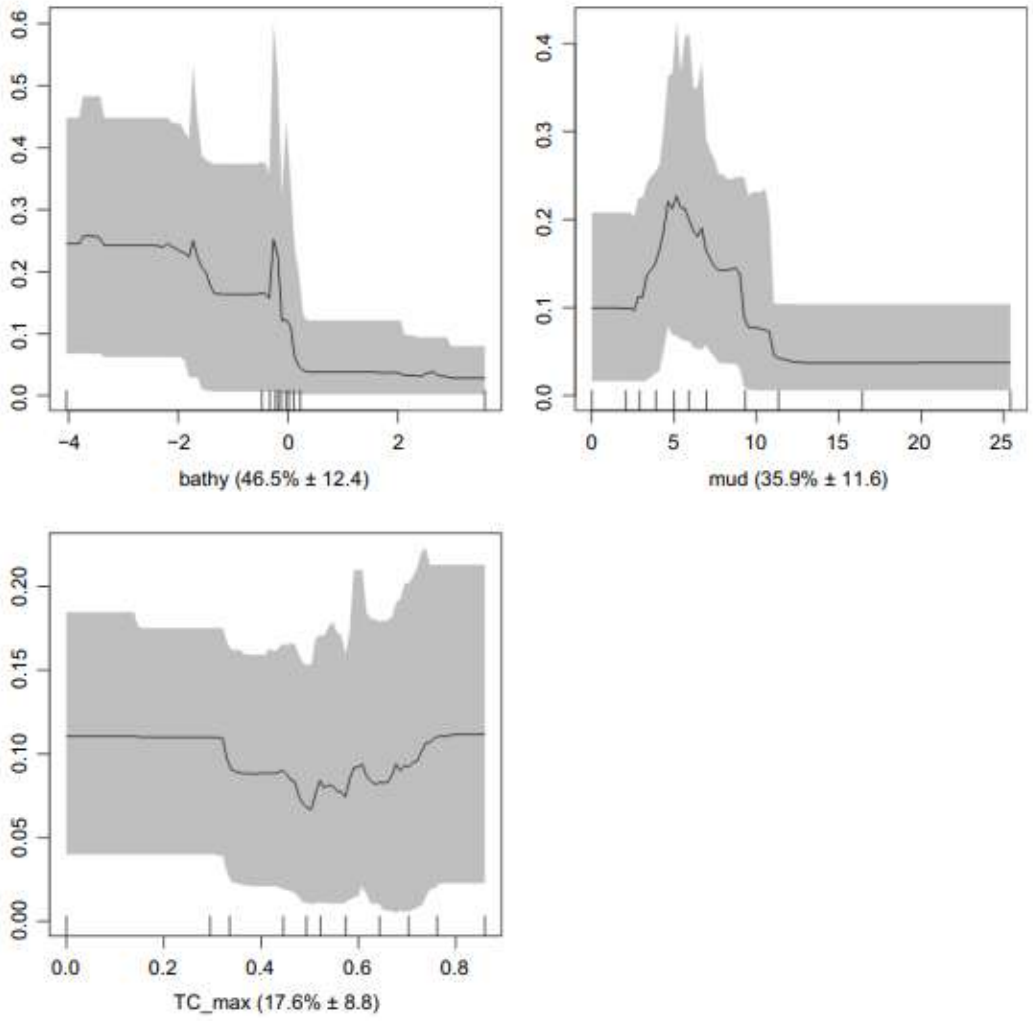
Note: Black lines represent the mean of 100 bootstrap predictions and shaded areas represent 95% prediction interval. Deciles of each environmental predictor are shown as ticks on the *x*-axes. Relative mean (±s.d.) percentage contribution of variables is provided in parentheses.

Based on the combined environmental conditions, the highest probability of occurrence of tuangi was predicted throughout the intertidal areas of the harbour, and areas with >0.5

probability of occurrence covered over 58,157 km^2, representing 99.9% of the study area (Figure 20a). However, high tuangi abundances were predicted adjacent to the deeper subtidal channels running from the harbour mouth to the western side of the harbour (with abundance in many areas of >350 individuals per m^2), and lower abundance predicted in the upper arms and to the south of the harbour (200 individuals per m^2). Larger tuangi were predicted to occupy 0.44 km^2 (1.5%) of the study area, located in three key locations throughout the harbour (see Figure 21).

Figure 19

Partial Dependence Plots Showing the Relationships Between Predictor Variables and Large Tuangi Occurrence Modelled Using Bootstrapped BRT.

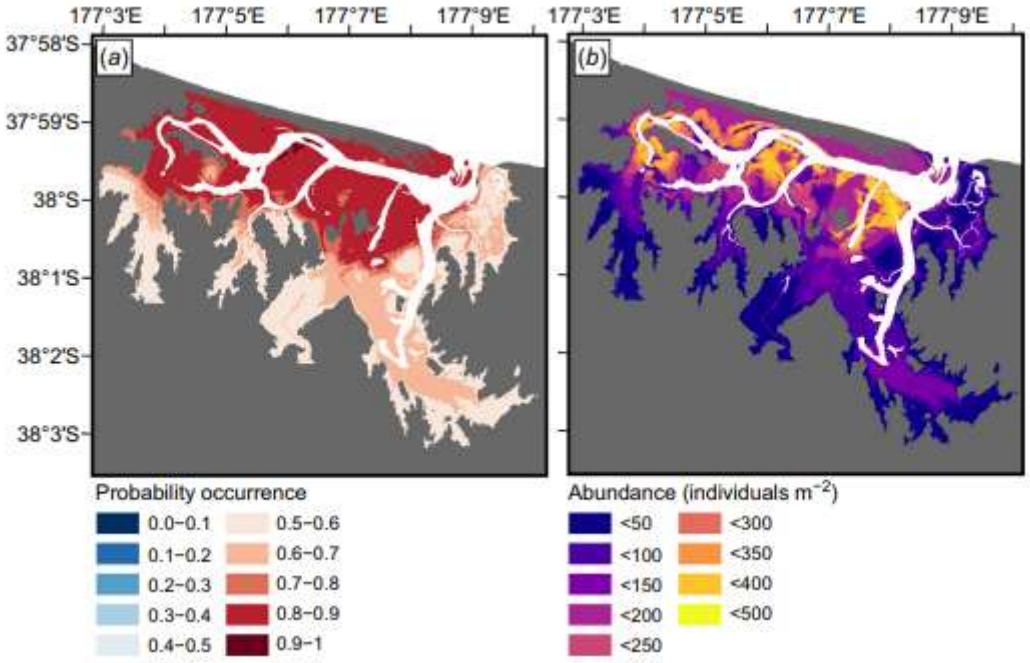


Note: Black lines represent the mean of 100 bootstrap predictions and shaded areas represent 95% prediction interval. Deciles of each environmental predictor are shown as ticks on the *x*-axes. Relative mean (±s.d.) percentage contribution of variables is provided in parentheses.

Traditional harvesting beds, as identified by Ngāti Awa Elders, T4 and T5 were located on the periphery or within the large main channel of Ōhiwa with known populations of larger tuangi (Figure F1). Our model and field survey results confirmed the highest densities of tuangi abundance were recorded at the T4, T5, and Ohi 10 sites, correlating with the abundance distribution map (Figure 20b), which shows the spatial distribution of abundance over the harbour. Coverage of environmental space was also considered, indicating that the areas of highest predicted abundances of tuangi (Figure 20a) generally occurred in areas with the highest environmental coverage (Figure 21).

Figure 20

Mean Spatial Prediction of (a) Probability of Occurrence (0–1) and (b) Abundance (Number of Individuals/m^2) of Tuangi in Ōhiwa Harbour



5.4 Discussion

> He manu hou ahau, he pīka rere
> I am like a fledgling, a newborn bird just learning to fly.
> —Ngāti Awa whakataukī

Contextual historical mapping as well as predictive current-day habitat mapping was undertaken to identify potential survey areas for a co-managed and co-implemented shellfish restoration and monitoring programme in Ōhiwa Harbour. Mātauranga Māori shared by Ngāti Awa kaumātua provided a critical knowledge layer that strengthened the SDM, extending beyond conventional biophysical parameters and enriching model performance through the integration of culturally grounded place-based ecological

insights. If the SDM predicts high suitability and abundance in locations known through Indigenous Knowledge to support tuangi, this concordance provides strong, independent validation of model structure and predictor choice. Here, we utilised the technical distribution data and mātauranga Māori knowledge to "ground truth" the modelling, which has the potential to elevate the benefits of both knowledge systems by complementing the gaps between the two systems (Bulmer et al., 2024); for example, we ground truth the model with the known tuangi beds versus estimated modelled locations. This approach is comparable to Skroblin et al.'s (2021) study, where the Martu Indigenous peoples of the Martu Native Title Determination Area in Western Australia wove their traditional knowledge with an SDM to understand changes in the culturally significant Mankarr (Greater bilby, *Macrotis lagotis*), the last of a species of desert bandicoots that were once prolific and now significantly in decline. Our interviews within Tribal Elders indicated their elevated concerns regarding the decline in tuangi species, which we recorded and visualised (Reihana et al., 2025). Past mapping of the traditional beds in our modelling delineated similar trends of decline. This correlation between knowledges is consistent with results from B. L. Campbell et al. (2022) and Skroblin et al. (2021) showing multiple evidence of signally similar outcomes.

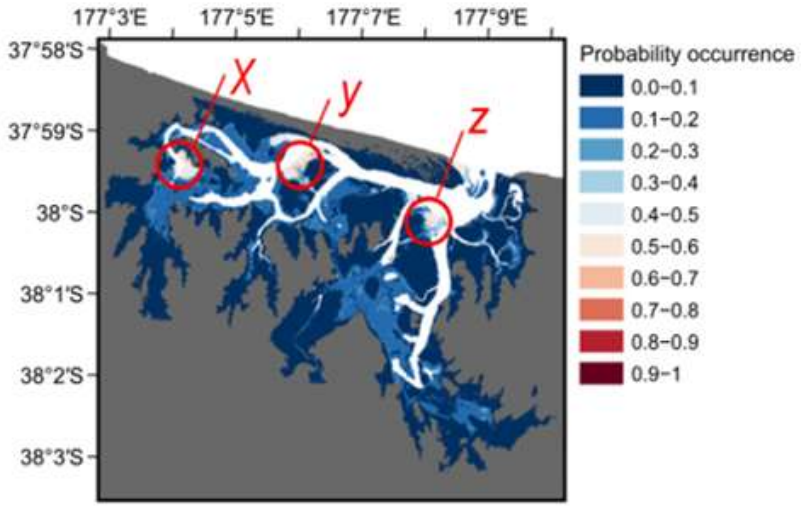
Bringing together and balancing contrasting knowledges is becoming more prevalent and even normalised in conservation research scapes (Bulmer et al., 2024; McAllister et al., 2020; Paul-Burke et al., 2020; A. J. Reid et al., 2021; Sterling et al., 2017; Winter et al., 2021). Our multiple evidence-based approach confirmed the locality and expanse of the tuangi and their environmental preferences within Ōhiwa Harbour, thus reinforcing the capability of the modelling software for rapid, predictive multiscalar analysis. Traditional harvest beds, which were still in use, were identified and mapped. Using mātauranga Māori to inform our surveying enabled sampling prioritisation to inform the SDM, offering the additional benefit of providing up-to-date information on the beds and their extent for Ngāti Awa tribal advisors.

This study built on an SDM originally developed for the distribution of kuku (mussels) in Ōhiwa Harbour (Bulmer et al., 2024). Probability of occurrence indicated a strong performance regarding the presence/absence of tuangi, suitable for informing management strategies within Ōhiwa Harbour. The somewhat lower model fit scores for the abundance models may reflect the species' relatively wide ecological niche (Reiss et al., 2011; Rullens et al., 2021; Tsoar et al., 2007). Comparisons between abundance predictions from the model and calculations gave two scales of prediction: harbour-scale

predictions, which were comparable with the results from Pawley (2011); and localised area predictions. These localised area predictions support the extension of additional sampling and surveying locations that would be beneficial for delineating areas to assist management action such as for restoration programmes. Pawley's (2011) survey area was located within Area Z of Figure 21; however, it was not included in the training data, externally validating the model. In contrast, Areas X and Y of Figure 21, which are well-known for their traditional beds and local council monitoring sites, did have samples in the training data. For the traditional harvesting beds, access and abundance predicted these locations (mostly land-based or accessible by small boat).

Figure 21

Predicted Environmental Coverage Depicting Confidence in the Predictions



Note: Confidence that can be placed in the predictions ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within Ōhiwa Harbour. Red circles depicting the three key predicted locations of large tuangi cockle, *Austrovenus stutchburyi*).

Ngāti Awa traditional place-based observations of the tidal and current nuances, as well as bed shifts and changes, are valuable insights for future iterations of this model. The relationships between tidal current, mud content, and bathymetry with tuangi occurrence and abundance were similar to those recorded by Rullens et al. (2021) for a different harbour in Aotearoa New Zealand. The strongest relationship with mud content was also observed in the partial dependence plots, as well as the depth locality of the tuangi. Tidal current preference was narrowed down to 30−40 cm s^{-1} in Kater et al. (2006), which is concurrent with findings in this study.

Location of larger tuangi under the presence/absence modelling illustrated their preference to locate themselves <0.5 m below the mid-tide line in 5%–10% mud content, with higher tidal current. Our study model predictions align with Pawley's (2011) findings from Motunau Island area, where historical records of larger sized tuangi were identified, providing addition external validation of the model outputs. Berkenbusch and Neubauer's (2019) findings indicated a similar preference range of sediment size fines (grain size <63 μm) from 0 to 17%, reiterating our findings.

SDM on presence/absence demonstrates that some habitats are unsuitable for tuangi. This is consistent with the random preliminary sampling conducted when scoping out the limits of the Indigenous harvest beds, which are focused on the most suitable tuangi for harvesting (size class) (Pawley, 2011, 2012; Pawley & Smith, 2014). When interviewing Ngāti Awa Elders for the mapping of the traditional harvesting beds, they expressed particular concern regarding the retraction of bed extents, and the population declines they had observed over the past decades. The methods in this study could be utilised as a tool to identify priority areas for when time and funding are limited. Ground truthing the current mapped areas with further sampling data for modelling and increased accuracy would also be beneficial.

Our study indicates that many areas of Ōhiwa Harbour have environmental conditions suitable for tuangi. Some of these locations align with traditional beds, but there is also a selection that has yet to be validated. Our results suggest that sampling in these other locations would be valuable to confirm the presence/absence of tuangi, which would then facilitate improved management of these resources throughout the harbour. While our model iterations do not account for dynamic fluctuations over time, it provides a prediction of the current variables and future possibilities, as a static assessment scenario. Our model can provide information on vulnerable locations that are currently not within our sampling zones. In addition, the data can be analysed to predict variable changes such as mud content increase to inform climate change modelling. Further potential analysis includes current run-off levels, predicting increases and current drivers of the abundance and/or distributions, and sea-level rise impacts.

5.5 Conclusion

Indigenous Peoples, as guardians of significant terrestrial and seascapes in Earth's ecological economies, play key roles in conservation of global biodiversity (B. L. Campbell et al., 2022; Garnett et al., 2018). Our study highlights the bringing together of

mātauranga Māori and science knowledges, techniques, and technologies to improve information for future management of a culturally significant species, the tuangi, in Ōhiwa Harbour. The addition of mātauranga Māori adds valuable spatial, temporal, and cultural context to the ecological findings. This process additionally reduces SDM weakness such as sampling bias and data gaps, improving robustness and confidence in predictions. The spatial overlap between the Indigenous Knowledge and SDM outputs constitutes mutual corroboration, strengthening confidence in model predictions while affirming the validity of Indigenous Knowledge observations. Although historically known tuangi beds and past data sets (e.g., Pawley, 2011) were not included in the SDM training data, the SDM predictions aligned with their known ecological characteristics. This functioned as external validation, demonstrating the SDM performs reliably beyond the data on which it was trained. More specifically, Indigenous Knowledge was used to identify sample location points to inform the model build, including the model assessment/fit, rather than as a specific post hoc validation step within the model build. However, the model outputs were compared (in the discussion section) to Indigenous Knowledge of tuangi bed locations (identified during semi structured interviews) to "validate" that the model outputs were consistent with Indigenous Knowledge and to help identify other areas of the harbour which may contain tuangi.

The SDM performed well for identifying the spatial distributions of occurrence and abundance of tuangi across Ōhiwa Harbour. These results aligned with mātauranga Māori on the locations of historic tuangi beds and survey data results collected in Pawley (2011), offering multiple evidence-based validation of our findings. Rather than undermining the SDM, Indigenous Knowledge helped interpret its limitations, ensuring results are contextualised rather than over interpreted. The model can be used to identify locations where tuangi may be present, with mātauranga Māori and other sampling helping to prioritise future sampling efforts. To expedite the next stage of sampling effort, focusing on large tuangi (harvestable sizes >30 mm) could allow rapid mapping and validation of target areas, informed by the model outputs. Given the ongoing decline in tuangi in Ōhiwa Harbour, management tools such as rāhui would allow a recuperation plan to be developed for the taonga species. Results from Reihana et al. (2025) presented evidence of the inability to harvest these species owing to their not having reached legal harvestable size since the 1990s. This plural validation increases trust, uptake and decision-making power across iwi, scientists, and management agencies. Coalescing mātauranga Māori and SDM provided a deeper understanding of these taonga species within Ōhiwa Harbour.

Knowledge creation based on multiple evidence approaches is imperative in meeting global mandates and conservation strategies, while addressing local inequities and injustices from ecocolonialism. Balancing multiple knowledge system models offers culturally appropriate, respectful, equitable, and reciprocating conservation partnerships that deliver shared socio-cultural and environmental benefits.

Wāhanga Tuaono—Chapter 6

Depths

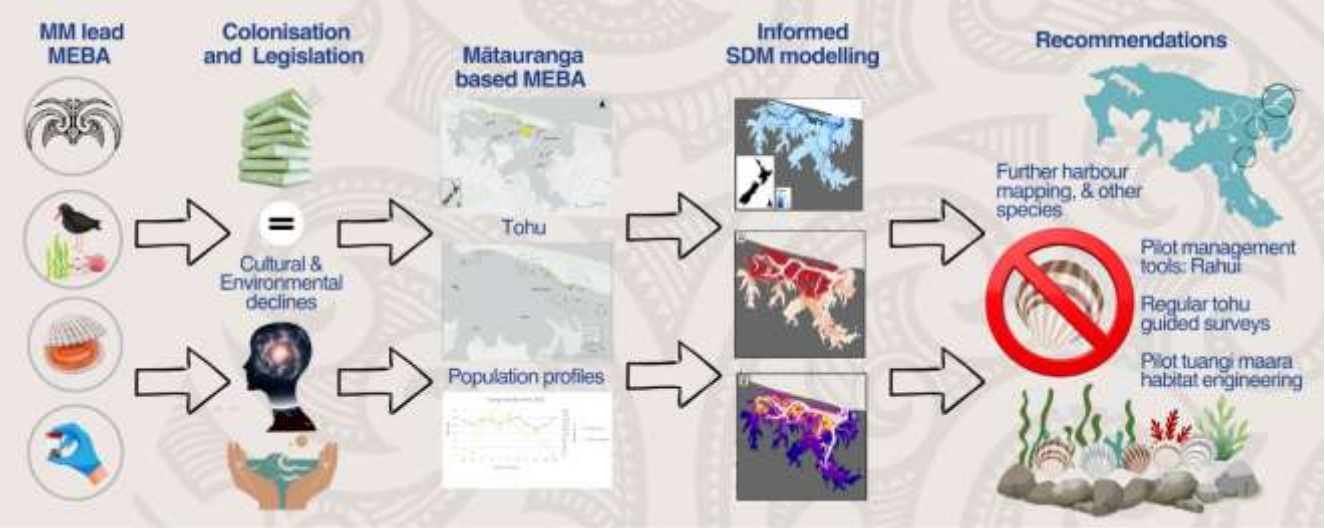
I am an entire ocean
And this you fail to understand,
When you think you can see all of me
Just by standing on the sand,
You cannot tell me who to be
Or how to treat my tide,
When you've never even dipped a toe
Into who I am inside
Erin Hansen

Wāhanga Tuaono—Chapter 6

Whakamutunga—Conclusion

Figure 22

Visual Illustration of Chapter 6 Outline and Key Concepts



6.1 Summary

My thesis positions mātauranga Māori at the forefront for exploring tuangi populations in Ōhiwa Harbour, examining how and why these populations have changed over time. This thesis traverses mātauranga Māori, marine sciences and technology in a Tīwaiwaka framework explored through a MEB approach, supported by consistent visual graphics as tangible examples of different ways of transmitting knowledge. Here I present mātauranga Māori, marine sciences and technology in a way that intentionally blurs the boundaries between art and science, both as a means of knowledge transmission and as a reflection of my own neurodivergent processing. This approach resonates with the view that art and science are not opposing domains but interconnected expressions of human creativity, as accentuated by the following quotations.

> How often people speak of art and science as though they were entirely different things … That is all wrong. The true artist is … imaginative and rational … the true scientist is … imaginative as well as rational … If he does not, his science suffers. (Asimov, 1983, p. 114)

> There is art in science, and science in art; the two are not enemies, but different aspects of the whole. (Asimov, 1988, p. 251)

> The difference between science and arts is not that they are different sides of the same coin … but rather, they are manifestations of the same thing. The arts and science are avatars of human creativity. (Jemison, 2002).
>
> The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. (Einstein, 1935) p.44
>
> Art and science are co-dependant phenomena … We explore the co-dependence of art and science in historical analysis of their interactions. (Bullot et al., 2017) p.453

Bullot et al. (2017) provided an extended discussion on the longstanding recognition that art and science are forms of human creativity, which underpins the methodological strategy of this thesis. Where science offers structure, measurement, and predictive capability, art offers relational thinking, narrative depth, and the ability to communicate complexity in ways that numerical models cannot. Mātauranga Māori itself operates through visual, symbolic and experiential modes—closely aligned with artistic epistemologies—while marine science and modelling contribute the analytical precision required to understand ecological declines. In this way, the mixed-modal evidence structure I have used throughout this thesis is not merely aesthetic but a methodological expression of the art–science synergy: kaumātua narratives sit alongside field surveys, tohu mapping complements ecological indicators, and SDM is strengthened by culturally grounded diagnostics. Together, these interconnected modes of knowledge embody the very co-dependence that Asimov (1983, 1988) and Jemison (2002) described, producing a richer, more culturally anchored understanding of tuangi populations than any single evidence stream could achieve alone.

This thesis not only foregrounds and celebrates the cultural lens of mātauranga Māori in sciences, expressed through art, but seeks to reinstate this world view within our collective consciousness, affirming its centrality in shaping knowledge systems and epistemologies. In doing so, this work challenges the entrenched norms of colonised scientific paradigms, actively engaging in the decolonisation of science by demonstrating an approach grounded in mātauranga Māori as an established, authentic and rigorous knowledge system.

This expression of Māori science, communication, technology and art is a reoccurring theme in my science career thus far. For example, one of my first projects at Manaaki

Whenua Landcare Research was designing an ecology game for Māori youth—initially for kura kaupapa (Māori total immersion schools), Eko (https://eko.nz/; Reihana et al., 2019). The continuation of this collision of disciplines resulted in the development of a graphic novel[1] called *Kaitiakitanga I te au Warawara* (see Figure 23), subsequently accompanied by a virtual reality experience of the same name (Reihana et al., 2021, 2023). This synthesis of artistic expression and scientific enquiry and its role in shaping modes of communication constitutes a natural, logical and integral foundation for my thesis.

Figure 23

Image From the Introduction of the Virtual Reality

Image courtesy of Waxeye.

At the core of this research is an emphasis on equity and the modelling of potential examples of this from a te ao Māori perspective. Yet, as I encountered concepts such as integration, amalgamation and assimilation, I recognised that these remained inherently located within a settler-colonial paradigm. Terminology such as *biocultural* can perpetrate tokenistic inclusion, reinforcing hierarchical power dynamics even when equity is the stated goal. This realisation highlighted the role of language in reproducing dominant cultural narratives, shaping how equity is articulated and enacted. In response, I adopted the concept of the tīwaiwaka framework with a MEB approach, which positions diverse knowledge systems as equally valid and contributory (Cooke et al., 2017). Unlike integrative models that risk creating a diluted third space, the tīwaiwaka framework with a MEB methodological approach, to me, emphasised parity, ensuring that Indigenous

[1] Graphic novel: Apple Store https://apps.apple.com/us/app/kaitiakitanga-i-te-au-warawara/id1533915392
Google Play https://play.google.com/store/apps/details?id=com.kiwamedia.android.qbook.TAN0015

sciences and neoclassical sciences co-exist without subsumption. This shift illuminated the tensions inherent in striving for equity within conservation sciences, promoting critical reflection on how methodologies and technologies can advance inclusive research practices, both in Aotearoa and globally. Comparisons of the tīwaiwaka framework and general integration or amalgamation model approaches have been laid out in Table 4.

Table 4

Comparison Tīwaiwaka Framework Approach and "Integration" or "Amalgamation" Research Model Descriptions Across Key Research Dimensions in My Thesis

Dimension	Tīwaiwaka framework - Multiple evidence-based (MEB) approach	Integration/amalgamation models
Epistemological position	Treats all knowledge systems (e.g., mātauranga Māori, Western science, local Indigenous expertise) as equally valid and self-contained; no hierarchy of credibility.	Assumes knowledge systems can be synthesised into a single combined framework, often privileging dominant scientific epistemologies.
Primary goal	Parity: maintain integrity, authority, and explanatory power of each knowledge system while bringing them into dialogue.	Coherence: produce a unified or harmonised model, often requiring translation/adaptation of Indigenous Knowledge into Western categories.
Power dynamics	Explicitly acknowledges and mitigates colonial inequities; equal decision-making authority is a design requirement.	Tends to reproduce asymmetrical power (e.g., scientists interpret/ extract/reframe Indigenous Knowledge).
Validation logic	Each system validated using its own internal criteria (e.g., tikanga, whakapapa, maramataka; scientific statistics for marine sciences).	Validation defaults to Western scientific criteria, potentially marginalising Indigenous forms of evidence.
Risk profile	Avoids assimilation, tokenism, and "third-space" blends that erode cultural distinctiveness.	Risks dilution, tokenistic inclusion, or epistemic extraction; nuance lost in translation.
Outcome of collaboration	Co-developed outputs where Indigenous and scientific perspectives co-exist without subsumption.	Singular output reflecting a merged worldview, typically closer to Western science than to Indigenous epistemology.
Suitability for decolonisation	Actively advances decolonising practice by maintaining Indigenous authority, context, and decision rights.	Often insufficient for decolonisation because it centres scientific norms and universalises Western categories.
Application in this thesis	Adopts MEB approach: mātauranga Māori leads epistemology; marine science + modelling + tohu follow; iwi-led governance (ŌHIF) maintains parity.	Integration models are explicitly avoided due to tokenism/flattening risks in colonised governance contexts.

Emerging scholarship such as Skroblin et al. (2021) in Australia, Cooke et al. (2017) in Canada, Vaughan et al. (2017) in Hawai'i and Watson et al. (2021) in British Columbia demonstrated how participatory frameworks and co-production of knowledge can

dismantle extractive practices and strengthen Indigenous sovereignty in environmental governance. Methodological innovations, including co-designing SDMs with Indigenous partners (B. L. Campbell et al., 2022) and Bayesian Iñupiat hunter knowledge as existing knowledge or informed assumptions before the model analyses the data (Gryba et al., 2025), further illustrate how epistemic justice can be operationalised in ecological modelling. Ultimately, embracing the tīwaiwaka framework reframes conservation as a collaborative endeavour, challenging colonial power structures and affirming that Indigenous communities have always possessed the authority to define and sustain their own ecological futures.

Chapter 2 established the methodological framework underpinning this thesis, by articulating the above-mentioned approach grounded on the foundational principles of kaupapa Māori research. This tīwaiwaka framework was operationalised through the MEB approach, led out by mātauranga Māori, marine sciences and technology. Mātauranga Māori serves as the guiding epistemology, ensuring that scientific enquiry is informed by cultural values and relational ethics. All research practices and methodological decisions were systemically evaluated against the tīwaiwaka values, which functioned also as a cultural integrity benchmark throughout the research process. This alignment not only safeguarded the authenticity of Māori world views within the study but also reinforced the ethical imperative of conducting research that is both scientifically rigorous and culturally responsive.

Chapter 3 situated Aotearoa's marine governance within a global context, critically examining how settler-colonial laws and policies have systematically excluded Māori from ownership, lawmaking and management of marine spaces. It argued that Western conservation paradigms rooted in dualist ontologies that separate humans from nature have dominated frameworks from The Native Land Acts and early fisheries regulations to contemporary instruments such as the Resource Management Act 1991, marine protected areas and the latest Marine and Coastal Area (Takutai Moana) Act 2011. These regimes undermined Māori rights, interests and tino rangatiratanga, correlating with cultural and ecological declines. In contrast, the chapter foregrounded a te ao Māori perspective, where marine stewardship is embedded in whakapapa, tikanga and values such as kaitiakitanga, mana and utu, positioning humans as integral to ecosystems through reciprocal obligations of care. It called for a paradigm shift from extractive and exclusionary governance to relational charters that uphold Māori authority and knowledge systems, advocating for legal pluralism, co-design and shared jurisdiction as

pathways to reconcile biodiversity protection with cultural continuity, creating a third space for collaboration in marine management. This chapter mapped the historical trajectory of marine environmental decline in Aotearoa, then situated Ōhiwa Harbour within the wider chronology. This established a national-scale perspective that informed the following chapters' local narrative, narrowing the focus to examine the tuangi declines, while providing a critical lens for understanding the ecological and cultural dimensions of this research.

Chapter 4 introduced the local tribal perspective of Ōhiwa Harbour as a culturally and spiritually significant marine space, framed through the poetic invocation Ko Ōhiwa e, by Ati Teepa. As with Ati, the local tribes Ngāti Awa, Te Whakatōhea and Ngāi Tūhoe view her as a living ancestor. This chapter explored the complementarity of Indigenous and Western knowledge systems in natural resource management, emphasising the recognition of mātauranga Māori as a scientific practice and highlighting global and local examples of the successes of woven knowledge systems. This chapter positions Ōhiwa within its historical and cultural context, underscoring the deep whakapapa ties, tūrangawaewae (rights to belong) and values such as kaitiakitanga and manaakitanga as maintained by the local tribes. Using the tīwaiwaka framework, semi structured interviews with Ngāti Awa elders identified traditional tuangi beds, and tohu were observed and mapped over a full calendar year, while field surveys collected ecological data. The contemporary challenges, including degradation of traditional food sources and loss of mana, were discussed alongside iwi-led responses, such as Ngāti Awa restoration initiatives and the ŌHIF as a co-governance model.

The chapter concluded by articulating the research rationale, addressing the decline of tuangi as a taonga species through integrated, culturally responsive marine management grounded in intergenerational knowledge and environmental tohu. The mātauranga and biological data collected within this phase of the research went on to inform the body of work in the following chapter: that is, the SDM.

Chapter 5 explored the weaving of mātauranga Māori, marine sciences and technology through SDMs to enhance conservation and restoration strategies for tuangi in Ōhiwa Harbour. By combining Indigenous Knowledge with Western scientific modelling, the research aimed to improve habitat prediction, guide sampling and support sustainable management of the culturally significant species. Boosted regression tree models predicted occurrence and abundance based on environmental variables such as

bathymetry, tidal currents and sediment composition. Findings indicate tuangi thrive in shallow waters with low mud content, and traditional harvesting sites align closely with model predictions. This model highlights mātauranga Māori for informing restoration priorities and promotes co-management strategies that uphold cultural integrity.

Ultimately, this study demonstrated the weaving of mātauranga Māori and scientific modelling offers a culturally respectful and effective framework for marine conservation in Aotearoa and beyond. Integrating Indigenous knowledge into ecological modelling not only enriches scientific understanding but also advances equity by elevating Indigenous epistemologies and fostering co-produced conservation strategies (B. L. Campbell et al., 2022; Skroblin et al., 2021). Such intercultural approaches align with the tīwaiwaka framework management principles, ensuring that biodiversity governance is both ecologically robust and culturally inclusive through participatory decision making (Cooke et al., 2017). Methodological innovations, such as co-designing SDMs with Indigenous partners, transition research from extractive practices to equitable knowledge co-production, embedding Indigenous priorities into conservation (B. L. Campbell et al., 2022; Reihana et al., 2025). Collectively, these approaches underscore that ethical weaving of Indigenous knowledges is not only a scientific imperative but also a pathway to culturally responsive and inclusive environmental governance.

6.1.1 Repositioning for Change

This body of work spans legal and policy analysis, Indigenous-led estuarine science and advanced species modelling technologies, all situated within the context of Aotearoa marine governance and conservation and informed by international scholarship. This research adopts a transdisciplinary approach that extends beyond the integration of academic disciplines to include the meaningful collaboration of diverse knowledge holders. Through the Tīwaiwaka framework, mātauranga Māori, environmental science, legal scholarship, policy analysis, artistic inquiry and expression, and predictive modelling technologies are brought together alongside the experiences and aspirations of iwi, hapū and local communities. Rather than positioning one knowledge system above another, this approach enables reciprocal learning and co-production of knowledge directed toward a shared environmental outcome. Within this approach, artistic praxis functions not merely as a means of communicating knowledge, but as a mode of inquiry through which relationships between people, species, and place can be understood, explored, and expressed. The result is a research process that not only generates new

understandings of estuarine ecology and governance but also strengthens these relationships in ways that support enduring ecological and cultural wellbeing.

Beyond its application to marine conservation, the Tīwaiwaka framework has implications for the future evolution of science as an institution. Contemporary scientific institutions are increasingly being challenged to address complex socioecological problems that cannot be resolved through disciplinary expertise alone. The Tīwaiwaka framework offers one potential response by demonstrating how Indigenous knowledge systems, scientific inquiry, artistic praxis, law, policy and technology can coexist within a shared research ecology while retaining their distinct epistemological integrity. In doing so, it challenges longstanding assumptions that scientific knowledge must occupy a privileged position in relation to other ways of knowing. Instead, it positions science as one contributor within a broader network of knowledge relationships founded on mutual respect, reciprocity and shared responsibility. As global scientific communities increasingly seek more equitable approaches to knowledge production, the Tīwaiwaka framework provides a model through which research institutions may move beyond extractive and hierarchical paradigms toward more collaborative, relational and ethically grounded forms of scientific practice.

It is designed to catalyse a paradigm shift; from protecting to respecting relations, anchored in te ao Māori-values and operationalised through these values. This research responds to national and international biodiversity-decline strategies and global trends such as the UN Decade of Ocean Science 2021–2030 for equitable knowledge co-development that sustains ocean health and Indigenous rights. It operationalises global Indigenous declarations and conventions such as the enactment of Article (8)j of the Convention for Biological Diversity and the UN Declaration of Rights of the Indigenous Peoples (2007). It positions Māori, the Indigenous peoples of Aotearoa, as equal partners in the redesign of marine law, policy and practice. This research contributes to international scholarship in modern conservation through rebuilding relationships between people, places and species, and delivering practical tools for estuary management, and recentres respect as the relational ethic required to sustain taonga such as tuangi for future generations.

More broadly, it demonstrates how scientific institutions might be reconfigured to support multiple knowledge systems as equal contributors to research design, evidence generation and decision-making, offering a practical model for the ongoing decolonisation and

transformation of science. In doing so, it contributes to a globally relevant model for the decolonisation of marine science and policy while also offering a transdisciplinary blueprint for how scientific institutions can evolve to support knowledge equity, Indigenous self-determination and more relational approaches to environmental stewardship

This thesis investigated key aspects of the tuangi populations in Ōhiwa Harbour, to inform evidence-based recommendations to inform a shellfish management action plan. To achieve this, I addressed the following core questions designed to deepen understanding.

- What is the status and distribution of tuangi populations within Ōhiwa Harbour?
- How have these populations changed over time, and what factors have driven these changes?
- To what extent can a species distribution model predict unsurveyed locations for future monitoring and assessment?
- How can mātauranga Māori inform rapid assessments of potential tuangi beds and guide ongoing surveying and monitoring efforts?

These research questions were comprehensively addressed, and the resulting knowledge disseminated among iwi, local authorities and at the ŌHIF. Collectively, these findings provide a robust evidence base for designing targeted restoration strategies and adaptive management frameworks that weave ecological modelling with Indigenous Knowledge systems. By bridging predictive analytics and mātauranga Māori, this research establishes a foundation for co-governance approaches that advance both biodiversity objectives and cultural imperatives within Ōhiwa Harbour.

6.2 Recommendations

Based on the findings of the marine field research and modelling, the following recommendations are set out:

- **Implement Pilot Management Tools**

  Initiate culturally grounded management interventions, including imposition of rāhui for a minimum 2-year period, with subsequent reapplication as required to safeguard key tuangi beds. Complement these measures with trials of culturally appropriate enhancement techniques and, where feasible, reseeding initiatives to accelerate population recovery.

- **Deploy Rapid Diagnostics Frameworks**

  Establish a quarterly monitoring regime utilising tohu-guided surveys to integrate Indigenous indicators with ecological assessment. Expand survey coverage to include high-suitability and low-coverage sites identified through SDM, ensuring robust spatial representation of tuangi habitats.

- **Comprehensive Harbour and Taonga Species Mapping**

  Undertake harbour-wide mapping of tuangi and other taonga species to identify restoration and reseeding opportunities, develop a multi-species distribution model, and establish a spatial baseline for ecosystem condition, adaptive management, and long-term monitoring.

- **Development of the Tīwaiwaka Framework and Multiple Evidence-Based Approaches Methodology**

  Develop the Tīwaiwaka framework and methodology as an Indigenous transdisciplinary framework that brings together mātauranga Māori (Indigenous knowledges), marine science and technology. Using the Multiple Evidence-Based (MEB) approaches to strengthen knowledge equity, collaborative innovation, co-governance, and culturally responsive environmental stewardship.

- **Expanding Art–Science Methodologies**

  Advance the use of artistic praxis alongside scientific inquiry as complementary modes of knowledge generation, communication, and engagement, enabling richer understandings of human–environment relationships and more accessible research outcomes.

- **Advance the Kaupapa Māori Research Agenda**

  Strengthen kaupapa Māori research through the continued development of Indigenous-led methodologies, research sovereignty, and Māori authority within science, policy, and environmental governance to support ecological, cultural, and community aspirations.

- **Transform Scientific Practice Through Indigenous Methodologies**

  Explore the application of the Tīwaiwaka methodology across Indigenous lands and waters as a model for conducting more equitable, relational, and culturally grounded science, advancing Indigenous self-determination, knowledge equity, and environmental justice within scientific institutions.

6.3 Future Research

This research undertaken in Ōhiwa Harbour has highlighted significant gaps in both ecological understanding and methodological approaches for supporting the long-term sustainability of tuangi populations, and the wider harbour ecosystem. While important questions remain regarding tuangi distribution, recruitment dynamics, and the drivers of populations decline, further research is also required to advance Indigenous-led monitoring, restoration, and transdisplinary research approaches capable of addressing complex socioecological challenges. Building on the findings of this study, several priority areas for future research have been identified, including:

- Evaluating the effectiveness of rāhui and enhancement trials on population recovery.
- Investigating habitat modification strategies, such as pilot tuangi maara informed by international clam garden scholarship.
- Validating tohu-based monitoring frameworks alongside quantitative metrics e.g., undertaking harbour-wide 10x10 grid spatial mapping exercises.
- Create a Multiple SDM for other taonga species within Ōhiwa harbour to provide a more granular understanding of ecosystem health and support long-term ecological planning and restoration trajectories.
- Advancing the Tīwaiwaka framework as a research methodology for Indigenous-led transdisciplinary research that brings together mātauranga Māori, Indigenous knowledge systems, science, art, law, policy, and technology to address complex socioecological challenges.
- Explore the application of the Tīwaiwaka methodology as a model for conducting Indigenous science, advancing knowledge equity, Indigenous self-determination, and more relational, and pluralistic scientific practices.

6.4 In Closing

This body of work positions Aotearoa at the forefront of intercultural marine conservation by operationalising respect-based governance and knowledge co-production—demonstrated here by weaving mātauranga Māori and marine sciences and advanced modelling technologies to offer a transformative pathway for estuarine restoration and governance. By centring Indigenous epistemologies with the Tīwaiwaka framework and MEB methodology approach, this research not only addresses critical ecological questions but advances equity and co-governance in marine management. The integration

of SDM outputs with tohu-led monitoring and iwi-led decision making provides a scalable template for estuarine restoration nationally and internationally.

Beyond its contribution to marine conservation, the Tīwaiwaka framework offers a potential pathway for transforming the institution of science itself. Rather than treating Indigenous knowledge as supplementary to scientific inquiry, the framework positions mātauranga Māori as an equal and essential partner in knowledge creation. By bringing together mātauranga Māori, environmental science, law, policy, artistic praxis and advanced technologies through relationships founded on whanaungatanga, respect and reciprocity, Tīwaiwaka provides a transdisciplinary model for addressing complex socioecological challenges. In doing so, it challenges long-standing disciplinary boundaries and hierarchical approaches to knowledge, creating space for more collaborative, inclusive and relational forms of research. The framework demonstrates how science can evolve from a system primarily concerned with the production of knowledge to one equally concerned with the quality of relationships through which knowledge is generated, shared and applied. Such a shift has implications far beyond Aotearoa, offering a model for scientific institutions seeking to support Indigenous self-determination, knowledge equity and more ethical approaches to environmental stewardship.

As biodiversity declines accelerate globally, the approaches developed in this research articulate a growing trend of anchoring approaches in culturally grounded values such as whakapapa, kaitiakitanga and mātauranga Māori, which offer more than one-dimensional technical solutions, presenting a paradigm shift towards ethical, inclusive and relational marine management. These findings underscore that culturally grounded diagnostics; predictive modelling and participatory frameworks can collectively inform adaptive strategies that restore biodiversity while upholding tikanga and rangatiratanga. Beyond Ōhiwa Harbour, this work contributes to a globally relevant model for decolonising conservation science—one that reframes marine stewardship as a relational ethic of respect, ensuring the resilience of taonga species and the cultural continuity of the communities who sustain them. Future research will build on these foundations to refine habitat enhancement strategies, strengthen co-governance mechanisms and embed Indigenous authority in marine planning, ensuring that the health of our moana and its taonga species endures for generations to come.

Ka ora te whenua, ka ora te tangata **…**

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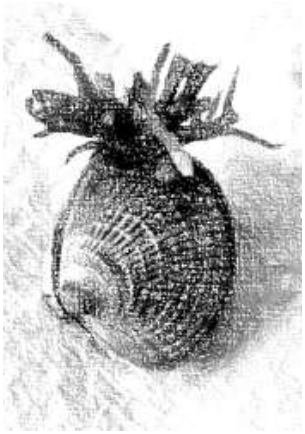

Appendices

Appendix A: Authors Consent Form Manuscript 1: Chapter 3

THE UNIVERSITY OF WAIKATO

Co-Authorship Form

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This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work.** Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 3 of my PhD thesis: Publication titled: From Protecting to Respecting marine relations in Aotearoa, New Zealand. Accepted in Journal Alternative, 2026

Nature of contribution by PhD candidate	Conceptualisation, writing of original manuscript draft, draft legal review, manuscript review and editing
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Prof Elizabeth Macpherson	Conceptulisation, methodology, legal review and authentication, mansucript review and editing
Dr. Joanne Ellis	Conceptulisation, methodology, mansucript review and editing
Dr Richard Bulmer	Conceptulisation, manuscript review and editing
Prof Kura Paul-Burke	Conceptulisation, methodology, mansucript review and editing

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

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Dr Richard Bulmer	[redacted]	09/02/26
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Appendix B: Authors Consent Form Manuscript 2: Chapter 4

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 4 of my PhD thesis: Publication titled: Ko Ōhiwa e, (Our Ōhiwa), How weaving knowledges is shaping marine research in Ōhiwa harbour. Published in the Journal Ocean Technologies, Special edition: Indigenous Ocean Technology: Priorities adn Practices. Winter 2025

Nature of contribution by PhD candidate	Conceptualisation, writing of orginal draft, methodology, investigation, formal analysis, validation, visualisation feidl data design, collection and data collation and analysis
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Prof Kura Paul-Burke	Conceptualisation, methodology, Feild data design & collection, manuscript review
Dr. Joanne Ellis	Conceptualisation, methodology, analysis editing, manuscript review
Dr. Richard Bulmer	Conceptualisation, methodology, analysis editing, manuscript review
Joe Burke	methodology, feild data, collection and review
Tuwhakairiora O'Brien	Feild data design, MM mapping, manuscript review
Charlie Bluett	Feild data design, MM mapping, manuscript review

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- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
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July 2015

Appendix C: Authors Consent Form Manuscript 3: Chapter 5

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This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work.** Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 5 of my PhD thesis: Publication titled: Multiple Evidenced Based Approaches for ecological conservation practices in Ōhiwa harbour, Aotearoa New Zealand. In submission to Pacifica Conservation Biology, 2026

Nature of contribution by PhD candidate	Conceptualisation, writing of orginal draft, methodology, investigation, data analysis, validation, visualisation
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Dr. Richard Bulmer	Conceptualisation, methodology, Data analysis, validation, review and manuscript editing
Prof Kura Paul-Burke	Conceptualisation, feidl data design and collection, methodology, manuscript review
Dr. Joanne Ellis	Conceptualisation, methodology, data analysis, manuscript review
Joe Burke	Conceptualisation, feild data collection methodology, manuscript review
Dr Fabrice Stephenson	Conceptualisation, methodology, Data analysis, validation, review and manuscript editing

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

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Prof Kura Paul-Burke	[redacted]	10/2/26
Dr. Joanne Ellis	[redacted]	03 February 2026
Joe Burke	[redacted]	10/2/26
Dr. Fabrice Stephenson	[redacted]	03 / 02 / 2026

July 2015

Appendix D: *Ko Ōhiwa e* by Ati Teepa (2023)

He taitimu,	It's the incoming
He taipari,	it's the outgoing tide.
He waitī,	It's the brackish
He waitā	and the salty waters.
He awa,	It's the tributaries,
He repo,	it's the wetlands.
He whanga.	That make this harbour,
E taku moana e hora nei,	who lays before us.
ko Ōhiwa e.	Our Ōhiwa.
He hōhōnū,	It's in the depths,
He pāpākū,	and in its shallows.
He kirikiri,	It's in the sediments,
He oneone,	of sand,
He anga,	of soil,
He uku,	of shell,
He paru,	of clay,
He puehu,	of mud,
He kōhatu,	of dust,
He tāhana.	of pebbles,
O taku moana e hora nei,	of basalt.
ko Ōhiwa e.	That lay beneath this harbour, our Ōhiwa.
He moutere.	It's the islands.
Ko Hokianga,	Hokianga
Ko Uretara.	Uretara
Ko Ohakana	Ohakana.
Ko Motuotū,	Motuotū.
Ko Whangakōpikopiko,	Its Whangakōpikopiko.
Ko Pātaua.	It's the cliff,
He pari,	and the hills.
He hiwi,	It's the ancient Pa.
He Pā kainga.	Tauwhare.
Ko Tauwhare,	Paparoa.
Ko Paparoa,	Upokorehe.
Ko Ūpokorehe,	Hiwarau.
Ko Hiwarau,	It's Onekawa.
Ko Onekawa.	It's a sanctuary,
He āhuru,	It's security,
He maru,	It's what anchors us,
He tumu.	To the harbour that lays before us
Taku moana e hora nei,	our Ōhiwa.
ko Ōhiwa e.	

He Pōhutukawa,	It’s the Pohutukawa
He Kākāho,	it’s the Reeds.
He Raupō,	It’s the Rushes,
He Mānawa,	it’s the Mangroves.
He Karamu,	It’s the Karamu,
He Ngaio,	it’s the Ngaio.
He Wīwī,	It’s the Sedges,
He Rimu,	it’s the seaweed
e tiemiemi ana.	that sway in the tides.
I ngā wai o taku	Of this harbour that lays before us,
moana e hora nei,	our Ōhiwa.
ko Ōhiwa ē.	
He kōhanga,	It’s a nursery
he rua,	It’s a refuge.
he kainga,	It’s a home,
he mahina,	It’s our larder.
he pātaka,	It is constant and consistent,
he ohu kai,	So, we can endure next to
mo ngā uri.	this harbour
O taku moana e hora nei,	that lays before us.
ko Ōhiwa e.	Our Ōhiwa.
He kupenga,	It’s the nets
he hīnaki,	it’s the Eel traps.
he pouraka,	It’s the cray net,
he tāruke,	it’s the crab pot.
he pīhuka,	It’s the gaff,
he tao,	it’s the spear.
he hei,	It’s the lure,
he matau,	it’s the hook.
he aho.	It’s the line that descends
E hī nei i nga wai	Into this harbour that lays before us.
o taku moana e hora nei,	Our Ōhiwa.
ko Ōhiwa e.	
He mātaitai,	It’s the shellfish.
He Tītiko,	It’s the Periwinkle,
He Pūpū,	it’s the Snails.
He Kōkota,	It’s the Pipi,
He Pipi,	It’s the Cockles.
He Tūangi,	It’s the Barnacles,
He Pātitotito	It’s the Oysters.
He Tio,	It’s the Scallops,
He Tupa,	It’s the black,
He Niania,	it’s the green lipped mussels.

He Kuku. E takoto ki taku moana e hora nei, Ko Ōhiwa e.	Dispersed across this harbour that lays before us. Our Ōhiwa.
He Ururoa, He Mangā, He Kanae, He Kahawai, He Tāmure, He Pātiki, He Tuna, He Ngīoreore, He Īnanga, He Kōkōpu, He Aua. Ko Moutohora kei waho o taku moana e hora nei, ko Ōhiwa e.	It's the Hammerhead Shark it's the Barracuda. It's the Mullet, it's the Kahawai. It's the Snapper, it's the Flounder. It's the Whitebait it's the Cockabilly. It's the Sprats, it's the Herrings. And it's Whale Island, Laying beyond this harbour. Our Ōhiwa.
Ko Nukuhou, Ko Oukai, Ko Wainui, Ko Kutarere, Ko Ruatuna, Ko Waiotane, Ko Awaraputuna, Ko Matekerepu, E whangai i taku moana e hora nei, ko Ōhiwa e.	It's Nukuhou, It's Oukai, It's Kutarere, It's Ruatuna, It's Waiotane, It's Awaraputuna, It's Matekerepu, that feeds fresh water into this harbour that lays before us. Our Ōhiwa.
He atua, He tipua, He kaiwhakaora, He kaiwhakamate. He tauranga, He kainga. Taku Moana e hora nei Ko Ōhiwa e.	She is godly, She is ancient, She is the giver and taker of life. She is safe harbour. She is home. This harbour that lays before us, Our Ōhiwa.

Appendix E: Supplementary Material, Chapter 4

Table E1

Density and Abundance Calculations for Our Survey Sites, Traditional Beds, and Ambient Bed, Based on an Aggregated Stratum Across Site

	Site	Bed area m²	Mean density rate/m²	Abundance Totals	Density /m²
Traditional harvesting beds	1a	3157.23	305	962955.15	4.05
	1b	16265.92	151	2456153.92	2
	1c	59596.94	1485	88501455.9	19.71
	2	128107.61	1810	231874774.1	24.03
	3	135943.94	1139	154840147.7	15.12
	4	45301.59	1902	86163624.18	25.25
	5	51577.48	1200	61892976	15.93
Total		439950.71			
Ambient bed	6	128035.32	854	5124	11.34

Table E2

Mean Size and Mean Densities Across Sites, Showing Our Traditional Beds and Council Sites, as well as Pawley (2011) and Pawley and Smith (2014)

Years	Site	Mean size	Abundance Mean density m²	Density m²	% Organic content	% Mud content averages	% Sand content averages
2021-2022	1a	23.5	305	4.05	2.33	6.83	93.04
	1b	20.6	151	2	1.74	2.26	97.73
	1c	17.7	1485	19.7	2.14	6.34	93.48
	2	20.3	1810	24.0	3.13	14.07	85.75
	3	17.8	1139	15.1	2.60	7.14	92.85
	4	14.5	1902	25.3	2.26	3.28	96.71
	5	19.7	1200	15.9	3.03	5.43	94.49
	6	19.6	854	11.3	2.25	10.21	89.79
	P8	19.5	1046	13.9	3.04	12.61	87.39
	P9	12.74	515	6.83	2.08	16.97	83.03
	P10	21.25	84	1.11	1.26	16.14	83.36
Pawley (2011)							
2009		17	304.7	0.61			
2006		17	51.4	0.77			
2005		22.2	175.7	8.01			
Pawley & Smith (2014)							
2012		17	340.6	1.9			
2009		17	304.7	1.4			

Note: Sediment characteristics at each of our sampled sites show organic, mud, and sand content as percentages. Colour coding: Light blue represents lows, apricot correlates to consecutive positive trends, and red represents highs in the data.

Table E3

Mean Size, Mean Densities, and Density/m² Across P8, P9, and P10 From Bay of Plenty Regional Council. Annual Data From 1990-2021

Years	Site	Mean size	Abundance Mean density m²	Density m²	Years	Site	Mean size	Mean density m²	Density m²	Years	Site	Mean size	Mean density m²	Density m²
1991	**P8**	2.5	8	0.10	1991	**P9**	26.7	136	1.80	1991	**P10**	24	58	0.77
1992			63	0.83	1992			75	1.00	1992			38	0.50
1993			28	0.37	1993			40	0.53	1993			45	0.60
1994			40	0.53	1994			53	0.70	1994			60	0.80
1995			325	4.31	1995			128	1.70	1995			206	2.73
1996			427	5.67	1996			91	1.21	1996			38	0.50
1997			314	4.17	1997			35	0.46	1997			66	0.88
1998			681	9.04	1998			94	1.25	1998			78	1.04
1999		21.5	113	1.50	1999		25.8	28	0.37					
2000		26.3	22	0.29	2000		20	6	0.08					
2001		4	430	5.71	2001		6.4	44	0.58	2001		2.6	191	2.54
2002		8.2	863	11.46	2002		3.9	144	1.92	2002		13.2	446	5.92
2003		8.30	304	4.04	2003		24	455	6.04	2003		10.3	1482	19.67
					2006		20.7	75	1.00	2006		26	126	1.67
2007		19.40	78	1.04	2007		21.1	430	5.71	2007		26.3	85	1.13
2008		10	28	0.38	2008		11.2	201	2.67	2008		12.5	436	5.79
2009		7	31	0.42	2009		11	1547	20.54	2009		8.2	135	1.79
					2011		14.7	389	5.17	2011		12	374	4.96
					2012		11.4	1761	23.38	2012		15.8	565	7.50
2013			1158	15.38	2013		17.6	1127	14.96	2013		19.1	590	7.83
2014		13.50	1306	17.33	2014		17.4	1424	18.90	2014		9.18	565	7.50
2015		15.42	998	13.24	2015		19.3	1469	19.50	2015		15.70	643	8.54
2016		16.96	1573	20.88	2016		19.9	1375	18.25	2016		19.17	170	2.25
2017		23.87	1218	16.17	2017		21.3	957	12.71	2017		7.96	1099	14.58
2018		10.99	477	6.33	2018		21.3	723	9.60	2018		20.67	392	5.20
2019		16.19	512	6.80	2019		22.2	497	6.60	2019		15.49	949	12.60
2020		5.50	949	12.60	2020		15.5	816	10.83	2020		10.48	1138	15.11
2021		13.43	967	12.83	2021		12.7	515	6.83	2021		21.25	84	1.11111

Note: Colour coding: Light blue represents lows, apricot correlates to consecutive positive trends, and red represents highs in the data.

Figure E1

Survey Sites From This Study

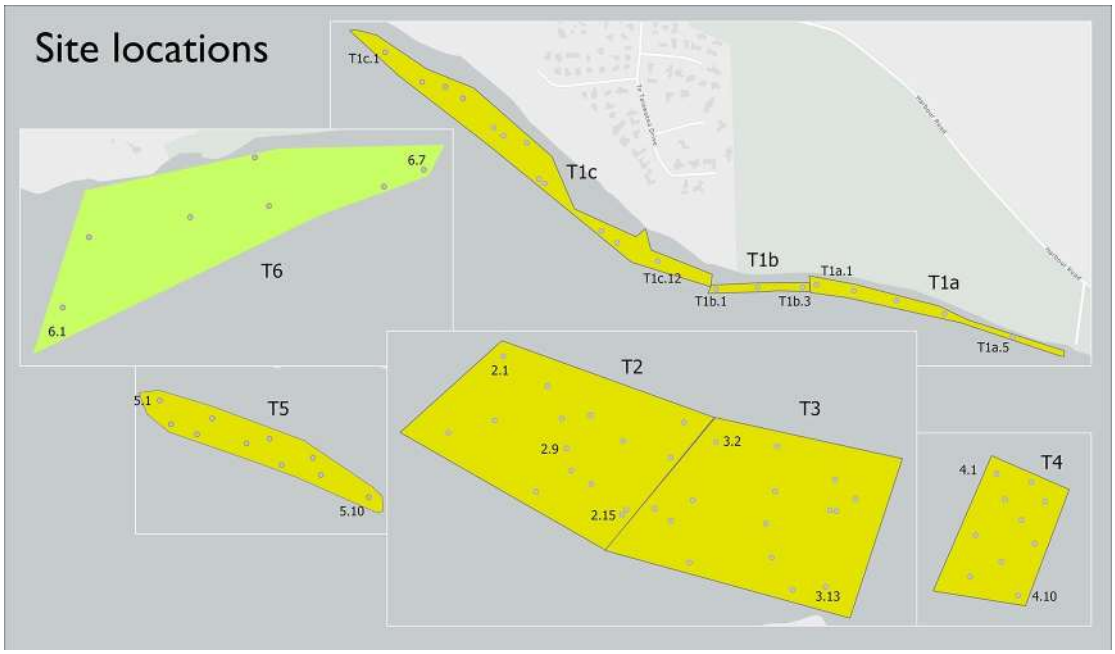
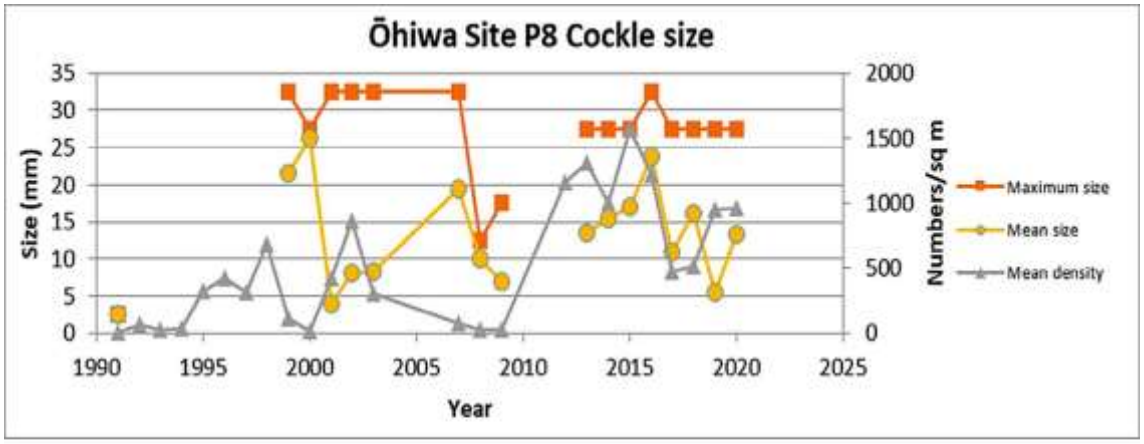
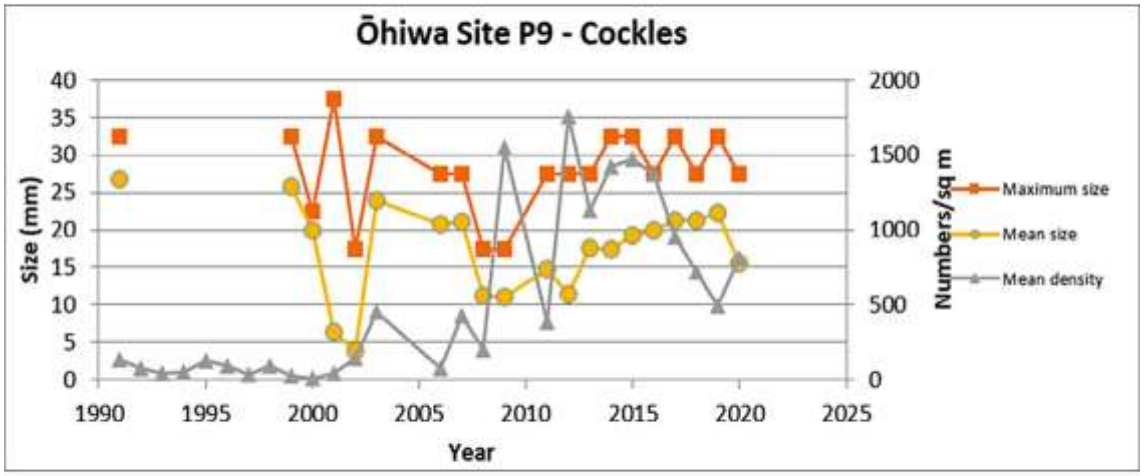


Figure E2

Maximum Size, Mean Size, and Mean Density Trends Over Time at P8, P9 and P10





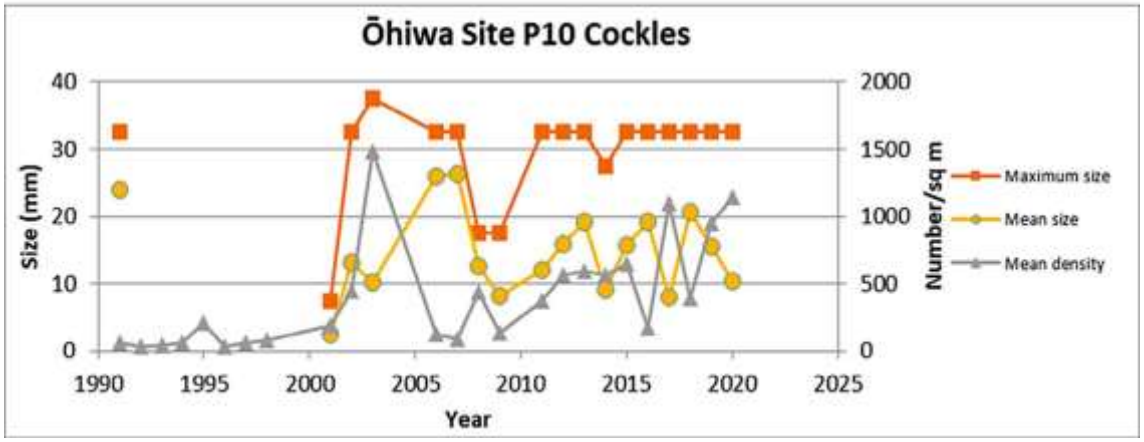


Figure E3

Mean Size and Density Across All Survey Sites T1a to P10 for the Year 2022

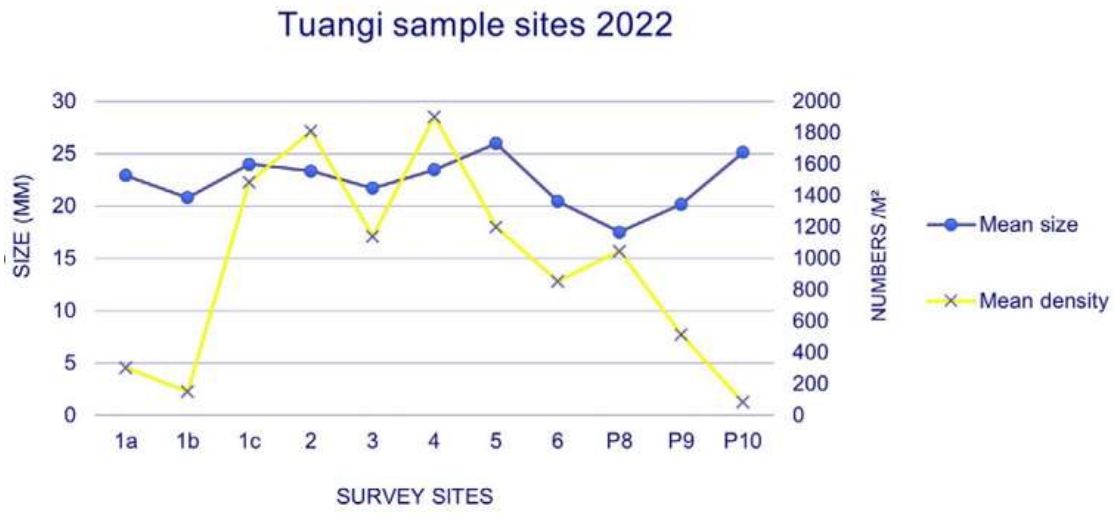


Figure E4

Population Structure Over Traditional Harvesting Beds and Ambient Site From 2021-2022. Grey Bars Denote Harvestable Tuangi <30 mm

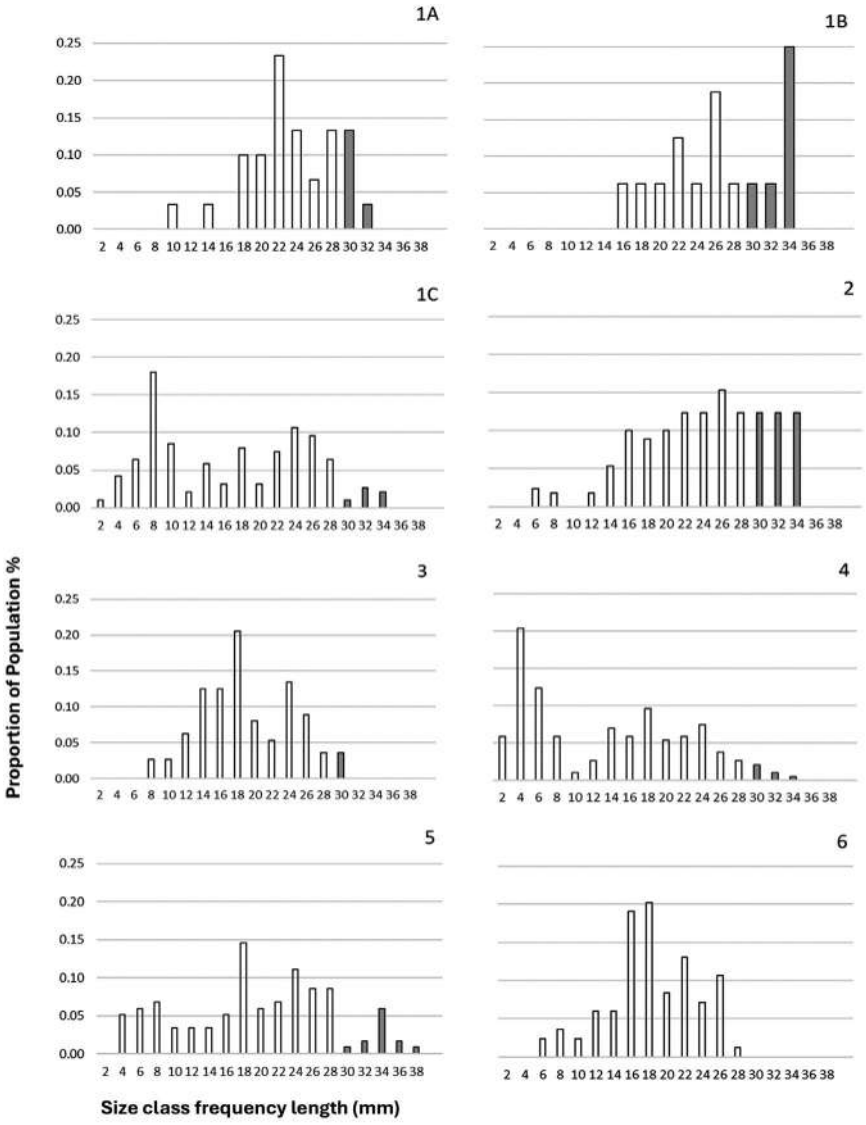
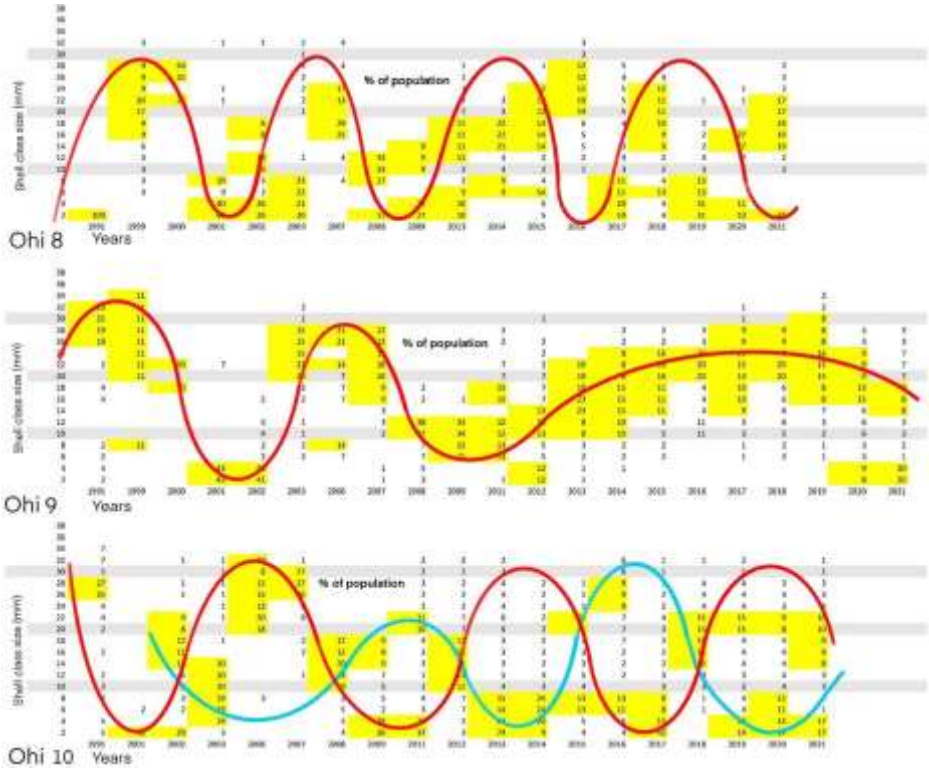


Figure E5

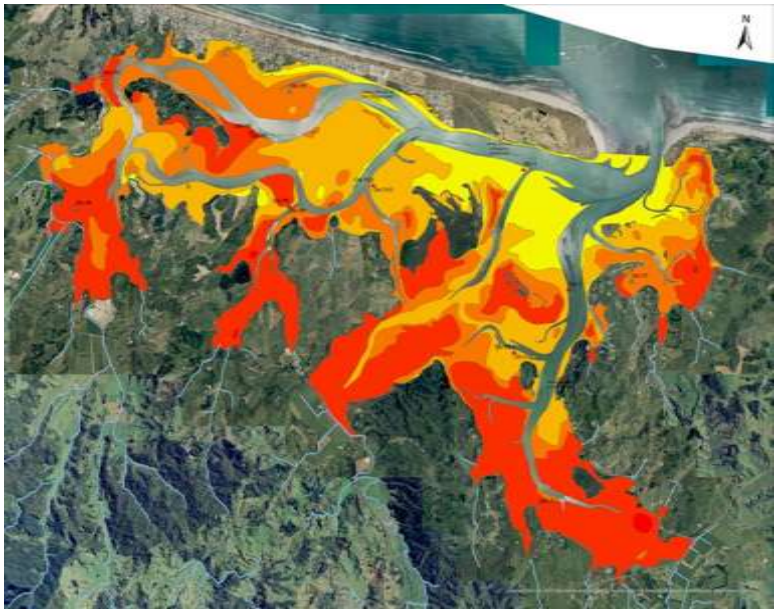
Frequency of Size Classes From Council Sites, Along With Population Percentages for Each Size Class



Note: Highlighted in yellow are the 8th percentile and above size classes. Clear trough and peaks are observed over the time series, indicated by the red trend line. In site P10, the blue line suggests a secondary trend line from the primary red trend line.

Figure E6

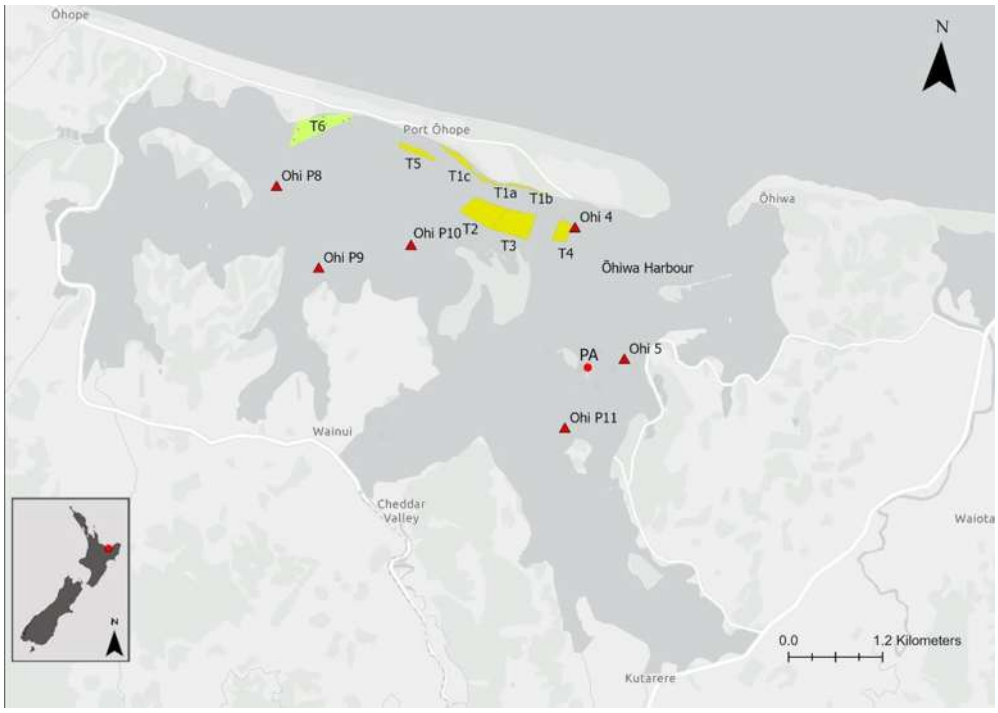
Bay of Plenty Regional Council Percentage of Sediment Characteristics in Ōhiwa Harbour 2015 Showing Sediment Sites Across the Harbour



Appendix F: Supplementary Material, Chapter 5

Figure F1

Mapped Traditional Harvesting Beds T1 to T5, T6 Ambient Beds for Comparison



Note: Council sites Ohi P8–P11, Ohi 5, and PA = Pawley Survey site, all sites which informed the SDM. Partial reproduction of Figure 1, from Reihana et al. (2025)

Table F1

Description of Model Variables, Units and Definitions and the Data Used to Inform the Variable

Variable	Unit and definition	Informed by	Figure
Tuangi (cockle) density and distribution	Number of individuals per m^2	86 samples collated from the following sources: Iwi-led quantitative surveys from 77 sites throughout Ōhiwa Harbour, collected in 2022, with site selection informed by mātauranga/expert opinion of current bed locations. Bay of Plenty Regional Council monitoring data from 9 sites throughout Ōhiwa Harbour, collected in 2021. Additional 192 sites of tuangi density and paired environmental data were used to inform underpinning BRT models was collected from Tauranga Harbour (Ellis et al., 2013; Rullins et al., 2021)	
% Mud	% Mud (silt and clay) % by dry weight of surface sediment (top 2 cm) particles in a sample < 63 um in diameter	246 samples collected throughout Ōhiwa Harbour and collated from the following sources: Iwi-led quantitative surveys from 80 sites, collected in 2022–2023. Bay of Plenty Regional Council spatial sediment survey from 155 sites, collected in 2010 Bay of Plenty Regional Council monitoring data from 11 sites, collected in 2021	Figure 2
Water depth/elevation	Depth (m) below lowest astronomical tide	Bathymetric surveys conducted in 2020 and regional LiDAR (Bulmer et al., 2023)	Figure 1
Tidal current	Max tidal current speed (m s-1)	2D Hydrodynamic model developed by the University of Waikato (Bryan et al., 2023)	Figure 1